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A method for monitoring the spatfall of mussels (*Mytilus edulis* L.)

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A method is described of monitoring the abundance of spat mussels (*Mytilus edulis*) in the sea, using rubberized hair sheet packing material. The spat are released from the hair pad collectors by immersion in sodium hypochlorite solution, and sieved into fractions for examination by reflected light under the microscope. Collectors may be preserved in 5% formalin without affecting the sieving of the spat.

The collectors retain both "primary" and "secondary" spat, from lengths of 0·25 mm upwards, and they are more effective than polystyrene tiles. Their use over a three-year period in the Irish Sea has revealed the continuous presence of mussel spat over a wide range of abundance. Modifications of collector design are discussed.

Introduction

Spatfall of the edible mussel (*Mytilus edulis*) occurs on a variety of natural and artificial materials. In nature, spatfall may depend upon the presence of marine algae, hydroids or barnacles on settlement surfaces (Corlett, 1948; Bayne, 1964; Board and Collins, 1965; Bøhle, 1968); settlements on artificial materials, such as ropes, may be affected by their texture (Mason, 1968). Although the relation of substrate quality to settlement intensity is not clear, spatfall seems to be encouraged by creviced and filamentous surfaces (Blok and Geelen, 1958). Experimental investigation of mussel spatfall in different places and seasons requires a standardized collector. Spatfall on smooth materials, such as plates of asbestos-cement (Boëtius, 1962), ground glass (Wiseley, 1964), and unglazed flooring tiles (Corlett, 1948), may be very dependent on previous growths of filamentous algae and diatoms. For example, Bøhle (1971) found that spatfall over 3-day periods was greater on polystyrene tiles previously settled by benthic diatoms than on clean tiles. The reduction of such variable factors in spatfall monitoring would seem to require an artificial filamentous or creviced collector material, itself sufficiently attractive to spat to outweigh the effects of previous fouling.

During experiments at Conwy, 1963–65, on inducing spatfall on gorse (*Ulex europaeus*), following Chilean methods reported by P. R. Walne (personal communication), rubberized hair packing sheet (trade name "Hairlok") was found to be a more effective and reliable spat collector than the gorse. Because of its more or less uniformly filamentous structure, reasonable durability in sea water and ready availability, this material was adopted for spatfall investigations from 1966 onwards. Part of its success depends upon the simple method used to extract the spat from the collector; this is based upon the observation by N. Reynolds (personal communication) that a solution of chloride of lime destroys the byssus threads of mussels.

Materials and methods

The spat collector

The essential part of the collector consists of a fibrous pad of animal hair and synthetic filaments matted together with rubber solution (Hairlok Co. Ltd., Magna Works, Kathie Road, Bedford, England). Various sheet thicknesses and densities are available, but higher densities than that used at Conwy may hinder the extraction of spat. The Conwy collector pad has a specified density of 32 kg/m^3 $\pm$ 10%, measures 15 $\times$ 15 $\times$ 2·5 cm and weights 21–26 g.

The hair pad is held in an envelope of semi-rigid plastic mesh (Fig. 1); the mesh size may depend upon various factors (see Discussion). The envelope measures 26·5 $\times$ 23·5 cm in height and width respectively, with a mesh diameter of 2·2–2·4 mm. The seams are stitched or welded, leaving the top open for inserting the hair pad collector. Since the envelope is changed with the collector it is labelled with waterproof gardening labels tied on with synthetic twine. The mouth of the envelope, 23·5 cm wide, is

