Science Series
Technical Report no.136

Bivalve cultivation: criteria for selecting a site

I. Laing and B.E. Spencer

Cefas

science series
technical report no.136

Bivalve cultivation: criteria for selecting a site

I. Laing and B.E. Spencer

The authors :
Ian Laing works as a Senior Shellfish Health Inspector at the Cefas Weymouth Laboratory, The Nothe, Weymouth, Dorset DT4 8UB.
Brian Spencer retired from the then Directorate of Fisheries Research in August 1996.

Contents

continued

List of illustrations

1. Introduction

In the UK, most of the bivalve molluscs produced for sale do not come from cultivated stocks. They are fished from natural stocks, mainly in fisheries that are managed to give a sustainable yield from year to year. At present, scallops are the most valuable species, worth about £34 million per year from landings of around 22,000 tonnes. This is about 30% of the 80,000 tonnes total weight landed for all types of commercially exploited bivalve molluscs (scallops, mussels, cockles, clams and oysters). Cultivated bivalves make up about 35% of the total bivalve molluscs landings in the UK. Mussels and oysters contribute the greater part of this total. Production of these is relatively small compared with that in the rest of Europe. About 28,000 tonnes of mussels and 1,600 tonnes of Pacific and native oysters are produced annually in the UK, and this is no more than about 5% of total European production of these species.

The native mussel (*Mytilus edulis*) is the species commercially cultivated in the UK. Two methods, seabed and suspended cultivation, are used. With seabed cultivation, seed mussels are collected from wild beds where there has been dense natural settlement, and re-layed at a new site. With suspended cultivation, collectors of a suitable material, such as suitably adapted synthetic rope, onto which mussel spat in the water will settle naturally, are deployed. Spat from these collectors are then suspended from rafts or longlines, in an area suitable for cultivation.

The Pacific oyster (*Crassostrea gigas*), a species originally from the Far East, is now regularly produced in UK bivalve hatcheries for on-growing in many estuaries, bays and lochs around our coast-line. The native flat oyster species (*Ostrea edulis*) is also important due to its higher market value. However, as a cultivated species, hatchery-reared flat oysters attract little attention at present because of their susceptibility to the disease organism, *Bonamia*, which was first recorded in the UK in 1982.

Cultivation of scallops (*Pecten maximus*), as for mussels, is currently dependent on wild-caught seed and is mainly undertaken in Scotland, particularly on the west coast. Suspended cultivation, using methods developed in Japan, with pearl and lantern nets, was widely practised initially, but problems of shell biofouling associated with this method led to a move towards cultivation on the seabed. This can only be done at sites where the substrate is suitable for this particular species. Due to the high value of scallops, much attention has been given to improved methods for harnessing natural spatfalls. The vagaries of nature make this a rather hit and miss process, so techniques for producing spat in hatcheries, to guarantee a reliable supply of good quality seed, have been developed.

Historically, species other than the Pacific oyster, have been introduced into the UK for assessment of their potential for cultivation. The Manila clam (*Tapes philippinarum*), the Chilean mussel (*Choromytilus choros*), the Chilean oyster (*Tiostrea chilensis*), the American oyster (*Crassostrea virginica*) and the New Zealand oyster (*Tiostrea lutaria*) were all introduced into the quarantine facilities of the Cefas Conwy Laboratory during the period 1963 to 1980. Of these, only the Manila clam was passed to the industry for commercial production. It has had limited success as a cultivated species, and only small quantities are grown at present. The introduction of non-native species has been of concern to nature conservation bodies who fear that these species may become established in the wild.

Shellfish cultivation in the UK hasd declined from a peak in the middle of the 19th Century. Annual production of flat oysters fell from more than 2,000 tonnes in the 1920s to a few hundred tonnes by the early 1990s. Alongside this decline, there has been an increase in imports of molluscan shellfish into the UK, which rose steadily from about 1,800 tonnes per year in 1975 to 8,000 tonnes in 1994. It is currently around 6,000 tonnes.

There is considerable potential for expansion of the bivalve cultivation industry in the UK. The number of sites available is not in itself a limiting factor, although all sites must have or obtain a classification, in accordance with EU Regulations, according to the degree of microbiological contamination of the waters in which the shellfish are cultivated. Growers may be able to protect their right to manage and fish their cultivated stock by obtaining a Several Order (see Section 3) or by gaining a lease on an existing Several Order. These currently include 28 areas (12 in England, 7 in Wales and 9 in Scotland) and extend to 3,300 hectares. Hybrid orders, which are fisheries controlled by Regulating Orders that include areas allocated as Several Orders, add a further 72,000 hectares, not all of which are in use. Several Orders cover sites that are known to be suitable for the cultivation of bivalve molluscs. Certain grounds are more suited to particular types of bivalve mollusc and methods of cultivation, but with the correct site it is possible to produce up to 15 tonnes of oysters, or 30-50 tonnes of mussels, or 10-25 tonnes of clams, per hectare per year. Thus, theoretically, just 1% (i.e. 750 hectares) of the area currently covered by Several and hybrid orders could produce 11,000 tonnes of oysters per year, compared with the current UK production of only 1,000 tonnes.

At many sites in England and Wales, Pacific oysters should reach market size in four years or less. However, at cooler or less suitable sites, they may take an extra year or more. Manila clams are ready for harvesting in 2-3 years and mussels usually in only 2 years. Scallops require 4-5 years to reach a marketable size.

The current distribution of bivalve fisheries in the UK shows a major concentration on the south east, south and south-west coasts of England, on the west coast of Scotland and at a few sites in Wales (Figure 1). An overview of existing bivalve mollusc cultivation sites and areas where there is potential for new sites around the coast of the UK, is given in Appendix I. Development is largely influenced by the location of sheltered estuaries, bays and lochs. Selecting a site suitable for bivalve cultivation is not, however, as simple as finding a sheltered site. It is a multi-factor problem which requires an assessment of a range of information to ensure that any new business stands a good chance of success. This Laboratory Leaflet examines the factors that require careful consideration to ensure that a site is suitable for the chosen species and method of cultivation.

