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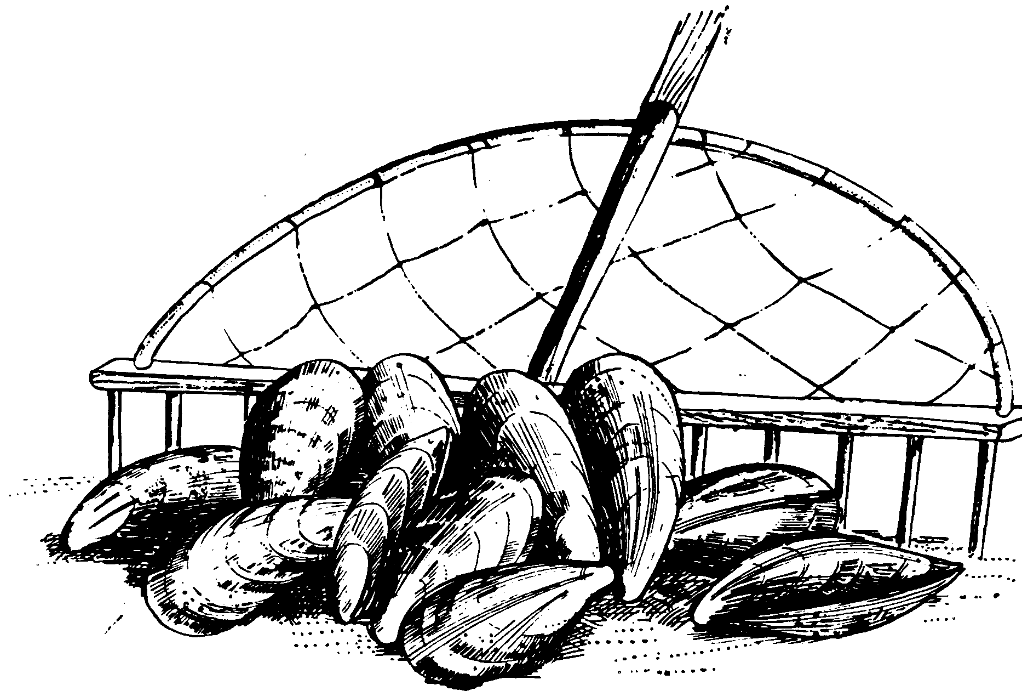
DIRECTORATE OF FISHERIES RESEARCH

MUSSEL CULTIVATION in ENGLAND AND WALES



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CULTIVATION OF MUSSELS IN ENGLAND AND WALES

by P. J. Dare

1. INTRODUCTION

This leaflet outlines the methods by which mussels are cultivated in England and Wales, and draws attention to the potential and problems of this form of sea-farming. More detailed information is obtainable by reference to the reading list on pages 15-16. For specific advice, the reader should write to the address given at the end of this leaflet.

The edible mussel (Mytilus edulis) is an adaptable bivalve mollusc which occurs in a great variety of situations around our coasts, ranging from about mid-shore level down to 20 metres (approx. 10 fathoms) or more below low-water mark. Most natural stocks of mussels, which are often very extensive, are not suitable for direct exploitation because of the poor meat quality resulting from such factors as overcrowding and excessive exposure to air or wave action. However, mussels can be cultivated so as to produce crops of the required size and flesh quality. Their ability to attach and re-attach, with the aid of strong elastic and adhesive threads (the 'beard' or byssus), to various natural and man-made surfaces makes them eminently suitable for cultivation by a variety of methods.

Table 1 The average annual production from mussel fisheries in northern and western Europe, 1970-75

Country	Tonnes	Type of fishery
Spain	111 000	Raft cultivation (ropes)
Holland	103 000	Bottom cultivation (lays)
France	41 000	Bouchot (pole) cultivation and staked rope cultivation in lagoons
Denmark	27 000	Natural beds and bottom cultivation
Germany (West)	11 000	" " " " "
UK	6 000	" " " " "
Ireland	4 000	" " " " "

Notes: 1. 90% of UK landings were from England and Wales.

2. Since 1975 there has been very small scale production from rafts and floating net culture in Scotland and Ireland.

Mussels are cultivated widely in northern and western Europe where, for example, France, Holland, Denmark and Spain together harvest some 260 000 tonnes per annum (Table 1). A closely related species, M. galloprovincialis, is fished and cultivated in many Mediterranean countries. The production of mussels in England and Wales, by comparison, is small. In our eight natural and cultivated fisheries (Figure 1), annual output has increased from around 2 500 tonnes in 1965 to 10 500 tonnes in 1977 (Figure 2). There has however, been only a modest and erratic rise in production from cultivation and it has contributed only about 1 250 tonnes a year on average since 1965. The UK production goes mainly to home markets and is supplemented by varying imports of frozen or brined meats from Holland, Denmark and Ireland. Ireland also sends fresh mussels to some English markets. Recently, export of live mussels from UK natural beds to France has begun and there is scope for expanding this market with high quality cultivated mussels.

2. GENERAL BIOLOGY OF MUSSELS

Mussels are filter-feeders and mainly herbivorous, eating phytoplankton (the microscopic plant life floating in the sea), but they also eat some zooplankton (minute swimming and floating animals) and much organic detritus. The food particles are filtered from a current of water drawn by the gills into the shell cavity through an inhalant siphon. This current also serves for respiration and the water is subsequently expelled through an exhalant siphon, carrying with it also the waste products in the form of faeces and pseudofaeces (unwanted organic matter bound in a mucous secretion). Large volumes of water are pumped through a mussel - up to 45-65 litres (10-15 gallons) in 24 hours by a 75 mm (3 inch) adult - so that a mussel bed acts as an enormous biological water filter.