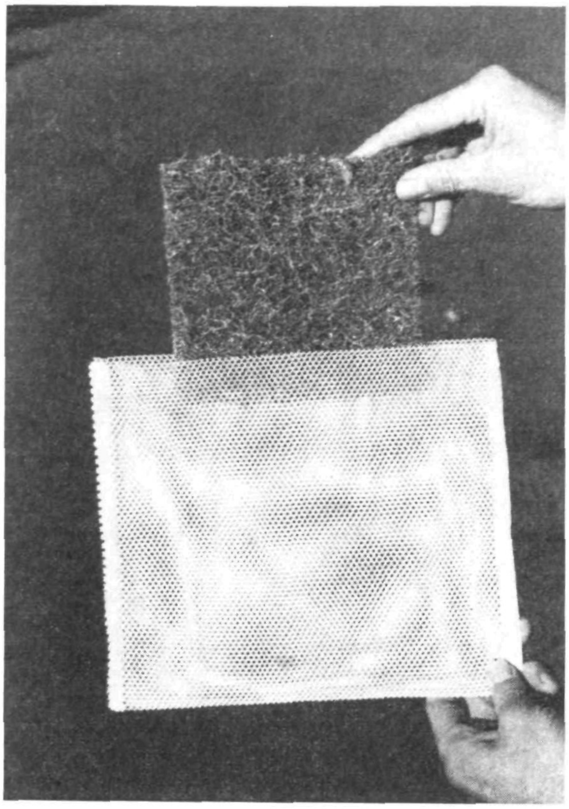

Figure 1. A "Hairlok" collector pad and protective mesh envelope.

held closed between two battens of wood, 38–45 × 1·9 × 0·8 cm. The ends of the battens are tied firmly to the collector frame, and clamped together with a strong wire U-clip.

The collector support

In monitoring intertidal spatfall the collector frame (see Fig. 2) consists of two stakes knocked into the ground slightly more than the width of the collector apart; cross battens on the envelope are tied firmly to these at 30 cm or more above ground. On young mussel beds which, in summer, rise rapidly on their mud, the collectors may become buried in a month. To avoid this, the collectors can either be tied higher, on taller stakes, or inverted above the cross battens so as to leave a larger gap below the collector. The stakes are best made of round metal piping, 2·0–2·5 cm in diameter, and 1·0–1·5 m long, standing 30–40 cm high.

In experiments at Bangor, Menai Straits, and at Roosebeck, Morecambe Bay (P. J. Dare, personal communication), it was found that the standard errors for the spatfall on six hair pads (Table 1) were not more than 14% of the mean. This variation is considered acceptable, and in subsequent investigations the six collectors have been set tangentially around a circle to minimize the effects on their spatfall of changing tidal direction (see Table 5).

To measure sublittoral spatfall the collectors were tied to a horizontal frame hung from a jetty. Sublittoral sampling might be feasible from a boat, using framed horizontal collectors worked like lobster pots. The measurement of spatfall at the surface was accomplished by tying the collectors vertically to the sides of an oblong wooden frame with a float on each corner, and moored to a sinker. A frame of 5·0 × 2·5 cm timber measuring 2 × 1·5 m supported three collectors a side, which were held vertically between taut wires stretched between "dagger plate"

Figure 2. An array of "Hairlok" collectors in place.

Table 1. Typical numbers of spat mussels (*Mytilus edulis*) caught by their pad collectors at low water mark of spring tides in two areas of contrasting spat abundance: (A) Bangor, Menai Straits; (B) Roosebeck, Morecambe Bay

Exposure time	Numbers of spat caught per hair pad Mean	s.e.
1968		
A Jun–Jul	54·6	5·3
Jul–Aug	78·6	8·0
Aug–Sep	128·0	7·3
Sep–Oct	107·6	8·8
1969		
B Mar–Apr	6 529	966·1
May–Jun	31 696	1 538·2
Jun–Jul	28 648	1 962·0
Jul–Aug	49 078	6 557·8
Aug–Sep	6 224	432·4
Sep–Oct	9 885	601·1

corner fins. The bolted corners of the frames were strengthened with synthetic twine in case the wood split or rotted.

Changing and preserving collectors

The pads and envelopes are changed at intervals prescribed by the investigation; these should be restricted to 2–4 weeks for best results, owing to the deterioration of the rubberized hair in the sea (Fig. 3). When changing collectors, new hair pads are used, although used pads will still catch spat after chlorination and washing. The envelopes are also changed, because mussel spat may be found on them. In the changeover, only one end of the battens is untied; after reloading, the end of the twine need not be knotted, but may be jammed tightly between the battens, of which the ends are faired in a V for the purpose.