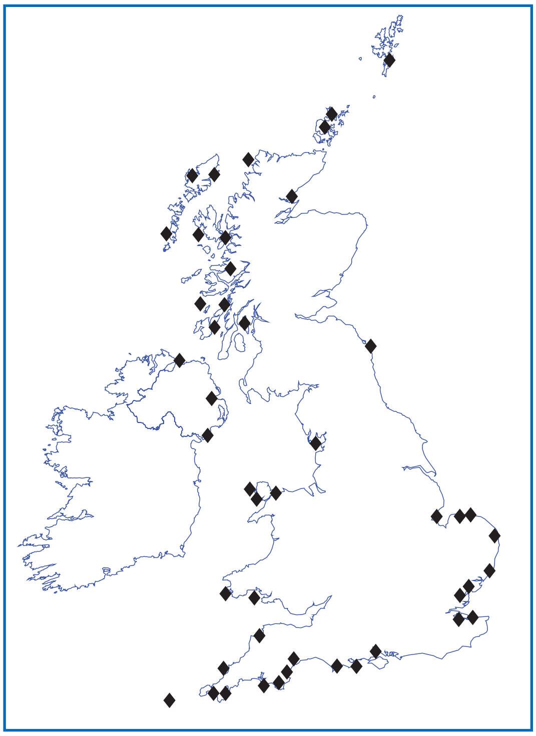

Figure 1. Distribution of bivalve cultivation sites in the UK

2. Environmental factors

2.1 Physical factors

Sea water temperature

Sea water temperature has a major effect on the seasonal growth of bivalves and may be largely responsible for any differences in growth between sites. The range and seasonal pattern of sea temperature around the UK coast is influenced by factors such as latitude, water depth, shelter, and tidal exchange. It also varies between years. In summer, the highest mean temperatures are recorded on the south coast of England. Waters around the north of Scotland may be as much as 4-5°C lower. In the south and west of Britain mean temperatures do not usually fall much lower than 8-9°C in winter, whereas on the east coast they may decline to 5-6°C or lower. It should be emphasised that these are average temperatures and that considerable variation from these values is to be expected between years and specific locations. Shallow creeks and estuaries usually have a higher average summer temperature but a wider daily and seasonal range, than deeper, more stable bodies of water. Shallow and enclosed waters warm up rapidly in the spring and early summer and can provide excellent nursery growing facilities.

Growth of bivalves usually begins when sea water temperatures rise to 8-9°C. This is usually during April in southern England and along the west coast. Fastest growth occurs in July and August, when temperatures are typically around 16-18°C. Growth declines to a low level again by November and December when temperatures fall below 8-9°C.

In very hot summers the water temperature in some shallow areas may rise to a level which, in combination with other factors such as high stocking density, limited food availability and low water exchange, is stressful to the bivalves. Although many bivalves may tolerate temperatures of 25°C or more, evidence from field and laboratory experiments indicate that, in the above circumstances, temperatures above 20°C can be stressful and can result in mortalities, even after the animals have been transferred to ideal conditions.

Oysters and clams are tolerant of low winter temperatures down to around 3-5°C, below which deaths may occur. Mussels on the other hand are very resistant to low temperature and are able to ingest food particles and show some growth even during the winter. Other factors may influence the ability of bivalves to tolerate low temperature. For example, scallops can survive temperatures as low as 3°C at salinities above 30 practical salinity units (psu), but they may die at temperatures below 5°C if salinity falls to less than 26 psu. This further illustrates the point that two or more environmental factors acting together may induce a stress in bivalves that is much greater than that of any one factor acting alone.

Salinity

Changes in salinity do not affect the growth of bivalves as much as variation in temperature. However, most bivalves will usually only feed at higher salinities, so they should be sited where, for as long a period as possible, salinity is within their optimum range. Open coastal areas are usually fully saline with small seasonal variations of between 30 and 35 psu. Flat oysters and clams prefer these higher salinities. Scallops are very intolerant of salinities lower than 30 psu, so sites with a high inflow of fresh water are not suitable for the cultivation of this species. Mussels grow well above 20 psu and Pacific oysters prefer salinity levels nearer to 25 psu, conditions typical of many estuaries and inshore waters. Estuaries have a daily input

of freshwater and consequently have a continually varying salinity pattern, with values ranging from as low as 0 (freshwater) to about 35 psu, depending on their proximity to the sea, state of the tide, and rainfall. Sea water is denser than fresh water and sinks to the bottom, so that in some circumstances, for example, in sheltered areas after heavy rainfall, as much as the top 2 to 3 metres of water can be completely fresh water. Clearly, this could be a problem for bivalves in suspended cultivation, compared with those grown on the bottom.

Exposure to air, wind and currents

Where temperature and salinity of the sea water are suitable, it must be remembered that bivalves can only feed and grow when they are submerged. Thus, growth rates are strongly influenced by the length of time during which the animals are covered by the tide. For flat oysters and scallops, the preferred methods of cultivation usually ensure that the animals are continually submerged. This is essential for scallops, since the body tissues soon desiccate if the animals are removed from water for more than about an hour, or even less in windy and/or warm conditions. This is because the two shells do not fully close together. Desiccation of the tissues leads to irreversible damage and to the death of the scallops, even if they are re-immersed. Young oysters and clams cultured on the foreshore should be kept as near as is practical to low water of spring tides to ensure almost 100% immersion, while still allowing access for maintenance.

Freezing winter temperatures can kill bivalves if they are exposed at low water for prolonged periods. Submerged bivalves have a better chance of survival because sea temperatures are usually higher than air temperatures in severely cold conditions. However, if small (8-12 mm shell length) juvenile American oysters are stored in humid air then they can be held at 0-6°C for up to 6 months, with survival greater than 80%.

This may be a useful method to adopt for keeping new seed at sites where sea water temperatures are likely to fall below 4-5°C for prolonged periods, rather than planting them out immediately.

Growth of oysters in trays or clams in ground plots stops when they are exposed to air for more than about 35% and 50% of the time respectively (Figure 2). However, this fact can be used to advantage by the cultivator who may wish, for commercial reasons, to slow down or temporarily stop the growth of the stock. This can be achieved by moving the stock higher up the beach. There is usually no danger of causing undue mortalities or reducing the meat quality of the stock if this is done during the summer, when extremely low temperatures are unlikely. It is a practice that is routinely adopted in Korea and Japan for 'hardening off' wild-caught spat prior to sale. However, in very hot weather there is a risk of the animals becoming stressed if they are exposed for long periods during the hottest part of the day.

The prevailing weather conditions of a site, especially wind strength and direction, need to be considered carefully. Strong onshore winds can generate extreme wave action and this can cause physical damage to mollusc growing installations, or to the animals themselves. At more exposed sites, robust installations are necessary to withstand the extra buffeting by the waves. These are usually more expensive to build and potentially more difficult to service than installations at less exposed sites.

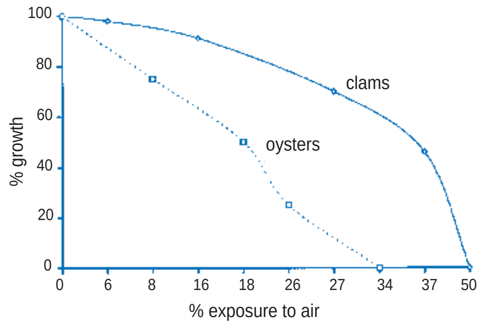

Figure 2. Growth of Pacific oysters and Manila clams at various levels of tidal exposure

Equipment can also be damaged by strong tidal currents. Sheltered areas with tidal flows of 1-2 knots (50-100 cm per second) usually provide the best conditions, and will give sufficient water exchange to supply the animals with an adequate supply of food and oxygen and for the removal of wastes. In fact, tray cultivation of oysters can be successful at sites which have a minimal flow of water, where water exchange is driven only by the rise and fall of the tide and gentle wave action.

Substrate

With shore or seabed cultivation of bivalves, the physical environment includes not only the sea water in which the stock are grown, but also the substrate onto or into which they are placed. This is an important consideration in site selection. Oysters and mussels cultivated on the ground require a sediment sufficiently firm to prevent them from sinking and smothering. Scallop and clam cultivation requires a softer sediment, such as mud, sands and mixtures of the two, since this is their natural habitat. Hard sediments are unsuitable for these species and will lead to loss of stock as they are unable to bury themselves sufficiently to avoid predation.

