CENTRE FOR ENVIRONMENT, FISHERIES AND
AQUACULTURE SCIENCE

Scallop Cultivation in the UK: a guide to site selection

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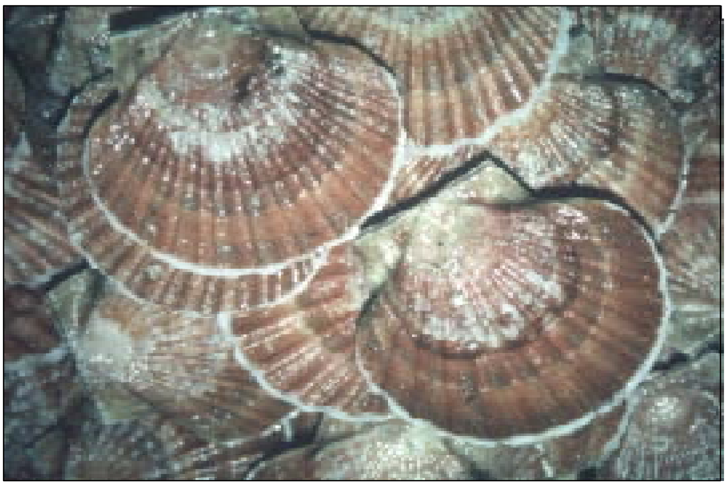
The king scallop (*Pecten maximus*) is one of two species of scallop cultivated in the UK, the other being the queen scallop (*Aequipecten opercularis*). King scallops live on the seabed, preferring substrates of clean firm sand, fine gravel or sandy gravel. They recess into the sediment to a level with the upper shell; sometimes they are partially covered.

Selecting a site that is suitable for king scallop cultivation is clearly of fundamental importance. It requires careful consideration of a range of different factors. The information in this booklet is intended as a guide to anyone thinking of moving into scallop cultivation, with a view to increasing the chances of success. It should also act as a reference for existing cultivators and will hopefully assist them in site management and in forecasting performance of their stock.



King scallops

It should also be remembered that for successful and profitable scallop cultivation good husbandry and management of the stock are needed, as well as a suitable site.

Production

King scallops are a valuable seafood product with large established markets both within Europe and world-wide. In the UK, the majority of king scallops produced for the table market are fished from natural stocks. This fishery is extremely valuable, worth about £30 million per year from landings of just under 20,000 tonnes. However, production seems to have reached a peak at this level (see Figure 1) and measures to conserve this fishery are increasingly being introduced.

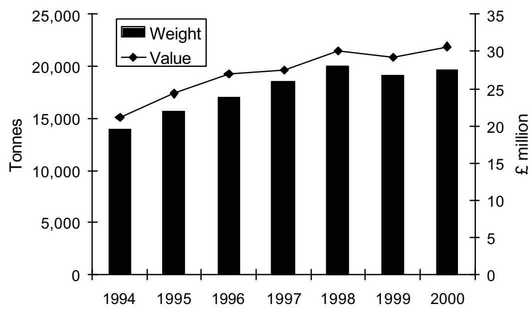


Figure 1. Scallop landings in the UK 1994-2000

There remains a significant retail demand for good quality scallops. Any increase in production within Europe to satisfy this demand is likely to come from cultivation. To date, just 40 tonnes of scallops are produced in this way in the UK, mostly from the west coast of Scotland.

Globally, cultivated scallop production has grown significantly over the last two decades, reaching 950,000 tonnes in 1999. However, this production is dominated by just one species - the Yesso scallop (*Pecten yessoensis*). The majority of the world's cultivated production of this species comes from China (76%) and Japan (22%).

Seed supply

Cultivation of scallops in the UK is currently mainly dependent on wild-caught seed. This is obtained by deploying suitable collectors. The most usual type of collector is a mesh onion bag filled with monofilament nylon mesh netting. A series of these can be attached to a rope with a weight on the end and suspended in the water from a float. The spat settle onto the netting, and when they detach, as they do naturally in order to drop onto the seabed, they are retained in the onion bag. Collectors must be deployed when and where larvae are most abundant in the water column. The 'window' for this is short and a collector will only be effective for a few days. If it is not done at exactly the right time, when peak settlement of scallop larvae is imminent, the collectors may attract other species. Natural seed collection is also dependent on a good tidal flow, as this ensures that spat will attach strongly to collectors and prevent them from being lost again. Commercial spat producers operate in some areas, such as around the Isle of Skye and in north-west Ireland, where conditions for settlement are favourable. These producers usually hold the spat for the first year after settlement before selling them for on-growing at a size of 20-30 mm shell height (shell height is measured as the length dimension perpendicular to the hinge).

Despite attempts to discover more about wild seed collection, so as to be better able to target the place and time of collection and maximise success, the vagaries of nature make this a rather hit and miss process, affecting the availability of seed for on-growing from year to year. Because of this, techniques for producing spat in hatcheries, to guarantee a reliable supply of good quality seed, have been developed. These have not been widely adopted commercially, due to the uncertainty of the markets. As the industry expands it is hoped that on-growers will make a commitment to hatchery seed production in order to secure a regular and reliable source of seed. This should then encourage the industry to develop further. Some operators have attempted, with varying success, to raise sufficient scallop seed for their own farms using a variety of low-technology methods. An advantage of this approach is that it eliminates the need to transport the seed.

Experiments have shown that performance of wild caught and hatchery-reared seed at on-growing sites is similar.

