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Experimental collection and handling of spat mussels (*Mytilus edulis* L.) on ropes for intertidal cultivation

P. J. DARE, D. B. EDWARDS and G. DAVIES

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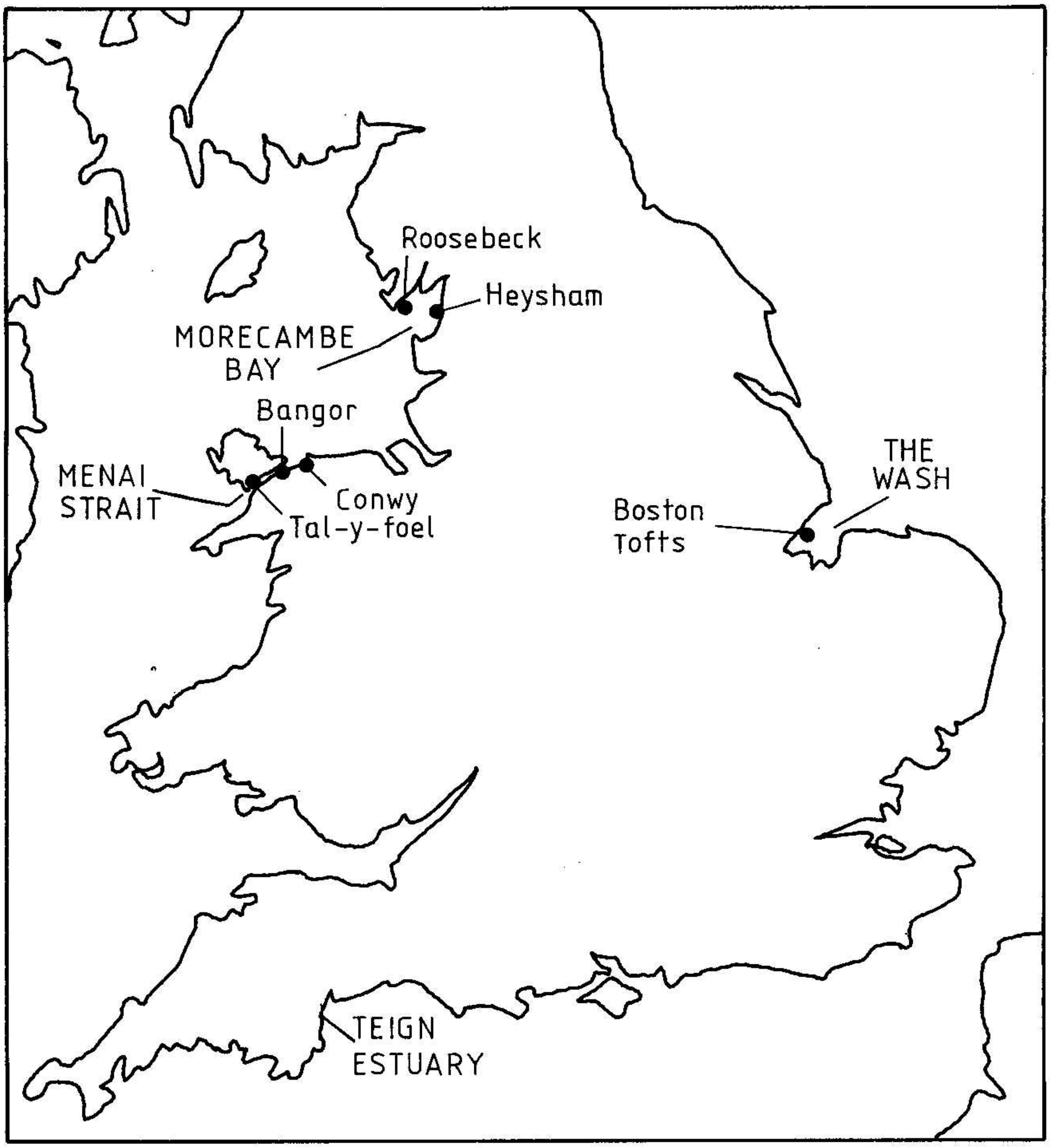


Figure 1 Location of the experimental sites

1. Introduction

The cultivation of mussels in England and Wales is hindered by the irregular supply of seed for relaying and by the high mortality of seed after relaying. The supply problem arises primarily from natural variation in spatfall, but destruction of seed beds by predators or by tidal forces also contributes to shortages (Dare, 1980). There may also be physical and logistical problems in dredging sufficient seed during summer and autumn before the young beds are destroyed or rough weather curtails the dredging season. After relaying, high mortality may result from predation by shore crabs (*Carcinus maenas*) and, on subtidal lays (ground onto which mussels are transplanted), also by starfish, *Asterias rubens*, (Dare and Edwards, 1976; Dare, 1980). A more effective use of the seed resources is therefore essential if mussel cultivation is to be made more productive.

The benefits to be gained by protecting intertidal seed lays within crab-proof fences are reported elsewhere (Davies *et al.*, 1980). The use of fences can increase yields from lays by as much as six times. Consequently, only one sixth of the tonnage of seed may need to be dredged for a given production. However, even this reduced quantity may prove difficult to procure in certain years and localities.

The younger stages or 'spat' of mussels – less than 2 mm in length – are found almost everywhere in British coastal waters. They occur in varying abundance throughout the year (Dare, 1976; Seed, 1969) and can be used for rope cultivation by various flotation systems, such as rafts (Mason, 1969; Dare and Davies, 1975). Recently the Ministry of Agriculture, Fisheries and Food has explored the feasibility of utilising spat settled directly on to ropes for cultivation within fences, as an alternative to dredging and relaying seed stock. The concept is to catch spat on rope collectors (collection stage) as for raft cultivation, and then to grow them still on the ropes attached to racks within fences (nursery stage) intertidally until they reach a size (15–20 mm) suitable for relaying as seed mussels onto the ground (ongrowing stage)

This report (1) presents the results obtained from monitoring the seasonal abundance of mussel spat at various localities in England and Wales, and (2) describes work undertaken during 1976-80 to develop an efficient rope spat collection system and to investigate the problems of handling spatted ropes until the catch has grown large enough to be transplanted to the ground within a crab-proof fence. The techniques developed took account of seasonal changes in spat occurrence and behaviour.

1.1 Definition of spat

For *Mytilus edulis* the term 'spat', which in general usage refers to newly-settled young bivalves, is imprecise, for it actually embraces two or three reasonably discrete stages in a complex early life history. Three stages may be recognised for present purposes characterised by the following size, behavioural and habitat features:

> 'Planktonic spat' which drift in the sea, are usually less than 1.5 mm in length, and are subdivided into spat of primary and secondary settlement stage plantigrades (Bayne, 1964). Primary spat are of size 0.25 – 0.4 mm shell length and are the first attachment stage following metamorphosis from a swimming larva. The spat attach briefly and to filamentous materials only, e.g., certain algae, hydroid colonies or fibrous ropes. This stage is restricted to the subtidal zone, apart from small numbers which sometimes appear briefly on the low shore, and is essentially a migratory and dispersive phase. Primary spat are plentiful only in May-July, soon after the main (spring) spawning, and sometimes again during October-November, after a subsidiary autumn spawning (Seed, 1969; Dare, 1976). At length 0.5 mm they are considered to be secondary spat which, at lengths between 0.5 and 1.5 mm, detach and become planktonic again. Secondary spat occur in the sea throughout the year in widely varying abundance. They attach eventually to hard or creviced surfaces, including ropes, to form visible settlements both intertidally and subtidally. They constitute the recruitment stage to established mussel beds and the colonisers of bare grounds.
>
> 'Ground spat' are secondary spat which have settled on the shore at an initial size of 0.5 – 1.5 mm and have grown to about 15 mm. In high density spatfalls, the spat usually have a mobile, crawling phase when they are 2–5 mm in size.

2. Materials and Methods

2.1 Sites investigated

Four sites were chosen for investigation (Figure. 1): one (Morecambe Bay) for spat collection trials only, one (Menai Strait) for nursery and ongrowing stages in fenced enclosures only, and two (The Wash and Teign Estuary) for evaluation of all stages. The Wash, Teign Estuary and Menai Strait sites were in areas of either mussel fisheries or cultivation, in contrast to Morecambe Bay where there was a known regularity and abundance of spat settlement but unfavourable cultivation conditions (Dare 1976). Details of sites and investigations are given in Table 1. In the Wash and Teign Estuary, intertidal spat collection was undertaken near mean low water of spring tides at the sites of 9 m x 6 m crab-proof fenced enclosures which the collectors were intended to supply with seed, and subtidal collection was attempted at stations respectively 2.3 km and 1.2 km from the fences. The Morecambe Bay trials were intertidal, at various levels between low water marks

Table 1 Sites selected for spat collection trials

Area	Site		Tide level	Year	Investigation stages	
					Spat collection	Nursery + on-growing
					Season	
Morecambe Bay	Roosebeck – A.	Main Skear	LWNT	1977–79	Jan. – May	
	B.	" "	LWST	"	"	
	C.	Out Skear	"	"	"	
	Heysham – Knott End Skear		"	1976	May – June	
Menai Strait	Tal-y-foel		"	1976–79		Jan. – Dec.
The Wash	Boston – A.	Tofts	"	1978-79	April–Oct.	Jan.–Dec.
	B.	Gat Channel	Subtidal	1979	"	
Teign Estuary	A. Mussel bed		LWST	1977–78	Jan.–Oct.	Jan.–Dec.
	B. Harbour		Subtidal	1978	Feb.–Oct.	
	C. Bridge		"	1979	April–Sept.	

(LWNT, LWST = respectively, low water of neap tides and low water of spring tides)

of neap and spring tides, and were intended to provide seed for stocking a 24 m x 10 m fenced enclosure in the Menai Strait, 320 km distant by road. During 1970–72, spatted ropes had been transferred successfully from Morecambe Bay to a raft in the Menai Strait (Dare and Davies, 1975). In France intertidal bouchot (post) systems are restocked with spatted ropes transported long distances by road from the settlement sites (Dardignac-Corbeil, 1975).

2.2 Materials

2.2.1 *Collector ropes*

In the 1970–72 spat collecting trials at Morecambe Bay (Dare and Davies, 1975) three types of collectors had been evaluated: (1) 25 mm diameter coir rope; (2) 10 mm diameter polypropylene rope; (3) lengths of 2.5 x 5 cm 'Hairlok' fibrous rubberized hair (Davies, 1974; Dare, 1976) fastened to stiff plastic mesh, or bound spirally around coir ropes, or enclosed within tubes or "stockings" of 6 mm mesh soft plastic netting. Both coir and 'Hairlok' collectors had captured numerous spat whereas the smooth polypropylene rope had attracted or retained few spat.

During the 1976–80 trials, reported here, coir and 'Hairlok' materials were again used, although mainly of different specifications, together with a new collector in the form of tufted ropes of fibrillated or split film polypropylene (SFP). The three main types of collector used in 5 m and 10 m lengths (Figure 2, Table 2) were:

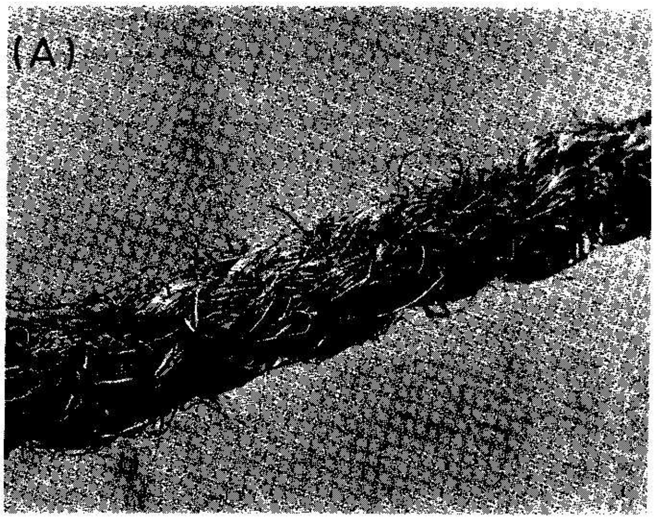
(i) Coir rope, 12 mm diameter, similar to but of a tighter lay than that used in the French industry. (Some 25 mm rope was also used in 1976–77.)

