Sea Fish Industry Authority
Aquaculture Development Service

Lobster hatcheries and stocking programmes: An introductory manual

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Section I BACKGROUND

1. Introduction

Over the past 25 years much effort has been put into developing hatchery techniques for both the European (*Homarus gammarus*) and American (*Homarus americanus*) Lobster. Almost without exception, it has been concluded that farming, in the true sense of the word, ie. rearing from cradle to table in controlled conditions (intensive farming), is unlikely to be economic in the foreseeable future. However, utilising hatchery-reared juvenile animals for stocking natural habitats, often called 'ranching', stock enhancement or extensive farming, has shown some success.

As the fishing industry learnt of the positive results from the trials, there was a demand for information about setting up hatcheries and stocking schemes from public bodies, companies and individual entrepreneurs. Until now this information has been supplied piecemeal, a collection of papers published by the various groups over the years. This is difficult for all concerned and can sometimes confuse more than it informs. Consequently, it was concluded that a 'user friendly', comprehensive, single publication was needed and this manual is an attempt to meet that need.

The manual pulls together the experience of researchers in the UK working with the European Lobster, but also draws upon information published by other groups around the world. It is intended as an introduction to the subject for those who are new to the field and may serve as an '*aide memoire*' for those with more experience. Techniques which have been used with success are explained and, where possible, currently accepted 'best practice' is highlighted. Every attempt has been made to avoid scientific jargon whenever possible, but some remains and these terms are explained in the glossary at the back.

Research continues and some parts of this manual will inevitably become out-of-date or be superseded by advances in the field. Readers are recommended to bear this in mind and make use of the contact list provided to request up-to-date information as required.

1.1 Basic Biology and Physiology

A more detailed account is given in appendix I.

The European Lobster, scientific name *Homarus gammarus* (Linnaeus 1758), is a decapod crustacean. It has 5 pairs of walking legs (10 in all), the first pair of which is heavily modified to form the large claws. The next two pairs of legs also have very small claws at the end and move food to the mouth. The front of the animal comprises the head and thorax, together they form the body and are covered by the carapace to form a continuous shield. The abdomen (tail) has 6 movable segments and ends in a fan-shaped tail of 5 parts.

Internally, the body contains all the vital organs, whilst the tail normally houses the tail muscle and the gut.

Lobsters can only grow in size by moulting or shedding the old shell after growing a new one underneath. A newly moulted animal is very soft and vulnerable. The new exoskeleton is expanded and stretched when it is soft by the animal taking in water from the outside. The shell hardens over a period of days. The cast shell is eaten in order to recycle minerals and nutrients. The frequency of moulting varies with size, age and nutrition. Larvae can moult every week and juveniles once or twice per month during the summer. Sub-adults may moult twice a year, whilst mature animals moult, on average, once per year. Males tend to moult in early summer, whilst females moult in late summer, early autumn, after their eggs have hatched.

Both sexes mature around the same size. In the UK this is about 85 mm carapace (body) length (CL). On average it takes approximately 6 - 7 years for wild animals to reach this size. This also corresponded with the previous UK minimum landing size (MLS), but in 2002 the MLS was increased to 87 mm CL. This should allow most animals at least one reproductive season before they enter the fishery. Some Sea Fisheries Committees in England and Wales anticipated the increase in MLS by instituting by-laws to this effect before 2002 and further increases (to 90 mm CL) are under discussion.

Mating takes place between a hard-shelled male and a freshly moulted, soft female. The spermatophore from the male is deposited in a receptacle on the underside of the female. Here it remains until it is used to fertilise the eggs as they are laid.

The eggs are laid once the female's shell has hardened. The eggs are cemented underneath her tail. Newly laid eggs are bottle-green in colour and can be seen, in the UK, from August to October. A female of 85 mm CL can carry up to 12 000 eggs and the numbers increase as the animals get bigger.

The female tends the eggs under her tail, removing diseased or dead material, providing protection and ensuring a good supply of oxygenated water. As the eggs mature their appearance and colour changes. Shortly before hatching they are a brown-blue colour and the dark eye-spot of the larva can be seen clearly. The speed of development depends upon water temperature. In the UK, hatching can begin in the south in March/April, whilst in the north it commences in April/May and continues into September

Newly hatched larvae are approximately 7 mm in total length (TL) and they swim up into the plankton, where they remain and feed for the next 30 days. They moult 3 times, finally metamorphosing into a juvenile lobster approximately 12 mm long (TL). This stage is referred to as a post-larva (plural: larvae) or Stage IV (being the 4 th moult stage).

At this point, they begin to settle on to the bottom, but they do not become truly bottom-dwelling until after the next moult. The juveniles shelter within cracks and crevices in rocky substrates or construct burrow systems in soft sediments. Here they live, feed and grow for the next 4 years. Little is known about their habits at this point in their life history.

Once the animal has grown to 40 mm CL (approximately 150 mm TL) it begins to emerge from the burrow and forage more openly. Commercial fishing gear seldom captures animals below 55 mm CL, but this is a result of their design and construction. At some point, it is not known precisely when, the animals vacate the burrows and begin the adult lifestyle.

An adult lobster of 85 mm CL is approximately 247 mm long (TL), weighs around 450 g and is in moult stage XXIV (24) or XXV (25). They can be found on all types of bottom, but have a preference for rocky substrates which have lots of holes, cracks and crevices.

A wide range of food items are eaten, from seaweed (macro-algae) to fish. They are skilled predators, but also take dead material.

The largest lobster caught in the UK weighed 9.3 kg (20 lb 8 oz) and measured 1 260 mm overall (claw-tip to end of tail). It was taken in Fowey, Cornwall in 1931. Specimens estimated to weigh between 9.5 - 10.4 kg have been reported in the past, but not verified.

Until very recently it was impossible to age wild lobsters. Previous assumptions were based on observations of the growth of captive specimens and applied to wild stocks. More accurate ageing may be possible by measuring the concentration of a chemical found in the brain. To date, the oldest animal examined by this method was estimated to be approximately 72 years old (± 9 years) with a length of 151 mm (CL) and weighing 2.069 kg. Potentially, this suggests that very large specimens, such as those noted in the paragraph above, are very old indeed, however this method of age estimation has still to be accepted fully by all fishery scientists.

1.2 A brief history of stock enhancement in the UK

A more detailed account appears in the appendix I.

The first attempts at hatchery rearing lobsters began at the end of the 19th Century. Further work was carried out in the 1930s in the Isle of Man, but the most recent developments were begun in the early 1970s at the MAFF laboratory in Conwy, North Wales. Methods and equipment were adapted from an American system to suit the needs of the European Lobster and by 1983 a reliable method had been devised.

Intensive culture was not economically viable and attention then focused on extensive rearing or stock enhancement. A partnership was formed between MAFF, the Sea Fish Industry Authority (Seafish) and the North Western and North Wales Sea Fisheries Committee (NWNWSFC) to examine stocking at different sites around the UK. MAFF performed their experiments in the North Sea off Bridlington, Yorkshire; NWNWSFC chose Cardigan Bay off Aberystwyth; whilst Seafish worked in Loch Ceann Traigh, Argyll and Scapa Flow, Orkney.

A unique feature of this programme was that each juvenile released was tagged internally with a small coded wire tag (CWT). This enabled the unequivocal demonstration that any animals recovered were of hatchery origin and also

allowed the year and season of release to be identified. This was the first time that this had been possible.

The main releases took place between 1983 and 1989 and the liberated stocks were monitored until 1996. In total, MAFF released approximately 49 000 animals; NWNWSFC released just over 19 000; and Seafish 3 000 in to Loch Ceann Traigh and 19 500 in Scapa Flow. A further 8 500 'small' juveniles were released during a second phase of the programme in Loch Ceann Traigh from 1989 - 1992.

1.2.1 Take-up by industry

Even before the experimental trials were complete sections of the UK inshore fishing industry were keen to take advantage of the research results.

The first hatcheries, in the early 1980s, were private enterprises, intending to supply juveniles for the pet trade or stocking. They were generally ahead of their time. Some converted to tourist-based display aquaria, whilst others closed.