Each collector, with envelope, is placed in a stout polythene bag of about 500 gauge thickness, 30·5 cm wide and 38 cm deep. If examination of the collectors is delayed for more than a day, these may be preserved in their bags in 5 % formalin, preferably neutralized for long storage. The bags are closed with paper clips and stacked upright in a covered trough. Live storage of collectors in seawater tanks risks intrusion by extraneous spat or losses through emigration.

Extraction of spat from the collectors

The formalin in the polythene bags is strained through

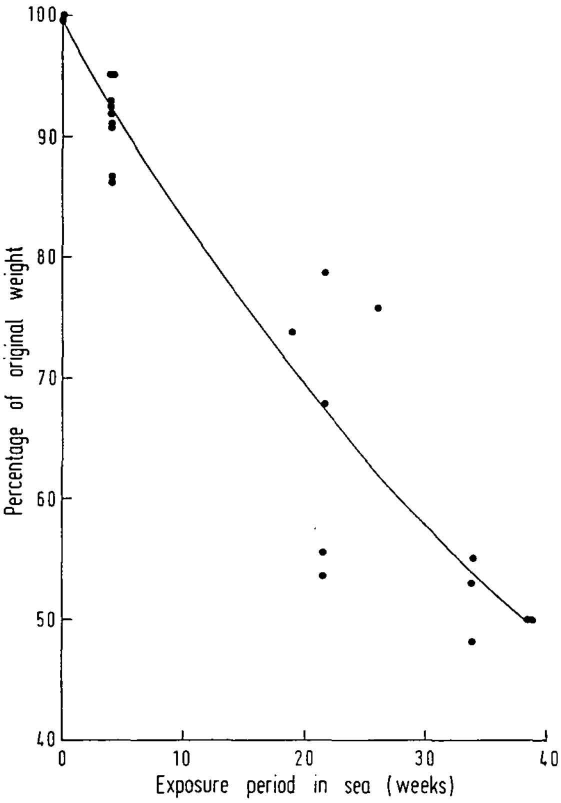

Figure 3. The loss in weight of "Hairlok" collectors during long-term exposure in the sea (curve fitted by eye; each point is the mean for a group of 2–10 collectors).

a 0·124 mm mesh sieve and allowed to settle for re-use. The hair pad and its envelope are thoroughly rinsed in a trough of water and then soaked for 3 minutes in about a litre of a 20 % solution of commercial sodium hypochlorite (we use "Chloros"). The hypochlorite solution, containing spat, is strained through the 0·124 mm mesh sieve, and used again for the next collector after the addition of a further 50 ml of the concentrated solution to maintain its strength. The envelope and hair pad are rinsed under the tap into the trough; with heavy spatfalls the pad may need shredding to free the larger mussels trapped inside. All the washing water in the trough is then strained trough the 0·124 mm mesh sieve to recover the spat and detritus. If, after a spot check, no "primary spat" (Bayne, 1964) are found in the sample, subsequent collectors from a given station may be extracted through a 0·210 mm mesh sieve, which lets through much of the silt and detritus but retains most of the spat usually found on the 0·124 mm mesh sieve.

Preparation of spat for examination

The material on the 0·124 mm mesh sieve is washed through a series of successively finer sieves in order to separate large and small particles for easier examination and to determine the approximate size composition of the sample. The mesh sizes used at Conwy were arbitrarily chosen; the sizes of spat retained by them are given in Table 2. Spat on the largest and smallest meshes vary in size according to seasonal growth rates and to their settlement times in relation to the exposure period of the collectors.

Each sieve is shaken 200 times in a bowl of water. The proportions of spat in the various fractions, in conjunction with Table 2, give a rough indication of the size composition of the whole sample. Table 3 shows a typical population graded by sieves. The sieved fractions are kept in water before examination to prevent entry of air bubbles which would cause spat to float under the microscope. The sieve-grading is unaffected by the treatments with formalin and hypochlorite, in which solutions the shell valves remain closed throughout, but long exposure to air before preservation and examination could make the valves gape.