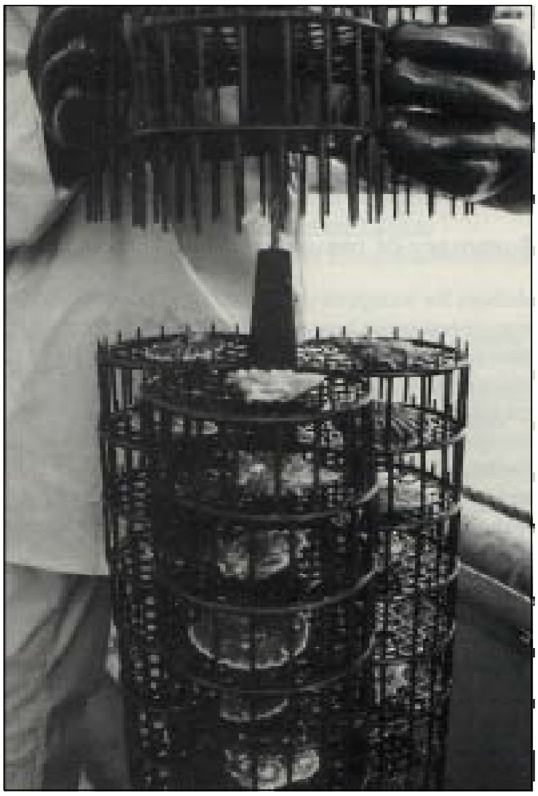
Transport

Scallops can be easily stressed during transport and to reduce this all scallops would ideally be transported under continually submerged conditions. Because of the high costs and logistical problems of transporting large volumes of seawater this is not always possible. Instead scallops are typically transported under cool and moist conditions. Some research has been carried out on transport of seed scallops. It was found, for example, that seed packed between layers of sponge foam rinsed in seawater would withstand 14 hours of transport at a temperature of 8 ^{0}C. Transportation time can be extended by the use of specialised misting techniques, which reduce desiccation of the scallops' gills and enables the tissues to receive sufficient oxygen to extend the transportation time significantly. However, this is expensive. In air, scallops transported for longer than 12 hours do not grow when returned to the water and high levels of mortality eventually result. The harmful effects are reduced at less than 12 hours out of water, and transportation of seed scallops, provided minimum handling, of no more than 4 - 6 hours of aerial exposure at low temperature (8 ºC) should not have any adverse affect on condition, growth or survival. These times are significantly reduced at higher temperatures.

Scallops in a lantern net

On-growing

Scallop seed are initially raised in suspended cultivation, in pearl and lantern nets suspended from long-lines. Pearl nets are generally used for small (10-30 mm shell height) scallops and lantern nets for larger animals. At first the pearl nets can be stocked at 50-80 scallops per net, reducing to 20-30 as they grow. From 30-60 scallops can be put into each compartment of a lantern net initially (at 30-40 mm) but this should be reduced to no more than 10-15 per compartment at 60-80 mm. Some companies have developed plastic mesh cages that can be stocked with bivalve molluscs, including scallops, and suspended in stacks from long-lines. However, it is very costly to use these suspended cultivation methods to raise scallops to market size. This is mainly due to the cost of the large number of nets or cages needed, to avoid crowding, which can lead to mortality, and maintenance and labour charges over a long grow-out period, usually about 4 years. Growth rates of scallops in suspended cultivation, provided that they have plenty of space to themselves, are similar to those for animals on the seabed. However, studies have shown that wave action, and thus movement in the nets, can be a stress factor as the scallops grow.



Purpose-designed 'Miniplat' basket for on-growing scallops

There can also be problems with fouling of the nets and bio-fouling of the shells with suspended cultivation methods. Shell bio-fouling is a major drawback of the ear-hanging cultivation technique, and can result in mortality. Nevertheless, cultivators on sites where there is little or no barnacle fouling may find the ear-hanging method worthwhile.

The above considerations have generally led farmers in the UK to cultivate scallops on the seabed, once they have reached a size (usually about 50-60 mm) at which they are less susceptible to predators such as crabs and starfish. Obviously this can only be done at sites where the substrate is suitable. However, at sites where growth rates are good the seed will reach the size at which they may be planted out on the bottom by the end of their first year. Some studies have shown that scallops kept in suspended cultures have thinner, more easily broken shells which could make them more liable to be predated by crabs when put onto the bottom, compared with wild scallops. These differences become more apparent with increasing size of animals. This emphasises the need to plant out the seed onto the bottom as soon as practical.

Transferring scallops to the seabed also helps to keep the shell clean from fouling organisms, due to the abrasive action of the sediment.

Scallops seeded onto the seabed will disperse naturally. Early experiments in a Scottish sea loch showed that most scallops remain within 30 metres of the point of their release, finding a density of less than one scallop per square metre. Some French and Norwegian studies have been based on reseeding at 1-2 scallops per square metre, although at sheltered sites with suitable substrate it may be possible to on-grow scallops at much higher densities than this.

Site security

The farmer will need to ensure that others cannot exploit his or her valuable investment once it is released onto the seabed. The right to manage and fish a cultivated stock in a defined area can be secured by obtaining a Several Fishery Order, or by gaining a lease on an existing Several Order. Many have already been granted for scallops, particularly in Scotland.

Further information on Several Fishery Orders can be found on the DEFRA web site at http://www.defra.gov.uk/fish/aquacult.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 I.

The site environment

Substrate

Scallops prefer substrates of clean, firm sand, fine gravel or sandy gravel, sometimes with an admixture of mud. This is their natural habitat. They will only survive on fine sediments provided current speeds are reasonably slow to prevent disturbance of the sediment, which could suffocate the scallops, if they became covered. Hard sediments are unsuitable, as the scallops are unable to bury themselves sufficiently to avoid predation.

Depth of water

Sites with depth of water between 15-30 metres are ideal. Allowing for tidal fluctuations, it is essential that nets should not be in contact with the seabed. This avoids predators such as starfish and crabs, which are the two main enemies of scallops, gaining access to the nets. Also, deeper water sites allow on-growing equipment to be sunk to a depth below the influence of wave action and excessive temperature fluctuations.

Salinity

Usually, cultivation sites are chosen at which salinity varies within 30-35 psu (practical salinity units) and where these salinity conditions prevail, it is temperature (see below) that is generally considered to be the most important factor affecting performance of the spat. However, cultivation sites may occasionally be subjected to lower salinity conditions, due to increased fresh water input from rivers and land run-off, following heavy rainfall. An ambient salinity of 28 psu or above is required for successful scallop cultivation (Figure 2). As can be seen from the figure, there is a dramatic decrease in growth rate below this salinity. At lower

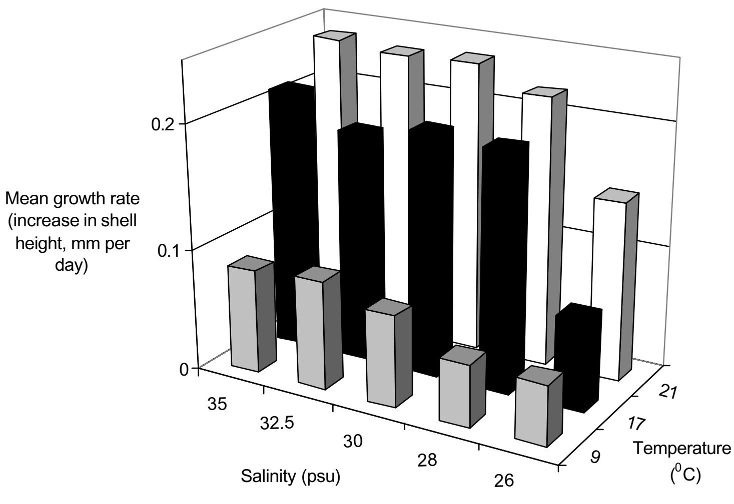


Figure 2. Growth in relation to salinity at different temperatures

temperatures growth at 28 psu will be slightly lower than at 30 psu.