Orkney began very small-scale trials of hatchery rearing along side a shellfish merchant's holding ponds. Seafish supported the development until the Orkney Fisheries Association (OFA) and the Islands Council took on the enterprise and a full-scale release programme began. During the 1998/99 season approximately 20 500 juveniles were released around Orkney and animals were also provided for other stocking experiments. The eventual target is an output of 60 000 juveniles per year.

Shetland constructed a small, experimental unit, with Seafish assistance, at the North Atlantic Fisheries College (NAFC). A larger facility has since been built and they were attempting, at one time, to develop a semi-automated unit with an industrial partner. A fishery management consortium on the islands became the first in Scotland to be granted an extensive Regulating Order, covering all their waters, in October 1999.

Groups in England and Wales also plan to use the technology. The National Lobster Hatchery supported by the Cornwall Sea Fisheries Committee has opened in Padstow, Cornwall, whilst in Wales, the two SFCs are discussing a similar programme. Other Committees are examining the prospects for their areas and some have begun initial experiments using juveniles obtained from the existing hatcheries.

The UK trials have influenced experiments elsewhere in Europe. The Irish were able to draw upon the results and experience when setting up their hatchery and release programme. Spanish researchers requested information in support of two regional stocking initiatives. In Italy, the techniques may be used to repopulate the northern Adriatic, where native stocks are almost extinct. Norway, which had its own very large-scale lobster stocking programme received advice and drew support for its own work. Other countries continue to approach the UK researchers to draw upon their knowledge and expertise in this field.

1.3 Results of the UK trials

Despite the very different characteristics of the fisheries and localities studied, all 3 groups (MAFF, Seafish and NWNWSFC) discovered that their results shared many common features. This offered reassurance when it came to extrapolating the results to new areas and allowed the results to be amalgamated to present an overall picture. They may be summarised in two parts, reflecting the phases of the programme.

Phase I.

- Hatchery reared juveniles released on to natural habitats in the wild at 3 months of age (stage XII) will survive to reach market size.
- Juveniles should be released directly on to the substrate to maximise survival.
- It takes an average of 5 years for a 3 month-old hatchery-produced juvenile to grow to market size under wild conditions
- Overall survival from release to market size is estimated to be around 38%.
- They can contribute between 5% - 20% of the total fishery landings per year and up to 40% of the legal sized lobsters in a haul.
- On average, 6 hatchery-reared lobsters were caught per 100 pot hauls.
- Once recruited, a cohort (year-class) can continue to contribute to the fishery for over 5 years (10 years in total after release).
- Recaptures peak around 6 - 7 years after release.
- Growth rates within and between year-classes vary widely.
- The animals mature sexually and reproduce naturally.
- There is a high retention of animals on suitable release grounds with little evidence of large-scale emigration.
- The animals can be caught in conventional fishing gear by commercial fishers.
- On recapture, the hatchery origin animals are almost identical in appearance to the wild stocks of the area.
- The flavour and texture of the mature animals is not affected by their hatchery origin.
- Size (length or weight) is not a valid indicator of chronological age.
- Coded wire tags form a long-lasting, durable marker for use in experimental stocking trials.

- Internally implanted coded wire tags do not adversely affect the animals in any way, even over extended periods.

Phase II

- Hatchery reared juveniles released on to natural habitats in the wild at approximately 1.5 months of age (stage VIII) will survive to enter the fishery.

- It was calculated that animals released at this age take an average of 7 years to reach market size.

- An increase in catch-per-unit-effort (cpue) was measured for some sites, demonstrating the possibility of enhancement.

- The sex ratio of the recaptured animals was approximately 1:1, demonstrating no sex bias in the recoveries.

1.4 UK legislation

Until recently any hatchery-reared lobster placed in to the sea became common property and could be fished for by anyone. Consequently, there was no way of safeguarding the 'investment' which groups undertaking stocking programmes might make.

In early 1997 the Sea Fisheries (Shellfish) (Amendment) Act 1997 passed into UK law. It altered the provisions of the Sea Fisheries (Shellfish) Act 1967 (as amended) and extended the coverage of Several and Regulated Fishery Orders to encompass lobsters and other crustaceans. Previously, these provisions had only applied to molluscan shellfish.

The Act allows additional management, over and above national or local regulations, for lobster fisheries where stocking is taking place through the use of a Regulating Order and sole harvest rights can be assigned using a Several Fishery Order.

This development removed the concerns expressed by many bodies interested in stocking programmes: namely, that vessels or fishers not involved in the enterprise could enter an area and legitimately 'steal' the lobsters they had paid to seed.

Fishery Orders have worked well in England and Wales where they have been used for many years by local Sea Fisheries Committees (SFC) to control molluscan fisheries and relaying programmes (eg mussels and oysters). In Scotland, where there are no Sea Fisheries Committees, Regulating Orders have only recently been approved. The first was awarded at the end of 1999 to a management group set up in Shetland and it covered both molluscs and crustacea.

2. Established Hatchery Systems

Hatchery designs tend to fall into 3 broad categories; those following the UK approach, those using the US/Irish methods, and the large-scale Norwegian system. However, all share some common features. It is the distillation of this collective experience which forms the basis of the advice given later. A brief outline of each system and its operation is given below.

2.1 Design and operation

2.1.1 UK

The early UK hatcheries adopted a common approach based around communal larval rearing and then separate, individual post-larval on-growing until release. All operations used heated seawater and partial recirculation.

Complete details of the methods used can be found in the references given in the Further Reading section. However, the basic outline is given below.

Egg-bearing (berried) females were bought in from the fishery in March/April and replaced throughout the hatching season as they became spent. If planning winter production freshly berried animals were purchased in September/October. They were held communally in tanks furnished with individual shelters.

Commercially available tapered, conical, polypropylene (or later, MDPE) tubs (or bins), filled to 80 litres (l), formed the basis of the larval system. A custom-made diffuser plate was fitted in the base to impart a swirling, spiral flow to the injected water. A standpipe regulated the water level and a 2 mm mesh screen prevented larval loss from the system.

Stocking levels were 2 000 larvae per bin (25 per litre, l^{-1}) or the total hatch over 3 days ('3-day rule'), whichever occurred first. The larvae were fed an alternating diet of either mysid shrimps or chopped fresh mussel each day. Very little use was made of Brine Shrimps (also known as *Artemia*).

Metamorphosed post-larvae were transferred to individual 50 mm square cells of an 80-cell tray. These were placed in shallow trough systems fitted with tidal-flow devices to promote flushing.

The post-larvae were on-grown to release size on a diet of mysids with a once per week supplement of chopped mussel. They were fed and cleaned every day.

Later hatcheries, especially the commercially sponsored ones, hold the berried females individually and have varied the designs of the equipment to meet their needs.

2.1.2 US / Ireland

The system used by Beal and co-workers in the US, which evolved from those used by Hughes, and Mercer and his colleagues in Ireland, differ in only a few minor details.

Ovigerous (berried) females are either bought in to the hatchery directly from the fishery or placed in communal ponds until required. Once transferred to the hatchery, the animals are either housed individually or in pairs, in tanks (500 l) with moderate aeration. Most of the animal, gills and mouth-parts excluded, is routinely dipped in an anti-fungal/ anti-bacterial/ anti-parasite bath (the iodophore *Betadine* [similar to *Buffodine*] is commonly used) before they are rinsed and placed in the hatchery tanks. They are held at 18 – 20 ^{o}C.

Larvae are collected as they hatch and transferred to rearing bins.

Larval rearing is conducted in two differing designs of tub. In the US, 'Hughes kreisels' were used originally, these are cylindrical containers with a gently curved base, but later standard 500 l tanks were used. The Irish opted for the same conical bins as used in the UK. Water in the tubs is not renewed and they are filled with specially reared algal cultures (*Chaetocerus* sp and *Isochrysis* sp) to form a 'green-water' system. Very vigorous aeration from the base prevents stagnation (plate 1). A transparent lid prevents cross-contamination between bins by any aerosols produced. Rearing takes place at around 20 ^{o}C (18 – 21 ^{o}C).

Plate 1: Vigorous aeration in a larval tub in Ireland

Stocking densities are lower, approximately 1 000 per tub (12 per litre) or the hatch over two days. The larvae are fed on decapsulated *Artemia* cysts or newly hatched nauplii, which are replenished each day.