M. edulis becomes sexually mature when one year old and it may live for 10-15 years or more. The sexes are separate and are usually distinguishable by the colour of the mantle flesh as spawning approaches; males are white to pale yellow, females a pale orange. The main spawning season in England and Wales occurs in April and May with a subsidiary peak in autumn, but some mussels may be found in spawning condition in most months. Eggs and sperm are shed into the sea where fertilization takes place. The fertilized eggs hatch into planktonic larvae which possess a well-developed swimming organ (Figure 3). The early life history is complex. The larvae develop a shell and remain drifting in the surface layers of the sea from one to two months, depending on water temperature, and thus may be carried more than 100 miles from the parent stock; for example, large numbers drift into the middle of the North Sea.

Eventually, when the larvae grow to 0.25 mm in length, they seek the sea bottom and metamorphose into spat. The spat secrete their first byssus threads and with these attach themselves to certain algae and hydroid colonies at or below extreme low-water mark. As the spat grow to 1.0-1.5 mm length they detach their byssus and are again carried by currents until finally they reach either an existing mussel bed or an uncolonized solid, pitted or creviced surface such as rocks, firm stone-shell substrates, buoy chains, jetty piles, oil rigs and fibrous ropes. Heaviest settlements occur near or below low-water mark of spring tides and densities of 100 000 spat per square metre are not unusual on the most suitable grounds.

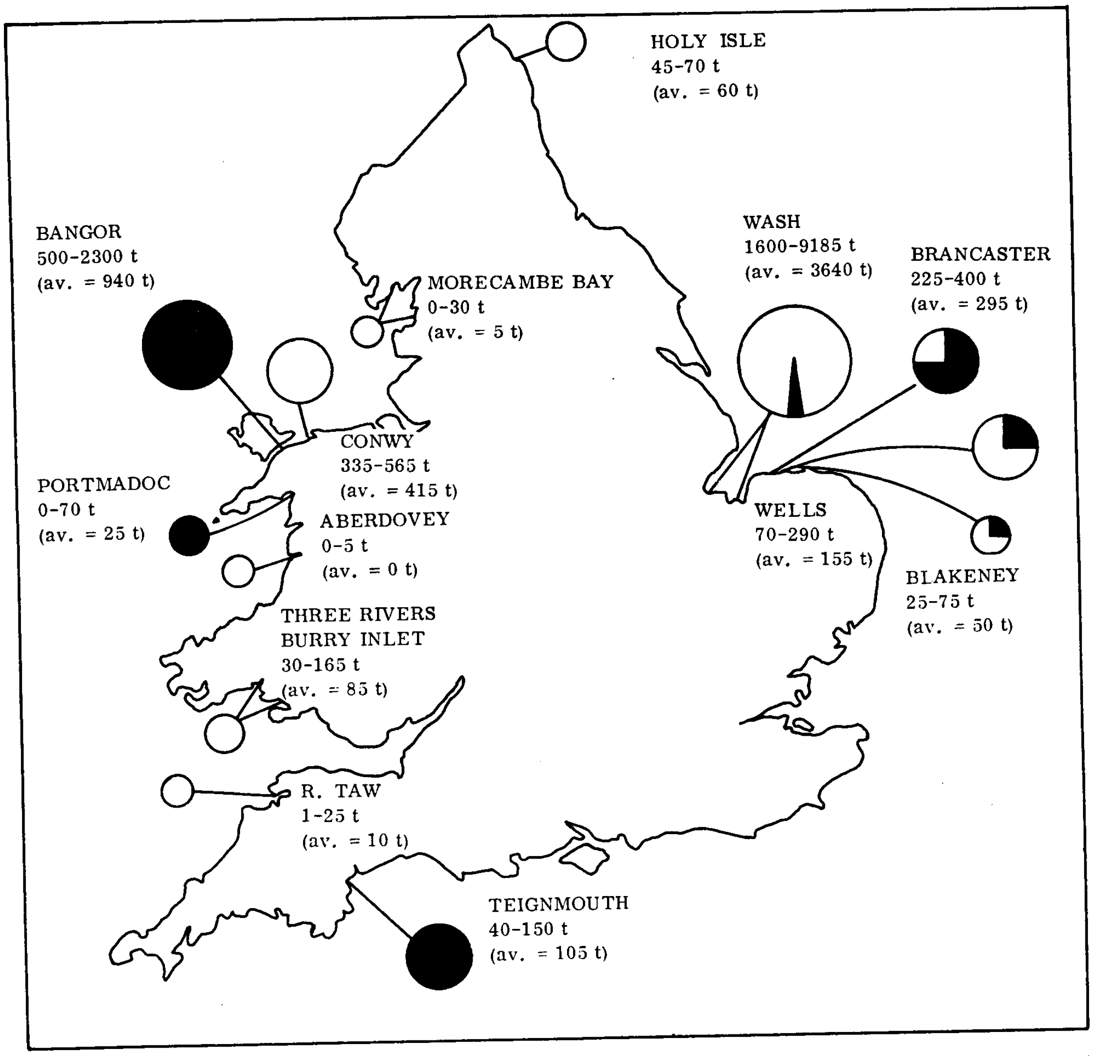

Figure 1 The mussel fisheries of England and Wales, 1970-77, showing the average annual production and range, to the nearest 5 tonnes. (O - natural fisheries; ● - cultivated fisheries; ◔ - mixed fisheries).