Lower salinity is stressful to king scallops. Growth rate is significantly reduced and mortality can result. Scallops are able to tolerate short exposure (for example, up to 6 hours per day for 3 days) to lower salinity (20 psu) although this will be followed by a short-term reduction in growth rate and may also result in mortality, particularly at temperatures less than 10°C (Figure 3).

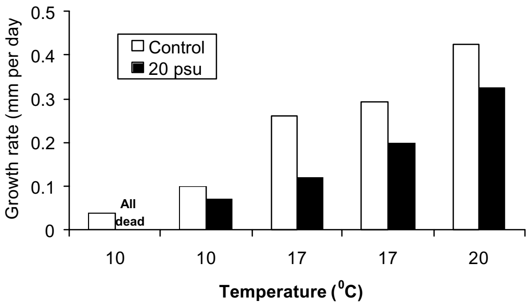


Figure 3. Growth rate (increase in shell height, mm per day) at 30 psu following exposure at low salinity (20 psu, for 6 h per day for 3 d) at a range of temperatures

It is generally recognised that the stressful effect of low salinity is greater at lower temperatures. For example, one study showed that scallops can survive temperatures as low as 3°C at salinities above 30 psu, but they may die at temperatures below 5°C if salinity falls to less than 26 psu. Other stress factors, such as crowding in the nets during the suspended cultivation phase, will reduce tolerance to the combined effect of these extreme conditions. This shows the importance of considering local salinity profiles at potential sites where the winter seawater temperature tends to be low. If the site is also subject to episodes of low salinity then that site is probably best avoided.

Fresh water is less dense than seawater and in some circumstances, for example in calm conditions in sheltered areas after heavy rainfall, will form a layer, as much as 2 to 3 metres in depth, on the surface. Scallops will not tolerate this and it emphasises the need to keep suspended cultivation equipment well submerged at sites where this problem may arise.

Temperature

It is well known that seawater temperature has a major effect on the seasonal growth of cultivated bivalve molluscs. Growth rates of scallops measured at existing cultivation and some trial sites in England and Scotland were strongly correlated with temperature. This is seen on Figure 4, where the information has come from monthly measurements of performance, including growth, at four sites at which continuous temperature recorders were deployed.

Collecting scallops held in lantern nets for monthly sampling. Continuous temperature recorders were deployed inside the nets.

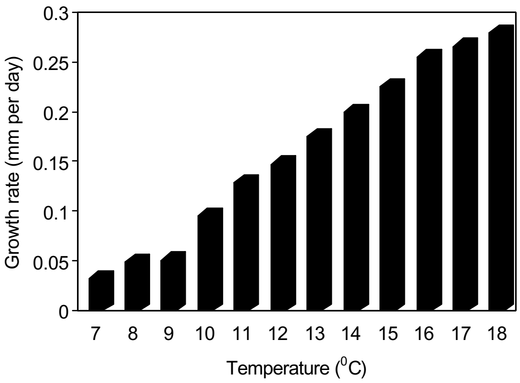


Figure 4. Mean growth rate (increase in shell height, mm per day) in relation to temperature (°C)

From laboratory experiments, we find that king scallops do not grow at all below 6.5°C. While measurable, growth is minimal between this temperature and 10°C. Studies measuring metabolic indicators of stress in scallops grown at a range of temperatures have shown that this is the point above which the metabolism of the scallops changes from 'winter' to 'summer' mode. Growth rates increase with temperature above 10°C, and will continue to increase up to a maximum tested temperature of 23°C. However, at temperatures above 17-18°C the condition of the animals becomes lower, and there is evidence that this is because these higher temperatures are stressful. It follows that the best sites for scallop cultivation are those where temperature is between 10°C and 17°C for the maximum length of time.

Exposure to air, wind and currents

The prevailing weather conditions, especially wind strength and direction, at a site need to be considered carefully. Strong onshore winds can generate extreme wave action and this can cause physical damage to cultivation equipment. This, as well as strong tidal currents, can also cause excessive buffeting of scallops in nets, which can lead to reduced growth and mortality. Sheltered areas usually provide the best conditions. Scallop cultivation can be successful in water of minimal flow, where water exchange is driven only by the rise and fall of the tide and gentle wave action. A current velocity of 0.4-1.8 knots (0.2-0.9 metres per second) is most suitable for suspended culture systems and will give sufficient water exchange to supply the animals with an adequate supply of food and oxygen. One knot is optimal for seabed culture, although up to 2 knots can be tolerated.

Food

Scallops feed by filtering mainly microscopic algae (phytoplankton), but also some organic detritus, from seawater. 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 seawater 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 (which may be attenuated depending on the turbidity of the water) 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. Other 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 scallops, yet it is the most difficult factor to assess for a given site. For the DEFRA-funded LINK Aquaculture study 'Environmental requirements for successful king scallop cultivation', water samples were collected weekly from the participating cultivation sites and analysed for chlorophyll, as well as for salinity and particulate organic content. It can be seen from Figure 5 that generally there appears to be abundant chlorophyll in the water during the summer growing season.

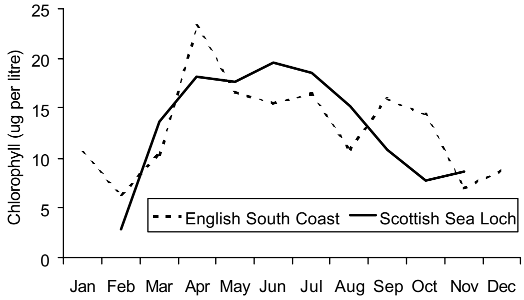


Figure 5. The annual chlorophyll cycle for two scallop cultivation sites; one in an enclosed area on the south coast of England and the other in a sea loch on the west coast of Scotland.