Every second day the developing larvae are transferred to a fresh bin and the cycle continues. An average survival to Stage IV of 47% has been recorded in Ireland and between 30 – 50% in the US (in the early days survivals were 10 – 15%, especially when using kreisels). Any surviving *Artemia* are separated and on-grown or frozen to be fed to later stages.

Post-larvae are collected and, where on-grown, individually housed. The size of the on-growing cells has been varied by different groups depending upon the target release size. Some hatcheries on-grow in a manner similar to that used in the UK, others stack the cells together and lower them into a tank filled with newly developed *Artemia* and the animals feed on those which swim through the containers (upwelling tank).

On-growing is conducted for only relatively short periods of time at 16 – 20 ^{o}C since releases are conducted using Stage IV or V post-larvae.

2.1.3 Norway

A large-scale hatchery (capacity 120 000 juveniles) was set-up with commercial intentions in the late 1970s. It subsequently passed to the government run Institute of Marine Research. Heated effluent water from the adjacent industrial plant was used, via a series of heat exchangers, to heat the water used by the hatchery.

The berried females were housed in individual tanks and the hatched larvae collected via an overflow system into a communal bin. Reports of the larval rearing system used in Norway are sketchy. They followed the UK system of larval rearing, using upwelling bins. Stocking density in the larval rearing tubs was not given, but *Artemia* was used as the feed and survival to stage IV of up to 30% was reported.

On-growing for 12 months took place in a 60 m diameter pool divided into 11 concentric rings (1.80 m wide, 0.24 m deep). Juveniles were individually housed, in 13.5 x 9.0 x 12.5 cm cells, and the frames were propelled around each ring by the inflow of water. Food, mostly mysids supplemented with *Artemia*, was added to a central hopper and distributed to the cells as they passed beneath an array of water jets. Oyster or mussel spat was used to promote the differentiation of the crusher claw.

The juveniles were used for stocking (ranching) trials. During the early part of the experiments none were marked, but later all were micro-tagged before release. Early results indicated that a juvenile released to the wild after 12 months in the hatchery would reach market size after a further 3 years.

Section II HATCHERY EQUIPMENT

3. Pipes and fittings

Within the various hatchery systems at the Marine Farming Unit there has been a move away from the standard uPVC based pipes and fittings used in the past. We now use either food preparation grade or ABS plastic pipes and fittings. They are more expensive, but they release less plasticisers and release agents into the water. This factor has become particularly important when dealing with very sensitive marine fish larvae or making greater use of recirculation technologies. We now advocate the use of this type of pipe and fittings in all hatcheries.

When constructing the pipework, incorporate flushing points at strategic locations within the pipe runs so that they can be flushed to waste to eliminate the build up of detritus or after they have been left static for a period. These points also allow the systems to be drained completely for maintenance or repair.

The main seawater intake pipes are of heavy-duty flexible plastics, similar materials to those used for domestic water mains. The diameter of the pipe to be used will be determined by the expected water requirement and the capacity of the pump(s). Consult the manufacturers or specialist engineering companies. Again, incorporate flushing points and access flanges so that internal fouling can be removed periodically.

Avoid the use of any metallic pipes or fittings, especially copper and its alloys (eg. Brass, Bronze, Phosphor-Bronze, Gunmetal etc, even if 'chromed' or otherwise coated) and zinc (ie galvanised pipes or fittings). Be particularly careful in any area where they can come into contact with the water used in the hatchery. Nearly all metals are toxic to crustacea, but copper and zinc are especially so, even at low concentrations. High-grade marine stainless steels (eg A2, A4, 316, 420 etc) can be safely used around the hatchery and in direct contact with circulating water with few problems, but keep the quantity to the minimum. If in any doubt about the composition or suitability of any metal fitting or pipe, try and find a plastic or similar alternative.

4. Broodstock tanks

Tanks made from a wide variety of materials and of differing designs have been used to house the broodstock. Most are bought from commercially available ranges, although some are custom made or modified.

Communal storage or holding tanks are generally concrete* as they mirror commercial storage ponds. Normally, they have a minimum depth of around 0.3 m. The other dimensions can be varied to suit. Ideally, they will be provided with individual shelters and stocked at no greater than one animal per shelter. (* New concrete tanks must be flushed with flowing seawater for at least a week before stocking in order to avoid toxicity from the 'lime' used in construction.)

Communal hatching tanks tend to be oblong GRP tanks (plate 2), although polyethylene, polypropylene (and other plastics) and occasionally concrete have been used. They should be deeper, 0.5 – 0.7 m, but the other dimensions can be

varied to suit their location. However, as a guide, the width should be approximately twice the length of any shelters used so that the animals can emerge and turn round. Tanks housing from 2 to 15 females have been used.

Plate 2: GRP tanks used for housing broodstock

Individual hatching tanks have been made from a variety of materials; most types of plastic, acrylic or glass. They should be of a size that will comfortably accommodate the largest female expected to be used in the hatchery; allowing room for the animal to turn around and be deep enough to allow the hatching posture to be assumed (see appendix I and plate 17). Ideally, this would be around 1 m x 0.75 m x 0.7 m, although due to space constraints tanks of around 0.75 m x 0.5 m x 0.7 m may have to suffice. Clear tanks allow each female to be observed and the development of the eggs monitored closely. However, the females can be stressed by too much activity around the tank(s) and may produce fewer larvae as a result.

5. Larval tubs

Tapered, conical 90 litre MDPE or polypropylene hoppers, which are readily available commercially, have become almost standard within the UK hatcheries (plate 3). A few custom-made clear acrylic tubs have been produced for public display purposes, but such units will not be needed by the majority of facilities.

Plate 3: Conical larval rearing tubs

A bespoke water diffuser and/or simple air agitation system is fitted at the base and a screened overflow pipe allows the water to escape and be returned to the filters (plate 4, plate 5).

Plate 4: Diffuser and screen for larval tub

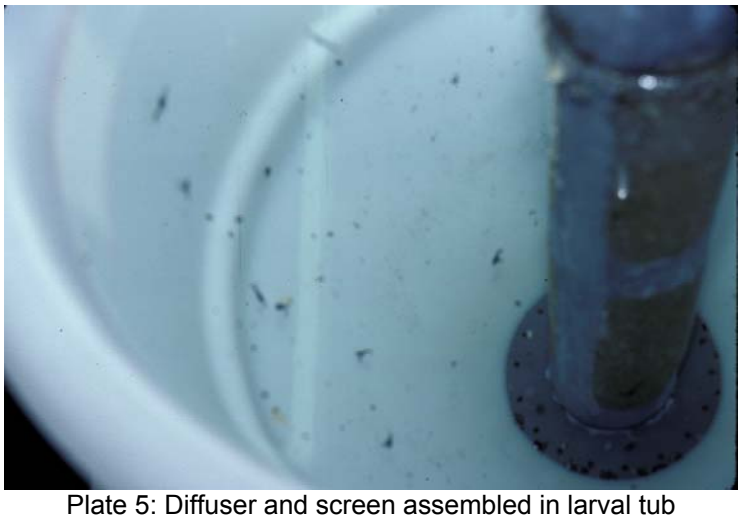


Plate 5: Diffuser and screen assembled in larval tub

6. On-growing containers

These are probably the most problematic items of equipment to obtain. The type of container used for on-growing juveniles during the trials, 80-cell arrays of 5 cm x 5 cm x 9 cm cells (referred to as 'trays', plate 6), produced originally as shop ceiling fittings, are no longer available. Their base was covered with a 2 mm square plastic mesh.

Subsequent hatcheries have had to find their own solutions to supply these items. Some have chosen to commission trays of similar design to the originals using slot-together or similar production techniques. In contrast, Orkney chose to invest in custom moulded 4.5 cm x 4.5 cm x 9 cm individual plastic cells, with a perforated base (referred to as 'cups'), that slot together to form the on-growing array (plate 7). Some hatcheries elsewhere, such as Ireland, that intend to release very small animals have opted to use much smaller, shallower cells and stack them within a deeper on-growing tank. This has some disadvantages and is probably best avoided.