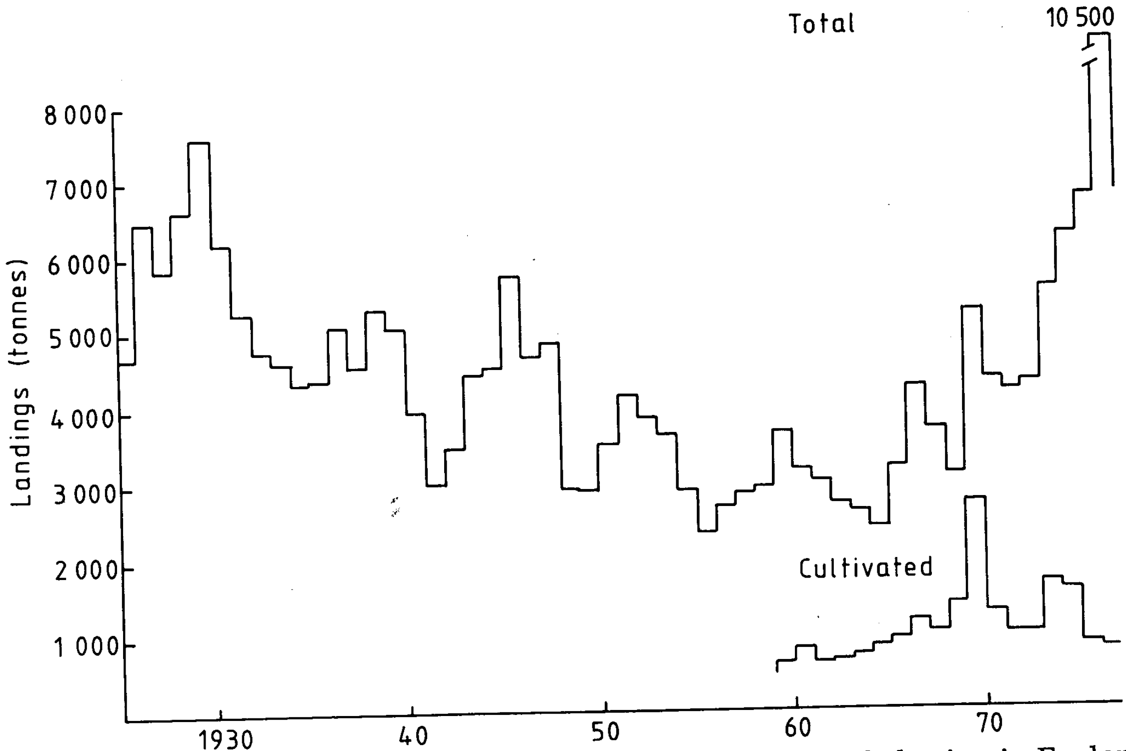

Figure 2 Fluctuations in the annual landings from mussel fisheries in England and Wales during 1926-1977, showing also the quantities produced by cultivation since 1960.