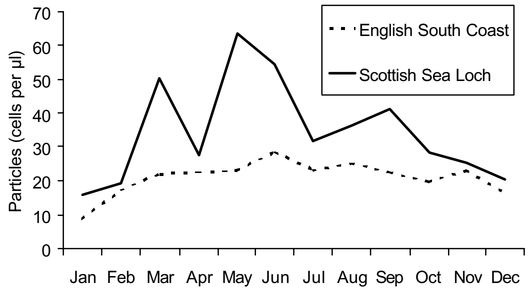


Figure 6. The annual particulate concentration cycle for two scallop cultivation sites; one in an enclosed area on the south coast of England and the other in a sea loch on the west coast of Scotland

The English south coast site exhibits minor peaks of 'primary production' in spring and, to a lesser extent, autumn, whereas chlorophyll levels at the Scottish site are maintained throughout the summer.

The amount of food being consumed by the scallops at these field sites was also estimated. This was done from the measurements taken of particulate content of the seawater from the weekly water samples (Figure 6), using estimates of the filtration rate of scallops in relation to particulate content of the water (Figure 7) and the prevailing temperature (Figure 8), as determined by laboratory experiments. The result can be compared with estimates of the amount of food that the scallops require at any given temperature, also determined by laboratory experiments.

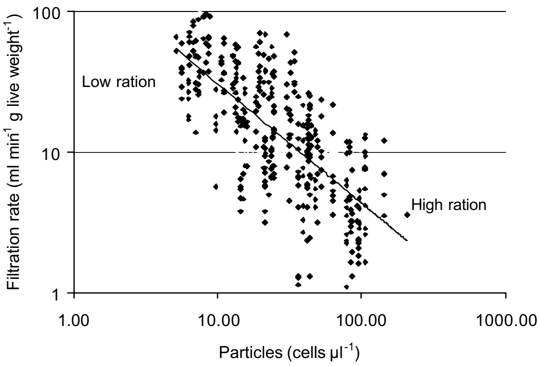


Figure 7. Scallop filtration rate in relation to particle concentration

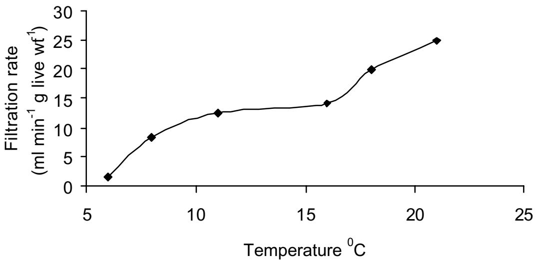


Figure 8. Scallop filtration rate in relation to temperature

At low food densities (low ration) in the seawater, estimated by food particle concentration, scallops are able to maintain an adequate food intake by increasing their filtration rate, as shown on Figure 7, where the data are taken from measurements made in experimental outdoor nursery systems over several weeks. At higher rations they obtain the food they need by a lower filtration rate. Very high particle concentrations, beyond the range shown on Figure 7, can inhibit scallop filtration activity. Above a critical threshold the filtration rates are depressed to such a severe extent that the scallops can no longer obtain sufficient food. For this reason sites where there are regular and intense blooms of algae, perhaps as a result of very high nutrient loading of the seawater coupled with low exchange, are best avoided. A further reason for avoiding such sites is that death and decay of these blooms can use up the available oxygen in the water.

The estimate obtained of the algae ration consumed by scallops throughout the year at two widely separated field sites shows that there was always more food consumed than the amount required for maximum growth, as determined by laboratory experiments (Figure 9).

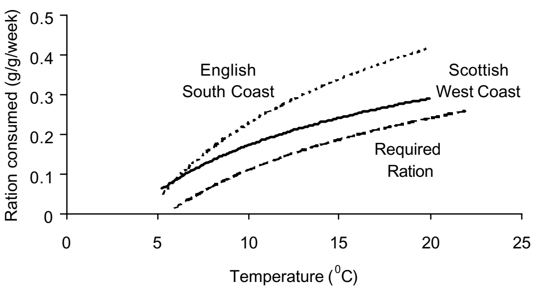


Figure 9. An estimate of the ration consumed by king scallops at two cultivation sites; one in an enclosed area on the south coast of England and the other in a sea loch on the west coast of Scotland, compared with the ration needed for maximum growth

As temperature increases scallops will consume more food (a bigger ration). At each temperature, any increase in the ration consumed initially gives an increase in growth, until a point is reached at which higher rations give no greater growth. This level of ration is represented by the lower curve on Figure 9.

The quality of the algae diet also has an influence on performance. Food quality is much more difficult to assess from water samples than food quantity (chlorophyll/particulates). Filtration rates of scallops also vary with the type of algae available, being lower when species with a low nutritional value are present. Data collected at existing cultivation and some trial sites in both Scotland and England showed that performance of scallops varied from that expected from the prevailing temperature, with a sufficient quantity of food available. These differences were attributed to the quality (nutritional value) of the algae species present in the seawater.

In other studies, carried out in France, periods of slow growth have been observed during blooms of certain diatom and dinoflagellate species, particularly toxic species (e.g. *Gymnodinium*). The effect is generally greater for older scallops.

Water quality

As scallops filter phytoplankton from the seawater during feeding, they also take in other small particles, such as organic detritus, bacteria and viruses. Scallops farmed in inshore coastal waters can bio-accumulate human microbial pathogens derived from sewage contamination in a similar manner to that of other commercially farmed bivalve shellfish (Figure 10). Some of these bacteria and viruses, especially those originating from sewage outfalls, can cause serious illnesses in human consumers if they remain in the scallops when they are eaten.

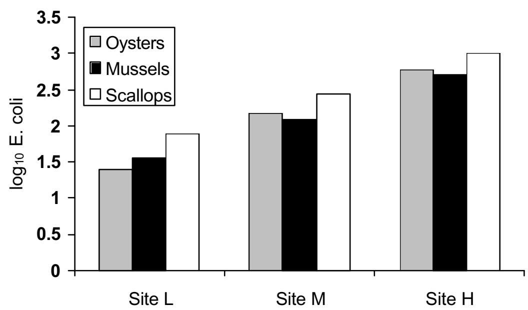


Figure 10. Mean numbers (as logarithm to the base 10) of E. coli bacteria per 100 g of shellfish flesh at three experimental sites. The sites were chosen to represent a range of contamination levels; low, medium and high (designated L, M and H)

There is a statutory requirement for shellfish beds to be classified according to the faecal coliform (or *Escherichia coli*) levels of the bivalve flesh (see Table 1).

