An investigation of the movement of the scallop, *Pecten maximus*

RICHARD G. HARTNOLL

Zoology Department, Queen's University, Belfast, Northern Ireland
and
Marine Biology Station, Portaferry, Northern Ireland

KURZFASSUNG: **Eine Untersuchung über die Fortbewegung der Kammuschel *Pecten maximus*.** Obgleich *Pecten maximus* (L.) normalerweise im Meeresboden ruht, kann dieses Mollusk recht aktiv schwimmen. Frühere Untersuchungen über die Fortbewegung werden durch Wiederfang markierter Individuen mit Hilfe einer Dredsche durchgeführt; eine derartige Methode kann lediglich etwas über weiträumigere Ortsveränderungen aussagen. In der vorliegenden Studie wurde nun ein kleines Areal mit fixierten Bezugspunkten versehen und – unter Anwendung der Methode des wissenschaftlichen Schwimmtauchens – in bestimmten Zeitabständen 8 Wochen lang überwacht. Auf diese Weise konnte sowohl die Häufigkeit der Ortsveränderungen als auch die Orientierung erfaßt werden. Durchschnittlich verblieben nicht eingegrabene Individuen nur 6 Tage am gleichen Ort, eingegrabene Tiere dagegen auf Grund von Beobachtungswerten 17 Tage (Berechnungen deuten jedoch auf einen korrigierten Endwert von 27 Tagen hin). Es wird angenommen, daß spontanes Schwimmen im wesentlichen nur im Anschluß an Störungen durch andere Tiere erfolgt. Die Orientierung am Boden richtete sich vorwiegend nach dem am Untersuchungsort praktisch nur in einer Richtung laufenden Wasserstrom. *P. maximus* orientierte sich dabei im allgemeinen derart, daß die Wasserströmung ihre Freßströmungen unterstützt.

INTRODUCTION

The scallop is a large bivalve mollusc of commercial importance, which normally occurs sublittorally in depths greater than 10 m. It lies recessed in the bottom in a hollow, which it excavates itself, so that the upper valve is level with, or slightly below, the surface. It can swim by repeatedly closing the valves to expel jets of water, but progress is ungainly and inefficient. Previous studies of the scallop by diving include measurements of density on the bottom, and observation of various aspects of behaviour (BAIRD 1958, 1966, BAIRD & GIBSON 1956).

The ability of scallops to swim has resulted in suggestions that they make considerable migrations. This has been investigated by tagging and releasing scallops, and later recapturing them by dredging. The results have indicated that any movement is local (GIBSON 1956, MASON 1957). Confirmation was provided by tank observations that on a suitable substrate scallops recessed and did not move thereafter (BAIRD 1958). In addition, an examination of neighbouring populations on contrasting bottoms, whose members differed in size and colour, indicated little or no interchange (BAIRD & GIBSON 1956). However, to date there have not been any prolonged observations of particular specimens under natural conditions. The aim of this in-