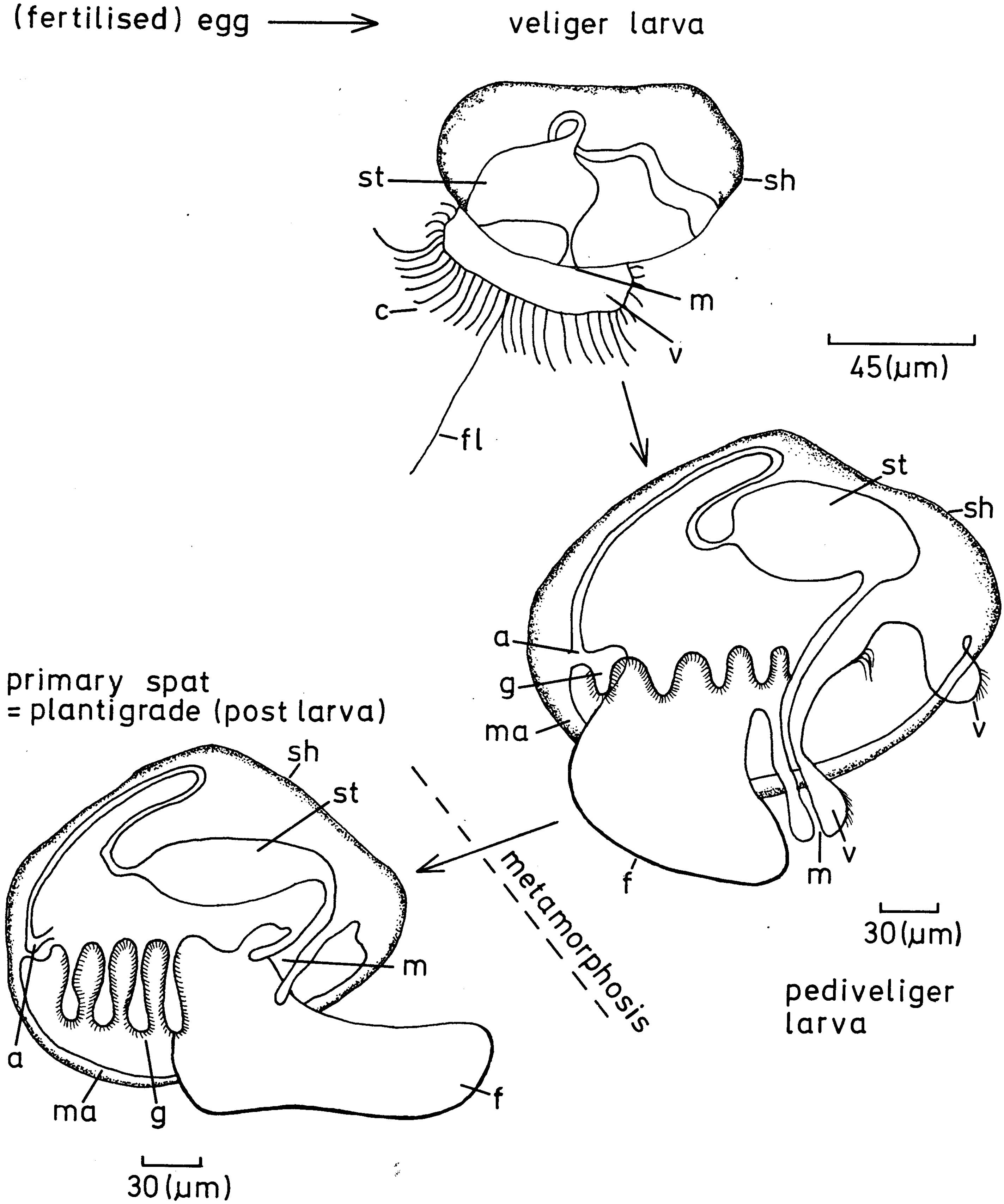

Figure 3 Simplified early stages in the life history of the mussel (st - stomach; sh - shell; fl - flagellum; v - velum (swimming organ); c - cilia; m - mouth; f - foot; g - gills; a - anus; ma - mantle).
Note: One shell valve removed from 2 later stages.

Figure 4(A) A bed of young mussels in Morecambe Bay, in September, stocked with 23 mm seed at an average density of 150 tonnes per hectare, before the onset of autumn storms.

Figure 4(B) The same ground devasted by September storms, showing large areas of 'mussel-mud' recently exposed. Some seed still survive to the right of the picture.

On the sea bed and shore young mussels grow rapidly during their first summer to form dense surface populations or beds (Figure 4A) with mean shell lengths up to 30 mm. These beds soon accumulate deposits of 'mussel-mud' (faeces and pseudo-faeces mixed with silt) and can develop into raised banks up to 1.0-1.5 m in height. The young (seed) mussels maintain position on top of the rising bank by linking byssus threads loosely and forming a thin layer only one mussel deep. Eventually a bank may reach an unstable height and then be lowered or destroyed by tides, currents and storms (Figure 4B). Other young mussel settlements may be overwhelmed by shifting sandbanks or be destroyed by invasions of predatory starfish, Asterias rubens ('five-fingers'). In some light settlements the young mussels may remain protected from predators, such as shore-crabs, Carcinus maenas, because they attach within the clumps of old mussels.

Growth rate in mussels (Table 2) depends on various factors, particularly shore level (controls feeding time), degree of exposure to waves, population density, salinity and, above all, on temperature and the amount of food in the water. Some examples of contrasting growth rates are given in Table 2. Fastest growth occurs

Table 2 Typical growth rates of mussels under various conditions in England and Wales

Situation	Average length (mm) from spatfall after			Comments
	1 year	2 years	3 years	
Sublittoral - estuarine	45	60	67	Fastest growing zone for cultivation
Low intertidal - estuarine (MLWMST)	35	50	57	Best level for intertidal cultivation
Low intertidal - estuarine (MLWMST)	30	45	52	Average growth for intertidal cultivation
Intertidal - estuarine (MLWMNT)	20	35	42	Highest level for intertidal cultivation
High intertidal - exposed to severe wave action	3	5	7	Exceptionally slow

Note: MLWMST and MLWMNT refer to mean low-water mark of spring tides and neap tides respectively.

below low-water mark around the mouths of estuaries and in other sheltered inshore sites where the sea water is rich in phytoplankton and organic debris. Conversely, the poorest growth is found high up on wave-beaten rocks or in the higher reaches of estuaries where salinity is greatly reduced. Growth varies seasonally, being fastest from June to September and slowest between December and February. Intertidal mussels may cease growing in winter. Mytilus edulis normally grows to a final length of about $2\frac{1}{2}$-$3\frac{1}{4}$ inches (65-80 mm) in British waters, but mussels in the poorest growing situations may never exceed $\frac{1}{2}$ inch (12 mm). In the best situations deep-water mussels can reach an average length of $2\frac{1}{2}$ inches in three years.

The minimum market size for mussels in most districts of the UK is 50 mm (2 inches), which can be attained in under $1\frac{1}{2}$ years by mussels growing in deep water, but only after 2-3 years if growing on the lower shore. Comparative growth rates for mussels cultivated by other European methods are given in Table 3.

Table 3 Approximate times required for mussels to reach minimum market size by cultivation in various European countries

Country	Minimum market size (mm)	Approx. growth period (months)		Cultivation method	Source
		From spatfall	In cultivation		
UK	50	27-32	23-24	IL	MAFF
		15-16	14-16	SL/R	MAFF
Holland	55	18-20	15-16	IL/SL	Korringa, 1976
Spain	80	16-18	14-16	R	Korringa, 1976 Figueras, 1978
France	40	12-14	12-14	B	Korringa, 1976 Dardignac-Corbeil, 1975

IL = intertidal lays R = ropes (raft)
SL = sublittoral lays B = bouchot (post)

Note: Growth periods refer to times taken for crops, and not fastest mussels, to reach marketable size.