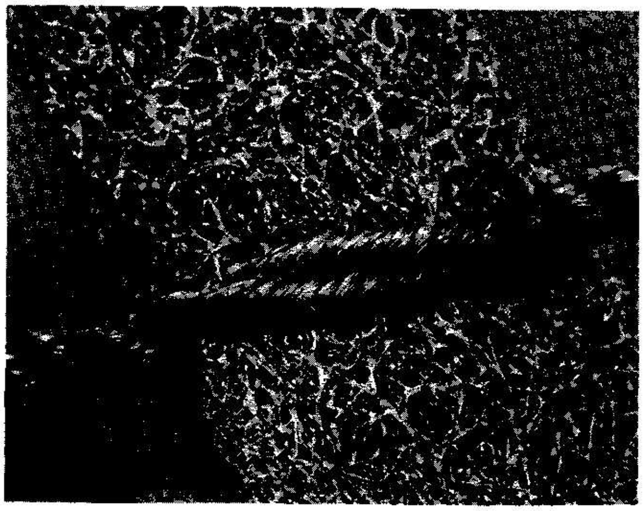
(ii) SFP tufted rope, based on a successful type first used in New Zealand (Tortell, 1976), consisting of a 10 mm diameter polypropylene 'carrier' rope into which were inserted transversely 15 cm long tufts of SFP at 10 cm intervals. Each tuft was frayed and separated manually to produce a ~5 cm wide 'brush' at its ends.

(iii) 'Hairlok' rope, for which, two densities of 'Hairlok' material, 32 and 64 oz/cu ft (32 and 64 kg m^{-3}, but referred to henceforward by the manufacturer's specification as 32 oz and 64 oz) were used and deployed in two modes: (a) in long strips enclosed within 6 mm mesh soft plastic netting (as in 1970–72), the strips being 5 x 5 cm in cross section for 32 oz and 5 x 2.5 cm for 64 oz 'Hairlok'; (b) as pieces 15 cm long and 5 cm x 2.5 cm cross section inserted into 10 mm diameter polypropylene carrier rope at 20 cm intervals, i.e., 5 pieces per metre.

The seasonal patterns of settlement on collectors were monitored by means of monthly test strips which were two

0.5 m long strips of each type of collector placed alongside the ropes. Test strips were exposed for approximately one month, then removed for examination and replaced by new strips. Some strips were exposed for the duration of each trial in order to estimate final catches and to compare those with the cumulative totals of monthly settlements.





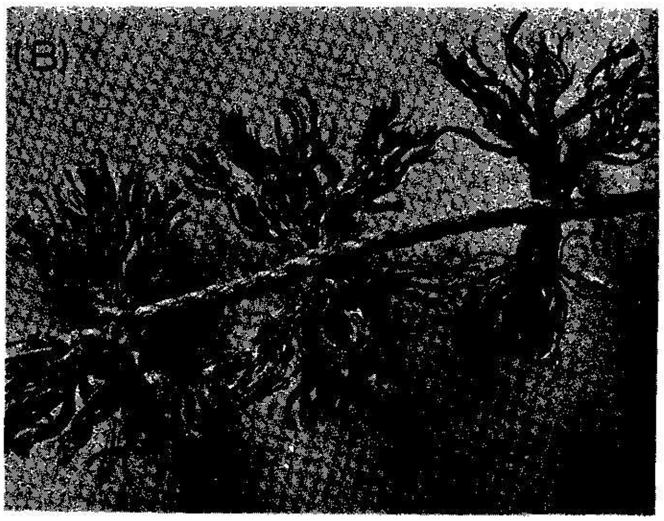


Figure 2 The three main types of spat collector material used in the trials: (A) coir rope (12 mm diameter); (B) split-film polypropylene tufted rope (SFP); (C) 'Hairlok' – close-up view of a 64 oz/ft^3 piece inserted into 10 mm diameter polypropylene carrier rope.

Table 2 Specifications and costs of spat collecting materials

Type	Amount of inserted material per m of 10 mm diam. polypropylene carrier rope	Collector weight (dry) kg/10 m	Cost £/10 m of collector (1981)		
			Materials	Preparation Labour *	Total
SFP tufted	1.5 m	1.2	2.80	2.16	4.96
'Hairlok' 32 oz	0.75 m	0.5	2.20	1.84	4.04
'Hairlok' 64 oz	0.75 m	0.5	2.90	1.84	4.74
Coir (12 mm diam.)	0	0.5	1.80	0.16	1.96

* Labour @ £2/h

2.2.2 *Collector frames*

At intertidal sites collector ropes were stretched horizontally and fastened with strong synthetic twines to frames constructed from steel rods or tubing (Figure 3). Wooden frames had proved satisfactory in Morecambe Bay during 1970–72. Frames measured 10 x 2.5 m and were 1 m in height. Each frame accommodated 150 m of ropes, in a single tier, with 15 cm spacing between ropes (Figure 4). The ropes were usually 0.5 m above the ground but could be raised to about 1 m or lowered onto the ground to collect ground spat.

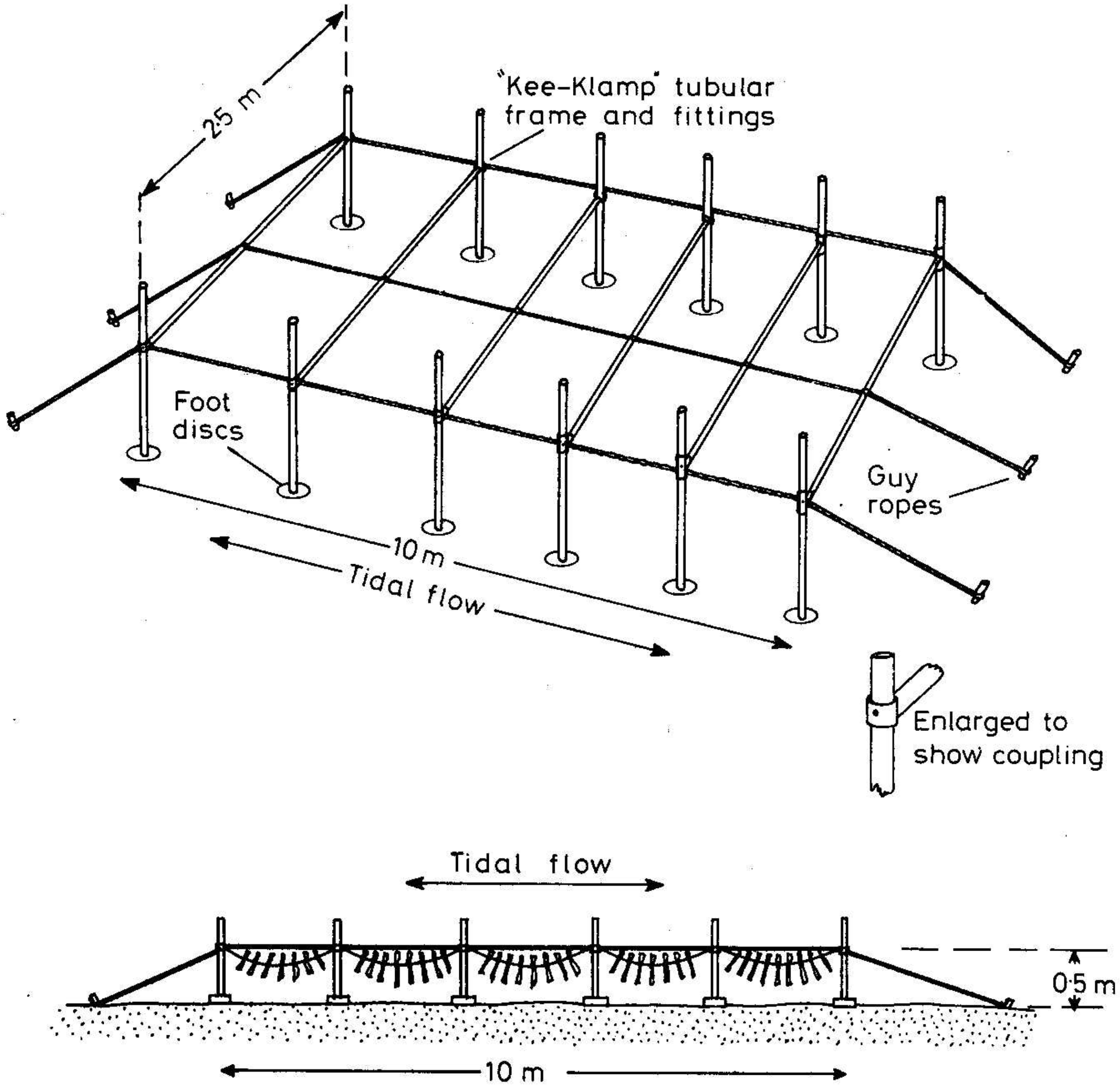


Figure 3 Diagram of the intertidal spat collector system used at Morecambe Bay. The frame accommodated 150 m of SFP tufted collector ropes.

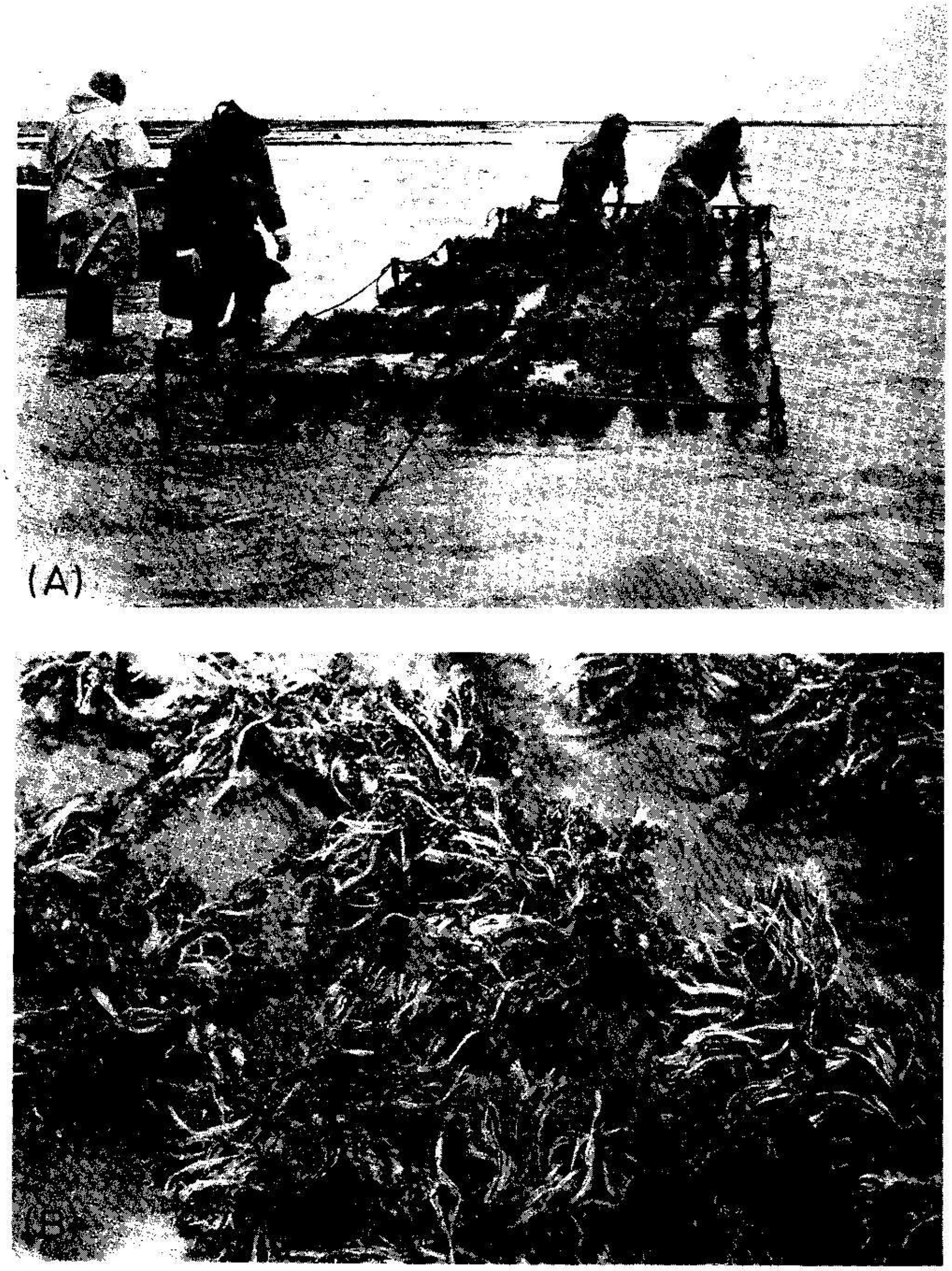


Figure 4 SFP spat collector ropes at the Roosebeck site in Morecambe Bay, May 1979: (A) A frame holding 150 m of ropes; (B) close view of some of the ropes showing heavy settlement of mussel spat after 4 months exposure.