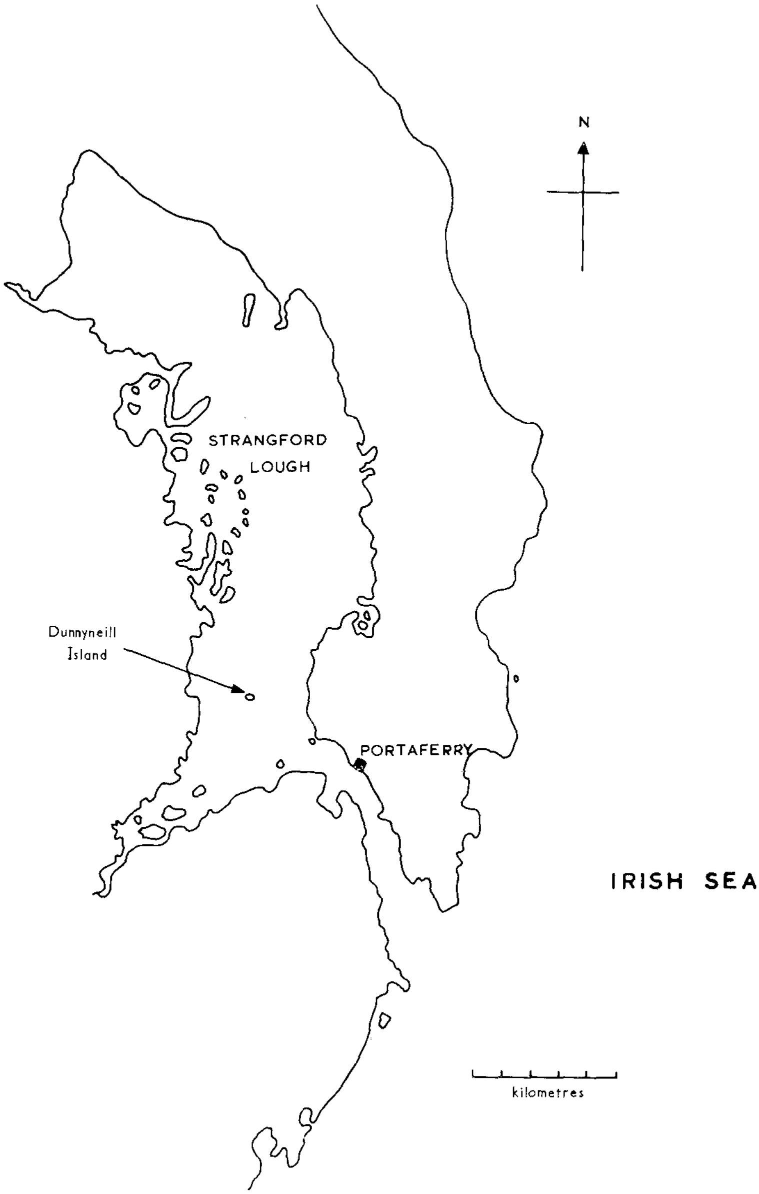

Fig. 1: Map of Strangford Lough to show the position of Dunnyneill Island where the observations were made

vestigation was therefore to examine a number of scallops at regular intervals, and thus to determine the frequency with which they moved.

The area chosen for this study lay in Strangford Lough, a large inlet opening to the Irish Sea by a narrow channel (Fig. 1). Within the Lough, conditions are sheltered, but the tidal currents are very complicated and generally strong, and there are large variations in depth and substrate. Consequently, the scallop beds are restricted to a

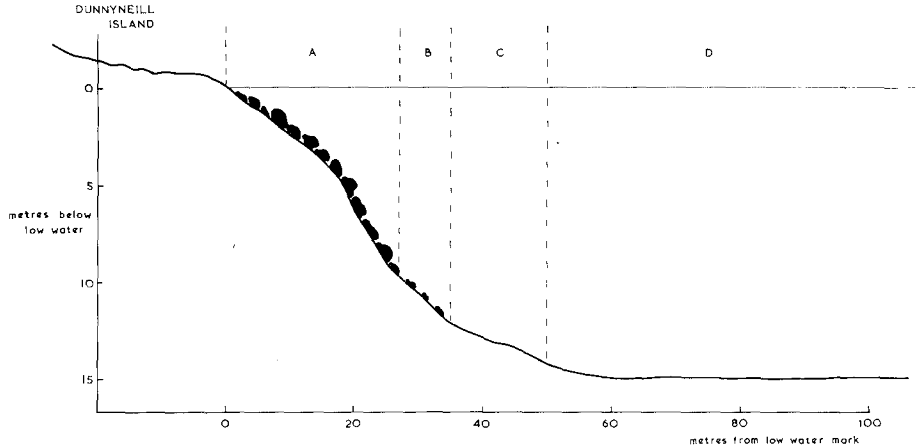

Fig. 2: Profile of the experimental area. The vertical scale is magnified three times. A to D are the different substrates described in the text

number of small areas where conditions are suitable. The programme was carried out on one of these beds, off Dunnyneill Island, and Figure 2 is a profile of the area with the vertical scale exaggerated. The substrate is readily divisible into four regions. (A) Rocks with a dense cover of algae; (B) Sand, with scattered rocks bearing algae; (C) Coarse muddy sand, with a very dense population of *Ciona intestinalis;* (D) Muddy sand, the scallop bed itself.

The work was carried out on area D, a level bottom in a depth of 15 m at low water, composed of muddy sand with a scattering of small stones. The larger members of the epifauna are listed in Table 1 and are predominantly echinoderms and tunicates, with a smaller number of crustaceans and molluscs. The scallops themselves occurred at a density of about one to every $1^1/_2$ m^2, and over 90 percent of them were recessed in the bottom.

The area experiences unusual tidal currents. During the ebb tide the water flows between east and east-south-east, with a velocity up to 2 km per hour. During the flood tide there is at first a slight westerly current, but afterwards an easterly current of irregular velocity, but at times as strong as during the ebb. The overall result is that all the strong tidal flow is towards the east.