Plate 6: Lateral and plan views of a lobster 'tray'

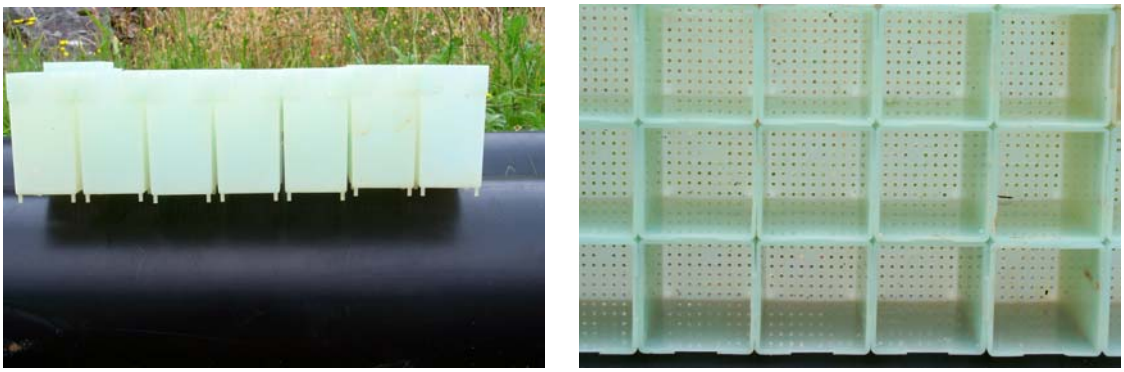


Plate 7: Lateral and plan views of Orkney lobster 'cups'

Whatever solution to the problem is adopted, the main requirement is to keep each individual juvenile separately whilst it is grown to the release size. The container should allow them to be inspected, cleaned and fed easily. It must be possible to remove the containers from the on-growing tank so that the juveniles can be removed and the cells cleaned and sterilised between uses.

Whenever possible choose inert, durable plastics since these items take a lot of abuse during the course of a year.

7. On-growing tanks

These can be of any size or shape, providing they accommodate the on-growing containers efficiently (plate 8, plate 9). If possible try and ensure that they are slightly shallower than the total height of the on-growing containers when they are in their final position. That way, in the event of a malfunction, the tank overflows before juveniles are liberated and lost.

Plate 8: Profiled on-growing troughs in the MFU hatchery

Plate 9: Experimental vertical stacking on-growing system

Elevated supports on the base of the tank, incorporated during manufacture or fitted afterwards, raise the on-growing containers off the bottom. Alternatively, the supports can be part of the design of the on-growing container, as with the Orkney 'cups'. Around 0.5 – 1 cm is sufficient. This feature allows waste material to drop out of the cells on to the bottom of the tank from where it can be removed.

Automatic, intermittent siphon devices of various designs (figure 1) are often fitted to provide a tidal rise and fall in the level of water in the tank. This promotes water exchange within the cells. The lowest water level achievable by the siphon should be above the base of the cells so that in the event of a malfunction, the animals are not left exposed to the air.

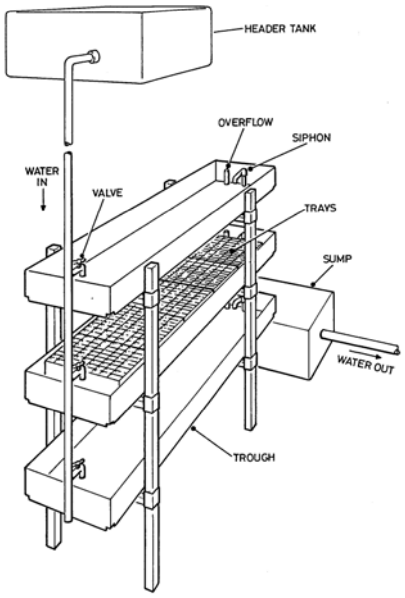


Figure 1: Siphon and overflow arrangements in a trough on-growing system

8. Filtration

In most circumstances the hatchery set-up is suitable for a biological filtration system. It is only systems that undergo rapid changes in stock density and biological loading, such as commercial storage ponds and transport systems, where mechanical and/or chemical filtration is preferable.

A schematic diagram of a suitable bio-filtration system is shown in figure 2. Ideally, each area, broodstock, larval rearing and on-growing, should have its own system. If the hatchery is very large, these may be further divided in to smaller units treating a proportion of the larger area.

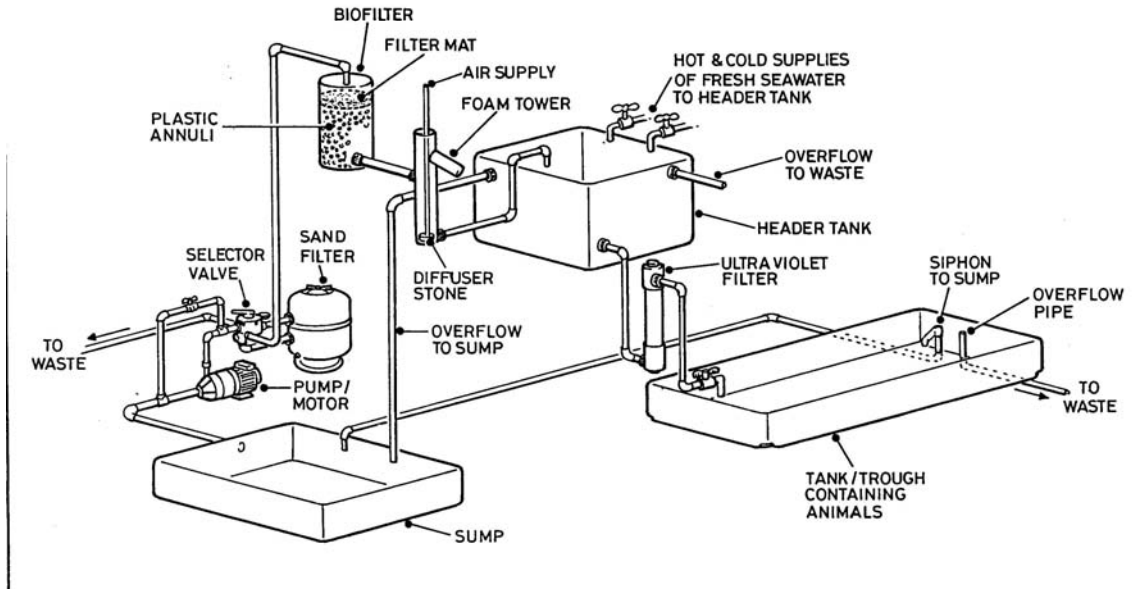


Figure 2: Diagramatic representation of a filtration system

Starting as the water leaves the rearing tanks, the circulation can be described as follows. Firstly, a mechanical filter or settlement tank is used to remove larger suspended material from the wastewater (plate 10). This water then passes to the biological filter, where denitrification takes place (plate 11). A foam fractionation tower removes any remaining smaller particles and strips larger organic molecules from the system (plate 11). The water may then return directly to the header tank or it may undergo final particulate filtration. Fresh filtered seawater from the primary seawater header tanks may be added to top up the system at this point and any heating of the water that is required may also take place. On delivery back to the tanks the water may first be treated with ozone and then UVc light, to ensure it is free of pathogens, before a final passage through an adsorbent filter material, such as activated carbon. If there is particulate material in the water flowing from the header tank, it should be removed by mechanical filtration as the water leaves the tank. Some facilities dispense with ozonation and rely entirely on UVc treatment (plate 12); this is less than ideal, if possible include ozonation.

Plate 10: A sand filter used for mechanical filtration

Plate 11: Simple biological filter towers and foam fractionators

Plate 12: Individual wall-mounted UV units

In recirculation systems, it is important to maintain the pH balance of the water. This can be achieved either through the use of carbonate-based media in the bio-filter or by incorporating a separate treatment area where the water can flow through or across a shell-based medium. This can be as simple as a screened area under the inflow in the header tank. Oceanic seawater has a pH of 8.2 (alkaline).