Sublittoral collector ropes were arranged horizontally in several ways according to site conditions. In the Teign Estuary they were stretched across vertical iron frames suspended from floating or fixed structures. In 1978, a 2.25 m x 1.25 m frame holding 16 m of coir and SFP ropes was fixed beneath a pontoon moored in the main channel so that the top of the frame was 2 m below the surface in some 8 m of water at low water spring tides (Figure 5). In 1979, 30 m of SFP ropes were attached to three nets suspended from horizontal bars, each net 2.5 x 1.5 m, slung in parallel between the paired piles of a bridge in only 3 m depth at low spring tides (Figure 6). In The Wash, in 1979, 92 m of SFP ropes were suspended in the Gat Channel on four floating net units (Figure 7). Each unit carried 23 m of ropes threaded horizontally 15 cm apart through the 7.5 cm (stretched) meshes of a 3m wide x 1.5 m deep, vertical net. It was anticipated that spat would spread from the ropes onto the nets. Surface flotation for the top of each net was provided by a block of 'Ethafoam' (closed-cell polythene foam) 3 m long and 15 cm x 15 cm thick; the bottom edge of the net was weighted. The nets were moored in line with the current where the water depth was about 6 m at low water of spring tides. The top ropes were 30 cm below the surface. All collector frames were orientated so that the ropes were roughly in line with the main current flows, to minimize drag and vibration.

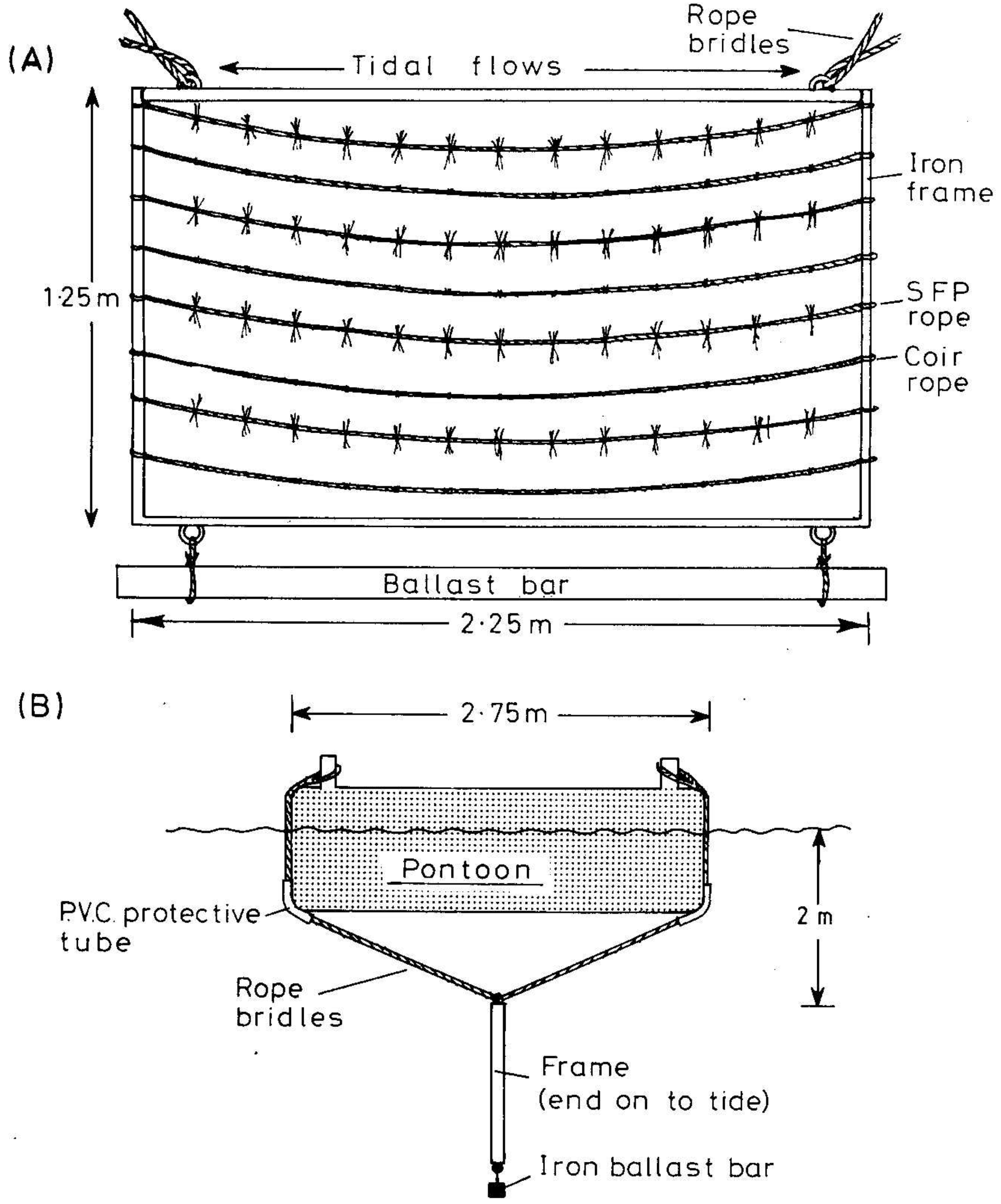


Figure 5 Diagram of the sublittoral spat collector system used under the pontoon in the Teign Estuary in 1978, showing (A) details of the frame and ropes; (B) the method of suspension. The frame held 16 m of SFP tufted ropes and 16 m of coir rope.

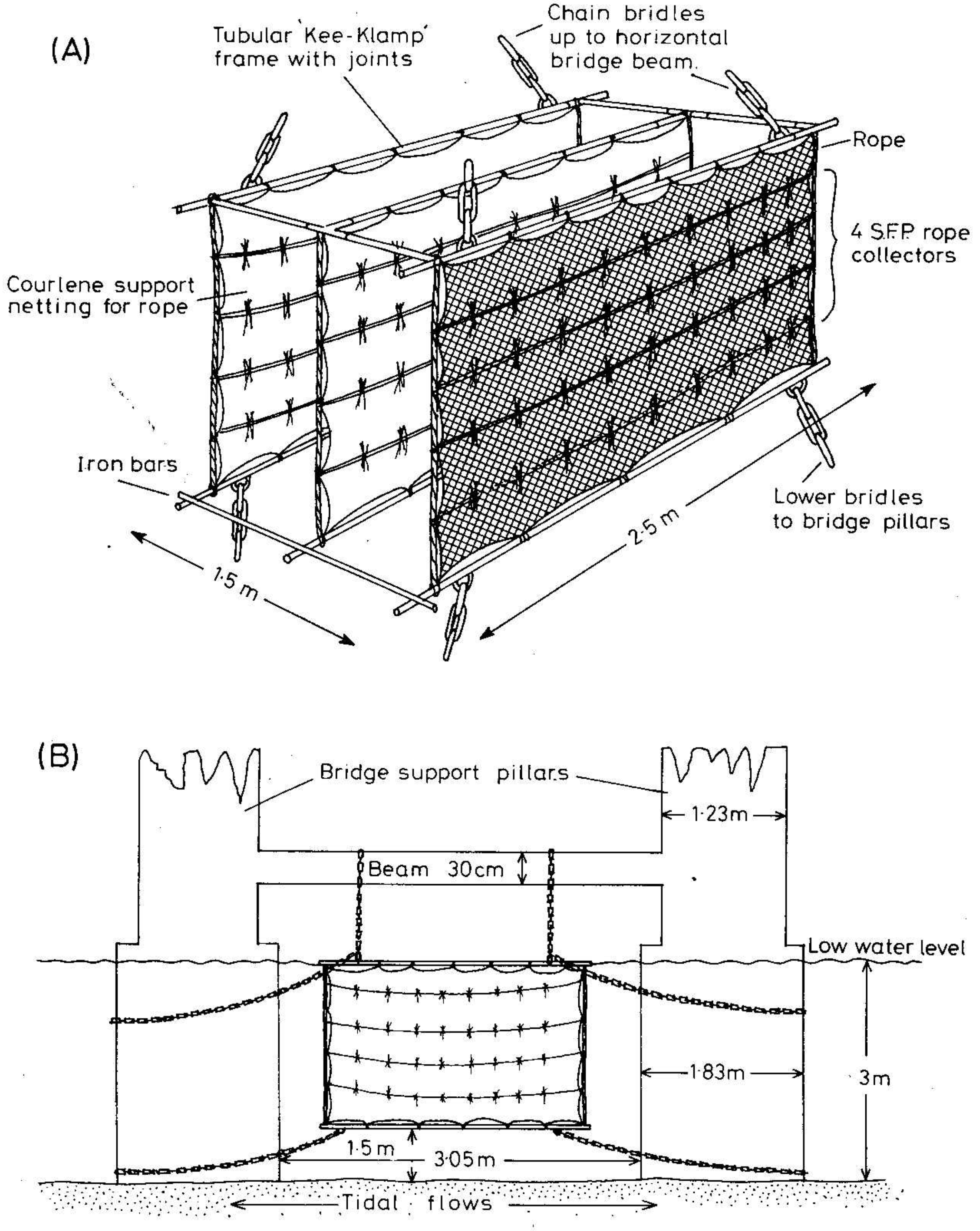


Figure 6 Diagram of the sublittoral spat collector system used under the bridge in the Teign Estuary in 1979, showing **(A)** details of the collector units; **(B)** the method of suspension. Each of the three vertical nets held 10 m of SFP tufted ropes.

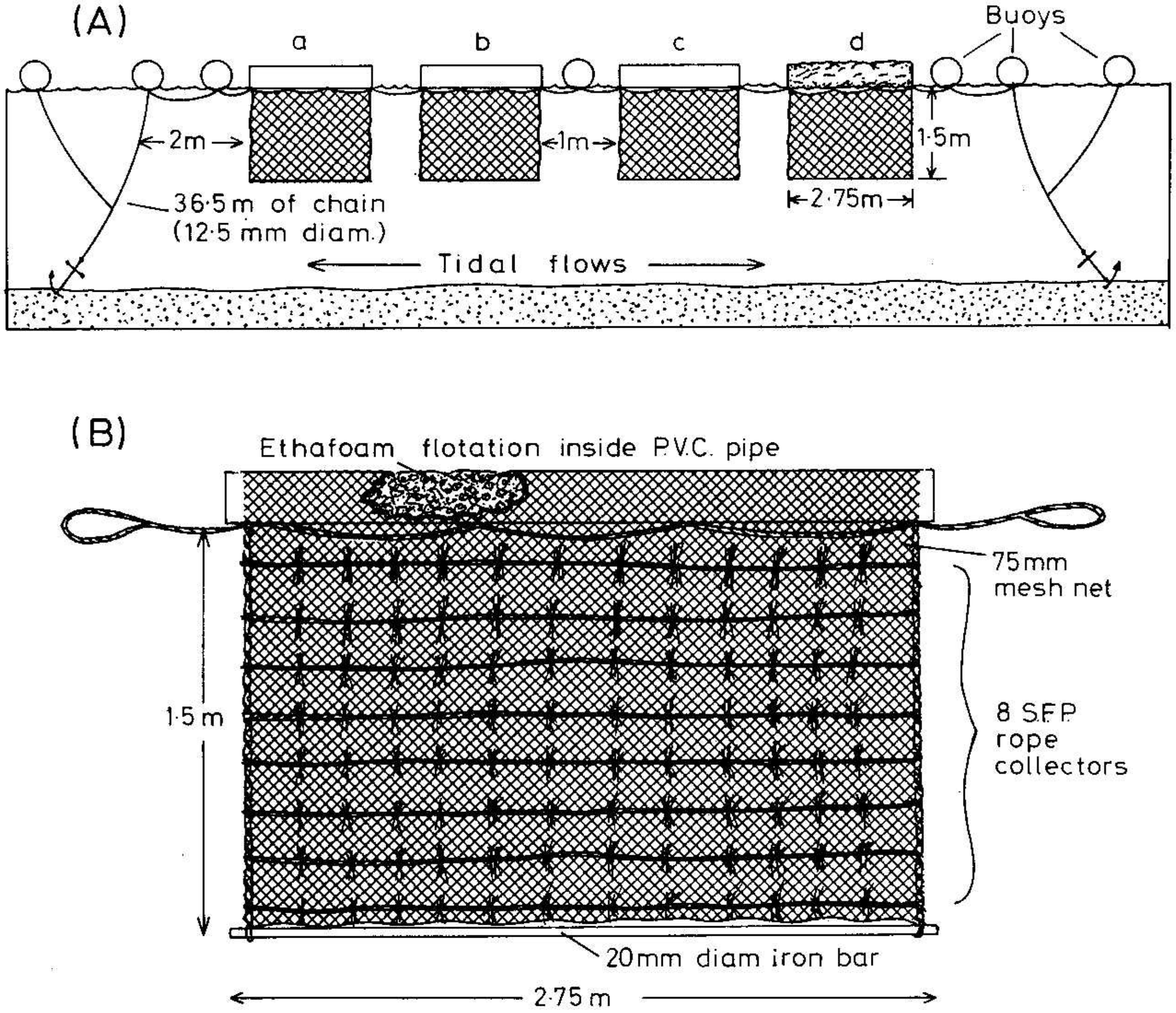


Figure 7 Diagram of the floating net units used to collect spat in the Wash in 1979, showing (A) the general layout with moorings; (B) an individual unit in detail. Each unit carried 23 m of SFP tufted rope collectors. The 'Ethafoam' floats of units a, b and d were enclosed within 15 cm diameter PVC pipes, that of c was unprotected.