METHODS

It was first necessary to locate a series of reference points on the sea bed. A weight with a line and marker buoy were put down to act as a base (Fig. 3), and along a line running north from this a series of wooden pegs were driven into the bottom. The pegs were 60 cm long, they were easily driven in with a hammer, and none came loose during the experiment. Sixteen numbered pegs were used, placed at 2 m intervals. The experimental area was a strip $1^1/_2$ m wide to the west of the base line,

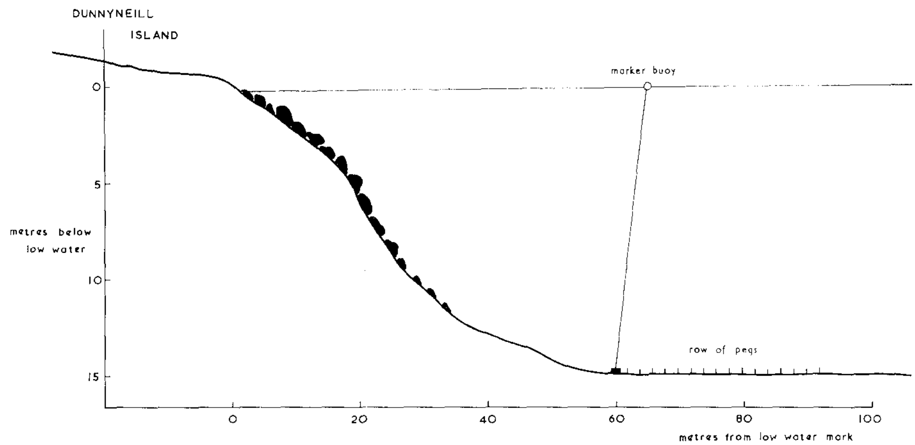

Fig. 3: Profile of the experimental area to show the location of the marker buoy and the reference pegs

covering an area of 45 m² and containing about thirty scallops. The position of each of these scallops was recorded by using a special measuring frame made from aluminium strip (Fig. 4). This consisted of a base scale, which in use was located against two of the reference pegs, and a sliding scale at right angles to it. As the sliding scale was moved along the base scale the position of each scallop it passed over was recorded as a pair of co-ordinates obtained by reading the two scales. Additional information was noted for each specimen at the same time – whether it was recessed, and its orientation on the bottom, recorded as the direction in which the dorsal margin faced. The frame was moved along the line of pegs, covering the area between successive pairs, until the whole strip had been examined. These observations did not cause any serious disturbances in recessed specimens; they would retract their tentacles and close the valves of their shells, but none attempted to swim. However, scallops lying free on the surface did occasionally swim when a diver approached.

As far as practicable these observations were repeated at intervals of 4 or 5 days. Because of the importance of disturbing the specimens as little as possible, it was not considered practicable to mark those under observation in any way. However, the frame enabled their position to be accurately recorded, and since they are quite widely spaced, when a scallop was found in the same position on succeeding visits, it was reasonable to assume that it was the same specimen which had not moved in the interval. This assumption was supported by the observations on orientation, and by notes made on scallops of unusual size or appearance. By this means the arrival and depar-