The exact size and capacity of the various filters is dependant upon the water capacity of the facility, the flow rates and the expected biological load. Manufacturer's or supplier's literature should be consulted to ensure that filters of sufficient capacity are purchased. Examples are also given in the literature cited. In the Ardtoe hatchery, the filter capacities (m^3 h^{-1}) were chosen to equal the approximate water capacity of the area they served.

9. Flow-rates

Average water flow-rates (l min^{-1}) used to supply the tanks in the different hatchery areas are given below.

Water flow rates (litres per minute) within the hatchery areas

Area	Seafish	MAFF
Broodstock	15 – 25 l min^{-1}	42 l min^{-1}
Larval rearing	10 l min^{-1}	7 – 12 l min^{-1}
Post-larval on-growing	6 –10 l min^{-1}	12 l min^{-1}
Header tanks	7 – 10 l min^{-1}	1 – 9 l min^{-1}

A standard type of pump was used in each area, so that the units were inter-changeable in the event of breakdown. They were capable of pumping 220 l min^{-1} up to a 7 m head. Individual operators may have different requirements.

10. Aeration

The hatchery will require large volumes of low pressure air. A rotary vane type blower can deliver up to 50 cubic metres of air per hour. Above this requirement alternative designs are used, one such type is a positive displacement roots blower. A particulate filter should be fitted to the blower intake and the discharged air should be filtered to remove particulates, moisture and oil mist before it is fed into the supply to the hatchery. If the feed-pipe runs are particularly long, then an in-line filter should be fitted immediately before the air is fed into each tank.

Incorporate bleed points in the air supply main at strategic, but easily accessed, locations. Keep them as low down as possible (perhaps spur them off the main pipe) and use them frequently to flush out any build up of undesirable contaminants in the line. If possible, try and avoid the creation of dead spaces in the system.

11. Electrical equipment

Seawater and electricity do not mix well. Hatcheries often have circuits rated at 415 V, 240 V and 110 V depending on the equipment and areas they serve. All can be dangerous.

Employ a qualified electrician to carry out all work. Ensure that all materials, fitments and other equipment used meet current national regulations or legislative requirements for use around or in saltwater. The Electrical Contractors' Association of Scotland publish a Code of Practice which offers some guidance (see Further Reading).

Tungsten filament lighting can be dimmed using a rheostat and can be used to vary light levels in the broodstock area. Sophisticated, and expensive, control units are available to perform a similar function with the more expensive high frequency fluorescent lighting units. Dimmer controls enable the stocks to be maintained at low light levels (generally 5 – 10 lux), but allow for the intensity to be increased (greater than 200 lux) for ease of working when required. Elsewhere in the hatchery, the tendency is to use suitable fluorescent lighting units.

There are a wide variety of fluorescent lighting tubes available, each balanced to different colour temperatures and spectra. It is not known whether any particular type of tube (eg daylight or sunlight) has an advantage over any other type (eg standard domestic). This could be the subject of experimentation, but, until then, the choice of tube is normally dictated by price and availability.

12. Heating/Chilling

In most circumstances, for optimum development times, the hatchery will make use of water warmed above that of the ambient supply. The water can be heated by various methods; recovery of waste heat from another process; solar heating methods; electrically; using gas, oil or coal-fired boilers etc. Alternative-energy systems are becoming increasingly efficient and cost-effective and deserve serious consideration. The individual circumstance of the hatchery and the resources available are likely to influence the choice of heating system. Whatever the method chosen, efforts must be made to ensure that the energy is utilised efficiently and conserved as far as possible. Reducing the energy costs of the hatchery is one of the key areas for reducing overall production costs.

If possible, design and site the hatchery buildings to make maximum use of the available solar energy and insulate them to conserve the gain. Consider carefully the costs and benefits of installing wind or other energy-efficient power generation systems for the facility. Evaluate whether heat can be recovered from any wastes produced by the hatchery.

Where it is necessary to chill the water supply to small numbers of animals, such as selected broodstock for 'out of season' larval production, this can be achieved economically using commercially available units made for the refreshment industry (eg beer chillers). Some manufacturers recommend replacing the standard stainless steel cooling coils with titanium ones when they are to be used for marine applications, but standard units have been used with success for over 5 years without

significant problems. Laboratory equipment suppliers also supply chillers of various capacities. These tend to be more expensive, but they are more sophisticated and accurate in operation, allowing greater precision in temperature selection and maintenance. It is seldom necessary to chill large numbers of animals or the entire broodstock area, but should it be required then large capacity air-chiller units should be considered. As a by-product of their operation, chillers produce large amounts of waste heat. Using suitable technology, this can be utilised elsewhere in the hatchery.

Section III HATCHERY OPERATION

This section summarises the current views on 'best practice' for hatchery operations within the UK. Not everyone will agree with everything, and where disagreement is wide the alternatives are given. No one view yet prevails and there is scope for future operators to adapt or devise new ways of doing things. The following are guidelines, not absolutes; there are circumstances where it may not be possible to follow one or all of them. It is for the operator to decide and, where necessary, evolve a system which works for them.

Hatcheries may be operated on two bases; a flow-through to waste system, or a recirculation system. Some will use a mix of both approaches to meet requirements at different times. In either case seawater quality is paramount. For a flow-through system the source of the water is very important. In the recirculation scenario, it is the design and operation of the filtration systems which are of prime concern. Filtration and water treatment systems were discussed in Section II (8). Idealised water quality parameters are given below.

Ideal water quality parameters for hatchery operations

Temperature	15 – 22 ^{o}C
Salinity	29 – 35 $^{o}/_{oo}$ (see appendix V)
pH	7.8 – 8.2
Dissolved oxygen	98 – 102 % (see appendix IV)
Total ammonia/ammonium	0 – 0.1 mg l^{-1}
Nitrite	< 3.0 mg l^{-1}
Nitrate	< 50.0 mg l^{-1}

Hatchery design, size and layout will be tailored to meet individual need and circumstance. Each one is likely to be unique. In most cases, the principles involved are more important than tank size or appearance. The guidelines presented here are based on an idealised system and apply no matter what the size of the operation.

It is important in any hatchery to keep the facilities clean and hygienic at all times. Avoid transferring equipment between systems or areas and sterilise it between uses*. Colour-coding the equipment in different areas can help in this. (* Do, however, remember to rinse off all traces of the disinfectant before putting the item in to a tank).

Whenever possible in the hatchery, keep movements controlled and unhurried. Sudden, movements or appearance above a tank are likely to startle the animals, stressing them and leading to escape/avoidance responses, such as tail flipping. This can result in egg-loss and other unwanted consequences.

13. Broodstock Procedures

Captive broodstocks are not cost effective for commercial production, so in most situations egg-bearing (berried) females will be bought in from the wild fishery.

- Source the broodstock from the area where the progeny are to be released. This prevents 'genetic pollution' of the stocks caused through the introduction of non-indigenous individuals with potentially different traits.

- Educate the fishers in correct handling and storage of berried females whilst on board the boat. This reduces stress and damage to the eggs. The procedures to follow are outlined below.

- When first caught a berried female should be gently removed from the trap, the tail tucked under (to protect the eggs) and the claws banded. Where possible, she should be transferred to a tank with a flow through of fresh seawater. If aerial storage is the only option, she should be gently placed flat, with the tail still tucked under, in a storage box and covered with damp protective material. The box should be stored out of direct sun and protected from heat, wind and rain. Ideally, this will be in a chilled area, but not below 5 ^{o}C. DO NOT USE ICE.

- Avoid large and sudden changes in temperature as much as possible.

- When back on shore, handle the broodstock gently during landing, selection and transfer to the hatchery. If it is a very hot day, use temperature controlled transport for the transfer.

- Select only intact animals and maintain them close to ambient seawater or storage temperature.

- Select broodstock according to the time of year and hatchery requirements. Newly laid eggs are seen from August to November. They are bottle-green in colour and appear tightly attached to the underside of the tail. As the eggs mature they swell, turn first black (plate 13) and then progressively browner (plate 14). When very close to hatching they are a blue-brown colour and loosely adhered beneath the tail. Females carrying eggs of this stage are likely to be available from late April to September, depending on which part of the country they are from and the sea temperature that year.