Table 2. The sizes of spat mussels (*Mytilus edulis*) separated by a series of sieves of successively smaller mesh diameters

Sieve mesh diameter (mm)	Shell lengths (mm) of mussels retained		
	Mean	Minimum	Maximum
2·3	–	4·5	–
1·050	2·85	2·0	4·5
0·780	1·73	1·25	2·25
0·611	1·27	1·00	1·75
0·348	0·87	0·50	1·25
0·124	0·50 (approx.)	0·25	1·00

Table 3. A typical size composition for spat mussels (*Mytilus edulis*) settling on hair pad collectors at mean low water mark of spring tides at Bangor, Menai Straits (collectors exposed for the period 4 July 1969 to 1 August 1969)

Sieve mesh diameter (mm)	Number of spat per sieve fraction		Proportion (%) of spat
	Mean	s.e.	
2·3	4·50	1·27	2·3
1·050	38·75	11·15	19·8
0·780	72·50	15·45	37·1
0·611	27·25	4·49	13·9
0·348	43·75	10·14	22·4
0·124	8·75	16·32	4·5

Table 4. A comparison of the numbers of spat mussels (*Mytilus edulis*) caught by rubberized hair pads and polystyrene tile collectors, at mean low water mark of spring tides, Heysham, in Morecambe Bay

Exposure time	Mean number of spat per collector (number of collectors in parentheses)	
	Hair pad	Polystyrene tile
1968		
9 Oct–22 Nov	8 700 (6)	466 (3)
22 Nov–23 Dec	2 650 (6)	999 (1)

Buoyant debris mixed with the spat in some fractions can be floated off on the elutriation principle, in a regulated flow of water, while other fractions are being examined. With silty samples the spat can be washed out if water is run down a gently sloping chute over constantly agitated material.

Examination of spat

Each sieved fraction is examined separately in water. Spat retained by sieves of mesh sizes over 0·611 mm are counted on a gridded white tray, using a hand counter and usually a hand lens (× 1·5). For smaller spat a swinging arm binocular microscope (× 12·5) is convenient; this scans a transparent perspex dish 15 × 10 × 1·2 cm, with a 7 mm grid scratched on the bottom – one square just occupies the field of vision. The dish is lit from one side, slightly above or below its own level; it is held over a completely dark background for maximum contrast.

When spat numbers exceed 1000 per fraction, subsampling is accomplished by counting them only on every fifth grid-square. With very large numbers the fractions are weighed, and spat numbers are determined in weighed subsamples. This method is particlarly useful when it is necessary to pool samples from several collectors in order to save sieving time.

Results and observations

The effectiveness and reliability of the rubberized hair pad as a collector of mussel spat may be judged from the size range of the spat caught, its catching power in comparison with those of other collectors, and its durability in the sea.

Size range

An example of the sizes of spat settling on hair pad collectors is shown in Figure 4. The abundance of 0·25–0·50 mm length spat shows that this material

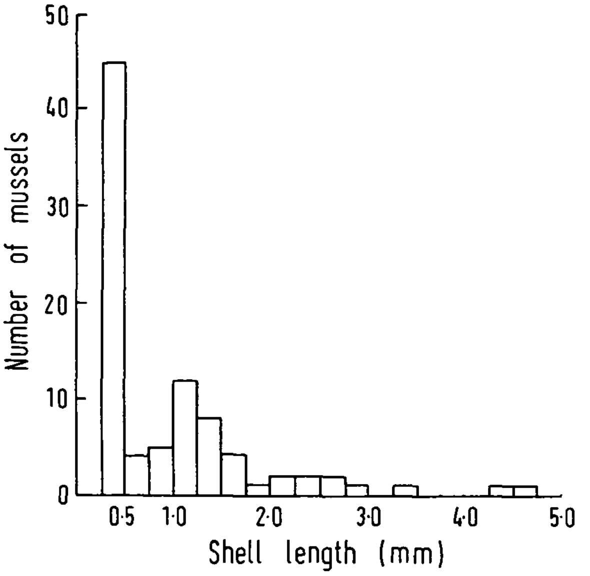

Figure 4. The size composition of the mussels on a "Hairlok" collector exposed at low water mark of spring tides at Bangor, Menai Straits, 22 June–21 July 1967.

retains the "primary" spatfall found in nature on filamentous algae and hydroids (Bayne, 1964), as well as the larger "secondary" spat stage.