Table 1. Criteria for classifying shellfish harvesting areas

Classification category	Faecal coliform bacteria (*E. coli*)* per 100 g shellfish flesh	Comment
A	All samples less than 300 (*230*)	Suitable for consumption. Can be marketed
B	Less than 6,000 (*4,600*) in 90% of samples	Depuration needed (*or* relaying in category A area *or* cooking by an approved method)
C	All samples less than 60,000 (*46,000*)	Relaying (minimum of two months in approved relaying area *or* cooking by an approved method)
Prohibited	Above 60,000 (*46,000*)	Cannot be taken for placing on the market

** Classification in England and Wales is based on E. coli content of flesh*

Treatment of shellfish before marketing is dependent on the classification of the area from which they are harvested. Scallops cultivated in harvesting areas with a 'B' classification must be purified of any faecal bacterial content in cleansing (depuration) tanks before sale for consumption. Further information on scallop depuration can be found later in this booklet.

The local Environmental Health Department (EHD) or Port Health Authority (PHA) may be able to provide you with information on shellfish hygiene and water classifications if your site is already a shellfish harvesting area. New sites must be graded. You should collect samples of scallops from your selected area or place them in the area for testing. If the EHD/PHA can be involved and the sampling is done every 2 weeks for 3 to 4 months, according to strict protocols, it may be possible to get a provisional classification almost immediately thereafter. If the sampling is done independently, the results will not count towards a provisional classification. Full classification may be achieved after a year of continued 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, of from historical monitoring.

Scallops from areas with a 'C' classification must be re-laid for several months in areas with an 'A' or 'B' classification to allow time for them to reach an acceptable bacterial standard before further treatment or marketing. Relaying in cleaner areas, even if these are available close by, is an additional expense likely to significantly reduce profitability. For this reason harvesting area classification is a very important site selection criterion. Grounds close to or likely to be affected by the flow from untreated sewage outfalls should be avoided. Fortunately, there are now very few outfalls of this type, due to continued improvements to sewage waste disposal systems. Scallops sold as a processed product using an approved heat treatment (cooking) process is permitted for both Category 'B' and Category 'C' areas. Scallops in areas classified 'Prohibited' cannot be harvested under any circumstances. For further information on classification of designated shellfish harvesting areas in your area contact your local EHD/ PHA or visit the FSA web site at http:// www.foodstandards.gov.uk/foodindustry/shellfish.

Waters subject to pollution from industrial areas (e.g. heavy metals and organic compounds) are unsuitable for any type of bivalve cultivation and must be avoided.

Other important factors

There are various other factors, which may be at least partially site-related, that are important considerations for potential cultivators.

Depuration

Cultivated scallops may accumulate levels of faecal contamination above those that would allow the marketing of live animals without prior depuration (see above). Experiments funded by Fisheries II Division of DEFRA and carried out at the CEFAS Weymouth laboratory have shown that it is possible to successfully depurate Category 'B' level scallops to required end product standards without any detrimental effects on the quality of the scallops. Standard equipment and techniques commonly used in the UK to depurate a range of shellfish species, in which they are purified for a minimum of 42 hours in UV-treated re-circulated seawater, can be used.

Other conditions, specific to depuration of scallops, must be met. These are -

- Only natural seawater may be used.
- Salinity must be maintained at 30 psu or above.
- Temperature must be maintained at 10°C or above.
- Purification must commence within 10 hours of harvesting.
- Scallops may be loaded up to a maximum of 2 layers high with the cup side shell down.
- Scallops must be prevented from escaping from baskets during depuration. Any method used to contain shellfish in baskets must not interfere with their ability to open and filter.
- Scallop to water ratios should not be any less than 1:12 (kg:litre).

Although the use of artificial seawater during depuration is suitable for a wide range of bivalve mollusc species it is unacceptable for scallops. In the CEFAS experiments, scallops failed to depurate properly and some mortality was observed. There was some indication that it was an unknown constituent of the laboratory tap water used to prepare the artificial seawater that was responsible. As it has not so far been possible to identify the

One of the CEFAS systems used for scallop depuration experiments

exact cause of the problem the use of artificial seawater cannot be recommended at the present time. This may be a constraint for cultivators, particularly if their depuration plant is inland, although collecting and transporting natural seawater is an alternative. The requirement for salinity of greater than 30 psu may be a further constraint, depending on the location of the water source, as estuarine water may frequently have lower salinity than this.

It seems that the salinity and temperature conditions under which scallops will depurate effectively are similar to the environmental optima for performance at on-growing sites. Note that no upper temperature limits on depuration are set. This is because higher temperatures do not usually compromise the depuration process. However, excessively high temperatures may detrimentally effect the quality of the marketable product. In one of the CEFAS experiments the temperature in the control was set at 20°C and while the scallops depurated effectively there was some mortality of scallops kept in tanks for further observation for a few days. Information from the environmental studies described above suggest that temperatures greater than 18°C should be avoided.

It was shown that scallops can successfully be depurated in a double layer and it was possible to load up to sixty scallops in one of the standard plastic mesh baskets (72 mm long x 42 mm wide x 12 mm deep) used in the trials. Scallops have a considerable tendency to move and if left unconfined some will escape from the basket and deposit themselves on the base of the tank. This is unacceptable as much of the faecal material excreted by the scallops during the depuration cycle settles here and movement of the scallops will re-suspend this material. This may then be re-ingested and re-contaminate the scallops with the microbiological organisms present in the sediment. Placing plastic mesh over the baskets is a simple and effective method to prevent the scallops escaping. The recommended scallop to shellfish water ratio of 1:12 (kg: litre) was the maximum that could be achieved using the double layer arrangement described above in a typical commercial system. This compares with some of the high intensity systems used to depurate other bivalve mollusc species, which may have shellfish to water ratios as low as 1:3 when fully loaded. If operators wish to use lower ratios in more high intensity arrangements then the suitability of their individual system would have to be determined through trials.

Predators and competitors

In the suspended cultivation phase problems may arise through settlement of predator and competitor organisms in the nets containing the scallops. This can be avoided to a certain extent by keeping nets at least 5 m off the bottom.

Scallops cultivated on the seabed can be vulnerable to predation, particularly from crabs and starfish, although predation by whelks is also documented for some sites. Seeding larger spat can significantly reduce the risk of losing stock, although this increases the costs of rearing in the suspended cultivation phase. Scallops are mobile animals and can swim short distances to escape from predators.

It is possible to control predators to a certain extent. They can be removed while diver harvesting and it is particularly important to remove larger starfish before seeding takes place and for the few weeks immediately following. Baited traps can be set to remove crabs and these can also be sited to lure the crabs away from seeding areas.