Intertidal cultivation of oysters in containers on trestles requires a firm sediment to prevent the equipment from sinking, although horizontal plates fitted to the feet of the trestles serves to reduce this effect.

Areas vary considerably in the silt content of their waters. Turbidity varies with the state of the tide and weather conditions. Areas of low turbidity, such as the Menai Strait, River Teign, and most Scottish sea lochs would usually have less than 50 mg (dry weight) of particles per litre of sea water. A more turbulent flow, such as might be found at Brancaster on the Norfolk coast, could induce higher levels of particulate matter in the sea water, of up to about 7,000 mg per litre during parts of the ebb tide. Sites with high silt loads can be used successfully for cultivation providing trays are serviced regularly. Trays, particularly those with small mesh, may quickly clog with silt. This can smother the animals or cause them to grow more slowly because of the poor exchange of water. In very turbid waters, trays may need cleaning every two weeks.

The placement of large numbers of trestles and other structures on the foreshore or seabed can significantly reduce current flow. At some sites, this reduced flow may accelerate the natural siltation rate and lead to accumulations of sediment beneath, between and around the equipment. This process, which can occur sufficiently quickly to require regular removal to prevent the equipment being buried, is expensive to remedy and should be avoided if possible.

A high load of suspended sediment in the water may, over a long period of time, lead to the deposition of excessive amounts of very fine sediment, as a result of the filtering activity of the animals themselves. Beds affected in this way can be brought back into productivity by harrowing the ground before relaying new stock.

Other considerations associated with substrate, at intertidal cultivation sites, are related to access and harvesting. It is important to consider the type of equipment likely to be used for planting, maintenance and harvesting, particularly for intertidal clam beds. Some beaches will support wheeled or tracked vehicles, while others are too soft and will require the use of a boat to transport equipment.

2.2 Biological Factors

Primary productivity

Bivalves feed by filtering mainly microscopic algae (phytoplankton), but also some organic detritus, from sea water. Algae are simple types of plant and, like all plants, contain chlorophyll, which utilises the energy from light to convert inorganic nutrients and carbon dioxide dissolved in the sea water into organic growth. Primary productivity is the rate at which new algae cells are produced in the sea, and is dependent on various environmental factors, including nutrient availability, light (turbidity) and temperature. It has been estimated that when bivalves are grown under similar conditions at different sites, up to 85% of any difference in growth observed between sites can be attributed to water temperature and primary productivity. Studies have shown that the growth of small scallop spat is positively related to the concentration of chlorophyll in the water. This indicates the importance of primary productivity for growth of cultivated bivalves, yet it is the most difficult factor to assess for a given site. The amount of naturally-occurring food available at a site cannot easily be evaluated by inspection of water samples, since seasonal abundance, annual variation and quality of microalgae fluctuate widely.

Accurate sampling is also a problem as the distribution of phytoplankton can be very patchy, and varies with depth. Identification of species is also notoriously difficult and very little is known about the nutritional value of many naturally occurring species. In general, however, primary productivity is relatively high in coastal and estuarine waters from March to October, thereby ensuring that sufficient food is normally available, in relation to prevailing temperature, to support reasonable growth. Maximum abundance of phytoplankton occurs in the spring, with a second, lower period of production in the autumn

Productivity is higher in southern than in northern Britain. It is usually measured as the total organic weight of algae produced in a year for each square metre of sea surface area (to include the water column beneath). Within the UK, primary production measured in this way ranges between 600 and 1,200 g per m^2 per year. The carrying capacity of a body of water, (ie the biomass of animals that the algae food it contains can support) can be exceeded by overstocking, leading to reduced growth and sometimes mortalities. Other aspects of primary productivity are discussed under the sections dealing with toxic algae (later this Section) and dissolved nutrients (Section 2.3).

Many marine bivalves, including clams and scallops, can remove small organic particles (detritus) from natural sea water at rates that provide a significant supplement to algae food. However, a very high particulate organic content, such as might be found in the near vicinity of some sewage outfalls, is detrimental to bivalves. Both treated and untreated sewage may have a high organic content, and these areas should be avoided in any case because of the likelihood of the bivalves accumulating an unacceptably high number of bacteria and viruses from untreated discharges (see Sections 2.2 and 3).

Seed supply

A bivalve cultivation business is dependent on a regular annual supply of small juvenile animals, known as seed or spat, for growing on to market size. For mussels, stocks of seed may be available locally, either from spatfalls on natural beds or from spat collected on ropes. Such supplies may not be sufficiently regular to sustain restocking on an annual basis. In such cases, it may be necessary to collect or purchase seed from distant areas which may involve expensive transport costs. Morecambe Bay, Dornoch Firth, Solway Firth and Portland Bill frequently provide sizeable quantities of seed mussels for cultivation elsewhere.

Dredging for seed mussels may require a special licence. For further information on this apply to Defra (address in Appendix IV) or see the guidance notes on the Defra web site at http://www.Defra.gov.uk/corporate/regulat/forms/fish/mus2.htm.

For flat oysters, the natural fisheries of the River Fal and the Solent have traditionally supplied seed to other areas. The Essex native oyster fisheries have not been self-sustaining since most of the stock were killed in the cold winter of 1962/63, although in recent years there have been promising signs of a recovery. However, a number of oyster fisheries, located in the creeks of West and East Mersea and at Walton-on-the-Naze, and in Poole Harbour, continue to flourish from the deposit of half-grown Solent oysters on the beds for one growing season. The short relaying period is necessary to reduce the risk of high mortalities of these oysters from *Bonamia* disease.

In Scotland, the scallop cultivation industry is based on the collection of wild seed, but irregularity in the annual supply is causing the industry to consider the use of hatchery-reared seed to overcome this problem. Whichever source of seed is used, scallops are easily stressed during transport, and special techniques must be used to minimise losses. Hatchery technology in the UK is amongst the best in the world and supplies the home and some overseas growers with large quantities of high quality seed of some of the more valuable species of bivalves such as flat oysters, Pacific oysters, Manila clams, Atlantic palourdes (*Tapes decussatus*), and American hard shell clams (*Mercenaria mercenaria*). Pacific oysters form the backbone of the shellfish cultivation industry and supply of seed is entirely based on hatchery-reared stock. They survive well during transport and are not expensive or difficult to send through the post due to the small size (5-10 mm) at which they are usually planted out. Their small size at stocking does, however, necessitate careful husbandry practice in the early stages of cultivation to ensure good growth and survival.

It is worth noting that there are restrictions on movements of some shellfish seed for shellfish disease control purposes (see Section 3) and, depending on the location of the bivalve mollusc cultivation site, there may be limits on the areas from which seed stock can be obtained.

Predators

Unprotected bivalves may be eaten by various predators, in particular crabs, starfish and, for mussels especially, by birds. The cultivator must take steps to minimise predation. It is usually possible to protect intertidally-grown oysters and clams by keeping them in trays or bags supported on trestles above the substrate, or on the ground under mesh. Animals grown using suspended cultivation methods are largely safe from crabs and starfish, but mussel cultivation in northern Britain is at risk from predation by eider ducks. Oystercatchers are the other important avian predator around the UK, where they feed on mussels on intertidal beds. Scallops cultivated on the seabed are particularly vulnerable to predation from crabs and starfish. The risk of losing stock from crab predation is reduced by seeding larger spat, although this increases the costs of rearing the seed in the hatchery or nursery.