Catching power

Examples of the range of spat numbers caught by a 15 × 15 × 2·5 cm hair pad collector are shown in Table 1. The variations in catch between collectors on a station may be due partly to differences in their orientation to the tidal stream, in their fouling by marine organisms, weeds and debris, or in their smothering by mussel mud.

Spat numbers on hair pads were compared with those on polystyrene tiles, similar to those used in Norwegian experiments (Bøhle, 1971). The hair pads measured 15 × 15 × 2·5 cm, the polystyrene tiles 15 × 15 × 0·65 cm. Six of each type were set out together in Morecambe Bay; after one month in the sea the tiles were buckled inside their covers, whereas the hair pads stayed flat throughout. Table 4 shows that the hair pads caught much greater numbers of spat. A further disadvantage of the polystyrene tiles is that some spat are trapped in pits in the material, and can be extracted only by dissection (P. J. Dare, personal communication).

Orientation of collectors to the tidal stream

Four comparisons were made of settlements in hair pad collectors set vertically at right angles to each other under moored floats swinging with the tide. In each trial 12 collectors were broadside to, and 12 were parallel to, the tidal flow at all times (Table 5). In periods 1 and 2 there were no significant differences in collector catches, but in Periods 3 and 4 the collectors broadside on to the tide had significantly more spat. In Periods 1 and 2 algal fouling was heavy, and in Period 3 this was markedly heavier on collectors placed broadside on to the tide. This clogging of the collector cover meshes by seaweeds could have masked the effects of tidal orientation on catches, which was greatest when the collectors were cleanest, in Period 4. Although these results are based on very small numbers of spat, they suggest that tidal orientation might affect catches on flat pad collectors.

Any effect that changes in tidal direction might have on catches in vertical collectors can be reduced by setting these tangentially in a circle, to give a mean catch for a given station. Cylindrical vertical collectors might also overcome this problem, but these have not been investigated. Alternatively, flat pad collectors may be set horizontally.

Table 5. Comparison of the numbers of spat mussels (*Mytilus edulis*) on hair pad collectors set vertically on a floating frame either at 90° to or parallel to the tidal flow

Period	Exposure time	Degree of algal fouling on collectors	Number of spat per collector				Significance of difference
			90° to tide		Parallel to tide		
			Mean	s.e.	Mean	s.e.	
	1967						
1	21 Jul –23 Aug	heavy	25·7	2·8	20·2	1·9	n.s.
2	23 Aug–22 Sep	heavy	12·1	1·3	9·3	1·3	n.s.
3	22 Sep – 2 Nov	moderate	19·6	3·3	11·1	1·1	$P < 0·05$
4	2 Nov–29 Nov	very slight	14·0	1·1	3·3	0·7	$P < 0·001$

Table 6. A comparison of the numbers of spat mussels (*Mytilus edulis*) caught on vertical and horizontal hair pad collectors in the Menai Straits, at mean low water of spring tides

Station	Period	Exposure time	Numbers of spat caught per 20 g hair pad collector: Vertical pads Mean	Vertical pads s.e.	Horizontal pads Mean	Horizontal pads s.e.
		1967				
I	1	22 Jun –20 Jul	71·1	6·1	49·0	10·3
	2	20 Jul –22 Aug	132·1	6·3	78·5	6·7
	3	22 Aug–21 Sep	181·3	13·2	240·0	52·1
	4	21 Sep –19 Oct	220·6	21·5	172·7	19·2
		Total	605·1		540·2	
II	1	22 Jun –20 Jul	56·8	5·5	51·5	3·3
	2	20 Jul –22 Aug	84·8	8·7	78·8	16·0
	3	22 Aug–21 Sep	109·4	6·0	98·5	11·2
	4	21 Sep –19 Oct	93·6	8·3	99·0	11·2
		Total	344·6		327·8	
III	1	22 Jun –20 Jul	42·8	4·4	37·5	4·4
	2	20 Jul –22 Aug	152·6	11·2	131·0	18·8
	3	22 Aug–21 Sep	140·9	7·7	102·3	13·0
	4	21 Sep –19 Oct	121·0	5·7	113·5	10·9
		Total	457·3		384·3	
		Grand total	1 407·0		1 252·3	

Note: Catches are expressed in terms of collector weight in order to minimize possible effects of small variations in consistency of the manufactured material. At each station four pairs of vertical and two pairs of horizontal collectors were set out. The end stations were one n. mile apart.