Net fouling

Fouling can be a costly problem for scallop growers; it significantly increases the weight and drag of cultivation equipment and can adversely affect scallop growth and mortality. Cleaning or changing the pearl or lantern nets in which scallops are grown is labour intensive and can stress scallops, reducing growth rates. Handling should be kept to a minimum, particularly in the winter (see later). However, experiments done in Manx waters with seed scallops suggest that some fouling of pearl nets may actually encourage scallop growth rates in winter months and have no effect or only a slightly negative influence in the summer. However, excessive fouling can be harmful, as the scallops may become trapped in or smothered by the fouling organisms and so unable to function properly.

Disease

King scallops are not susceptible to any serious diseases. However, as it is not known for certain that they do not act as vectors for shellfish diseases that affect other commercially valuable bivalve species, particularly native oysters, movement controls may be applied.

The UK has been granted approved zone status for two diseases of native oysters. This covers the whole coastline for *Marteilia* and, for *Bonamia*, the whole coastline except for the three restricted areas where this disease is found. These are (1) from the Lizard to Start Point; (2) from Portland Bill to Selsey Bill and (3) from Shoeburyness to Felixstowe (Commission Decision 2002/300/EC of 18 April 2002). Movements within the UK of all bivalve molluscs, including scallops, are controlled according to the health status of these areas. Anyone wishing to deposit or relay scallops taken from the controlled (restricted) areas listed above must apply for permission to the Fish Health Inspectorate (FHI) at the CEFAS Weymouth Laboratory (for England and Wales) or the Fisheries Research Services (FRS) at the Marine Laboratory, Aberdeen (in Scotland). Addresses are given in Appendix I.

Import controls aimed at preventing the introduction of shellfish diseases from abroad are also in force. Further information is available on the CEFAS web site at :http://www.cefas.co.uk/fhi/movements.htm #Shellfish. Anyone wishing to deposit or relay imported molluscan shellfish, including scallops, must apply for permission to the FHI or the FRS.

Toxic algae

Certain types of naturally occurring algae produce toxins that can accumulate in the flesh of the bivalve molluscs feeding on them. People eating bivalves containing these toxins can become ill. These toxins may cause 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. ASP toxins are the ones most commonly found in scallops. Cooking does not denature the toxins nor does depuration eliminate them. These toxic algae do not seriously harm the shellfish themselves, although there may be a short-term reduction in growth.

The risks to consumers from shellfish poisoning due to the presence of algal toxins in the tissues are minimised by a statutory requirement for sampling and testing. Monitoring programmes are undertaken on behalf of the Food Standards Agency (FSA) and FSA (Scotland). You may be required to provide samples. Further information on the algal toxin monitoring programmes, together with a list of the areas currently affected can be found on the FSA web site at: http://www.foodstandards.gov.uk/foodindustry/shellfish/

In some years, marketing may be temporarily suspended due to the detection of toxins in the scallop flesh samples. 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 the May issue of *Shellfish News*. Copies may be obtained from the library at the CEFAS Lowestoft Laboratory or from the CEFAS web site (http://www.cefas.co.uk/publications/shellfish_news.htm).

Predicting performance

Temperature

As noted above, temperature is the major factor affecting growth of scallops. For this reason, scallop cultivation in the UK is largely confined to the south and west coasts. Sites on eastern-facing coasts of England and Scotland are generally unsuitable, due to low winter temperatures, which may fall to 5-6°C or less. There is in any case a lack of sheltered sites on the east coast and salinity tends to be lower than optimum here.

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. Differences are less in winter, but note from Figure 11 how the main 'growing season' (time when temperature is above 10°C) is longer in the south, starting about 6 weeks earlier in the spring. This, together with the higher summer seawater temperatures will give shorter grow-out times in the south.

This is confirmed by following the performance of scallops planted out at these sites, where growth rates were measured monthly. Figure 12 shows that scallops planted out at the same size (13 mm shell height) and time of year (July) were, on average, over 8mm larger at the southern site after 15 months. This difference was shown to be consistent, as two further batches of seed, planted out in later years, gave similar results. Nevertheless, the seed at both sites reached a size at which they could be put out onto the seabed after 12-14 months. Survival at this stage was excellent (greater than 80%). The performance of seed scallops collected from the wild or reared in the hatchery was identical in this respect.

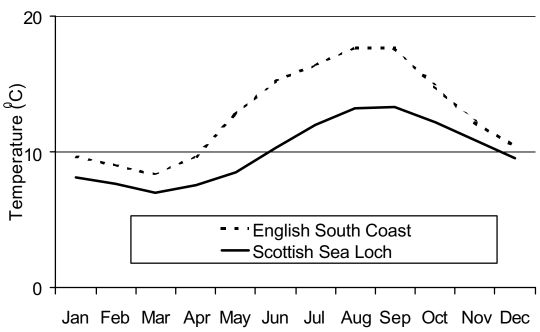


Figure 11. ***The annual ambient seawater temperature cycle for two scallop cultivation sites; one in an enclosed area on the south coast of England and the other in a sea loch on the west coast of Scotland***

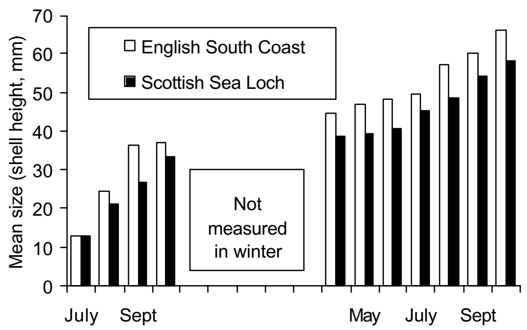
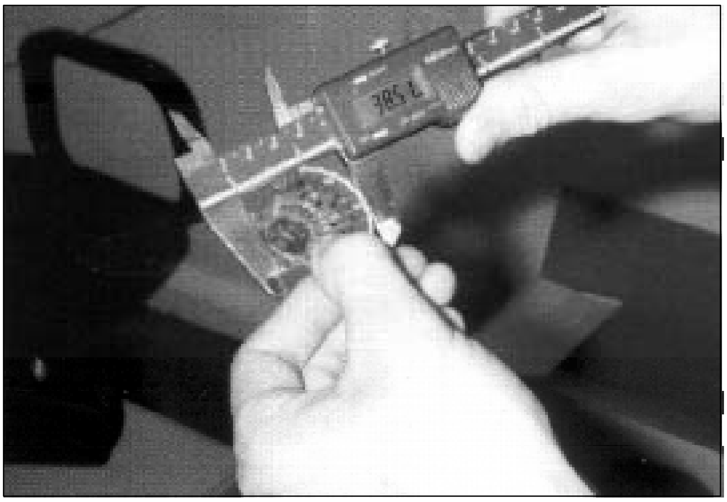


Figure 12. ***Growth performance of scallop seed at two cultivation sites; one in an enclosed area on the south coast of England and the other in a sea loch on the west coast of Scotland***



Measuring seed scallops

Survival of scallops kept in nets for much longer after they have reached this size was not so good. In the field trials, there was no further noticeable additional mortality over the following winter months, but by the end of the next summer growing season, when the scallops had grown to 70-88 mm, only half of them survived. It is difficult to estimate survival of the scallops once put out onto the bottom, as any attempt to contain them affects their performance, including survival. However, observations by divers immediately after seeding them onto the seabed and periodically thereafter suggested that survival rates are very high.