Plate 13: Immature eggs under the tail of a female

Plate 14: Eggs close to hatching

(Both plates courtesy T Scovacricchi)

- Accurate estimation of egg development can be made using an eye-index scoring system, (Appendix II) but it is largely un-necessary as experience is gained.

- Damaged egg-masses may not be apparent at the quayside, but will show themselves in the hatchery. The rapid loss of many eggs shortly after arrival in the hatchery and the appearance of brick-red eggs within the main mass are sure signs of a damaged brood.

- On receipt, transfer broodstock to tanks as soon as possible. Ideally, this will be individual tanks supplied with a copious flow-through of seawater. Avoid inducing a strong current. Try and match water temperature with that of the animals - it avoids a thermal shock.

- It is now considered best practice to use a short antimicrobial/fungal dip of the eggs under the tail of the female, before placing them in the tank. This prevents the introduction of parasites or diseases (see Section IV). Preparatory preparations such as, *Buffodine®*, *Kick-Start®* or, exceptionally, *FAM*, prepared in accordance with the instructions on the packaging, are often used. Malachite Green was used until recently, but its use is now prohibited in the EU and severely restricted in many other parts of the world. (See also Appendix III).

- For preference, house the broodstock females separately (plate 15) and arrange an automatic larval collection or separation system. This can be as simple as a screened area of the tank, a weir overflow in to a separate collection area or the outflow pipe from the tank can be lead into a screened container. Other designs have been used with success by different operators.

- Communal storage tanks require a high flow of seawater and the provision of an excess of shelters. Shelter designs have varied from the simple air-brick and ridge-tile approach (plate 16) to the segmented, tailored box system (figure 3). None have been proven to be better than any other.

Plate 15: Individually housed female lobster
(Courtesy T Scovacricchi)

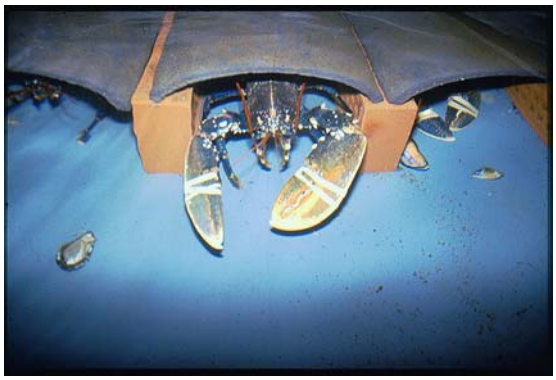


Plate 16: Females in ridge-tile and air-brick hides

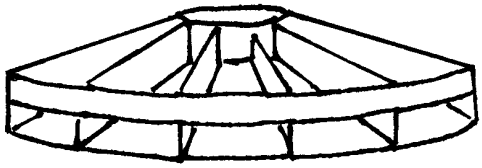


Figure 3: Segmented plastic lobster hides with cover removed

- The depth of the hatching tank should be sufficient to allow the largest females used in the hatchery to adopt the optimal head-down, tail-extended hatching posture (plate 17). This may be between 0.5 - 0.70 m.

Plate 17: Female lobster in hatching posture with larvae being released
(Courtesy T Scovacricchi)

- When introducing animals to the tanks, keep the tail tucked under and immerse the female with her tail against the side of the tank. This avoids a reflex tail-flick when she is released and prevents eggs being shed as a result. Release gently and allow her to sink to the bottom. Keep all movements smooth and unhurried.

- Handle or interfere with the broodstock as little as possible. Transfer them to their final tank and keep them there until the hatch is complete, if you can.

- In an undisturbed communal tank it is seldom necessary to maintain claw banding once the animals are settled. So long as there is no undue fighting or damage, it is preferable to leave unbanded animals alone. The animals establish a pecking order and the disruption caused by the removal of a lobster to re-band it results in aggression and fighting when it is re-introduced. More often than not this leads to egg-loss, particularly if they are close to hatch.

- Feed the broodstock every day. Non-oily fish and shellfish are ideal. Fresh Shore (Green) Crabs, halved or quartered, are a welcome supplement as are shrimps and prawns. Feed only the amount that will be consumed that day. Under-fed animals will consume their own eggs or the eggs of others.

- Each day, gently remove uneaten food and siphon any debris from the bottom of the tank. Use a slow, unhurried, methodical approach. Poor hygiene will decrease water quality and damage the egg-mass. It will also serve a route of infection for pathogenic fungi and bacteria.

- Females brood the eggs under their tail. They remove dead or diseased eggs using their rear walking legs and fan the pleopods to maintain oxygenation.

- When using elevated temperatures, warm the animals slowly. Be aware that broodstock from different areas can acclimate to different temperatures. In England and Wales temperatures between 18 - 22 ^{o}C were used for the broodstock. Whereas, in Scotland 16 - 18 ^{o}C was found to be optimal. This is thought to be due to natural variations in acclimation to normal ambient temperatures within populations around the country.

- Dawn/dusk controllers on the main lighting system, to increase or decrease the light intensity gradually, can be used to avoid the sudden flash of illumination, which often occurs on start-up, and may aid synchronisation of the hatch. Use dim lighting (around 25 W or equivalent, 5 – 10 lux at the surface) and long day-length (greater than 16 hours illumination).

- A small, permanently lit, clear-lensed, 12 V, 5 W white light, or similar, above the larval collection area attracts the larvae and aids their harvest.

- The hatch is not an 'all-or-nothing' affair. It begins slowly, reaches a peak and then tails away. Five days duration would be typical, but it may last up to 8 - 10 days, depending on the female.

- Under ideal conditions a 500 g female could be expected to produce in the order of 10 000 larvae.

13.1 Conditioning broodstock for ‘out of season’ production

Year-round production of larvae can be achieved by manipulating the temperature at which berried females are stored or conditioned. If they are held at elevated temperatures (above ambient), then egg/embryo development is faster, if temperatures are reduced, development is slowed. In either case, the period of

manipulation should be kept as short as possible; the longer it is the greater the chance of damaging the brood beyond viability.

When considering manipulating hatching time by altering temperatures, it is better to start with newly-laid eggs rather than those close to hatching. In the UK, females bearing newly-laid eggs are caught from August onwards. They can be recognised since the eggs are bottle-green or dark black in colour, small and tightly cemented under the tail.

The rate of embryo development and the expected time to hatching can be monitored using the eye-index (Appendix II) or, for these purposes less accurately, by egg colour.

'Out of season' hatching is generally less successful than 'in season' hatching. This is thought to be linked to depletion of the energy reserves within the egg and newly hatched larva, bought about by the acceleration or retardation of embryo development. The underlying mechanisms have not been elucidated fully and this is an area which requires further research.

13.1.1 Elevated temperatures

If females are purchased from the fishery with newly-laid eggs between August and October and they are maintained at 'normal' broodstock temperatures (16 – 18 ^{o}C), the hatch can be expected to occur from January onwards. By staggering the purchase of the females or holding them for a period at ambient temperatures before warming to incubation temperatures, hatching can take place from January through until 'natural' production begins in April/May.

13.1.2 Reduced temperatures

This technique is more difficult to carry out successfully than elevating temperatures and it has been little used in the UK. However, it can be used to provide larvae between the end of the natural hatch, in September, and the start of the 'elevated' hatch, in January.

Berried females are again purchased at the end of the fishing season, but in this case they are slowly chilled in the hatchery to a storage temperature below that of the ambient supply. As a guide, this should not be less than minimum sea temperatures likely to be encountered during the coldest winters. In most areas of the UK this will be between 5 – 8 ^{o}C.

The broodstock are stored at these temperatures until the ambient sea temperatures begin to rise in the spring. They are then warmed slowly, always being kept behind the rise in ambient temperature. The first animals should achieve 'normal' incubation temperatures by late May, early June at the latest. By staggering the commencement of warming and the rate of warming, hatching can be achieved from October to January.

The use of the eye-index (Appendix II) to monitor embryo development is strongly recommended with this technique. To avoid disturbance to the main broodstock, it

may be worth considering maintaining a separate animal solely to provide egg samples for this purpose.

It is advisable not to attempt to retard the development of eggs on animals purchased at the start of the fishery in the spring or early summer. Embryo development will be too advanced and this is likely to severely compromise the viability of the brood and result in an unsatisfactory outcome, in terms of both hatch and larval quality.