2.3 Methods

Two collecting seasons were investigated, January–May (for secondary spat from spawning in the previous autumn) and May–July (for primary spat from the spring spawning), although inevitably there was some overlap, notably in the Teign Estuary (Table 1). In Morecambe Bay the ropes on frames at Roosebeck were set from January to early May in order to catch the planktonic secondary spat which were usually plentiful early in the year (Dare, 1976). Alternatively, ground spat were obtained there, as required, by lowering ropes onto the stone and shell substrate of the mussel beds. In other areas where monitoring showed that secondary spat were scarce during January–April collection was aimed mainly at the primary spat to be expected during May–July. Nowhere were attempts made to catch spat from late summer to early winter. It was anticipated that spatted ropes were to be transferred to within fences either in May, soon after the start of the growing season, or in July–August, midway through the growing season.

Ropes were inspected at approximately monthly intervals, when excessive fouling by macro-algae was removed and rope tensions and heights off the ground were adjusted as necessary. At Morecambe Bay silt tended to accumulate under intertidal frames, especially when ropes were set on or within 1 m from the ground. In transit by road from Morecambe Bay to the Menai Strait the spatted ropes were kept cool and moist between wet sacks or polythene sheets for up to 20 hours without obvious adverse effects to the spat. Such transfers were not required at the Wash and Teign Estuary, but a few long-distance transfers from The Wash to Menai Strait were tried. Collection rates on monthly and long-term test strips were assessed using the techniques devised by Davies (1974).

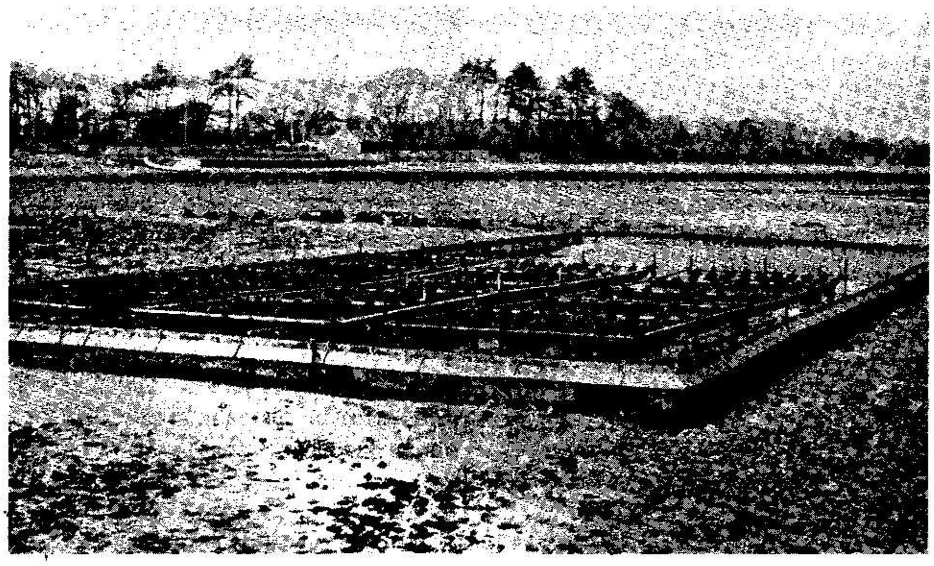


Figure 8 Spatted ropes from Morecambe Bay during the nursery stage within a crab-proof fence at Tal-y-foel, Menai Strait, June 1979.

Figure 9 Ropes heavily stocked with seed mussels nearly ready for stripping and relaying, Tal-y-foel, August 1977.

During the 3–6 months nursery stage when the spatted ropes were held on frames within fences or on the subtidal units ropes were inspected at monthly intervals, driftweed fouling was removed, and samples of spat were taken for growth studies. Occasionally, a few ropes were weighed to obtain a rough indication of crop growth. At the Menai Strait fence (Figure 8), 40 km from the laboratory, baited traps were set within the fence for 1–3 nights each month to catch shore crabs climbing into the enclosure via drift-weeds fouling the walls.

Yields of relayable seed (Figure 9) were estimated in late summer or autumn by stripping the mussels from the ropes by hand and weighing them after first washing off mud and removing entangled clumps of weeds. The mussels could be induced to loosen their byssal attachments, to ropes and each other, by placing the seeded ropes in sacks and leaving them in the sea for 24 hours. The stripped seed were then spread onto plots of ground within fences at initial densities of around 5 kg m^{-2}, in accordance with previous experience described by Davies *et al.* (1980).

During the on-growing stage the growth, survival and final yields of the rope seed relaid into fenced enclosures were assessed by the methods described previously (Davies *et al.*, 1980).

3. Results

3.1 Occurrence of spat in the sea

Seasonal patterns of abundance or availability of spat in the sea are presented here for the three spat collection areas – The Wash. Teign Estuary and Morecambe Bay. Also included are previously unpublished spat abundance data for two areas in North Wales – Menai Strait and Conwy Estuary – where spat collection for relaying experiments was not attempted. Catches on monitoring 'Hairlok' pads or on test lengths of collector rope are shown for approximately monthly periods.

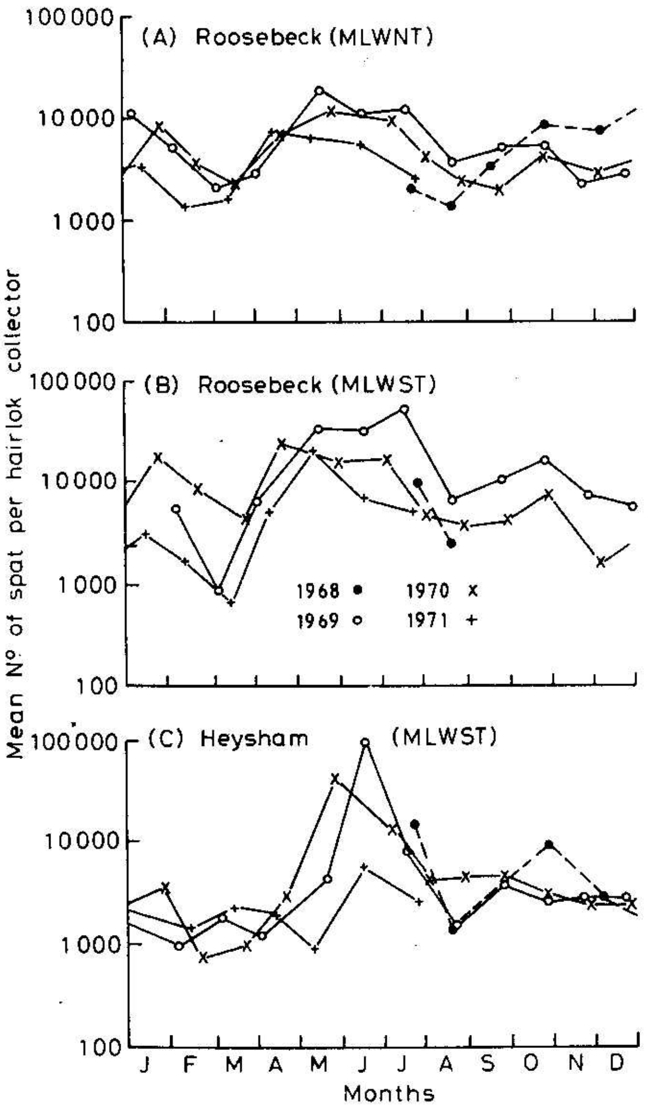


Figure 10 Seasonal and annual variations in mussel spat abundance on 'Hairlok' pads at three sites in Morecambe Bay: (A) Roosebeck, MLWNT; (B) Roosebeck, MLWST; (C) Heysham, MLWST. Approximately monthly observations are plotted at the mid-points of exposure periods: 1968 (•); 1969 (o); 1970 (x); 1971 (+). (From Dare, 1976.)

3.1.1 *Morecambe Bay*

Results for the years 1968–71 (Figure 10) are redrawn from Dare (1976). Monitoring was by means of 'Hairlok' pads at three intertidal stations on mussel beds, two near MLWST (Heysham and Roosebeck) on opposite sides of the bay and one near MLWNT (Roosebeck). General observations in the area after 1971 gave no reasons for suspecting that the 1976–79 seasonal pattern differed significantly from that during 1968–71.

There was considerable annual, seasonal and station differences in spat abundance, but the general pattern is similar for each station. Spat were present throughout the year and were often very numerous. They were least plentiful in March and August, and most abundant between April and July. Peak abundance occurred usually in May–June with 10,000–90,000 spat per pad. A second and much shorter period of abundance was sometimes evident in autumn from mid-September to early November.

Secondary stage spat occurred every month, and exlusively so during December–April. Large numbers were drifting about at Roosebeck also in May, but these had apparently been displaced from dense ground spatfalls by the onset of spring growth and mobility. Primary spat, from April spawnings, were largely responsible for the peaks at Heysham between mid-May and early July. Primaries sometimes occurred again in autumn, thus indicating a second spawning period. Primaries partly contributed to the June–July peaks at Roosebeck low-shore station in some years, but they were never recorded at the higher station.

3.1.2 *Menai Strait*

This locality supports mussel fisheries from both natural and cultivated beds. Two stations in the northern entrance to the Strait at Bangor, one at MLWST and the other subtidal, monitored during 1968–69 by means of 'Hairlok' pads showed marked differences in spat abundance and seasonality (Figure 11). At the low-shore station, spat were generally scarce (< 1,000 spat per pad per month) in both years, and much scarcer than at a comparable tide level in Morecambe Bay (Figure 10). No trends were discernible and only secondary spat were observed. At the subtidal station an almost complete absence of spat (< 100 spat per pad per month) in winter and spring was followed in both years by a brief peak in numbers in June and, in 1968 only, by a longer peak during September–November. Both peaks were comprised mainly of primary spat, but numbers (1,000–4,000 spat per pad per month) were much less than in Morecambe Bay.

3.1.3 *Conwy Estuary*

A single intertidal station, at MLWST on the commercial mussel beds at the mouth of the estuary, 20 km east of the Menai Strait stations and at the opposite side of Conwy

Bay, was monitored by 'Hairlok' pads for 12 months during 1969–70. Results plotted in Figure 11 show that, as in the Menai Strait spat (secondaries) were very scarce in winter and spring (< 100 spat per pad per month); they were also scarce in autumn but were comparatively plentiful (1,000 – 3,000 per pad per month) in July–August when primaries were also recorded.