The green shore crab (*Carcinus maenas*) is the most abundant and widespread predator in estuaries and coastal sites and has a voracious appetite for young bivalves, which it eats after cracking open the shells. The largest crabs (over 65 mm wide) can eat molluscs of 10 g or more in size. Since crabs of this size are few in number, stock larger than 10 g may be considered to be relatively safe, as smaller crabs cannot attack it. The abundance of shore crabs may not always be obvious because of their habit of advancing up the foreshore on the flood tide and retreating into deeper water or hiding on the ebb.

The common starfish (*Asterias rubens*) attacks and eats bivalves by pulling the shells apart slightly and then everting its stomach through the gap and digesting the flesh *in situ*. Starfish are restricted to high salinity areas, usually in the sub-littoral zone, and prefer to eat mussels and scallops. They can occur in high abundance on shellfish beds and consume large numbers of stock in a relatively short period of time. They are only a minor pest of oysters.

Oyster drills or tingles are marine snails which eat bivalves by rasping a hole through the shell to gain access to the flesh. The distribution of these pests is fairly limited, with the American whelk tingle (*Urosalpinx cinerea*) historically centred around the Thames Estuary in Essex and Kent, and the European rough tingle (*Ocenebra erinacea*) occurring in some of the important oyster grounds of the Fal, Helford River, Solent and estuaries of the east and south coast. Over half of the oyster spatfall in the River Crouch was devoured by the American whelk tingle in 1954, and in Southampton Water in 1978, Ocenebra killed about 10% of 30-45 mm (shell length) flat oysters in plastic mesh containers. In recent years, tingle abundance in some areas has been reduced by the presence of tributyl tin (TBT), previously used in marine anti-fouling paints, in the water. Following the introduction of restrictions on the use of TBT, its concentration in the environment has continued to diminish and it is possible that tingles will re-emerge as serious predators in the future.

Disease

Unlike predators, bivalve diseases are not common in the UK, and historically have been associated with imported stock. The only disease prevalent at the present time is *Bonamia* which infects the blood cells of the flat oyster causing high mortalities under certain conditions of cultivation. It was introduced into the UK, possibly with unauthorised deposits of oysters from the Continent, into the River Fal in 1982, where it became established in local stocks of oysters. Before controls over movement of oysters could be enforced, the disease was unintentionally transferred with movements of oysters, as part of normal trade, to the Rivers Blackwater and Walton Backwaters in Essex, and to Poole Harbour, the River Beaulieu, Emsworth, Langstone and Portsmouth Harbours and some parts of the Solent on the south coast. The disease has also been found in oysters at Plymouth, the Fleet, Dorset, Milford Haven in Wales, Loch Sunart in Scotland and Lough Foyle in Northern Ireland. Controls on movement of flat oysters are in force to prevent the further spread of the disease.

The red worm (*Mytilicola intestinalis*), a copepod parasite of the gut of mussels that is now endemic in many areas of Great Britain and the rest of Europe, is no longer considered to be the problem that it was once thought. The condition of mussels is not affected by the presence of this parasite, other than in sublittoral animals in those few winter months when the mean intensity of infestation is over about 25 parasites per host. The variation in size of mussels and their state of maturity due to the effect of seasonal cycles and other environmental factors, is always greater than that due to the effects of parasitism.

Competitors

As well as predators and diseases, stock can be at risk from competition for food and space from other animals living in the same marine environment. However, well managed bivalve mollusc stocks should be largely unaffected by competitors. The main competitor is the slipper limpet (*Crepidula fornicata*). This was introduced accidentally into this country with imported oysters from America in about 1880 and has now spread around the coast of England and Wales to most oyster producing areas. In the 1950s, it was estimated that the biomass of this competitor exceeded that of cultivated oyster stocks by as much as tenfold in some areas, such as the River Crouch in Essex. Mechanical dredging and disposal is the main means of control, so the costs of reclaiming or maintaining grounds is high. Slipper limpets compete with bivalves for food and space and, in silty waters, also produce a muddy substrate which is unsuitable for cultivation. However, the presence of slipper limpets can also benefit the fishery, as happens in the Solent, by providing a suitable surface on which the flat oyster spat can settle.

Fouling organisms

Fouling is a general term used in aquaculture to describe animals and plants which attach themselves to immersed equipment and to the bivalves. Some of these fouling organisms may also act as competitors for food. Typical fouling organisms include various seaweeds, sea squirts, tube worms and barnacles. The type and degree of fouling varies with locality. The main effect is to reduce the flow of water and therefore the supply of food to bivalves cultivated in trays or on ropes and to increase the weight and drag on floating installations. Fouling organisms grow in response to the same environmental factors as are desirable for good growth and survival of the cultivated stock, so this is a problem that must be controlled rather than avoided.

Green filamentous seaweed (*Enteromorpha*) can be controlled by spraying with dilute copper sulphate solution (10% w/v), followed by exposure to air for one hour. However, such anti-fouling compounds are toxic to other species and it is better to adopt the less harmful practice of pressure hosing (2000 pounds per square inch), or, with bags on trestles, to turn them over frequently. In the summer, netting covering clam ground lays gets fouled by weed and usually requires cleaning monthly with a scraping device such as a squeegee. Larger areas may need the use of a tractor-driven brush several metres wide.

Individual or colonial sea squirts (tunicates) can be killed, without harming the bivalves, by immersion in saturated brine solution for 5-10 minutes followed by exposure to air for one hour.

Barnacle and worm encrustations are not usually a problem on bivalves, but can be removed from empty containers using high pressure water sprays, or by leaving the containers ashore for several months. Barnacles attached to mesh bags can be crushed using a garden roller if the empty bag is sufficiently flexible, while immersing plastic trays in hot water is effective but costly.

Mussel spat may also settle in oyster trays and removing them can cause the cultivator extra work. Large settlements of mussels create competition for food and space whereas sparse settlements cause localised clumping of bivalves which become bound together by mussel byssal threads. The addition of a few dogwhelks (*Nucella lapillus*), which preferentially prey on small mussels, may help to control this problem.

Bacteria and viruses

As bivalves filter phytoplankton from the sea water during feeding, they also take in other small particles, such as organic detritus, bacteria and viruses. Some of these bacteria and viruses, especially those originating from sewage outfalls, can cause serious illnesses in human consumers if they remain in the bivalve when it is eaten. The stock must be purified of any faecal bacterial content in cleansing (depuration) tanks before sale for consumption. There are regulations governing this, which are based on the level of contamination of the molluscs in the local area, and these are explained more fully later (see Section 3). Faecal bacterial content of young bivalves during the early years of cultivation is not in itself a problem.