14. Larvae

- All-plastic, rigid strainers of different sizes are ideal for collecting the larvae. Soft nets tend to tangle the larvae and damage spiny processes.

- Use separate collection containers for each female tank and avoid over-crowding the larvae. Keep densities as low as possible (approximately 25 larvae per litre maximum).

- Most larval rearing systems use elevated temperatures for efficiency. Normally, this was between 17 - 20 ^{o}C. Too higher temperature (>22 ^{o}C in the UK) can damage the larvae and decrease survival. If the temperature difference between the broodstock and larval systems is greater than 0.5 ^{o}C, slowly equalise the temperature of the larvae and the tubs by floating the container(s) in the bin before transfer. Aerate the larval containers whilst this is in progress.

- Use an appropriate stocking density. UK hatcheries stocked at approximately 25 larvae per litre, whilst in Ireland it was 12 per litre. In general, the lower the stocking density, the higher the percentage survival. The final choice will be determined by the available space and desired through-put. In the UK the tendency is to stock at 25 larvae per litre in order to maximise the use of space and tanks (plate 18).

Plate 18: Larval tub stocked at 25larvae per litre

- Count the larvae across from the collection container in to the rearing tank using a plastic strainer and keep accurate records.

- The basic tenets of larval rearing are to keep the larvae in suspension, maximise separation and to supply an abundance of food.

- The larvae are cannibalistic and will eat each other. They are encounter feeders and will latch on to anything they meet and test it for edibility. If this is another larva, one will be consumed and the other is usually damaged beyond long-term viability.

- The feeding regime will depend upon the system chosen. In all cases the larvae must be fed every day and the goal is to provide an excess of food particles over larvae, in order to decrease losses. Ideally, they will be fed two or three times per day until the density of food particles is judged, by eye, to just exceed that of the larvae.

- Freshly prepared, natural foods of high quality promote the best larval growth and survival. Unfortunately this is not always practical, it would render hatchery rearing uneconomic, so a compromise of once or twice per week supplementation with fresh chopped mussel, live *Artemia* or mysid shrimps is normally used. The rest of the time fresh-frozen, freeze-dried or pelleted diets are fed. Although, in the latter case, it should be noted that restricted success has been recorded with many of the formulations currently on the market. There is, as yet, no commercially available lobster pellet. Semi-commercial hatcheries have reported success using commercially available freeze-dried krill as their sole diet.

- *Artemia* nauplii can be fed with little preparation other than rinsing, whilst mussels (plate 19), mysids and adult *Artemia* are chopped to give a particle size around 1 mm long. Freeze-dried material is crumbled in the hand to provide similar particles whilst pellets of the preferred size are chosen from the manufacture's list. Any foodstuffs which were fresh-frozen should be thawed before preparation.

Plate 19: Preparing mussels as a supplement

- Food is distributed to individual rearing tanks by hand so that the operator can observe the stock and assess the process.

- At operating temperatures between 17 - 20 ^{o}C larval development to metamorphosis (Stage IV) takes approximately 12 - 18 days (plate 20). The individual developmental stages are illustrated in Appendix I. Those that metamorphose first are larger, more robust and 'fitter' than those that develop later. Any larvae which have not developed within the above time should be discarded.

Plate 20: Developing stage III and stage IV larvae in a larval tub

- UK hatcheries recorded overall survivals of 14 - 20% to Stage IV when stocked at 25 per litre. Lower larval stocking densities increased survival. No formal trials were conducted at lower stocking densities, but where larval densities were approximately 12 per litre (as in Ireland) survivals were approximately 40 – 50 %. Hatcheries in the US and Ireland have published results of 30 - 50% survival under their regime.

- Clean and sterilise each tub between each batch of animals using *Chloros* or *Kick-Start®*. Rinse and flush them properly with freshwater before use. Do not allow the cleaning materials to get into the hatchery water circulation system! When replaced in the system allow the tank to flush with saltwater for a short period (one or two complete changes) before restocking.

15. Post-larvae

- Harvest post-larvae (Stage IV) as soon as they appear in the larval bins. They are soft after the moult and are easily damaged or eaten by the large, hard Stage III larvae still present in the same tank. This must be done every day; first thing in the morning, continually through the day and last thing at night.

- Post-larvae are easily distinguished in the tubs. They look like a miniature lobster (plate 21), swim with their claws held out in front of them and frequently swim against the prevailing current in the tank.

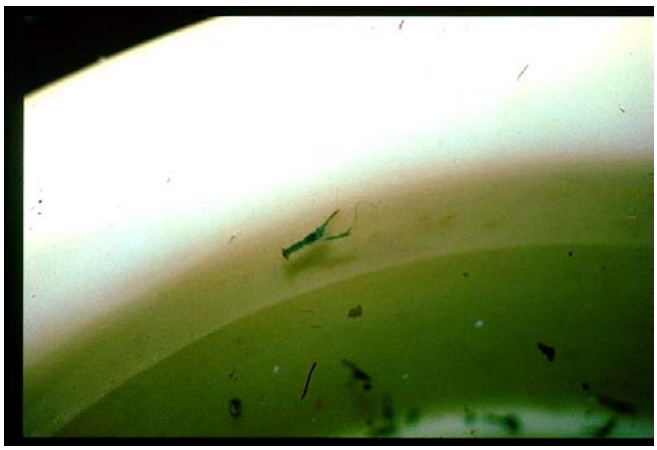


Plate 21: Newly metamorphosed stage IV in larval tub

- Treat each one gently on capture, they are easily damaged. The rigid plastic strainers are again ideal for this purpose.

- Ideally, transfer each post-larva straight to an individual on-growing container. Crowding a lot together in a collection container results in fighting, which leads to damage, which serves as a route for infection and death is the likely outcome.

- Try and run both larval and on-growing systems at the same temperature (17 – 20 ^{o}C). This allows direct transfer of post-larvae without thermal stress. If this is not possible, allow the post-larvae to cool (or warm) slowly to the on-growing temperature (using the technique described above) before introducing them.

- Keep aerial exposure to a minimum.

- Count the post-larvae in to the individual on-growing containers (plate 22) using a plastic strainer and keep accurate records.

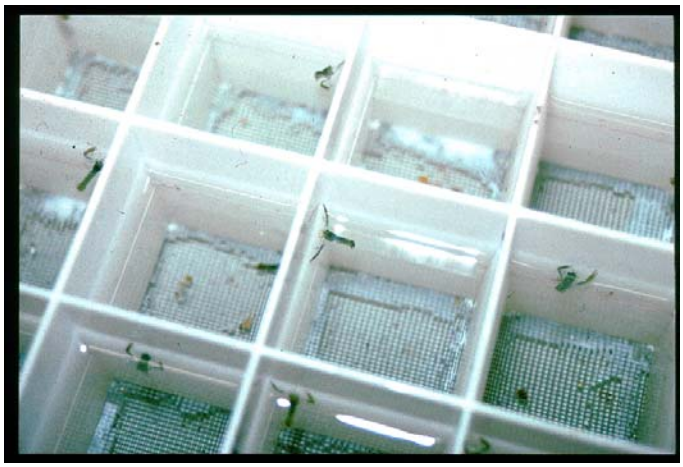


Plate 22: Newly transferred stage IV post-larvae in individual on-growing 'cells'

- Feed them individually every day for optimum growth (plate 23). Keep the ration to that which can be consumed in the day. If staffing levels do not permit this, then feed each day during the week and feed only the newly transferred post-larvae at the weekends. Growth will be slower, but the staff commitment is less.

- Remove all uneaten food, using either gentle siphoning or by hand, before adding a fresh quantity.

- Freshly prepared natural foods are the best on-growing diet. Once more, this may not be practicable on a daily basis. Freeze-dried krill (Euphausiacea) from the aquarist pet trade has been used successfully and appears to produce good quality animals. Pelleted or fresh-frozen diets can be used, supplemented once or twice per week with fresh mysids, *Artemia*, or Mussels. Other shellfish can also be fed occasionally. The feeding of Squid (*Loligo* spp) results in very pale, almost white animals of poor quality, if the diet is not heavily supplemented. Periwinkles (*Littorina littorea* and related spp) can be used as a supplement to promote a bluer shell colour.