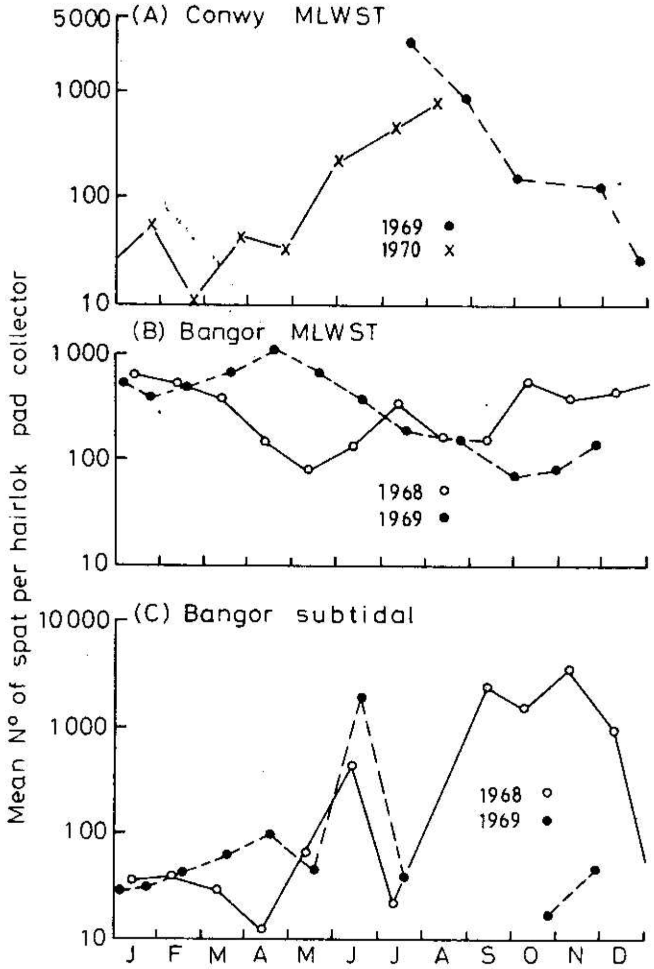


Figure 11 Seasonal and annual variations in mussel spat abundance on 'Hairlok' pads at Menai Strait and Conwy Estuary sites: at (A) Conwy, MLWST; (B) Bangor, MLWST; (C) Bangor, subtidal. Approximately monthly observations are plotted at the mid-points of exposure periods: 1968 (o); 1969 (•); 1970 (x).

3.1.4 *The Wash*

From an intertidal station at MLWST on the offshore Tofts bank in the Boston Channel on ground where mussels formerly were cultivated, data are available for 1970–71 ('Hairlok' pads) and for April–October in 1978 and 1979 (test strips of coir and SFP ropes). In addition, a subtidal station in the nearby Gat Channel was monitored from May to October 1979 using SFP ropes suspended from floats. Secondary spat were very scarce on intertidal 'Hairlok' pads during autumn, winter and spring of 1970–71 (Figure 12), and probably also on ropes during 1978–79. By contrast, in each year from late May until July or early August there was a period of great spat abundance, with ~ 10,000 spat/month on 'Hairlok' pads and 10,000–100,000 spat per m per month on rope. Many primary spat and very small secondary spat were captured during June. A very similar pattern was shown by the subtidal test ropes on which enormous numbers (100,000–400,000/m) of mainly very small secondary spat were recorded during June–July 1979.

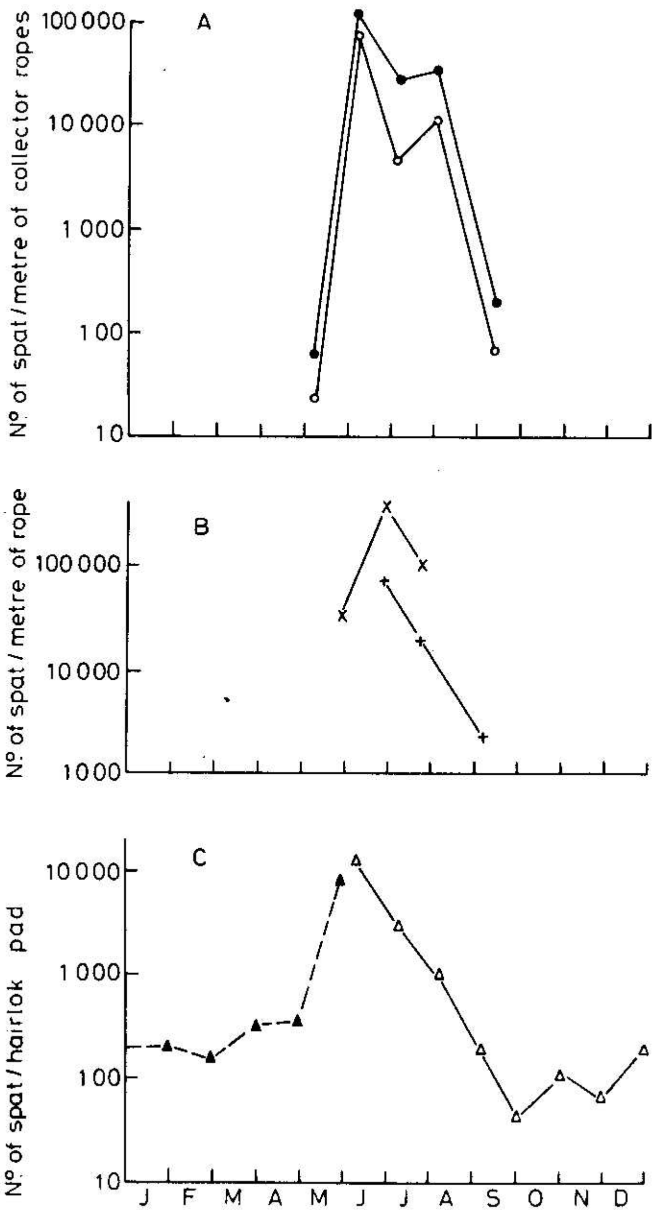


Figure 12 Seasonal variations in mussel spat abundance on different collector materials in the Wash: A. SFP (•) and 12 mm diameter coir (o) at Boston Tofts, MLWST, 1978; B. SFP at Boston Tofts (+) and Gat Channel subtidal (x), 1979; C. Monitoring 'Hairlok' pads at Boston Tofts, MLWST, 1970 (Δ), 1971 (▲).

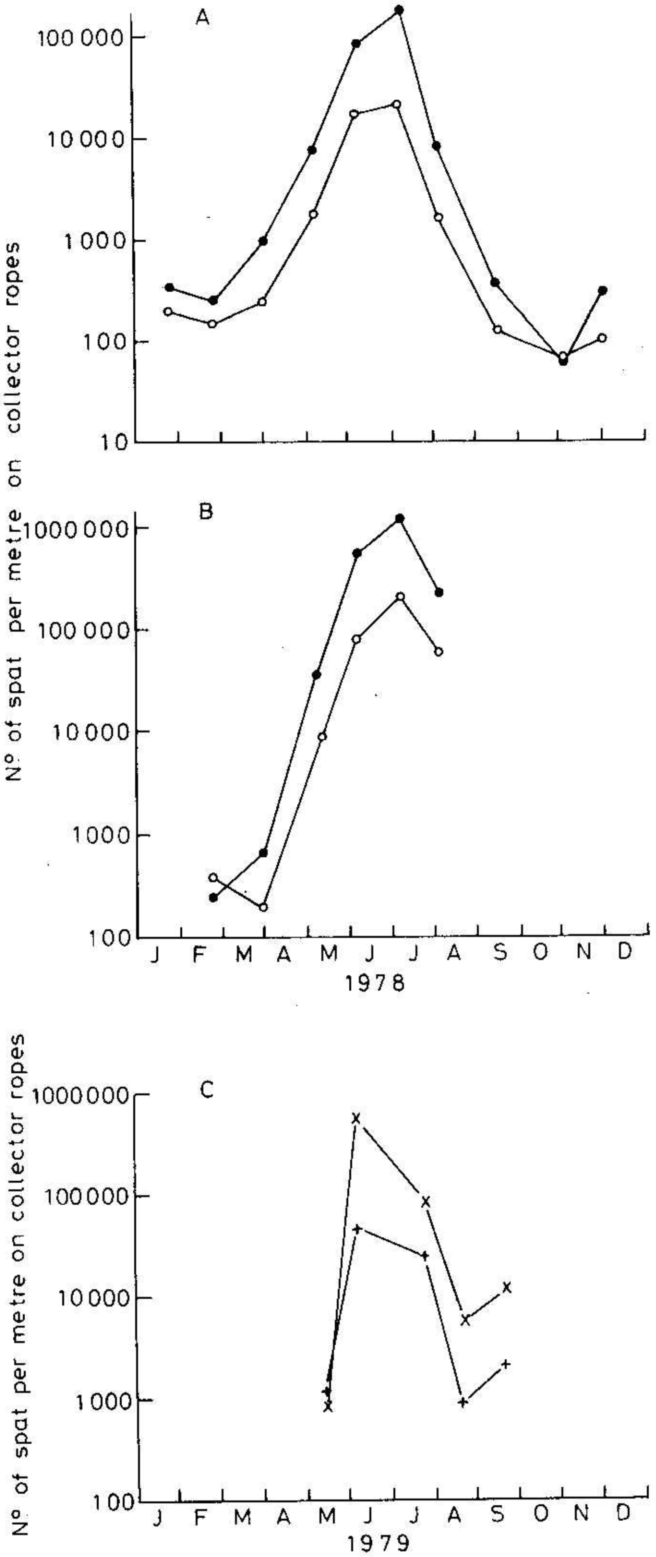


Figure 13 Seasonal and annual variations in mussel spat abundance on collector ropes in the Teign Estuary: A. SFP (•) and 12 mm diameter coir (o) at MLWST, 1978; B. SFP (•) and 12 mm diam. coir (o) at subtidal site, 1978; C. SFP at MLWST (+) and at subtidal site (x), 1979.

3.1.5 *Teign Estuary*

Spat abundance was monitored, with SFP and coir rope lengths, during 1978–79 at three stations: at MLWST on cultivated mussel beds upstream from Shaldon bridge, January–November 1978 and May–September 1979; subtidally, beneath a floating pontoon near the docks at Teignmouth, January–August 1978; subtidally, at Shaldon bridge, May–September 1979. The results (Figure 13) show a pattern almost identical with that found in The Wash (Figure 12) and with very close agreement between the intertidal and subtidal station trends. In 1978 spat were very scarce during January–March at both levels, and again from September to December at the intertidal station. No data were obtained for the subtidal station in autumn 1978, but in 1979 numerous spat – including primaries – were present subtidally during September. The results are notable for the vast abundance of spat at all stations from May to early August, with a peak through June and July in both years. More than 1,000,000 spat/m were caught in June–July 1978 on SFP subtidal ropes, and more than 500,000/m during June 1979. Many of the spat were primaries or very small secondaries when the ropes were examined.

3.1.6 *Summary of all areas*

Although there were large annual, seasonal and locality differences in spat abundance, some common trends were evident. Thus, while some secondary spat were present in every month at each site, there was usually a major period of abundance sometime between May and August generated by primary and secondary spat from the spring spawning. This peak was most spectacular at The Wash and the Teign Estuary, less so at Heysham (Morecambe Bay), and comparatively insignificant in the Menai Strait and Conwy Estuary. A subsidiary autumn period of primary spat abundance was noted occasionally at the Menai Strait, the Teign Estuary and Heysham. Primary spat appeared most regularly and in greatest profusion subtidally; they were of irregular occurrence and normally much less plentiful in the low intertidal zone, and absent from higher levels. From September to April, secondary spat were scarce in all localities except Morecambe Bay where they were numerous throughout the year, even up as high as low water mark of neap tides. In this bay, winter and early spring settlements of secondary spat annually produce the major crops of intertidal seed mussels (Dare, 1976).

Contrasts in spat availability between localities are summarised in Tables 3 and 4 which show the number of months in the study periods when various monthly catch levels were attained on 'Hairlok' monitoring pads and on rope test strips. For 'Hairlok' pads only monthly catches exceeding 1,000 spat per pad are considered to be indicative of worthwhile spat resources. For the years covered, Morecambe Bay was clearly superior to all other areas.