Not all viruses are removed by normal depuration processes, and they can cause illness if the bivalves are eaten raw or only lightly cooked. These viruses can only be detected by using sophisticated equipment and techniques, although research is being carried out to develop simpler methods. It has been found that they come from sewage outfalls other than those subject to full treatment, and this includes many coastal and estuarine outfalls. The position, size and type of existing and planned outfalls should be noted when selecting a cultivation site. Grounds close to, or likely to be affected by the flow from, outfalls discharging significant amounts of untreated sewage should be avoided.

Toxic algae

Bivalve cultivation can frequently be carried out successfully in areas affected by blooms of toxic algae. This is because the bivalves themselves are not seriously harmed by these algae. The worst that the cultivator can expect is a temporary closure of the fishery, usually during the spring or summer, a time of year when many bivalves are out of season. The risk, therefore, is much less serious than that from competitors, predators and fouling organisms, some of which may be present for all or most of the year. The incidence of occurrence of blooms of toxic algae in the UK is low. The north-east of England and some areas of the east and west coasts of Scotland and the Orkney Islands are most affected. Certain types of naturally occurring algae produce toxins which can accumulate in the flesh of mussels, oysters, clams and scallops which are feeding on them. People eating shellfish containing these toxins can become ill from paralytic shellfish poisoning (PSP), amnesiac shellfish poisoning (ASP) or diarrhoetic shellfish poisoning (DSP). The first two are more dangerous since, in exceptional cases, they can result in human deaths. The toxins responsible are not denatured by cooking nor are they eliminated by cleansing the shellfish in depuration tanks. The risks to consumers are minimised by a statutory requirement for samples from shellfish harvesting areas throughout the UK to be tested for toxins. This is done regularly, during the period April to November. If the amount of toxin exceeds a certain threshold, the collection of shellfish for consumption is prohibited until the amount falls to a safe level. Samples of sea water from selected sites are also examined routinely for the presence of the phytoplankton species that produce these toxins, as an early warning system.

Further information on the algal toxin monitoring programme, together with a list of some of the areas currently affected, can be found on the Food Standards Agency web site at http://www.foodstandards.gov.uk/foodindustry/shellfish/algaltoxin/.

An overview of the areas where sites are most likely to be affected by closures can be found in the summary of results from the toxin monitoring programmes for the previous year. This is published annually in *Shellfish News*. Copies may be obtained from the library at the Cefas Lowestoft Laboratory or from the Cefas web site at http://www.cefas.co.uk/publications/shellfishnews/default.htm

2.3 Chemical factors

Dissolved nutrients

Primary productivity relies on dissolved nutrients, especially nitrate, phosphate and silicate, but also traces of iron, manganese and other metals, supplying the requirements of the phytoplankton. Much of this supply comes from re-mineralisation of dead and decaying organic material, some of it from previous blooms of phytoplankton. Nutrient levels in coastal and estuarine sea water are naturally high in winter, when there is very little growth of phytoplankton, and low in summer when plant growth flourishes. Additional nutrients may be supplied through human activity, such as run off in rivers from excess fertilisers from agriculture. This can lead to various degrees of eutrophication, or nutrient enrichment, of the sea water. Small quantities of extra nutrients are often beneficial, as they encourage the production of more phytoplankton food species. There are very few sites that receive excessive additional nutrient input. At these sites, the additional fertilisation effect together with the imbalance of nutrient ratios may lead to the development of intensive blooms of unsuitable types of algae. These algae may reduce the growth of bivalves. Excessive algae blooms may also cause serious depletion of oxygen from the sea water when they eventually break-down. The growth of seaweeds, such as *Enteromorpha*, as fouling organisms (see Section 2.2) is also more likely to be encouraged in an area where nutrient levels are elevated. High mineral levels are not generally harmful in themselves to cultivated bivalves.

Oxygen

All marine animals, including bivalves, use the oxygen that is dissolved in sea water for respiration. The oxygen content of sea water is usually sufficient for them to respire at normal rates. In some circumstances, however, for example in hot, calm weather during periods of low water movement, at low water of neap tides, or during periods when algae blooms are decaying, the dissolved oxygen levels in sea water may become very low. These periods are usually of short duration and do not usually constitute a major problem. Bivalves generally have a fairly high tolerance to low dissolved oxygen concentrations and can also adapt by reducing their metabolic activity rate, to the extent of using anaerobic respiration to provide energy needs. However, prolonged periods of very low oxygen, particularly at high temperature, can stress bivalves, causing them to gape and possibly to die. There will sometimes be other indications of dangerously low dissolved oxygen levels in the sea water, such as large numbers of dead fish and crustaceans, especially crabs, on the shoreline. At sites occasionally at risk of low

oxygen levels, the water should be monitored regularly at the time of greatest risk so that remedial action, such as reducing stock density or moving stock to suitable waters, can, if possible, be taken.

Pollutants

Waters subject to heavy industrial contamination (eg heavy metals and organic compounds) are unsuitable for bivalve culture and should be avoided. Some areas naturally contain high levels of heavy metals, (eg copper and zinc), washed out from either disused mine workings or natural bedrock. These metals do not harm the bivalves but may accumulate in the flesh, rendering it unpalatable due to the unpleasant flavour that they impart. Copper tainting, for example, has been reported from some areas of the Rivers Fal, Tamar and Lynher. This type of contamination and others, such as oil taint, can be removed by relaying stock in uncontaminated waters for several months.

During the 1980s, it was found that tributyl tin (TBT), a component of marine anti-fouling paints, was highly toxic to bivalve molluscs at extremely low concentrations in the sea water. Pacific oysters cultivated in areas in which large numbers of small vessels were moored showed stunted growth and thickening of the shell, and natural populations of flat oysters failed to breed. The use of this compound on small vessels was banned in July 1987, and since then the oyster industry has recovered. This illustrates the risk from trace amounts of certain chemicals, particularly the active ingredient of marine biocides, to bivalve mollusc cultivation. Government regulations now require thorough tests on any new compounds before they are used in the marine environment.

3. Economic and legal factors

Rights of shellfish cultivators in the sea

At present, the cultivator has limited legal protection of the stock. Bivalves grown in containers in public waters are protected by Theft and Criminal Damage legislation, while shellfish beds covered by private right of fishery or by Several Order are protected against theft or damage by the provision of section 7 of the Sea Fisheries (Shellfish) Act, 1967, provided that the beds are adequately marked.

Public rights

The public has a common law right to fish tidal waters, in rivers and estuaries and in the sea within territorial waters (12 nautical miles from baselines), except where a private property right (see below) has been obtained, which excludes the common right. Subject to certain constraints, anyone can grow molluscs where a public right of fishery exists.

These constraints require that:

- there must be no interference with the public right of fishery;
- bivalves may only be taken in accordance with the terms of any Regulating Order, if one exists;
- the consent of the Crown Estate Commissioners, and of the Department of Transport (DoT) must be obtained if the cultivator wishes to erect frames, trays, or other structures on the seabed or foreshore.

If the structures are considered to be hazardous to navigation within the limits of planning authority (i.e. MLWOT), the cultivator must also have, and comply with, planning permission from the relevant local authority.

Sea Fisheries (Shellfish) Act

The Sea Fisheries (Shellfish) Act, 1967 has been one of the most important pieces of legislation to the present-day bivalve cultivation industry. It is the principle statute governing molluscan shellfisheries in Britain and its origins date back to the last century (1868). The Act, which was last amended in 1997, introduced the concept of ***Regulated*** and ***Several*** fisheries whereby the common law right of shellfishing is removed to ensure the protection of property rights in such fisheries. The areas currently covered by the act are listed in Appendix II.