The environment also determines the shape, thickness and colour of a mussel shell (Figure 5). The normal colour is black or dark-brown but young and fast-growing mussels are usually pale-brown and often striped. Old, high-level mussels often are pale-bluish due to abrasion of the external shell layer and are locally called 'blue nebs'. Fast-growing mussels (Figure 5A-C) have relatively thin, smooth, sharp-edged and and elongated shells whereas slow-growers are characteristically thick shelled, blunt and rounded with a roughened surface (Figure 5D). Such slow-growers are of little or no use as stock for cultivation.

3. CONCEPT AND METHODS OF CULTIVATION

Their adaptability and hardiness enable mussels to be cultivated by 3 main methods:

(a) on the sea-bottom - as transplanted mussel beds or 'lays';

(b) as a floating culture - in which mussels are suspended from rafts or floats, on ropes or in tubes of plastic netting;

(c) attached to vertical posts on the shore (bouchot culture) - either from direct settlement or by binding seed on with netting.

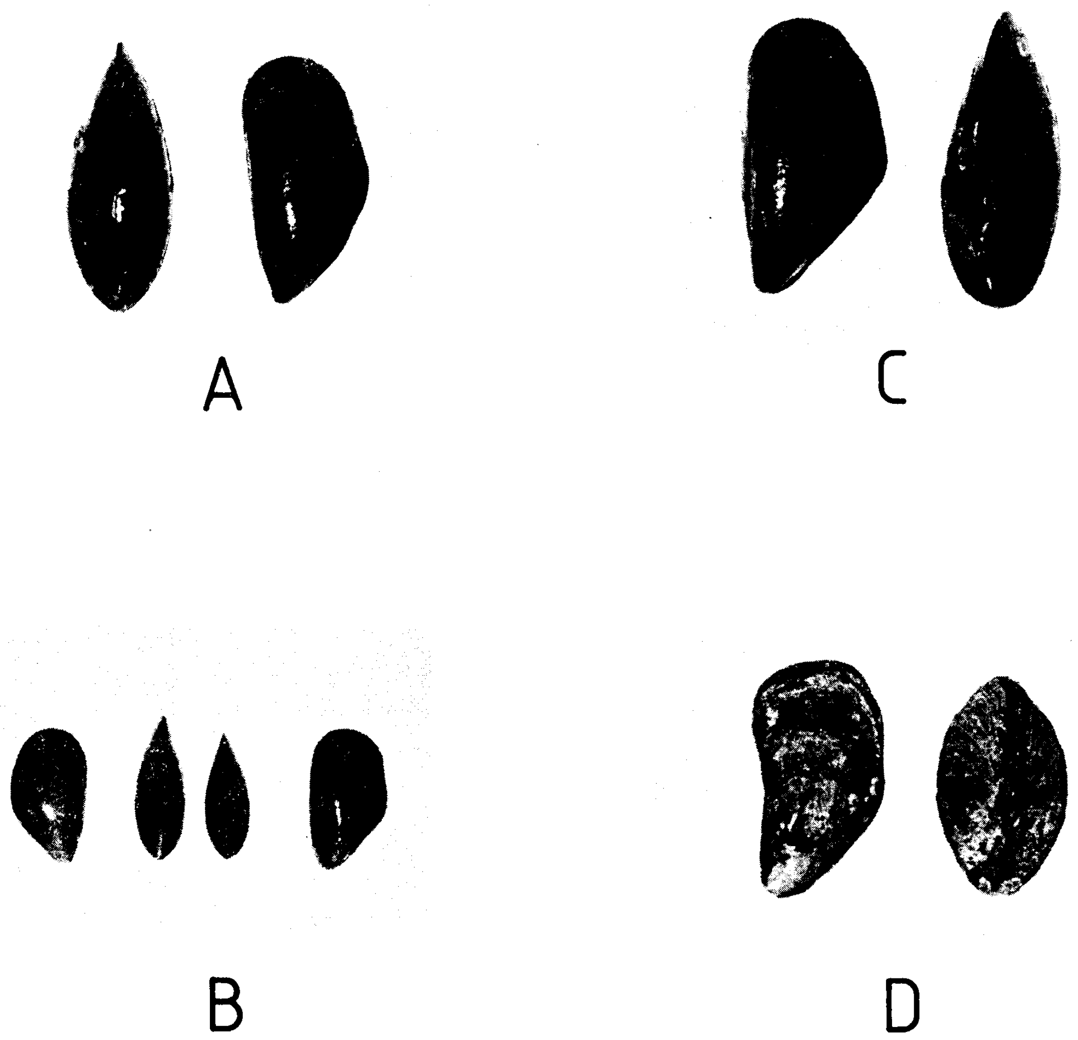

Figure 5 Types of mussel.

A. High quality marketable stock from MLWMST, Morecambe Bay; note: clean, sharp-edged shells of fast-growing mussels.

B. Seed mussels from lower shore, Morecambe Bay; ideal stock for relaying even though still vulnerable to shore crabs.

C. High quality marketable mussels from deep water, Conwy Estuary.

D. 'Blue nebs' of no commercial value, from the upper shore, Conwy Estuary; note: rough, stunted and rounded shells of very slow-growing mussels.

A detailed review of these, and other systems, is given by Mason (1972). The present report is confined largely to the two techniques - bottom and floating cultivation - which are most suitable for adaptation to British waters. Post culture is not likely to be a worthwhile method and will be only briefly discussed.