Summer monthly sampling of seed scallops in field trials

Handling

You will notice from Figure 12 that no measurements of performance were taken during the winter. Both laboratory experiments and field trials have shown that at this time, when the juveniles are in any case growing very slowly, sampling for measurement at intervals of less than 2 months inhibits growth and eventually leads to mortality. Handling of scallops in nets at this time should therefore be kept to a minimum. This should not be a problem due to lower maintenance requirements during the winter. The results from this work also confirmed that growth and survival of scallops at the field sites was not affected by handling for sampling and measurement at monthly intervals during the summer. However, there was some evidence that handling more frequently than this might be harmful.

Naturally, scallops will be continually submerged. If they are removed from water the body tissues will soon desiccate. This is because the two shells do not fully close together. If they are taken out of water during routine maintenance operations and left dry and uncovered for more than about an hour, or even less in windy and/or warm conditions, then desiccation of the tissues will lead to irreversible damage and death, even if they are then re-immersed.

Size

In predicting performance it should be noted that the growth rate of scallops, as increase in shell height (mm per day), varies with shell size as well as with temperature. Growth rates measured in this way diminish with increasing shell size (Figure 13).

Differences in growth rate due to temperature become less as the scallops grow. As they approach market size they grow at a similar rate at all seawater temperatures above 10°C. At low seawater temperatures (less than 10°C) the lower growth rate is almost independent of shell size.

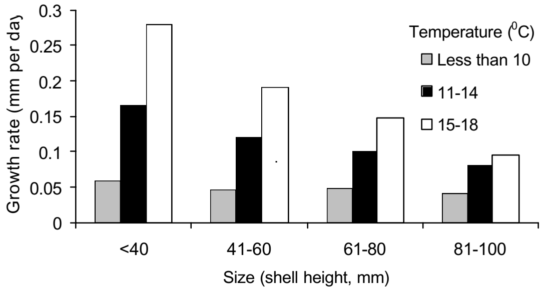


Figure 13. Mean growth rate (increase in shell height, mm per day) in relation to size of scallops and temperature

Yield

The 'yield' (the combined wet weight of the edible parts, i.e. the adductor muscle and gonad or roe) from market size scallops increases with shell size as shown on Figure 14.

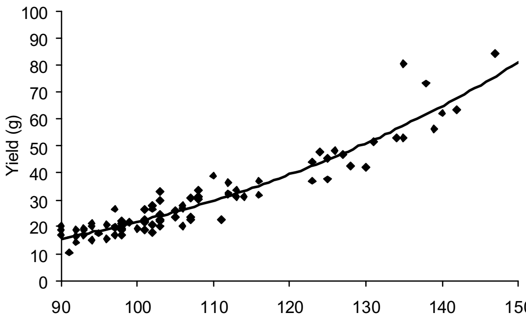


Figure 14. Yield (wet weight of adductor + gonad) of scallops in relation to shell size

It can be seen that a 20% increase in shell size, from 110 to 130 mm, gives a 70% increase in 'yield', from 30 to 50 g wet weight of edible scallop. This relationship has been shown to be true for scallops cultivated throughout the UK. It is similar for scallops grown in a Scottish sea loch and from an enclosed areas on the south coast of England. The cultivator will need to balance the additional costs, including restrictions on cash flow, of keeping scallops on the seabed longer to allow them to grow to a larger size against the benefits of an increased yield i.e. a superior and more marketable product.

The proportion of the edible part of the scallop that is composed of roe varies throughout the year. In spring the scallops will be ripe, with the roe comprising, on average, about 50% by weight of the total yield. Spawning occurs from late June/ early July onwards, and by late summer (August/ September) the roe will be, on average, just 10% of the yield. The size of the gonad is then restored gradually over winter, although the rate at which this happens will vary between individual scallops and between sites. It can be very slow at first, so that there may only be a small amount of roe in some scallops harvested for the Christmas market.

Costs

An assessment has been made of the resources required for rearing scallops from seeding to harvest, on a commercial scale, at a site on the south coast of England. Based on seeding 75,000 scallops per year, with 15% mortality and harvesting by diver collection, commencing after 3 years, the profit is 23% of costs. This is based on equipment purchase within the first 3 years, and so profit would be higher if based on depreciation costs over several years. Further information on the costs associated with scallop cultivation is available from SEAFISH (Appendix I) who have carried out an economic modelling study. Results from this suggest that commercial operations are potentially viable, particularly as a diver collected scallop is a superior product to dredged scallops and can thus command a premium price.

Appendix I. Useful addresses

NOTE: *Contact details can change, so you are advised to check the more up-to-date information that is published in each issue of Shellfish News. Copies can be obtained from the CEFAS Lowestoft Laboratory (see below) or they can be viewed electronically at http://www.cefas.co.uk/publications/shellfish_news.htm.*

(a) Policy Matters

Department for the Environment, Food and
Rural Affairs,
Nobel House,
17 Smith Square,
London SW1P 3JR
(Switchboard tel. 020 7238 3000)
(General fax. 020 7238 6591)
(http://www.defra.gov.uk)

Welsh Assembly Government, Agricultural and
Rural Affairs Department,
New Crown Buildings,
Cathays Park,
Cardiff CF1 3NQ
(Tel. 029 2082 3567)
(Fax. 029 2082 3562)
(http://www.wales.gov.uk)

Scottish Executive Environment and
Rural Affairs Department,
Pentland House,
47 Robbs Loan,
Edinburgh EHG14 1TW
(Tel. 0131 244 6224)
(Fax. 0131 244 6313)
(http://www.scotland.gov.uk/who/dept_rural.asp)

Department of Agriculture and Rural
Development for Northern Ireland,
Fisheries Division, Annexe 5, Castle Grounds,
Stormont, Belfast, BT4 3PW
(Tel. 028 9052 3431)
(Fax. 028 9052 2394)
(http://www.dardni.gov.uk)