Further information on Several Fishery Orders can be found on the Defra web site at http://www.Defra.gov.uk/fish/aquaculture.htm. This web page links to a document giving guidance notes on applying for a Several Order. These guidance notes may also be obtained by post from Defra at the address in Appendix IV.

Regulating Orders

A Regulating Order may be granted in England by the Department for Environment, Food and Rural Affairs (Defra) or in Wales or Scotland respectively by the Welsh Assembly Government (WAG) or Scottish Executive Environment and Rural Affairs Department (SEERAD) to a responsible body such as a Local Authority, Harbour Board, or sea fisheries committee (in England and Wales only), to enable it to regulate the fishery of a natural stock. The stock may then be fished under licence by the public in accordance with the terms of the order, subject to the observance of any by-laws or regulations made by the controlling body, and on payment of any tolls or royalties which may be charged by it. Whilst fishing effort is controlled by the licensing system, by-laws control, for example, gear specifications, minimum landing size, fishing season, quotas etc. New by-laws may be introduced or old ones deleted to meet current management needs, but only with the approval of Defra, WAG or SEERAD.

There are currently six regulating orders in England and two in Wales, which protect some of the major cockle, mussel and oyster fisheries. The total area involved is 154,880 ha with individual areas ranging from 116,000 ha (Thames Estuary Cockle Fishery Order) to 156 ha (River Teign Mussel Fishery Order). There are also two hybrid orders, covering Poole Harbour and the Wash, which are regulating orders with powers to grant leases of Several rights. These add a further 72,000 ha to the total area. In Scotland there is just one regulating order, the 'Shetland Islands Regulated Fishery (Scotland) Order 1999'. This covers all of the seabed surrounding the islands, extending to some 600,000 hectares and encompasses a wide range of shellfish species, to include oysters, mussels, cockles, clams, lobsters, scallops, queens, crabs, whelks and razorshells.

Several Orders

A cultivator who wants to have additional protection for stock kept in public waters, may apply for a right of Several fishery. Orders establishing these are granted in England by the Department for Environment, Food and Rural Affairs (Defra) or in Wales or Scotland respectively by the Welsh Assembly Government (WAG) or Scottish Executive Environment and Rural Affairs Department (SEERAD).

They are granted for a fixed period, to an individual, a co-operative, or a responsible body, to enable the grantee to cultivate the seabed within a designated area of water and to conserve, develop and enhance the specified stocks of shellfish thereon. The Several fishery concept is designed to give the lessee a much greater management control of the stocks. Several rights may also be granted to a sea fisheries committee which cannot cultivate stocks in its own right, but may lease rights of Several fishery, subject to the consent of the Fisheries Departments. The applicant must provide a management plan, and this must show that the fishery will benefit from cultivation. The driving philosophy is that the productivity of the fishery must be enhanced. Where natural stocks are concerned, enhancement may require encouraging spatfalls by the placement of collecting material (cultch), or relaying with partly-grown stock from elsewhere, for on-growing to market size. Some Several fisheries may be used for the cultivation of non-native bivalve species, such as the Pacific oyster, grown intertidally in containers on trestles, and the Manila clam, grown in ground plots covered with plastic netting. The Several fishery right may be terminated if the grantee fails to meet the terms of the order.

Application for, and granting of a Several fishery right can be a time-consuming process, which may take up to 3 years. Public objections to the application can force a public enquiry, the cost of which falls to the applicant. Subletting from a Several Order held by a sea fisheries committee, where this is an option, is often a faster way of obtaining a several right. However, areas covered by existing Several Orders may only be suitable for cultivation of certain species of bivalve. Where rafts, longlines or other significant equipment is to be used, the DoT may need to assess navigational rights, and this will also take time.

There are 12 Several Orders in England and seven in Wales with a total area of about 3,000 ha. These range in size from 894 ha to 12 ha, with an average size of about 190 ha. In Scotland, three scallop Several fisheries were established in the period 1990-1994 in sea lochs, in support of the emerging importance of scallop cultivation in these areas. There are now 9 Scottish Several Orders covering 350 ha of seabed, mainly for scallop cultivation.

Private ownership

Private property rights prevent public fishing in some tidal waters. These rights may have been acquired in various ways, including: granting of rights of a fishery to individuals by the Crown before the Magna Carta (1215); private Acts of Parliament (up to 1868) conferring Several rights on boroughs such as Rochester and Colchester or private companies such as the Seasalter and Ham Oyster Fishery Company Ltd, Whitstable, and the Whitstable Oyster Company. Beaulieu Estate is a private fishery with rights of cultivation granted by the estate.

Registration of shellfish farms

The Fish Farming and Shellfish Farming Business Order, 1985 obliges a shellfish farmer to register his or her business. The purpose of registration is to assist in dealing with outbreaks of disease if these should occur. Registered businesses are required to keep a record of the stock movements on and off site and to submit a simple summary of movements each year. Applications to register should be made to Cefas (in England and Wales) or the Fisheries Research Services (FRS) in Scotland (see Appendix IV for contact details). Further information on farm registration as well as on movement controls (see below) can be found on the Cefas web site at http://www.Cefas.co.uk/fhi/default.htm.

Restrictions on movement and control of deposit, immersion or relaying

There are certain restrictions on the deposit of bivalves around the coast of Great Britain, to prevent the introduction and spread of diseases. January 1993 saw the introduction of the Single European Market which was accompanied in many areas of trade with the removal of internal border controls between Member States. However, movements of shellfish into Great Britain, from both within and outside of the EU, continued to be controlled because of the risk such trade poses to the health of established disease-free stocks.

The controls apply to movements to Great Britain of all live molluscan shellfish and their eggs and gametes (seed stock), from other parts of the EU; from non-EU countries and to deposits within and between coastal zones of Great Britain.

For intra community trade, the controls operate through a system of ***approved zones*** and ***approved farms***, which are shown to be free from the notifiable shellfish diseases, *Bonamia* and *Marteilia*. As a general rule, shellfish may only be introduced into an approved zone or farm from areas of equal or higher health status. This framework is enforced through a system of ***movement documents*** (which accompany the consignment and are completed by the official fish health protection service where the shellfish are produced) and ***pre-notification of movements*** (which entails written 24 hour notice to Fisheries Departments of the arrival of the consignment).

The UK has been granted approved zone status for the whole coastline for Marteilia and approved zone status for the whole coastline for Bonamia except in the six restricted areas where the disease is found. These areas are (1) from the Lizard to Start Point; (2) from Portland Bill to Selsey Bill; (3) from Shoeburyness to Felixstowe; (4) Milford Haven: (5) Loch Sunart and (6) Lough Foyle. Movements within the UK are controlled according to the health status of these areas. Anyone wishing to deposit or relay molluscan shellfish taken from the controlled (restricted) areas listed above must apply for permission to the Fish Health Inspectorate at the Cefas Weymouth Laboratory (for England and Wales) or the Fisheries Research Services at the Marine Laboratory, Aberdeen (in Scotland).