In any form of cultivation the mussel-farmer aims to grow a series of crops until they are of an optimal size and meat content for harvesting either for processing or for sale fresh to the market. To maintain steady production, three prime requirements must be satisfied: (1) a regular source of spat or seed stock; (2) a suitable area for fast growth and 'fattening' of meats; (3) good husbandry e.g. thinning-out, protection from predators.

4. SEA-BOTTOM CULTIVATION

Bottom cultivation was introduced in 1960 on a large scale, to the Menai Strait, North Wales, where production at times has reached 2 000 tonnes per annum. It has also been practised on a modest scale for many years in Brancaster Harbour and the Teign Estuary (Figure 1). Other small cultivated fisheries, at Wells, Blakeney and Portmadoc in particular, have now virtually died out because of shifting sand banks, scarcity of seed stock or purification problems. Attempts to cultivate large areas of suitable ground in the Wash, near Boston, have also lapsed but because of starfish predation and social factors.

4.1 General features

In Britain and Ireland more than 95% of cultivated mussels are produced by this basically simple method which, on a large scale, is derived from traditional large-scale mussel-farming in Holland. Small (seed) mussels are transplanted from natural beds, where growth or survival is poor, onto 'lays' in sheltered inshore waters with a silty sea bed, favourable water currents and richer food supplies. Large mussels may be transplanted for a year so as to improve their meat quality ('fattening') before marketing. For best growth and fattening, mussels are relaid as low in the intertidal zone as possible and preferably in the sublittoral. Relaying should not be carried out above low-water mark of poor spring tides.

4.1.1 Growth and yields

Depending on the size at relaying, often only 25 mm shell length, and on the tidal level, a mussel crop may require from one to three years to reach the minimum marketable size (50 mm) in Britain (Table 4).

Mussels are highly productive in terms of flesh yield per unit area of lay. A properly managed ground will yield 100-125 tonnes live weight of mussels per hectare, or 20-25 tonnes of cooked meats, every two years. Overstocking lays, in excess of 125 tonnes per hectare, can result in slower growth and reduced meat content.

Table 4 Typical growth rates for 25 mm seed mussels relaid at various cultivation levels in England and Wales

Situation	Average lengths (mm) from relaying after:			Comments
	1 year	2 years	3 years	
Sublittoral	55-57	65-68	70-72	Fastest growing zone but highest predation risks
Lowest intertidal (MLWMST)	45-48	55-58	63-65	Best level for intertidal cultivation
Low intertidal (MLWMNT)	40-42	48-50	53-55	Highest level for cultivation

Note: 1. MLWMST and MLWMNT refer to mean low-water mark of spring tides and neap tides respectively.

2. Growth rates will vary according to site, year and stock density.

4.1.2 Equipment and handling

In the Menai Strait at Bangor the large-scale cultivation of 60 hectares is mechanised throughout. One or more dredgers (15-30 m length) are used for gathering and relaying the seed, for thinning and harvesting the crops, and for removing starfish predators. A variety of 1.5-2 m wide Baird*, Dutch and suction dredges is employed. Elsewhere in England and Wales, individuals or small groups of fishermen work seasonally on very small plots - some only 50 x 20 m - either by hand, sometimes using short-handled rakes, or from small boats fitted with 1.5-2 m dredges.

Every care should be taken when handling mussels in bulk. The powerful dredges, sorters and other machinery used in large-scale cultivation can cause unacceptable losses, both of seed and marketable mussels, through shell breakage or tissue damage (Dare, 1977). Even slight damage can assume significance when mussels subsequently are to be purified, stored alive or relaid. Excessively rough handling of mussels can reduce their ability to function and self-cleanse properly in purification tanks.

4.1.3. Relaying seed

Lays are stocked with seed mussels usually during spring and summer, i.e. between harvesting seasons, and as and when suitable seed stocks are located. The best seed is to be found on the low shore or sublittorally; stocks found above low-water mark of neap tides are often stunted and seldom respond well to being transplanted to lower levels. Seed smaller than 20 mm normally cannot be dredged because insufficient 'mussel-mud' has been deposited under the mussels to permit effective dredging. Further advantages of re-stocking lays during April-August are

* Based on the Baird escallop dredge (Baird, 1955).

that weather is then much more favourable for prolonged dredging operations and that relaid seed is able to establish itself and to grow before the onset of autumn storms. Seed should not be exposed to air for more than 24-36 hours in transit, and ideally it should be relaid at slack water on neap tides when current speeds are low.

4.1.4 Harvesting and marketing

The harvesting season is normally from September to March or early April, but it varies locally and annually depending on the weather, condition of the mussels, and market demands. The season is governed fundamentally by the annual cycle of spawning and flesh condition of the mussel. After spawning in spring, mainly April, the flesh of mussels is thin, watery and unappetising. During summer large reserves of carbohydrate (glycogen) are laid down in the mantle tissues which thicken and swell to a plump appearance indicative of 'good condition'. Peak condition is reached during September-October, after which there is a gradual decline through the winter. This decline can amount to 30-40% on a dry meat weight basis, as the mussels utilise their glycogen stores for maintenance purposes through the 'lean' winter months and for developing their reproductive organs.