Orientation of collectors to gravity

A comparison was made of spat settlements in horizontal collectors and in vertical collectors set in pairs at right angles to each other to give a mean value. The results, given in Table 6, show no consistent differences between the orientations tested, although the results show a trend towards higher catches on the vertical pads. Such comparatively small differences suggest that horizontal collectors might be almost as effective as vertical collectors in spatfall monitoring, especially where their tidal orientation could not be controlled, for example when setting collectors from a boat.

Durability and length of exposure

The effect of exposure on rubberized hair is shown in Figure 3, which shows weight losses of collectors left in the sea for 1–9 months. All the collectors were treated with 20% "Chloros" to extract the spat, and this may have caused some losses in weight. However, the decreasing weight with longer immersion times suggests that the immersion itself caused the main loss of hair pad material and, thus, it probably affected catching power adversely. In addition, heavy silting may occur in long-term collectors, especially with spat settlements under small-meshed covers. The effects of immersion and silting therefore suggest that the rubberized hair sheet is best used for short observation periods in the monitoring of spatfall. This conclusion is also supported by a study of the effects of immersion period on the survival of spat on collectors under meshes of different diameters (Tables 7 and 8).

Collector covers

The original purposes of the small-meshed collector cover were to keep the hair pad flat and make it

Table 7. Comparison of the numbers of spat mussels (*Mytilus edulis*) caught by standard hair pad collectors in large-mesh (51 mm) and small-mesh (2·5 mm) covers during 5 months on the shore at mean low water mark of spring tides, Bangor, in the Menai Straits

Sizes of spat (mm)	Numbers of spat caught per collector in mesh covers of diameter: 2·5 mm Mean	2·5 mm s.e.	51 mm Mean	51 mm s.e.
0–5	28·1	3·4	49·8	3·6
5+	175·7	12·3	27·1	3·4
Total	203·8		76·9	

Table 8. Comparison of the mean number of spat mussels (*Mytilus edulis*) caught on six hair pad collectors kept in cages of various mesh sizes at mean low water mark of spring tides at Bangor, Menai Straits

Exposure period	Size range of mussels (mm)	Mesh sizes of cages (mm)							
		2·5*	2·5	6·3	12·7	19·0	25·4	51	open
19 June 1967–1 Jan 1968...	0– 5	–	106	126	143	214	192	248	291
	5–35	–	49	33	32	61	60	54	42
	Total	–	155	159	175	275	252	302	333
15 Jan–29 July 1968.......	0– 5	234	155	284	239	264	242	240	–
	5–35	592	427	505	194	303	399	226	–
	Total	826	582	789	433	567	641	466	–

* Collector in flat envelope as used subsequently for spatfall monitoring.

easier to handle, to keep it intact (especially on wave-beaten shores), and to reduce predation of the spat by crabs (*Carcinus maenas*). Although these are still valid reasons for using a collector cover, the best size of mesh to use (2·5 mm) is problematical. In certain situations, the clogging of small-meshed covers by algal fouling may reduce spat settlement on the hair pads inside; the use of larger-meshed covers to minimize fouling is an obvious possibility and, perhaps surprisingly, one which is indicated by later investigations into the predation of mussels by *Carcinus*.

The great vulnerability of small (< 30 mm) mussels to crab attack suggested that predation might be even greater upon mussels at their settlement stage; indeed, predation by very small crabs (4–8 mm carapace width) on 3 mm length mussels was subsequently confirmed by Walne and Dean (1972). These observations suggested that the enclosure of collectors in small-meshed covers could protect spat settlements from predation. To test this idea, hair pad collectors were set out in 1966 inside sealed envelopes of mesh widths 2·5 mm and of 51 mm. Table 7 shows that, after 5 months (June–October), the small-meshed (2·5 mm) collectors contained very highly significantly ($P < 0·001$) more mussels over 5 mm in length than did the large-meshed (51 mm) collectors. Conversely, the large-meshed collectors contained highly significantly ($P < 0·01$) more spat under 5 mm in length than did the small-meshed collectors. Thus, the small mesh size did not cause any increase in the yields of recently-settled spat in comparison with those on the virtually open collectors.