Shellfish from non-EU countries may only be deposited in Great Britain so long as they are certified free from disease by a testing programme as stringent as that which applies to trade with the EU. Import licences and health certificates are required.

Classification of shellfish harvesting areas

It is a statutory requirement [European Food Hygiene Legislation] that shellfish beds from which harvested bivalves are intended for consumption, must be classified according to a microbiological standard (see Table 1). Areas where bivalves are currently harvested should already be classified, but new sites must be graded. Usually a provisional classification can be issued after sampling fortnightly for 3-4 months, while full classification may be achieved after a year of continuing sampling at monthly intervals. It may be possible to shorten the sampling period if additional information is available for the same species on nearby beds, from other species in the same area, or from historical monitoring. Sampling is done by the local Environmental Health Department or Port health Authority, but the results are collated and interpreted by the Cefas Weymouth Laboratory. This information is forwarded to the Food Standards Agency (FSA), who classify the beds according to the standards shown in Table 1.

The classification category then dictates what, if any, action must be taken before the bivalves are sold for human consumption. Bivalves harvested from ***A grade*** areas may be marketed live without further treatment, those from ***B grade*** areas require depuration (purification) or relaying, while those from ***C grade*** areas must be relaid for several months in areas of ***A*** or ***B*** classification to allow time for them to reach an acceptable bacterial standard before further treatment or marketing. Relaying bivalves in cleaner areas, even if these are available close by, is an additional expense which can be avoided with careful site selection.

For shellfish sold as a processed product, heat treatment (cooking) by an approved process is permitted for bivalves harvested from both Category B and Category C areas. Bivalves in areas classified as ***Prohibited*** cannot be harvested under any circumstances. These areas will invariably be close to untreated sewage outfalls, particularly in areas with restricted water exchange. Any areas likely to be awarded this classification must not be used for cultivation. There is as yet no equivalent classification for viral contamination and although viruses may be present in bivalves that are relatively free of bacteria, they are also associated with sewage outfalls (see Section 2.2).

Tables showing all currently classified shellfish harvesting areas in the UK, as well as lists of designated relaying areas and areas where production is prohibited can be found on the FSA web site at http://www.foodstandards.gov.uk/foodindustry/shellfish/

Security and Access

The security of a site needs careful consideration at the onset of the site selection process, since it is not usually possible to erect physical barriers preventing access. Theft (eg poaching) may be a problem in some areas, especially those within or adjacent to natural beds of bivalves.

Access to the foreshore will need to be determined from both the legal and practical points of view. At some intertidal sites, it may be possible to use motor vehicles to bring in equipment and for transport of stock, and in some cases it may even be possible to drive directly onto the beach. Not all beach sites are sufficiently firm to allow safe working by heavy vehicles such as tractors. Limited access to low water or subsidiary working areas may be possible in some circumstances, with a boat, or lighter all-terrain vehicle fitted with low pressure tyres, providing further access to the cultivation sites. At other intertidal sites, and for seabed or suspended cultivation, it will be necessary to use a boat. The proximity of a suitably accessible launch site then becomes an important consideration.

Table 1. Criteria for classifying shellfish harvesting areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 MPN E. coli per 100 g of flesh and intravalvular liquid[2]	None
B	Live bivalve molluscs from these areas must not exceed the limits of a five tube, three dilution Most Probable Number (MPN) test of 4,600 E. coli per 100 g of flesh and intravalvular liquid[3]	Purification, relaying in class A area or cooking by an approved method
C	Live bivalve molluscs from these areas must not exceed the limits of a five tube, three dilution Most Probable Number (MPN) test of 46,000 E. coli per 100 g of flesh and intravalvular liquid[3]	Relaying for a long period or cooking by an approved method
Prohibited	>46,000 E. coli per 100 g of flesh and intravalvular liquid[4]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from Regulation (EC) No 854/2004, via Regulation (EC) No 853/2004, to the Draft Commission Regulation on Microbiological Criteria for Foodstuffs (SANCO 4198/2001, revision 16).
[3] From Regulation (EC) No 854/2004.
[4] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.

Ideally, the shore base should be located adjacent to the sea. This is especially important where there is a requirement to provide pumped sea water for depuration tanks for cleansing the bivalves free from contamination prior to marketing. Some modern depuration plants are, however, located some distance from the sea. The need to transport sea water to a remote depuration facility is an extra cost, although this may be reduced by re-using the sea water a number of times or using the alternative, but relatively more expensive, artificial sea water.

Local management plans

Although bivalve cultivation within our estuaries and coastal waters has taken place for centuries, there is now a growing awareness that there is a diverse range of other legitimate users of these waters, all of whom wish to use the limited space and resources available. Many of these groups' activities appear, at first sight, to be incompatible with those of the fish or shellfish farmer, and *vice versa*. Other users of the coastal environment include bait diggers, anglers, boat owners, wild-fowlers, port authorities and industries. In recent years, local authorities or less formal voluntary bodies have convened groups either to provide a forum within which to discuss, and hence minimise, potential conflicts of interest, or to draw up voluntary management plans. It is in the best interests of all shellfish growers to maintain contact with, or to participate in such groups in their area. Details of such groups are available from the local offices of the national nature conservation agencies (English Nature - EN, Countryside Council for Wales - CCW, Scottish Natural Heritage - SNH).

At a more formal level, increasingly larger parts of our coast and coastal waters are covered by statutory nature conservation designations. The oldest of these is the *Site of Special Scientific Interest* (SSSI). Within such designated areas, the cultivator will need the permission of the national conservation agency (EN, CCW, SNH) to undertake certain operations. Permission will usually be given unless the operation conflicts with the specific conservation purposes for which the site was designated. Shellfish growers should be aware, however, that SSSIs do not extend seaward of land planning authority, ie mean low water of ordinary tides (MLWOT) in England and Wales (National Parks and Access to the Countryside Act, 1949; Wildlife and Countryside Act, 1981). The Wildlife and Countryside Act (1981) also makes provision for the designation of marine nature reserves (MNR) whose boundaries may go to MHWOT, and exceptionally to high water of the highest astronomical tides. Currently there are three MNRs which are located around Lundy Island (Bristol Channel), Skomer Island (SW Wales) and Strangford Lough (Northern Ireland). Many SSSIs are found in estuaries which accommodate significant populations of over-wintering wading birds. These migrant birds arrive to feed on the abundant invertebrates to be found on the intertidal mud flats. Shellfish farming activity on the foreshore of such estuaries is often cited as interfering with the feeding and roosting behaviour of waders. When this claim was investigated by independent scientists this was found not to be a problem. Far greater disturbance can be caused by people walking the family dog on the foreshore.

If the bird feeding areas are judged to be of particular importance, they may also be designated special protected areas (SPA - EC Council Directive on the Conservation of Wild Birds 79/409/EEC). Other coastal areas identified as outstanding examples of their type, including some which extend several miles out to sea, will be designated special areas for conservation (SAC - EC Council Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna, 92/43/EEC). The responsibility for managing these areas will fall to the national nature conservation agencies (EN, CCW, SNH). In England and Wales, however, the local sea fisheries committees will play a central role in managing marine SACs, particularly in drafting by-laws [The Conservation (Natural Habitats, etc) Regulations 1994]. The intention is that wherever possible, SAC management should rely on voluntary schemes and agreements. Also, the statutory conservation agencies have given an undertaking that established fisheries practice and levels of activity should continue with minimal additional restriction.