Harvested mussels are marketed fresh-in-shell or as cooked meats, or they may be processed by bottling in brine or vinegar, canning or quick-freezing. In lays of good quality mussels the cooked meat yield is 20-25% of total live weight. Because of risks of contamination from sewage pollution, fresh sales are widely prohibited under Public Health regulations unless the mussels have first been purified in an approved purification system. Purification methods based on chlorine and ultra-violet sterilisation of sea water are described by Wood (1969) and Ayres (1978). In England and Wales, there are only one or two cultivation areas from which mussels do not require any form of treatment before sale. In the remoter sea-lochs of western Scotland the pollution risks are usually much less.

Mussels are a low-priced shellfish, fetching only around £40 per tonne liveweight at first-sale, unpurified, in 1979. By comparison, purified mussels realised £170 per tonne to wholesalers, while higher prices could be obtained for small quantities sold to specialised outlets such as hotels and sea-food restaurants.

4.2 Biological problems

Two major problems confront the cultivator in this country: (a) irregular supplies of seed mussels; (b) poor survival of the relaid seed due principally to predators. The latter problem exacerbates the former.

4.2.1 Irregularity of seed supplies

A production system requires an adequate and predictable supply of seed mussels at least every other year, and preferably annually. By their nature, muddy cultivation sites are rarely also favourable areas for spat settlement. Consequently, gathering seed may entail return journeys of 15-30 km, or even up to 200 km, by sea.

A shortage of seed often arises from the unpredictable occurrence and ephemeral nature of spatfalls, which are vulnerable to rapid destruction by starfish and storms before they grow to a dredgeable size. Locating and dredging sublittoral beds may pose considerable problems in some areas, especially Morecambe Bay and the Wash, due to distance, tides and bad weather. The largest and most frequent seed sources, such as those at the Wash and Morecambe Bay, may fail at least once every four years. Elsewhere, there are erratic settlements of sublittoral mussels

Figure 6(A) A small (9 m x 6 m) GRP fence used for testing the suitability of sites for enclosure. This one is on the commercial mussel lays at Teignmouth, Devon.

Figure 6(B) The GRP fence enclosing 800 m^2 of mudflat at the Menai Strait: the enclosure contained about 5 tonnes of seed mussels when this photograph was taken in January 1978.

close inshore in Caernarvon and Cardigan Bays and off the south Devon coast, which help to sustain the cultivated fisheries in the Menai Strait and Teign Estuary.

4.2.2 Predators

Theoretically, without any mortality, 1 tonne of 25 mm seed would yield about 8 tonnes of mussels at the minimum UK market size of 50 mm. In commercial reality, however, the intertidal return ratio from such seed of harvested weight to relaid weight is usually only around 1:1, thus indicating very high losses on the lays. Losses can be reduced considerably by relaying large (40-50 mm) seed but then, even with only a light mortality, the return ratio would not be expected to exceed 2:1 because of the reduced growth potential of the larger seed. Thus, the maximum return for growth from 40 mm to 50 mm is 2:1, and from 45 mm to 60 mm it is 2.4:1. Providing losses can be minimised in some way, the greatest potential yields are to be obtained only by utilising small seed.

Very heavy losses of seed can be inflicted by starfish (Asterias rubens) and shore-crabs (Carcinus maenas), while oystercatchers (Haematopus ostralegus) may take a significant proportion of mussels from the smallest (e.g. 50 x 20 m) intertidal lays. Starfish swarms attack all sizes of mussels and can destroy acres of the best lays around and below low-water mark of spring tides although only in areas of high salinity. They seldom enter estuaries and, with proper husbandry and use of special dredges (Korringa, 1976) their depredations can be minimised although this may be a laborious operation.

Shore-crabs cause widespread, sometimes severe, losses of small seed on both intertidal and deep-water lays in many estuaries and in the Menai Strait. Mussels below 40 mm ($1\frac{1}{2}$ inches) in length are vulnerable, and losses are particularly heavy when relaying of 20-30 mm seed occurs in the summer, for then crabs are most numerous and active. Crabs are too abundant and mobile to be controlled directly by trapping, but intertidal seed lays can be protected to a large degree by enclosing them within crab-proof barriers or fences.

An effective design of fence is constructed with 45 cm high walls of rigid plastic mesh surmounted by a smooth 15 cm wide strip of fibreglass which slopes downwards and outwards at 45^{o} to form an overhang which impedes climbing crabs (Figure 6). Fence construction, operation, benefits and economics are described fully elsewhere (Walne, 1977; Davies et al., 1980). If small seed is thus protected during its vulnerable first year after relaying, yields can be increased by 5-8 fold compared with yields from unprotected lays. Enclosing 800 m^2 of ground by a crab-proof fence can produce 15 tonnes of 40 mm seed after one year from $3\frac{1}{2}$ tonnes of 20 mm seed.

4.3 Legal aspects

Mussel cultivation, including the erection of crab-proof fences, can only be conducted with the consent of the owner of the foreshore or bed affected and upon such terms and conditions as he may require. In most cases the owner will be the Crown Estate Commissioners or their lessees or grantees. Other statutory consents may be required, such as that of the Department of Trade, Harbour authority or others, and it is essential for the prospective cultivator to ensure that he obtains all necessary consents.

In addition, it is advisable that the cultivator should apply to MAFF for a

Figure 7(A) An experimental raft in the Menai Strait.

Figure 7(B) A rope from the raft stocked with seed mussels, after 5 months growth.

Several Order relating to the ground(s) which he wishes to cultivate. The granting of such an Order signifies that the cultivator has the exclusive rights to cultivate the named ground(s) and to the stocks of mussels thereon. Advice can be obtained from the local MAFF District Inspector of Fisheries or the local Sea Fisheries Committee.