(b) Shellfish Hygiene

Food Standards Agency (England)
Aviation House, 125 Kingsway,
London, WC2B 6NH
(Tel. 020 7276 8000)

Food Standards Agency (Scotland),
St Magnus House, 25 Guild Street,
Aberdeen AB11 6NJ
(Tel 01224 285100);

Food Standards Agency (Wales),
Southgate House, Wood Street,
Cardiff CF10 1EW
(Tel 029 20 678918);

Food Standards Agency (Northern Ireland),
10C Clarendon Road,
Belfast BT1 3BG
(Tel 02890 417711)
(http://www.food.gov.uk)

(c) Scientific and technical advice

CEFAS Weymouth Laboratory,
Barrack Road, The Nothe,
Weymouth, Dorset DT4 8UB
(Tel 01305 206600) (Fax 01305 206601)
Cultivation techniques, Health regulations and disease control, Shellfish hygiene classification and purification plant approvals, Shellfish water quality and effluent discharges (microbiology) - England and Wales.

CEFAS Lowestoft Laboratory,
Pakefield Road,
Lowestoft, Suffolk, NR33 0HT
(Tel 01502 562244) (Fax 01502 513865)
Shellfish stocks.

CEFAS Burnham Laboratory,
Remembrance Avenue,
Burnham-On-Crouch, Essex, CMO 8HA
(Tel. 01621 787200) (Fax 01621 784989)
Pollutants and their effects (contaminants)
(http://www.cefas.co.uk)

Fisheries Research Services,
Marine Laboratory,
PO Box 101, Victoria Road, Aberdeen AB9 8DB
(Tel. 01224 876544) (Fax. 01224 295511)
Shellfish stocks, cultivation, hygiene, and disease control - Scotland.
(http://www.marlab.ac.uk)

SEAFISH - Aquaculture Development Service:
(http://www.seafish.co.uk/aquaculture/development.htm)
For Scotland: Craig Burton, Marine Farming Unit, Ardtoe, Acharacle, Argyll, PH36 4LD
(Tel. 01397 875402) (Fax. 875001)
(email: c_burton@seafish.co.uk)
For England and Wales: Sue Utting, P.O. Box 68, Colwyn Bay, North Wales, LL28 5WR
(Tel/Fax. 01492 650884)
(e-mail: s_utting@seafish.co.uk)

SEAFISH Technology,
Seafish House, St. Andrew's Dock,
Hull, HU3 4QE
(Tel 01482 327837) (Fax 01482 223310)
(http://www.seafish.co.uk/marine_tech/dept_marine_technology.htm)

(d) Advice on commercial activities

The Shellfish Association of Great Britain,
Fishmonger's Hall, London Bridge,
London, EC4R 9EL
(Tel. 020 7283 8305) (Fax. 020 7929 1389)
(http://www.shellfish.org.uk)

The Association of Scottish Shellfish Growers,
Mountview, Ardvasar, Isle of Skye, IV45 8RU
(Tel/Fax: 01471 844324)

(e) Wildlife conservation and status of on-growing sites

Joint Nature Conservation Committee,
Monkstone House, City Road,
Peterborough PE1 1JY
(Tel. 01733 562626) (Fax. 01733 555948)
(http://www.jncc.gov.uk)

English Nature,
Northminster House, Peterborough, PE1 1UA
(Tel. 01733 455000) (Fax. 01733 568834)
(http://www.english-nature.org.uk)

Countryside Council for Wales,
Ffordd Penrhos, Bangor, LL57 2LQ
(Tel. 01248 385500) (Fax. 01248 355782)
(http://www.ccw.gov.uk)

Scottish Natural Heritage,
12 Hope Terrace, Edinburgh, Scotland, EH9 2AS
(Tel. 0131 447 4784) (Fax. 0131 446 2277)
(http://www.snh.org.uk)

(e) Other Useful Numbers

Crown Estate Commissioners,
Crown Estate Office, Marine Estates Division,
16 Carlton House Terrace,
London SW1Y 5AH
(Tel. 020 7210 4322, Dr Tony Murray)
(Fax. 020 7839 7847)
(http://www.crownestates.co.uk)

Central contact for local Sea Fisheries Committees - The Association of Sea Fisheries Committees of England and Wales,
24, Wykeham Village,
Scarborough, North Yorkshire, YO13 9QP
(Telephone and Fax: 01723 863169).

Appendix II. Further information

(a) Site selection booklet

The CEFAS publication 'Bivalve cultivation: criteria for selecting a site' by I. Laing and B.E. Spencer gives a general overview of site selection for bivalve mollusc aquaculture. This booklet includes important information on legal aspects including registration of shellfish farms, rights of cultivators, Fishery (Several and Regulating) Orders, controls on movements, and shellfish hygiene classification. It is available from the CEFAS Lowestoft library (see Appendix I for address) or on the CEFAS web site at http://www.cefas.co.uk/publications/bivalve_cultivation.pdf.

(b) Shellfish News

'*Shellfish News*' is produced and edited by CEFAS on behalf of DEFRA, Fisheries II Division. It is published twice yearly (May & November) as a service to the British shellfish farming and harvesting industry. Subscription is free; apply to the library at the CEFAS Lowestoft Laboratory.

Some articles relevant to cultivation of king scallops have been published in previous issues, and these are listed below. Apply to the library at the CEFAS Lowestoft Laboratory for reprints. The most recent copies are also available in electronic format (PDF files) on the CEFAS web site at http://www.cefas.co.uk/publications/shellfish_news.htm.

Articles on scallops	Reference - Shellfish News
Seed transport	Volume 6, November 1998, pp 14-16 Volume 7, May 1999, p 7
On-growing equipment	Volume 7, May 1999, pp 8-9
Handling	Volume 8, November 1999, pp 12-13
Nursery cultivation	Volume 9, May 2000, pp 9-11
Microbiological contamination	Volume 10, November 2000, pp 7-8
Net fouling	Volume 11, May 2001, p 21
ASP issues	Volume 11, May 2001, pp 24-25
Summary of recent studies	Volume 12, November 2001, pp 21-22

(c) SEAFISH Aquaculture hyperbook

The Sea Fish Industry Authority publishes a 'hyper-book' on CD-ROM that covers all aspects of scallop cultivation. This is one of a series that covers all commercially cultivated fish and shellfish species in the UK. An economic model is also available. For further information contact the Aquaculture Development Officer for your area (see Appendix I for address).