Table 3 Spat abundance compared between areas by the 'Hairlok' pads monitoring method

Site			No. full years observation period	No. months in period when monthly spat count per pad reached:			
				10–99	100–999	1,000–9,999	10,000–99,999
Morecambe Bay:	Heysham	LWST	3	–	3	12	3
	Roosebeck	LWST	3	–	1	11	6
	Roosebeck	LWNT	3	–	–	12	4
Menai Strait:	Bangor	LWST	2	3	12	1	–
	Bangor	Subtidal	2	8	2	4	–
Conwy Estuary:	Morfa	LWST	1	4	7	1	–
The Wash:	Boston Tofts	LWST	1	2	7	2	1

Table 4 Spat abundance compared between areas by catches on rope collector test strips (All intertidal ropes on frames 1 m off ground)

Rope type	Site		No. part years observation period	No. months in period when monthly spat count per metre of rope reached:					
				10–99	100–999	1,000–9,999	10,000–99,999	100,000–999,999	> 1,000,000
SFP	Teign Estuary	LWST	2, Jan.–Sep.	1	5	3	2	1	–
		Subtidal	2, Jan.–Sep.	–	3	1	3	2	1
	The Wash: Boston Tofts	LWST	2, May–Sep.	1	1	1	3	1	–
	Gat Channel	Subtidal	1, May–Sep.	–	–	–	1	2	–
	Morecambe Bay: Roosebeck	LWST	1, Jan.–April	–	4	1	–	–	–
Coir (12 mm diam.)	Teign Estuary	LWST	1, Jan.–Nov.	2	5	2	2	–	–
		Subtidal	1, Jan.–Aug.	–	2	1	2	1	–
	The Wash: Boston Tofts	LWST	1, May–Sep.	2	–	1	2	–	–
	Morecambe Bay: Roosebeck	LWST	2, Jan.–April	3	4	1	–	–	–
	Roosebeck	LWNT	1, Jan.–April	–	1	1	–	–	–
'Hairlok' 64 oz	Morecambe Bay: Roosebeck	LWST	2, Jan.–April	–	3	4	1	–	–
	Roosebeck	LWNT	1, Jan.–April	–	2	1	–	–	–

Table 5 **Spat catching powers of various collector materials, compared with standard 12 mm diameter coir rope. (Intertidal ropes were suspended 0.5–1m clear of the ground.)**

Site and exposure period			Relative numbers of spat captured per metre of rope*				
			Coir		SFP	'Hairlok'	
			12 mm	25 mm		32 oz/ft^3	64 oz/ft^3
Morecambe Bay	LWST.	Feb.–April 1977	1	2.51		3.45	3.45
"	LWST.	Feb.–March 1977	1	2.44			
"	LWST.	Jan.–April 1978	1		3.05	3.63	4.43
"	LWST.	Jan.–April 1978	1		4.38	4.41	4.18
The Wash	LWST.	April–Oct. 1978	1		3.19		2.53
Teign Estuary	LWST.	Jan.–Dec. 1978	1		3.74		
"	Subtidal	Feb.–Sept. 1978	1		4.25		
		averages =	1	2.47	3.72	3.83	3.65

* Based on average values from monthly collectors.

Table 6 **Seasonal changes in the relative effectiveness of SFP and 12 mm coir spat collecting ropes: Ratio of spat/m, SFP: Coir**

	Teign Estuary		The Wash
	LWST	Subtidal	LWST
Jan.–Feb.	1.69	–	–
Feb.–Mar.	1.67	0.84	–
Mar.–Apr.	3.93	3.60	–
Apr.–May	4.31	3.86	2.68
May–June	5.05	7.00	1.60
June–July	8.94	6.24	5.74
July–Aug.	4.95	3.95	3.01
Aug.–Oct.	3.04	–	2.91
Oct.–Nov.	0.86	–	–
Nov.–Dec.	2.99	–	–

Table 7 Estimated numbers and sizes of spat mussels caught by various collector materials in Morecambe Bay at different seasons, 1976–79

Trial			Collector		Spat catch	
No.	Period	Site and setting	Type	Length (m)	No./m	Mean length (mm)
1	12/5–15/6/76	H, LWST, g	Coir (25 mm diam.)	50	47,900	0.8
2	15/6–30/6/76	H, LWST, g	Coir "	22	6,000	1.4
3	18/1–3/5/77	R, LWNT, o + g	Coir "	25	19,700*	2.5
4	18/1–3/5/77	R, LWST, o	Coir "	25	16,500*	"
5	17/2–3/5/77	R, LWNT, o + g	Coir (12 mm diam.)	25	7,400*	"
6	17/2–3/5/77	R, LWST, o	Coir "	25	6,200*	"
7	6/4–3/5/77	R, LWST, g	Coir "	25	16,200	"
8	18/1–3/5/77	R, LWNT, o + g	'Hairlok' 64 kg/m^3	25	9,600*	"
9	17/2–3/5/77	R, LWNT, o + g	'Hairlok' "	25	8,700*	"
10	18/1–3/5/77	R, LWST, o	'Hairlok' "	25	26,600*	"
11	17/2–3/5/77	R, LWST, o	'Hairlok' "	25	21,300*	"
12	8/3–3/5/77	R, LWST, o	'Hairlok' 32 kg/m^3	25	19,200	"
13	6/4–3/5/77	R, LWST, g	'Hairlok' "	25	55,000	"
14	17/2–1/8/77	R, LWST, o	Coir (25 mm diam.)	180	1,900	12.5
15	17/2–3/5/77	R, LWNT, o	SFP	3.5	n.d.	2.5
16	17/2–3/5/77	R, LWST, o	'Hairlok' 64 kg/m^3	1.5	n.d.	"
17	10/1–22/5/78	R, LWST, o	SFP	60	1,800	3.0
18	10/1–22/5/78	R, LWST, o	Coir (12 mm diam.)	200	500	"
19	10/1–22/5/78	R, LWST, o	'Hairlok' 32 kg/m^3	130	2,600	"
20	6/2–22/5/78	R, LWST, o	'Hairlok' 64 kg/m^3	80	2,000	"
21	1/2–16/5/79	R, LWST, o	SFP	300	140,000	2.9

Notes:

Sites: R = Roosebeck, H = Heysham.

Settings: o = ropes off ground on frames; g = ropes on ground; o + g = ropes off ground initially but lowered onto ground later

* = values from cumulative score of monthly test-strips; comparative trials with long-term test-strips in 1978 indicated that long-term catch was ~ 75% of the cumulative monthly catches.

Table 8 Results of spat collection trials in the Teign Estuary at intertidal and subtidal sites, 1977–79

Trial			Collector		Final spat catch	
No.	Period	Site	Type	Length (m)	No./m	Mean length (mm)
1	4/5–27/9/77	Fence, LWST	Coir (12 mm diam.)	10	0	–
2	4/5–27/9/77	" "	'Hairlok' 32 oz in netting tube	10	0	–
3	10/1–18/10/78	" "	Coir (12 mm diam.)	10	0	–
4	10/1–18/10/78	" "	SFP	10	47	–
5	9/2–18/10/78	Pontoon, subtidal	Coir (12 mm diam.)	8	) 18,000	16.5
6	9/2–18/10/78	" "	SFP	8	)	
7	26/4– 3/10/79	Bridge, subtidal	SFP	30	0	–

However, The Wash and Conwy Estuary data were for one year only and Table 4 shows that in later years spat were found to be more plentiful in The Wash than in Morecambe Bay. The low spat levels in the Menai Strait have been confirmed by other observations in recent years. The rope monitoring data (Table 4) refer to incomplete years and to three types of material. Probably only monthly catches exceeding 10,000 spat per metre represent a worthwhile resource for exploitation. On this basis, both The Wash and Teign Estuary – with their enormous abundance of primary spat in late spring and early summer – were superior to Morecambe Bay. However, the Morecambe Bay catches on ropes refer to secondary spat overwintering and were for an unusually poor spatfall year (1978, see later); in a more normal year all monthly catches there on SFP rope would be expected to exceed 1,000 spat/m, with at least one month exceeding 10,000/m.

Taken together, the spat monitoring evidence indicates that spat collection exercises would stand the best chance of success in The Wash and the Teign Estuary if conducted from May to August, to utilise the primary and secondary spat from the spring spawning. The Morecambe Bay situation is exceptional, with plentiful spat being available throughout the year; it should permit utilisation of secondary spat in winter and early spring when other areas lack spat. The Menai Strait and Conwy Estuary compared unfavourably with the other localities and are likely to hold sufficient spat only during June–July in certain years.

3.2 Comparison of spat collector materials

The relative efficiencies of various collector materials in catching mussel spat can be assessed by using data from the spat monitoring studies at Morecambe Bay, The Wash and the Teign Estuary (Table 5). Coir rope of 12 mm diameter is taken as a standard against which other materials are compared.

Coir rope of 25 mm diameter caught, on average, about 2.5 times as many spat as did the standard coir, while SFP and 'Hairlok' ropes caught 3.5 – 4 times as many. Relative effectiveness varied, however, with the time of year (Table 6). During months when secondary spat are the predominant or exclusive stage, i.e., from January to April and again from August to December, SFP rope was some 2 – 3 times as effective as standard coir. During May–July, the peak season for primary spat occurrence, its effectiveness was 5 – 9 times that of the standard coir. SFP rope is therefore even more attractive to primary than to secondary spat, as might be predicted from its filamentous texture. The few data obtained for 'Hairlok' rope suggest that it may behave similarly to SFP.

3.3 Trial spat collection for relaying

The trials of substantial lengths of rope collectors in the various areas were planned using the information provided by spat monitoring. The aim was to collect sufficient spat for growing to a size suitable for relaying onto the ground within crab-proof fences.

3.3.1 *Morecambe Bay*

Details of the 21 trials made during 1976–80 are listed in Table 7 which also gives the estimated numbers and size of spat captured. Most of these trials, like those in 1970–71 (Dare and Davies, 1975), were designed to catch the secondary spat available at Roosebeck from December until early May, but trials 1 and 2 were to collect summer spat – primary and smallest secondary – which occur at Heysham. Coir and 'Hairlok' ropes were the standard collector materials at first but after its promising debut in 1977 SFP rope superseded the others in 1979. Altogether, 1,300 m of ropes were used: coir, 575 m; 'Hairlok', 362 m; SFP, 363 m.

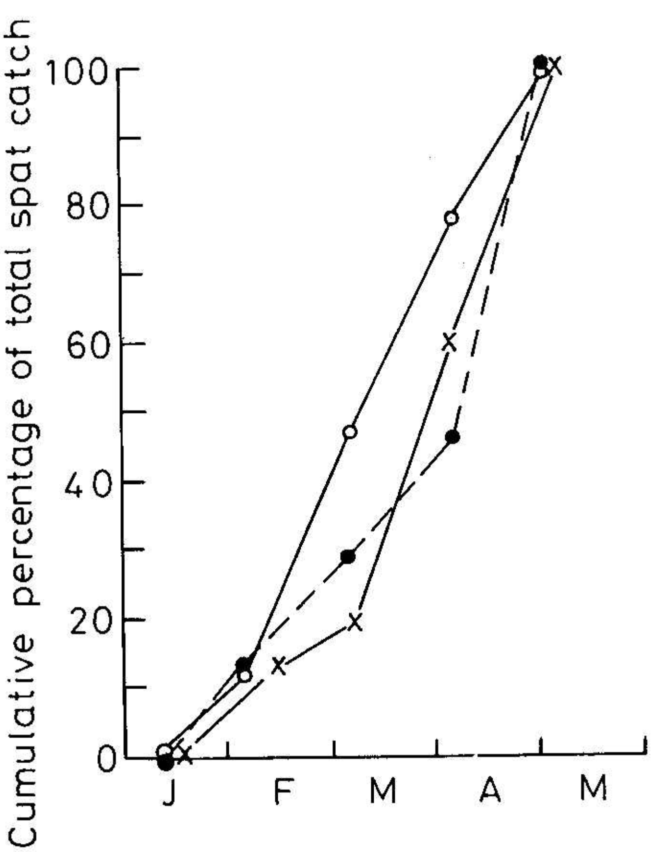


Figure 14 The pattern of monthly accumulation of mussel spat on intertidal rope collectors at Roosebeck, Morecambe Bay: Main Skear, 1977 (x); Main Skear, 1978 (o); Out Skear, 1978 (•).