In Scotland, the salmon farming industry has been criticised for polluting the environment with some ill-judged site selection for sea cages in sheltered, shallow lochs with poor water exchange. These conditions have led to an accumulation of debris from fish faeces and uneaten food on the seabed beneath and around the cage and the consequent smothering of the natural plant and animal communities there. Similar problems have also been seen with the shellfish industry, especially with floating mussel ropes or rafts in Spain, Sweden, Japan and Korea. It is essential, therefore, that site selection should incorporate an environmental assessment to forecast the likely impact not only on the marine animals and plants in the area, but also on the farmed shellfish.

Transport and marketing

Tactically, the location of a bivalve cultivation enterprise may have important economic consequences for transport and marketing costs. Access to markets is also of major importance to the business enterprise. Live bivalves may be sold to local or national markets and as a consequence require ready access to an efficient road system to ensure that the product reaches its destination quickly and without loss of quality. Much of the shellfish production in the UK is sold to markets on the Continent. This may require ready access to a ferry service and transport via refrigerator or vivier lorries if the journey is likely to last for several days. Generally, the relatively low value of market-size bivalves prevents the use of air transport, but the relatively more valuable, small, hatchery-reared oyster and clam spat are frequently shipped as air freight to ensure that they reach their destination as quickly as possible.

Transportation of shellfish is subject to Schedule 6 of the Welfare of Animals (Transport) Order 1997, which requires that they are "transported under such conditions (with regard to space, ventilation, temperature and security) and with such supply of liquid and oxygen as are appropriate for the species concerned". Bivalves such as mussels and oysters, especially if grown intertidally, are fairly hardy and capable of journey times of several days. Survivability, however, is influenced by a number of factors including the level of rough handling before the journey starts, and temperature and humidity during the journey. Some species of bivalves which normally live subtidally eg scallops, are particularly vulnerable to journey times of more than 24 hours. Specialised misting techniques during transport are being developed to reduce desiccation of the scallops' gills. This is to enable the tissues to receive sufficient oxygen to extend the transportation time significantly.

Insurance

It is difficult to select a site to prevent the unpredictable and exceptional losses of cultivated stock or equipment which can occur, albeit infrequently (for example due to flooding, storm damage, severe winters, major oil pollution, etc). However, insurance against such losses is possible now that aquaculture is recognised as an insurable risk. The premiums will be set against the perceived risk. For example, cultivation sites close to major oil terminals or near a regular tanker route, and sites exposed to the direction of prevailing gales may cost more to insure against the risk of oil spill or storm damage. It may also be possible to insure against theft at sites where this is thought to be a risk.

Grants

Funds are available throughout the UK. You should contact the relevant department (Appendix IV).

4. Summary

The prospective cultivator may be looking for a site on which to cultivate particular types of bivalve mollusc. Or he may already have a site in mind, and needs to decide which species would perform best and be most profitable for that site. Careful consideration of the criteria discussed above will help him to arrive at the most suitable choice. It is wise to approach site selection with caution, since once committed, any errors in judgement may prove expensive. A checklist of questions that must be addressed is given in Appendix III.

Environmental data and other information on sites may be obtained from various organisations. The local Environment Agency Office is a good place to start. When looking at environmental data, it is well to remember that there will be a certain amount of variation within and between years for the same site. Local authorities should also be consulted for current information on planning regulations and other by-laws, and for more general advice.

Very few sites, if any, are likely have the perfect blend of qualities for the cultivation of the chosen bivalve species. Choice of site will also be restricted by availability. Growers should avoid sites where several environmental factors provide less than optimum conditions, as each may impose a small stress on the bivalves, which together result in poor growth and possible mortality. Unfortunately, very little is known about the combined action of slightly adverse conditions, and more research is needed.

Where circumstances permit, the cultivator should evaluate the suitability of a number of sites in a pilot study with trial plantings of the chosen bivalve species. Growth differences between sites usually reflect differences in conditions which may be fairly specific to the sites. These conditions may vary widely between and within years, requiring long-term studies of at least one year and preferably longer, to get an accurate picture of the suitability of the site for cultivation.

Finally, it should be remembered that a successful and profitable bivalve cultivation operation requires good husbandry and management of the stock as well as the selection of a suitable site. Sources of further information on these aspects can be found in Appendix V.

Appendix III. A checklist of questions on site suitability

1. Making a general assessment

- Are there any harmful chemicals present in the water, as from an industrial outfall?
- Is it a recognised shellfish harvesting area?

  ⇒ If yes, what is the shellfish hygiene classification?
  (A = clean; B = purify; C = relay; Prohibited)

  ⇒ If no, is there an outfall discharging untreated sewage nearby?

  * will bacteria from this give a classification either preventing the marketing of bivalves or requiring re-laying before purification and marketing? Contact local Environment Health Office for further advice.

- What is the disease status of the area?

  ⇒ will this restrict the movement of bivalves and limit the areas from which seed stock can be obtained?

2. Making a more detailed assessment (with reference to the chosen species)

- Is a supply of seed available?
- Are the extremes of temperature within the limits of the species? (see Table 2)
- Does the seasonal variation in water temperature allow for a sufficiently long growing season? (see Table 2)
- Will the seasonal and daily variation in salinity significantly restrict growth and survival? (see Table 2)
- Is the substrate type suitable? (see Table 2)
- Is all of the site easily accessible?
- Is the site exposed and will this impose constraints in the design and maintenance of growing installations?
- Is the sediment content of the water unacceptably high?
- Is the nutrient input unacceptably high?

  ⇒ will this result in excessive growth of fouling organisms on growing installations, requiring extra maintenance?

  ⇒ does this result in dense algae blooms?

  * do these lead to oxygen depletion of the water?

- Is the site likely to be subject to closure due to the effects of the presence of toxic algae?
- Are markets available and accessible?

Table 2. Key requirements for physical environmental factors controlling growth and survival of cultivated bivalve molluscs.

Key Factor	Oysters Native	Oysters Pacific	Clams Native	Clams Manila	Scallops	Mussels
Temperature						
Minimum for growth (°C)	8-9	8-9	8-9	8-9	7	-1
Minimum for survival (°C)	3-4	5-6	5-6	3-4	3-5	-4
Maximum (°C)	26-27	29-30	26-27	29-30	20	27-28
Optimum salinity (psu)	25-35	20-30	25-35	25-35	>30	20-35
Maximum exposure (% of time, at which growth stops)	25-35	25-35	40-50	40-50	0	25-30
Substrate						
mud			✓	✓		
muddy sand			✓	✓	✓	
sandy	✓	✓			✓	
firm/solid	✓	✓				✓

3. Checking on site availability

- Is the site already covered by an existing right to cultivate bivalve molluscs?
- Will an application for a Several Order or lease of a Several Order be needed?
- Is the site in or adjacent to a designated nature conservation area?
  - ⇒ will this restrict rights of access or cultivation?
- Is there a local management plan controlling use of the site?