5. FLOATING CULTIVATION

Mussels can be grown attached to coir and various synthetic ropes suspended from rafts and buoyed long-line systems, or in net tubes and on netting similarly floated. Raft cultivation has been perfected on a large scale in Spain (Korringa, 1976). The Spanish success has stimulated many countries to investigate the potential of this approach, notably Venezuela, Chile and New Zealand. In the North Atlantic, exploratory trials have been made in Norway, Iceland, Britain, Ireland, Canada and USA.

The experiments in western Scotland (Mason, 1969) and North Wales (Dare and Davies, 1975) (Figure 7A and B) showed the biological potential of floating culture even in our cold-temperate waters. Mussel crops reached minimum market size in 1-1½ years and possessed high meat contents (30-35% cooked meat yields) and clean, smooth shells. In both regions, yields of harvestable mussels were obtained at a density of 10 kg per m of rope, equivalent to Spanish production levels.

In Britain the principal advantages of floating cultivation over bottom cultivation would be: (1) avoidance of crab and starfish predation; (2) best growth. The method is also flexible with regard to water depth and it is almost independent of seabed topography. Adequate shelter and water flow are required but localised turbulence and areas where current speeds exceed 1½ knots should be avoided. In the most favourable localities, spat settlements occur at, or close to, the cultivation sites themselves. Otherwise, spat collector ropes may have to be transported to the cultivation sites from distant settlement areas. Alternatively, net tubes can be stocked with clumps of seed mussels collected from rocks and mussel beds or stripped from spatted ropes.

Floating cultivation in this country is at a disadvantage at present because of: (a) the high capital cost of rafts, manufactured buoyancy materials and moorings; (b) the labour-intensive nature of handling operations, e.g. thinning and transplanting; (c) relatively slow growth and low market value of mussels; (d) problems with finding and leasing suitable sites. Capital costs can be reduced by ingenious use of scrap flotation materials. The problem of locating sites is particularly difficult in the congested inshore waters of England and Wales, but is less acute in Scotland. The legal and Public Health aspects are similar to those confronting the bottom cultivator.

In Scotland, various western sea lochs - from Loch Sween (Argyll) north to Loch Ewe (Wester Ross) - have been investigated with varying success by the staff of the Department of Agriculture and Fisheries, Aberdeen, and the Scottish Marine Biological Association laboratory at Oban. The most promising site to be found to date has been Linne Mhuirich, a small inlet off Loch Sween where water conditions, temperatures, food supply and spat abundance are unusually favourable. There, small crops of mussels have been grown to commercial size on ropes in little over one year, whereas 2-2½ years may be required in the colder waters of Loch Ewe. Some lochs, however, are unsuitable for floating cultivation through one or more adverse factors such as unreliability of spatfalls, heavy fouling of ropes and crops by barnacles, seasquirts and other organisms, seasonally calamitous reductions in salinity due to heavy rainfall runoff from the mountains, or inadequate water exchange with the open sea. As a result of the scientific investigations several pilot-scale commercial operations have been started at the more promising sites in recent years.

In England and Wales, biological and hydrographic conditions conducive to floating cultivation probably exist in several of the drowned-valley systems around the south-west coastline, especially in South Devon and Cornwall, or the middle reaches of Milford Haven. Exploratory commercial ventures seem unlikely to be undertaken in this region, however, unless the legal problems associated with obtaining culture sites are resolved by local authorities; recreational interests take precedence over the needs of prospective cultivators at present.

6. POST (BOUCHOT) CULTIVATION

This traditional technique is extensively used along the Biscay and Brittany coasts of France where the mussels are grown on numerous rows (bouchots) of 2 m high wooden posts placed in the low intertidal zone of bays and estuaries. The mussels either settle directly onto the posts or else spatted ropes may be brought from afar and wound round the stakes. The method is laborious and annual productivity is very low - approximately 25 kg of mussels per post, equivalent to a mere 8-12 tonnes per hectare. Bouchot cultivation is economically viable in France probably only because of the mystique attached to the particular flavour of these mussels, which command the highest prices. The low minimum size of 40-45 mm allows crops to be marketed after 12-14 months, and there is no competition from other cultivation systems.

Although bouchot cultivation may well be biologically feasible in the Wash and some other localities in England and Wales - as, indeed, early MAFF experiments indicated - it is very unlikely to prove economic in this country at the present time. The larger market size, slower growth rates and, above all, the restriction of navigation rights over the great expanses of intertidal flats required by bouchot cultivators all militate against the introduction of this system to our waters.

7. CONCLUSIONS

At the present time there are some 300-400 hectares of known intertidal and sublittoral lay-grounds suitable for mussel cultivation in England and Wales - including 150-250 hectares in the Wash near Boston (not utilised), 100 hectares in the Menai Strait at Bangor (not fully utilized), 30 hectares in the Teign Estuary (also incompletely utilised), and 10-20 hectares in the Exe Estuary (unused). Given adequate seed supplies and efficient husbandry, these grounds could yield an annual production of 17 000-25 000 tonnes, or about sixteen times the present average output by cultivators in England and Wales.

It is probable that floating cultivation will become more firmly established along the Scottish west coast, mainly Argyll, during the next ten years. However, no large-scale developments seem likely unless markets can be reached in England and France.

There is a great need to develop a market for 40-50 mm, or French-size, mussels in order to reduce growing times - by up to one year on intertidal lays - and thereby increase turnover and improve the economics of flotation systems.

8. READING LIST

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