Spat catches varied widely due to large annual and site fluctuations in spatfall and the different efficiencies of materials. At Roosebeck, general observations on ground settlements confirmed that 1978 was a very poor spatfall year, 1979 was very good, 1977 was about average. Figure 14, derived from monitoring data, shows the progress of accumulation of spat on ropes in 1977 and 1978. The largest collections of secondary spat obtained on ropes set off the ground for 3 or 4 months were: SFP, 140,000/m (~ 0.97 kg/m, trial 21); 'Hairlok', 26,000/m (trial 10); 25 mm coir, 16,000/m (trial 4); 12 mm coir, 6,000/m (trial 6). The total catch on SFP ropes in trial 21 was probably about 42 x 10^6 spat, weighing about 300 kg. By laying ropes on the mussel grounds for a month during April–May, ground spat in the crawling phase could be collected in still larger quantities, e.g., 55,000/m on 'Hairlok' (trial 13) and 16,000/m on 12 mm coir (trial 7). However, silt problems were encountered which prevented this approach from being adopted on a large scale. The results with coir were broadly comparable with those at Roosebeck over the same months in 1971 (Dare and Davies, 1975). By May, the mean lengths of spat on the ropes varied between 2.5 mm and 3 mm.

At Heysham, very large numbers of tiny, recently settled secondary spat of 0.8 mm mean length were collected on coir rope set on the mussel bed in June (trial 1).

3.3.2 *Teign Estuary*

Monitoring showed that spat collection was likely to succeed in this estuary only during May–August when primary spat were enormously abundant (Figure 13). In 1977–78 seven small trials totalling 86 m of rope were made both intertidally and subtidally, the latter under a floating pontoon in 1978 and beneath a bridge in 1979. The results, summarised in Table 8, were highly variable between sites although high numbers of spat settled on the ropes initially in both years. Subtidal ropes collected extremely large quantities of summer spat at both sites but those under the bridge (trial 7) failed to retain them. This failure probably was due to shore crab predation, the rope frame being close to the bottom, although water turbulence and particle bombardment may have been too severe and have unsettled the spat. By contrast, the pontoon ropes – which were 8 m off the bottom – were highly successful in retaining spat. Spat were first clearly visible in large numbers on these collectors in mid-July 1978. By mid–August, the settlements on SFP ropes weighed ~ 4 kg/m and comprised spat of 7 mm mean length at an estimated density of ~ 125,000/m. The mussel 'colonies' were up to 20 cm in diameter on SFP ropes and 7 cm diameter on coir, and adjacent ropes were becoming bound together. By mid-October, when the ropes were stripped, the then seed mussels had fused together in one large mass and only average values for the two rope types combined could be obtained. The average stock density then was about 8 kg/m of seed of 16.5 mm mean length with a density of about 18,000/m. Losses during the previous two months had therefore been extremely high; most seed had probably lost attachment and fallen off to be consumed by crabs.

Intertidal long-term ropes (trials 1–4) failed to retain any spat despite the heavy settlements of primary and small secondary spat in both years on the adjoining monthly test strips (Figure 13). The causes of these failures are uncertain but one or more of the following factors could be implicated:

(a) dense fouling growths of weeds (*Enteromorpha* sp.) which also induced siltation;
(b) crab predation;
(c) a behavioural response of primary spat to aerial exposure which might have induced detachment and migration.

Of these, weed fouling probably had the most adverse effect even though ropes were partly cleaned at monthly inspections; crabs and aerial exposure should have similarly affected the spat on monthly test strips. Whatever the reason, the results demonstrated convincingly that intertidal collection of summer spat is unlikely to succeed in the Teign Estuary.

3.3.3 *The Wash*

In 1978–79 nine small trials using 352 m of ropes were made, five of them intertidally at Boston Tofts in both years and four subtidally in Gat Channel in 1979. The intertidal ropes were divided between frames placed inside and outside a crab-proof fence. Trials lasted from April until October each year, thus spanning the period of summer spat abundance shown by the monitoring studies (Figure 12). The results are summarised in Table 9.

The 1978 intertidal ropes, like those in the Teign Estuary, initially collected large numbers of summer spat but subsequently lost them. By mid-August a heavy settlement, 45,000/m on SFP, 10,000/m on coir, had occurred, of mean length 3–4 mm, much of which was clinging to a loose fouling growth of a brown filamentous alga. By mid-October all ropes were bare except for a trace of small seed and some new settlement on the SFP rope (trial 2) inside the fence. It is uncertain whether the settlements were destroyed by shore crabs and starfish (*Asterias rubens*) or were lost with the detachment of the fouling algae. In August small starfish of 4–10 mm radius and several crabs had been observed on ropes both inside and outside the fence.

The 1979 intertidal ropes (trial 9) had collected a heavy visible spatfall by early July, together with a covering of fine algae. By early August, the ropes were heavily laden with spat of 5 mm mean length at a computed density of ~ 22,000/m. In early October there were still considerable amounts of spat on these ropes, including some of recent origin measuring only 1–3 mm, but the quantities were not weighed: the low mean length then of 8.6 mm was caused by recent recruitment, since the largest individuals from the earlier settlement had grown to 20–22 mm.

Table 9 **Results of spat collection trials in The Wash at intertidal (Boston Tofts) and subtidal (Gat Channel) sites, 1978–79**

Trial			Collector		Final spat catch	
No.	Period	Site	Type	Length (m)	No./m	Mean length (mm)
1	26/4–16/10/78	Fence, LWST	Coir (12 mm. diam.)	15	0	–
2	"	" "	SFP	5	350	11.0
3	24/5–16/10/78	" "	Coir (12 mm. diam.)	60	0	–
4	"	" "	'Hairlok' 64 oz	60	0	–
5	24/4–3/10/79	Subtidal	SFP	23	)	
6	"	"	"	23	) >3,800	14.7
7	"	"	"	23	)	
8	"	"	"	23	0*	–
9	24/4–3/10/79	Fence, LWST	SFP	20	n.d.	8.6

* Frame had broken adrift from its mooring and touched bottom; presumably its spat had been destroyed by predators.

The 1979 subtidal ropes attached to four vertical nets (trials 5–8) floating in Gat Channel proved very effective in collecting and retaining large quantities of summer spat. In early August, both ropes and nets were covered thickly with mussels of 8 mm mean length. By October, three nets were covered completely by seed of 15 mm mean length; the fourth net had broken adrift, touched bottom and lost its mussels, presumably to crabs and starfish.

3.3.4 *Menai Strait*

Only one trial was made; in 1978 SFP and 12 mm coir ropes totalling 20 m length were placed on a frame within a crab-proof fence near MLWST from January until August. Monthly test strips showed traces (< 150/m) of secondary spat each month during January–May inclusive, followed in June–July by a light settlement of small secondary spat, 6,500/m on SFP and 1,200/m on coir. Through August and September spat were again scarce. These results were thus in good agreement with those from the 1968–69 monitoring studies (Figure 11). The long-term ropes failed to attract or retain any summer spat, possibly due to silting or to predation by newly settled shore crabs.

From 1963 to 1968, attempts to collect spat in quantity on various materials in the Strait at Bangor failed except in 1963, which was a heavy spatfall year in other areas as well. Some minor spatfall was evident during winter and early spring in three of the years, during summer in three years, and during autumn in one year. The heavy 1963 settlement occurred as small secondary spat in summer and smothered branches of gorse (*Ulex europaeus*) attached to posts on the lower mudflats.

3.3.5 *Summary of all trials*

The collection trials were successful under certain conditions but failed under others. Winter and early spring secondary spat were captured in worthwhile quantities only in Morecambe Bay; at the other three sites, secondary spat were very scarce at this time of year. Summer spat proved to be difficult to collect despite their abundance in The Wash and the Teign Estuary during May-July. Although initially they were readily collected in these two areas on ropes intertidally and (especially) sub-tidally, it proved difficult to retain them; three of four intertidal collections were lost, and one of three subtidal collections also disappeared. Causes of these failures are uncertain but are probably varied and complex, including algal fouling, effects of aerial exposure on primary spat, and predation by shore crabs including swarms of newly settled individuals. Subtidal collectors seem to have the highest chance of success, but they must be placed in deep water well clear of bottom predators.

The Menai Strait was an area of prevailing low spat abundance compared with the other three areas investigated.

3.4 Seed yields for relaying

This section describes the yields of relayable seed ultimately obtained from spat collectors. The spat were grown-on, either *in situ* or after being transferred to another site, until they became seed of a size suitable for stripping and relaying onto protected ground in summer or autumn, i.e., 15 – 25 mm.

Table 10 Yields of seed mussels obtained from Morecambe Bay spatted ropes transferred to the Menai Strait and held on intertidal frames inside a crab-proof fence

Collection stage: Morecambe Bay		Nursery stage: Menai Strait					
Trial No.	Collector type	Period $t_0 - t_1$	No. spat or seed/m		Yield of seed†		
			N_{t_0}	N_{t_1}	$\bar{l}$ (mm)	Total wt. (kg)	kg/m
1	Coir (25 mm)	15/6–6/9/76	47,900	0	–	0	0
2	"	30/6–23/9/76	6,000	1,200	15.4	11	0.5
3	"	3/5–16/8/77	19,700*	5,800	17.9	(88)	3.5
4	"	"	16,500*	5,700	"	(85)	3.4
5	Coir (12 mm)	"	7,400*	2,000	"	(30)	1.2
6	"	"	6,200*	4,800	"	(73)	2.9
7	"	"	16,200	4,200	"	(63)	2.5
8	'Hairlok' 64 oz in net	"	9,600*	2,800	"	(43)	1.7
9	"	"	8,700*	n.d.	"	n.d.	n.d.
10	"	"	26,600*	5,700	"	(85)	3.4
11	"	"	21,300*	4,800	"	(73)	2.9
12	'Hairlok' 32 oz in net	"	19,200	n.d.	"	n.d.	n.d.
13	"	"	55,000	5,700	"	(85)	3.4
15	SFP	3/5–14/9/77	n.d.	9,000	21.0	32	9.0
16	'Hairlok' 64 oz in rope	"	n.d.	8,200	"	14	8.2
17	SFP	22/5– 1/12/78	1,800	1,400	23.0	120	2.0
18	Coir (12 mm.)	"	500	0	–	0	0
19	'Hairlok' 32 oz in rope	"	2,600	700	23.0	122	0.9
20	'Hairlok' 64 oz in rope	"	2,000	400	23.0	42	0.5
21	SFP	16/5–23/11/79	140,000	6,000	18.0	1,020	3.4

† Values in parentheses are estimates for all ropes, including those which sank in mud, based on data from surviving ropes.
* = values from cumulative score of monthly test-strips; comparative trials with long-term test-strips in 1978 indicated that long-term catch was ~ 75% of the cumulative monthly catches.
nd = no data

3.4.1 *Morecambe Bay*

All spatted ropes were taken to the Menai Strait where they were re-sited on frames in fenced enclosures at Tal-y-foel (Figure 8). Winter spat, with the exception of those in trial 14, were transferred in May, summer spat in June. The nursery stage then lasted 3–6 months until August–November, by which time some winter spat had been settled on the ropes for 10 months.

Performance data for spat on ropes in fenced enclosures are summarised in Table 10.

Stripped yields of 15–25 mm seed mussels were highly variable but generally low, due partly to variations in spatfall intensity and partly to high natural and handling mortalities during the nursery stage. If the two very promising, but very small, prototype trials (nos. 15 and 16) with SFP and 'Hairlok' tufted ropes are excluded, then the average yields from larger trials were:

SFP	2.70 kg/m	range 2.0–3.4 kg/m
'Hairlok' (all types)	2.13	0.5–3.4
Coir (25 mm diam.)	1.86	0 –3.5
Coir (12 mm diam.)	1.65	0 –2.9

Problems arose from crab predation, algal fouling, aerial exposure and substrate type. Crab predation caused heavy losses in 1979 when *Carcinus* appeared to be unusually plentiful and many climbed up to the spatted ropes via strands of hanging driftweeds which became entangled in the ropes and frames. In other years, growths of green *Enteromorpha* weeds had to be routinely removed from ropes. The predation problem in 1979 was exacerbated by an unusually poor growing season which prolonged the nursery period by about two months.