In two further experiments the relation of cover mesh size to spatfall yields was further investigated, by setting out hair pad collectors in cages of various mesh sizes (Tables 8 and 9). The results of these experiments partly confirmed those shown in Table 7; in Table 9 yields of spat under 5 mm in length were significantly greater in cages of large mesh size (51 mm) than in the small-meshed (2·5 mm) cages ($P < 0·01$).

Table 9. Comparison of numbers of 0–5 mm length mussels (*Mytilus edulis*) in individual hair pad collectors inside cages of 2·5 and 51 mm width meshes, at mean low water mark of spring tides, Bangor, Menai Straits

Immersion period	Collector	Numbers of mussels under 5 mm	
		2·5 mm mesh	51 mm mesh
19 June 1967–1 Jan 1968	A	83	283
	B	107	212
	C	101	239
	D	97	239
	E	149	240
	F	99	272
15 Jan–29 July 1968	H	135	194
	I	207	271
	J	122	255

The differences shown in Tables 7 and 8 between the relation of mesh size to collector yields of mussels over 5 mm in length may have been partly due to predation on spat by crabs trapped inside the cages. In the two experiments described, 70% of cages of mesh width under 19 mm were found to contain crabs of carapace widths up to 35 mm. Spat collectors in 2·5 mm mesh covers have been found in summer to contain hundreds of recently metamorphosed crabs after a month in the sea. From these experiments it may be concluded that the enclosure of spat collectors in small-meshed (2·5 mm) covers may not yield more spat over short periods than open collectors. It should be stressed that the idea of protecting spat with small-meshed covers arose when planning long-term spatfall experiments, in which greater predation effects would be expected than during the 2–6 weeks monitoring periods subsequently adopted with the hair pad collectors.

Discussion

The value of a spat collector in biological investigations depends mainly on how reliably it indicates spat sizes and numbers in the sea. This problem could be resolved only by a separate investigation to compare spat numbers and sizes on collectors with those in plankton samples taken concurrently. The value of a collector also depends upon its capacity to catch enough spat to give meaningful results. The performance of rubberized hair pads, indicated in Tables 1 and 3, shows that adequate data can be derived from a small quantity of collector material in areas of widely differing spat abundance. In Morecambe Bay, for example, monthly catches of a $15 \times 15 \times 2{\cdot}5$ cm collector sometimes exceeded 50 000 spat and rarely fell below 1 000 spat per collector (Dare, 1969).

The attractiveness of rubberized hair to spat is further emphasized by the comparisons with polystyrene tiles (Table 4). The size compositions of the spat caught by the hair pad collectors (see Fig. 4 and Table 2) show that all settlement stages are represented in the samples.

Spat yields on collectors are affected by survival rates with or without predation, by marine fouling, and perhaps by orientation to gravity and the tidal stream. Fouling organisms may increase spatfall, or they may reduce it by clogging the meshes of collector covers. On mussel beds collectors are sometimes buried by mud and debris, a problem which can, however, be overcome. Apart from fouling effects, the collector cover, especially when small-meshed, may itself obstruct spatfall on the hair pads by reducing the flow of water over the collector. These considerations, together with its fouling tendency, raise the question of how essential a cover is in this monitoring technique. The relationships between cover mesh size, fouling, predation and spat yields are likely to be complex; if larger-meshed collector covers are to be considered their catching power would need experimental comparison with that of small-meshed collectors, in order that future observations could be interpreted in the light of previous results. The maximum size of mesh which could be used may, ultimately, be limited by the amount of protection it would give the hair pads against damage by waves, especially on exposed shores.

The use of rubberized hair for catching mussel spat is at present restricted to research purposes. Its application to the collection of spat for subsequent commercial culture would require considerable development work to devise suitable handling methods and to make the best use of the maximum spat settlement period.

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