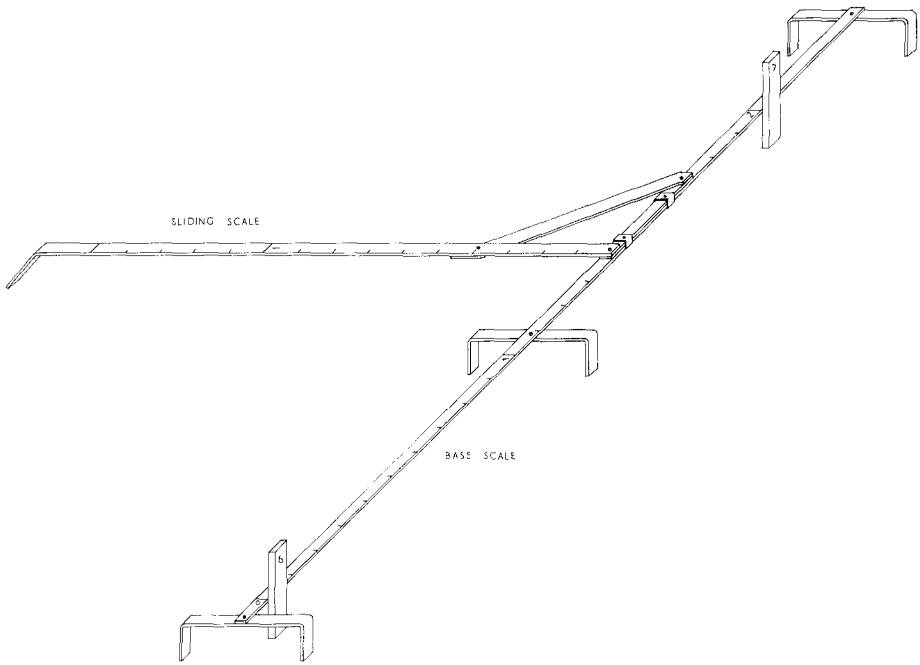

Fig. 4: Diagram of the aluminium frame used for plotting the position of the scallops. The base scale is shown in position against two of the reference pegs

ture of specimens was recorded, and the length of time between movements calculated. Unfortunately, this technique gave no indication of the nature of the distances which specimens moved, whether to and from adjacent parts of the experimental strip, or to and from distant parts of the bed. The programme extended over eight weeks, although the complete line of pegs was not in position for the first two weeks. The data accumulated on movement and orientation will be examined in turn.

FREQUENCY OF MOVEMENT

By the above methods it was possible to determine how long each scallop remained in one position on the sea bed. The results are summarized in Table 2 and in Figure 2. Those for recessed specimens are kept separate from those for unrecessed specimens, and complete observations, those of scallops whose arrival and departure were both recorded, separate from those on individuals present at the start or finish of the programme. The observations covered 79 specimens, of which only six did not move.

Table 1

The epifauna of the experimental area

Abundant – specimens found in every square	**Common** – more than six specimens found in each series of observations
Pecten maximus	*Eupagurus bernhardus*
Echinus esculentus	*Eupagurus prideauxi*
Ophiocomina nigra	*Buccinum undatum*
Ophiophrix fragilis	**Occasional** – one or two specimens found in each series of observations
Ophiura albida	*Cancer pagurus*
Ascidiella aspersa	*Eledone cirrhosa*
Ciona intestinalis	*Asterias rubens*
Clavelina lepadiformis	*Solaster papposus*

Table 2

Length of time for which scallops remained in the same position. Incomplete observations are those where the specimen was present at the start or finish of the experiment

Days	Unrecessed specimens		Recessed specimens	
	Observation complete	Observation incomplete	Observation complete	Observation incomplete
0 to 5	3	–	15	1
6 to 10	2	1	3	9
11 to 15			4	7
16 to 20			4	4
21 to 25			3	4
26 to 30			1	5
31 to 35			–	–
36 to 40			–	6
41 to 45			2	3
46 to 50			–	1

There were only six unrecessed specimens, but five of these provided complete observations. None remained in one place longer than 10 days, and the average stay was only 6 days. Of the more numerous recessed specimens the longest observed stay was 48 days, and the average stay was 17 days. But Figure 5 shows that this average is calculated from a considerable proportion of incomplete observations, which means that a longer period of study would certainly have given a higher average. However, it is possible to make an approximate correction for this. Consider the group of scallops already present at the start of the observations: provided that the great majority of these do move during the programme, as was the case, on average they will be observed in position for half of their true average stay. The same reasoning applies to those scallops which arrived during the programme, but were still present at its termination. Thus if the length of all the incomplete observations is doubled, these can be combined with the complete observations to give a corrected average of 27 days.

Table 3

Orientation of specimens recorded as the direction in which the hinge faced. The last column is the sum of the days for which the various specimens were observed in these positions

Direction (Degrees from North)	No. of scallops	No. of days
0 to 22.5	6	97
22.5 to 45	2	43
45 to 67.5	6	111
67.5 to 90	16	216
90 to 112.5	17	245
112.5 to 135	11	177
135 to 157.5	1	10
157.5 to 180	2	27
180 to 202.5	1	11
202.5 to 225	1	6
225 to 247.5	1	8
247.5 to 270	2	25
270 to 292.5	4	102
292.5 to 315	2	28
315 to 337.5	4	63
337.5 to 360	5	96

In summary, unrecessed scallops move regularly and do not remain more than a few days in one position. Such specimens will probably recess on finding a suitable position. When recessed, however, scallops remain in the same place for a period averaging nearly a month. It is probable that when satisfactorily recessed they do not swim spontaneously, but only if disturbed. The list of epifauna on the experimental area (Table 1) suggests possible causes of disturbance. The starfish *Asterias rubens* and