Table 11 **Yields of relayable seed stripped from spatted ropes, and the ultimate yields at crab-proof size**

Site		Collector type	Length (m)	Yield of stripped seed: Date	$\bar{l}$ (mm)	Total wt. (kg)	kg/m	Yield of crab-proof seed: Date	$\bar{l}$ (mm)	Total wt. (kg)	kg/m	Yield Increment
Morecambe Bay:												
Heysham	LWST	Coir (25 mm)	22	9/76	15.4	10.6	0.5	7/77	34.9	93.5	4.1*	x 8.8
Roosebeck	LWST	Coir (25 mm)	15	8/77	17.9	52	3.5	10/78)			11.6	
	"	Coir (12 mm)	30	8/77	17.9	66	2.2	10/78)	40.8 +	776 +	7.3	x 3.3
	"	'Hairlok'	40	8/77	17.9	117	2.9	10/78)			9.6	
Roosebeck	LWST	SFP	300	11/79	18.0	1,020	3.4					
Teign Estuary:												
Subtidal		SFP) Coir (12 mm)	8	10/78	16.5	64	8.0	8/79	44.3	176	22.0	x 2.75
The Wash:												
Subtidal		SFP	46	10/79	14.7	216	see text					

* estimated yield at $\bar{l} = 40$ mm is ~ 6 kg/m. + based on a combined plot.

Dense collections of summer spat, of 0.8–1.4 mm mean length, taken in June 1976 were almost totally lost within a month of being placed in a Tal-y-foel fenced enclosure. Suspected causes were predation by a heavy and coincident settlement of 2–3 mm crabs onto the ropes, silt deposition on ropes, and detachment following 13 hours out of water in transit. A similar transfer of summer spat from the Wash to Tal-y-foel in August 1978 failed even more dramatically. The heavily spatted ropes, which had been 29 hours out of water in warm weather, lost nearly all their spat within 24 hours of being re-immersed, presumably due to detachment.

It was necessary to site heavily spatted ropes in single tiers on frames placed on firm ground. When, in 1978, two tiers of ropes were placed in a muddy (oyster cultivation) fenced enclosure some losses resulted from smothering of the lower ropes as the frame sank under the weight of growing seed crop; the accretion of mussel-mud and enhanced natural siltation under the ropes accentuated the problem.

The results from relaying rope seed into fenced enclosures in 1976 and 1977 are given in Table 11, expressed as yields of crab-proof seed obtained after approximately one year's growth on the ground. The fairly large-scale 1977 trials ultimately yielded the equivalent of 7–11 kg/m of crab-proof seed, although the growth increment in the fenced enclosure was only x 3.3 compared with an expected x 5.6 (Davies *et al.*, 1980). It is estimated that the small 1976 trial, which was terminated prematurely, should have produced about 6 kg/m at 40 mm had it continued to full term.

3.4.2 *Teign Estuary*

Here only the 1978 subtidal spat collection trial (no. 5) produced a crop of seed mussels for relaying into an enclosure. When the rope unit was stripped in mid-October, 102 kg of seed with mean length 16.5 mm were obtained (Table 11). Of this quantity, 64 kg were attached to 8 m of ropes and the remaining 38 kg had spread over the metal frame due to overcrowding on the ropes. After 10 months on the ground, the seed had grown to crab-proof size, 44 mm mean length, and to 279 kg in crop weight; it was estimated that 176 kg of this was derived directly from the ropes, i.e., 22 kg/m of collector rope. The yield increment (x 2.75) was barely half that normally obtained in Menai Strait fenced enclosures (Davies *et al.*, 1980), probably due to an initially heavy crab attack facilitated by the luxuriant green weed growths on the fences in 1978.

3.4.3 *The Wash*

The 1979 subtidal floating ropes and nets were the only trials which produced relayable mussel seed. In October, two of the three surviving collector units (trials 5 and 6) were stripped; the other (trial 7) was left in position so that the overwinter survival of its catch could be assessed. The two units yielded 216 kg of relayable seed (Table 11) at a density equivalent to 25.8 kg/m^2 of net, or ~ 4 kg/m of SFP rope if it is assumed that the majority of spat had settled on the closely spaced ropes rather than on the netting. These yields are minimal because some seed was lost when the heavy units were towed 12 km from the catching site to the fenced enclosure.

Table 12 **Analysis of costs at March 1981 for spat collection systems using ropes of (a) tufted SFP (b) 12 mm diam. coir**

	SFP	Coir (12 mm diam.)
Rope materials	£0.28/m*	£0.18/m
Labour for preparation +	£0.22/m	£0.02/m
Total initial cost	£0.50/m	£0.20/m
Life expectancy	4 years	1 year
Annual cost	£0.12/m	£0.20/m
Max. expected yields		
20 mm (seed)	9 kg/m	3 kg/m
50 mm (marketable)++	50 kg/m	16.5 kg/m
Collector costs per tonne		
20 mm (seed)	£13.3	£66.7
50 mm (marketable)	£2.3	£12.1
All collection costs ** per tonne of seed		
A. collection on culture site	£29.3	£113.7
B. " away from culture site	£68.9	£190.2
All collection costs ** per tonne of marketable mussels		
A.	£5.2	£20.3
B.	£12.3	£34.0
All costs as % of crop value ϕ A.	3%	11%
B.	7%	19%

Notes: * 1 m of collector comprises 2.5 m of SFP rope.
\+ Labour costed @ £2 per man-hour throughout.
++ Based on x 5.6 growth increment for crop using fence cultivation.
** 'All costs' includes elements for frames (4 year lifespan), transport and handling, both when setting out collectors initially and during the nursery stage.
ϕ Crop value for purified mussels assumed to be £180/tonne; purification costs approx. £25/t, incl. sacks; transport costs will vary but may reach £30–£40/t.

3.4.4 *Summary of yields*

Very high losses of spat occurred during the nursery stage in all areas. Various factors were suspected or demonstrated, notably crab predation, algal fouling, aerial exposure and siltation of collectors. Yields of 15–25 mm seed from large-scale trials only once exceeded 4 kg/m of rope and usually averaged only 1–3 kg/m, according to type of collector. The most successful small trial, with coir and SFP ropes subtidally in the Teign Estuary, yielded 8 kg/m which was similar to that from preliminary trials there with SFP and 'Hairlok' tufted ropes.

The maximum potential yield of relayable seed is probably about 10 kg/m, at a size of 15–20 mm mean length, using SFP ropes.

3.5 Collection costs

The costs of purchasing materials and of making up SFP and 12 mm coir rope collectors are given in Table 12. Labour is costed according to the recorded collector manufacture rates of 10 m of SFP or 120 m of coir collector per man-hour. No figures are included for 'Hairlok' ropes because these types are considered unlikely to have a commercial application due to their high cost and short lifespan.

Although the initial cost of SFP collectors is more than double that of coir, the average annual cost of SFP is 40% less than for coir due to the greater durability of SFP. Coir lasts less than one year in the sea and normally is not reusable, whereas SFP collectors are virtually indestructible and can be reused certainly for at least four years.

In terms of the yields of seed and marketable mussels which can be obtained, the cost per kilogram of crop for the higher yielding SFP is only about one fifth of that for coir collectors. These calculations are based on (a) the maximum stripped seed yields so far obtained for SFP, i.e., 9 kg/m, (b) the final production at market size obtained from relaying the seed into fenced enclosures. The potential production from 1 m of SFP based on the anticipated average growth increment (Davies *et al.*, 1980) is about 50 kg of marketable mussels, i.e., 9 x 5.6 kg. So far, however, the average seed yield from SFP ropes has been only around 3 kg/m, with about 1 kg/m from coir.

Final costs for a spat collection system – including frames, handling and transport between collection and cultivation sites – are also given in Table 12 for each of two options, depending on whether spat collection is possible at the cultivation site or must be undertaken at a distant site. Costs are expressed in terms of the value of the final marketable crop and assume that the mussels would be purified before sale in order to realise an acceptable price. The calculations indicate that with maximum yields the cost of SFP collectors operated at, or close to, the fence site could be as low as £5 per tonne of marketable crop, or 3% of crop value. The average figure realized in our experiments was in fact 9%. If spat collection has to be carried out far from the fence site, as with the Morecambe Bay-Menai Strait operation, then total costs would be approximately double those for on-site collection. Proportionate costs with coir ropes would be three times greater than with SFP.

4. Discussion and Conclusions

The trials reported here have demonstrated the biological feasibility of producing seed mussels from spat collectors for relaying intertidally into crab-proof enclosures. However, large-scale commercial collection and handling of spat on ropes poses many problems.

A fundamental problem is the unpredictable variability in abundance and occurrence of spat. Variability in spat abundance, spanning several orders of magnitude, could mean that cultivators will have to deploy several times more collector materials than might be required in a 'good' spat year. Costs and time devoted to collection would thereby be increased greatly over the figures given in Table 12.

The experiments have quantified the seasonality of spat abundance and enable predictions to be made of the best months and situations for spat collection. The most reliable season anywhere for obtaining spat is likely to be during May–July, when primary spat are available. These summer spat, however, can usually be captured and retained only on floating collectors. Such systems present difficulties with respect to availability of suitable water space in estuaries, while for exposed sites such as the Wash heavier and more expensive gear would be essential.

Morecambe Bay, with its fairly regular settlements of secondary spat during December–April, offers considerable potential for spat collection. The advantages of utilising the Morecambe Bay (Roosebeck area) spat resource would be: (i) collection is intertidal and straightforward, (ii) easy site access and unlimited space, (iii) the hardiness of secondary spat compared with primary, (iv) collection and transference to nursery systems can be completed at the start of the main growing season and before summer spatfalls occur in other areas. Morecambe Bay could probably supply spatted collectors in April–May in most years to cultivation sites almost anywhere in the British Isles.

The SFP rope collector is shown to have great potential for commercial spat collection. Its catching power could probably be improved, for example, by increasing tuft size or by increasing the number of tufts per metre of carrier rope. Given a good spatfall, and with good survival during the nursery stage, SFP collectors have yielded relayable seed at a rate of about 9 kg/m of rope, which may well be economically viable.

Predation by small shore-crabs on spat during the nursery stage in fenced enclosures can be serious at certain sites in some years. Experiments are now in progress to determine whether suspending spatted collectors in a floating nursery system could be worthwhile. Such a system, apart from avoiding crabs, is confidently expected to increase growth rate and thereby permit earlier relaying onto enclosed ground.

The stocking of fenced lays with seed obtained from spat collectors should be regarded as an option open to cultivators who lack supplies of dredgeable seed. It would appear to be economic and practical in certain circumstances but it is unlikely at present to be a generally viable or attractive alternative to the dredging of seed, given especially the low market value of cultivated mussels in the United Kingdom.

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5. References

BAYNE, B. L., 1964. Primary and secondary settlement in *Mytilus edulis* L. (Mollusca). J. Anim. Ecol., **33**: 513–523.

DARDIGNAC-CORBEIL, M–J., 1975. La culture des moules sur bouchots. Sci. Pêche, (244), 10 pp.

DARE, P. J., 1976. Settlement, growth, and production of the mussel, *Mytilus edulis* L., in Morecambe Bay, England. Fishery Invest., Lond., Ser. 2, **28** (1), 25 pp.

DARE, P. J., 1980. Mussel cultivation in England and Wales. Lab. Leafl., MAFF Direct. Fish. Res., Lowestoft, (50), 18 pp.

DARE, P. J. and DAVIES, G., 1975. Experimental suspended culture of mussels (*Mytilus edulis* L.) in Wales using spat transplanted from a distant settlement ground. Aquaculture, **6**: 257–274.

DARE, P. J. and EDWARDS, D. B., 1976. Experiments on the survival, growth and yield of relaid seed mussels (*Mytilus edulis* L.) in the Menai Straits, North Wales. J. Cons. int. Explor. Mer, **37**: 16–28.

DAVIES, G., 1974. A method for monitoring the spatfall of mussels (*Mytilus edulis* L.). J. Cons. int. Explor. Mer, **36**: 27–34.

DAVIES, G., DARE, P. J. and EDWARDS, D. B., 1980. Fenced enclosures for the protection of seed mussels (*Mytilus edulis* L.) from predation by shore-crabs (*Carcinus maenas* (L)). Fish. Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft, (56), 14 pp.

MASON, J., 1969. Mussel raft trials succeed in Scotland. Wld. Fishg, **18**: 22–24.

SEED, R., 1969. The ecology of *Mytilus edulis* L. (Lamellibranchiata) on exposed rocky shores. I. Breeding and settlement. Oecologia (Berlin), **3**: 277–316.

TORTELL, P., 1976. A new rope for mussel farming. Aquaculture, **8**: 383–388.

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