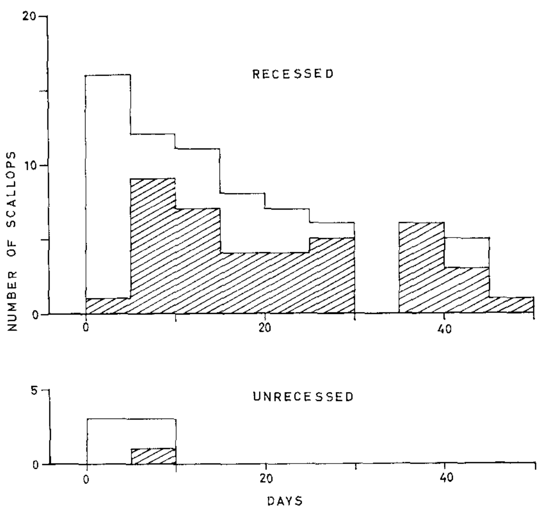

Fig. 5: Histogram of the time which scallops remained in the same position. Shaded areas are incomplete observations, clear areas are complete observations

the whelk *Buccinum undatum* are both known predators of the scallop, and the starfish at least can promote swimming by its proximity. The edible crab *Cancer,* with its bulk and its burrowing activities, and the lesser octopus *Eledone,* could both also result in disturbance. Thus sufficient causes are present to account for the observed incidence of movement without postulating spontaneous activity by the scallop.

ORIENTATION

This was recorded by noting the direction in which the dorsal margin, that is the side bearing the hinge of the shell, faced. Normally this did not change between observations, although a few specimens altered their orientation without changing their overall position. A preliminary examination showed that the scallops were not randomly orientated, and so a more detailed study was made in an attempt to correlate orientation with environmental factors. The 360 degrees of the compass were divided into 16 equal sectors of 22½ degrees, and the number of scallops facing each of these sectors was totalled (Table 3). In order to give due weight to specimens which remained facing in one direction for long periods, the number of days that these scallops faced each of the sectors was totalled (Table 3; Fig. 6). In fact, the two sets of results gave very similar distributions. The bias of the orientation is clearly shown when these figures are totalled for the four quadrants centred on the main points of the compass:

North-west to north-east	299 days	24 %
North-east to south-east	749 days	59 %
South-east to south-west	54 days	4 %
South-west to north-west	163 days	13 %

To account for this, some asymmetrical feature of the environment must be found, and the tidal flow is an obvious possibility. As mentioned above, due to the peculiar topography of this area the only strong tidal currents, on both ebb and flood tides, flow between east and east-south-east. Scallops are filter feeders, depending on relatively weak ciliary currents to carry water into and out of the mantle cavity. It is necessary to examine these currents, and determine how they were arranged with respect to the tidal flow.

A study of the literature revealed two different accounts of the currents of the scallop. According to DAKIN (1909) the water enters around the anterior and ventral margins, and leaves from the postero-dorsal margin (Fig. 7A). According to REES (1957) the water enters around the ventral margin, and leaves both antero-dorsally and postero-dorsally (Fig. 7B). Personal observations, using a mixture of milk and sea water to trace the flow, showed that DAKIN's interpretation was correct. There is a gentle inhalent current around most of the shell, but in the postero-dorsal quarter there is a stronger exhalent current; this emerges parallel to the top valve of the shell, and can be traced a distance of about 10 cm.

Figure 7C shows how these ciliary currents are related to the prevailing tidal flow when the scallops are orientated on the bottom in different ways. In two of the

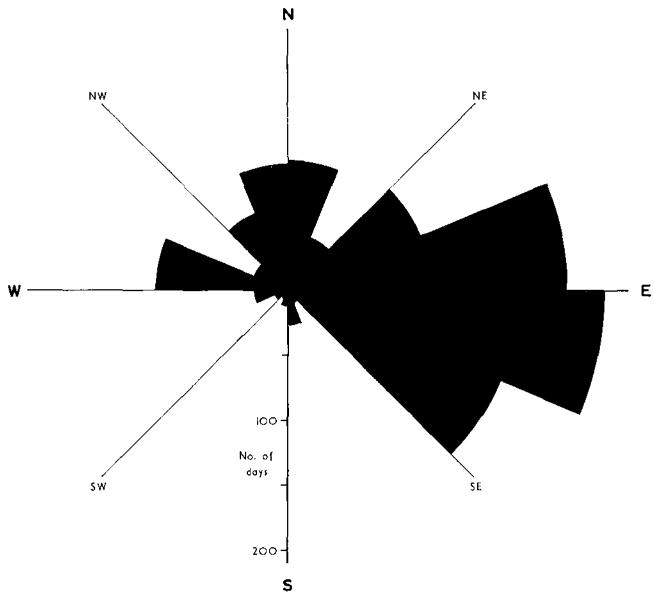

Fig. 6: Histogram demonstrating the non-random orientation of scallops. The figure for each sector is the sum of the days for which the various specimens faced in that direction

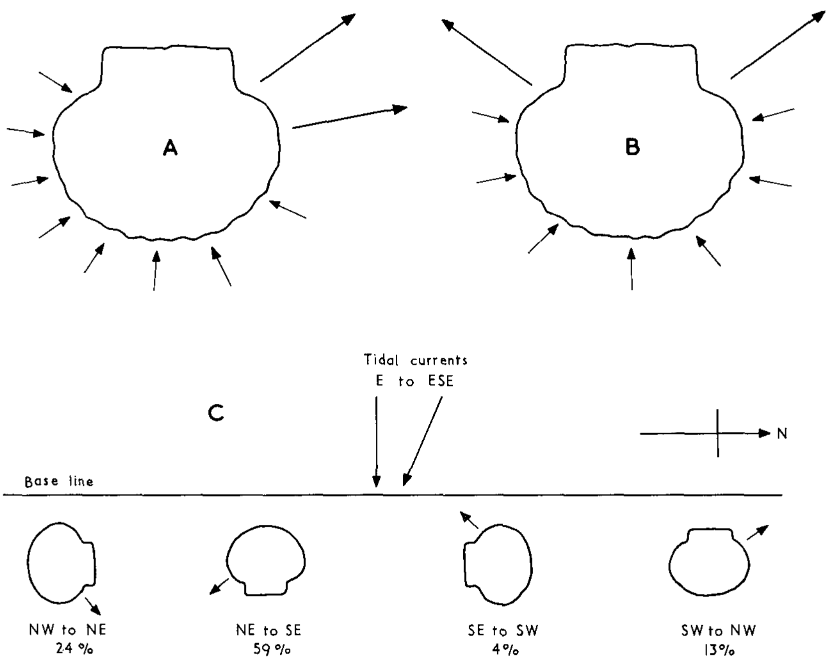

Fig. 7: (A) The currents of *Pecten* as described by Dakin (1909). (B) The currents of *Pecten* as described by Rees (1957). (C) Relation between orientation and tidal currents. The specimens are apportioned between four quadrants centred on the main points of the compass: the proportion in each is shown, together with the direction of the exhalent current

quadrants, facing north-west to north-east and north-east to south-east, the exhalent current is in the same direction as the tidal flow, which thus assists the currents of the scallop: 83 % of the observations lay within these sectors. In the other two quadrants, facing south-east to south-west and south-west to north-west, the ciliary currents are opposed by the tidal flow, and only 17 % of the observations lay within these sectors. Thus there is a good and understandable correlation between orientation on the bottom and the prevailing tidal flow.

It was quite fortuitous that an area with these peculiar conditions was selected for the experiment: at the start of the programme the pattern of tidal flow was not known in any detail. The next step will be a study in an area with normal reciprocating tidal currents, and perhaps experimental observations in a flow tank. Will this disclose a random orientation, or will changes in the direction of the current induce changes in orientation?

CONCLUSIONS

It appears that under the conditions of these observations adult scallops do not move frequently. However, this does not preclude small specimens from moving more extensively, or regular movements from occurring on other grounds or at other seasons. Under the unusual circumstances of virtually unidirectional tidal flow scallops tend to orientate themselves so that their ciliary currents are assisted by the tidal currents. The situation when there is a regular reversal of tidal flow is now known.

SUMMARY

1. In the experimental area specimens of the scallop, *Pecten maximus*, occur at a density of one every $1^1/_2$ m^2. Over 90 % are recessed in the bottom.
2. Unrecessed specimens remain in the same position on an average for 6 days. Recessed specimens remain on an average 27 days.
3. The experimental area has virtually unidirectional tidal flow. The scallops tend to orientate themselves on the bottom so that this flow complements their ciliary currents.

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Discussion following the paper by HARTNOLL

WIESER: Is it possible that the recessed scallops which do not move are in a dormant physiological condition?

HARTNOLL: My observations have shown that recessed scallops have slightly open shells and extended tentacles and appear to be feeding and behaving normally. They show no signs of being dormant.