Plate 23: Feeding mysids to post-larvae by hand

- The size of the food particle and quantity of the ration can be increased progressively as the animals grow. After initial transfer to the on-growing system the particle size should be slightly larger than that fed to the larvae (approximately 2 mm) and the quantity per individual can be increased to two or perhaps three particles providing that the ration is eaten in the day. As they get larger, so the preparation of the food can become coarser, but since younger animals will always be in the system alongside older individuals it is often easier to prepare all foodstuffs to the same level of fineness and just increase the quantity for older animals.

- There are no reliable automated individual food distribution systems for the freshly prepared diets. Those developed for pellets were better, but again the results were variable. None are available commercially. Unless the operator wishes to develop their own system, it is preferable to feed by hand. This allows the juveniles to be observed regularly, mortalities to be removed speedily and timely intervention to take place before developing problems become too severe.

- Oyster and mussel spat have been used as a supplementary dietary item to promote differentiation of the 'crusher' and 'cutter' claws. There is little evidence that this confers an advantage to the juveniles on release above those liberated with two cutting claws.

- Waste material should be removed from beneath the on-growing cells (on the bottom of the tanks) daily by either siphoning or draining and flushing the tank. Where this is not practical, detritus should be removed a minimum of once per week and the tank rinsed before refilling and restocking.

- On-growing is generally conducted at temperatures between 16 - 20 ^{o}C. The higher the temperature, the quicker the growth. However, there is some evidence that faster growth can result in more fragile shells and an exacerbation of moult problems, unless great attention is paid to feeding and nutrition.

- UK hatcheries generally recorded survivals above 80% when on-growing juveniles for 3 months prior to release.

- Acclimate juveniles to the ambient temperature of their destination before transporting them for release. This may necessitate incorporating a second seawater main to allow batches of animals to be slowly reduced in temperature to that of the ambient seawater. This is achieved by gradually incorporating greater proportions of cooler water. Other stock, not destined for release at that time, remain at the on-growing temperature. Waste water from the tanks being chilled is diverted away from the rest of the water supply system.

- Clean and sterilise the tanks and cells between batches (as described for the larval system). Make sure they are thoroughly rinsed and flushed before use. Once again, avoid contamination of the on-growing water supply with any chemicals used for cleaning.

Section IV DISEASE PREVENTION AND CONTROL

If the tanks in the various hatchery areas are kept free from uneaten food and other detritus and the water treatment systems are functioning correctly, then the facility should encounter few major disease problems.

Routinely dipping the eggs under the tail of a female in an antifungal/antimicrobial bath (as suggested in chapter 13), using similar protocols to those developed for disinfecting marine finfish eggs, before introducing her in to the hatchery can do much to reduce the introduction of potential pathogenic organisms.

National legislation covering permitted therapeutants and their use alters over time and the current situation should be clarified with a suitably qualified vet or government agencies (eg CEFAS Weymouth and FRS Aberdeen). In addition, it is necessary to have a discharge consent for the chemical(s) to be used in the hatchery from the relevant Environmental Protection agency (EPA, SEPA, NIEPA) or have in place suitable arrangements for the disposal of the treatment water to an approved liquid waste disposal site.

Manufacturer's and supplier's information and guidance sheets, supplied under the Control of Substances Hazardous to Health (COSHH) regulations, should be consulted for current recommended dosage rates and safety precautions before any chemical therapeutant is used in the hatchery. Examples of dosage rates are given in appendix III.

Malachite Green

The traditional treatment for most fungal (and many other pathogens) within a lobster hatchery was Malachite Green in varying concentrations. However, its use, for any purpose within aquaculture, has been prohibited within the EU and all discharge consents withdrawn. In 2002, no other more modern antifungal preparation has been approved for use in crustacean aquaculture in the UK. It is hoped that some treatments approved for finfish use, such as *Pices*, may be approved for crustacea, but the cost of obtaining such approval may be prohibitive. Hatchery operators faced with a fungal outbreak are strongly advised to seek advice and assistance from either CEFAS Weymouth or FRS Aberdeen to identify suitable alternative treatments.

References to the use of malachite green remain within the text to identify when it would have been considered as a treatment, but operators must now look for alternatives.

16. Fungal Pathogens

The most common organisms that cause problems within the hatchery are fungi. By enlarge these are *Lagenidium*, *Haliphthoros* or *Fusarium* species although others undoubtedly occur.

Lagenidium spp mainly affect the larvae and to a lesser extent the egg-mass. The larvae become opaque or white with a 'fluffy' appearance. Mortalities are high (>90%) and can occur within 48 hours. Traditionally, the treatment would have been to use Malachite Green (see above), but its use is now prohibited within the EU and severely restricted elsewhere in the world. At present there are no approved alternatives to Malachite Green, but modern antifungal preparations (eg. *Pices*) may be effective.

Haliphthorus spp can affect all life stages, but have their greatest effect on young post-larvae. Infection causes red-brown melanization around the walking legs and on or around the gills. Other areas of the exoskeleton can also be affected. Mortalities can be >40% and occur within 30 days. Recommended treatment is with Furanace, but other antifungal agents, such as Crystal Violet, Methylene Blue and Acriflavin, have been used successfully.

Fusarium spp mainly affect juvenile lobsters, causing black spots on the exoskeleton and brown discolouration of the gills. The first sign of infection may be white spots on the exoskeleton which turn orange and then black. It has been reported to cause up to 35% mortality. Prevention is the best control measure; no treatments are reported, but modern antifungal preparations may be effective.

17. Bacterial Pathogens

Bacteria which destroy the structure of the shell by attacking the chitin fraction (usually gram-negative chitinolytic bacteria) cause disease in all life stages of the lobster. The exoskeleton becomes pitted with melanized edges. Infection can cause mortality, particularly during moulting. Malachite Green was reported as the most effective treatment, but its use is no longer permitted (see above). Currently, infections would be very difficult to treat. The use of antibiotics is discouraged as this can lead to subsequent fungal infections.

The bacterial disease *Gaffkaemia* or 'Red tail', caused by the bacterium *Aerococcus viridans* (var.) *homari*, is not endemic to Europe and is extremely rare except in holding ponds which have previously stored American lobsters (*H. americanus*). A preventive vaccine has been developed in the US. *Gaffkaemia* should not be a problem to hatchery operators in the UK.

Bacteria from the genera *Vibrio*, *Pseudomonas* and *Aeromonas* have been isolated from lobsters displaying signs of disease. It is not known whether they were the causative pathogen or secondary facultative infective agents.

18. Epibiont Fouling

Epibiotic organisms can build up on the shell surface. They can be bacterial eg *Leucothrix mucor*, protozoal eg Vortecellids or blue-green algal (eg *Oscillatoria* or

Anabaena) in origin. Smothering can cause large-scale mortalities on occasion. Malachite Green was effective against all groups, but can no longer be used (see above). Antibiotics are also effective, but their use should be discouraged. High quality filtration and recirculating water with a low nutrient load does much to inhibit their formation and growth.

When light levels above the on-growing tanks are high, macro-algae (seaweeds) may grow upon the shell of the juveniles. In most situations this causes little problem, but if growth becomes excessive, moult difficulties or smothering can result. Some locations have shaded the on-growing tanks to reduce this fouling.

19. Other Problem-causing Organisms

Ciliate (eg *Mugardia* = *Anophrys* spp) infections of the bloodstream are known to cause problems in holding ponds and are a potential problem in the hatchery. Infection from the environment is usually via a wound which breaks the exoskeleton. Once infected death appears inevitable. No treatments are reported; good hygiene may offer some protection from infection.

Infection with the *Candida* type of yeasts has caused occasional mortalities with eggs and larvae.

The protozoan *Ephelota gemmipara* is reported to have destroyed egg-masses in hatcheries in the past. Infestation of the egg-mass with the annelid worm *Histriobdella homari* (plate 24) has been implicated in poor hatching success. The nemertean, *Pseudocarcinonemertes homari*, has also been identified as causing egg-loss. All can be controlled successfully by dipping the egg-mass before bringing the female in to the hatchery system (as chapter 13 and see appendix III).

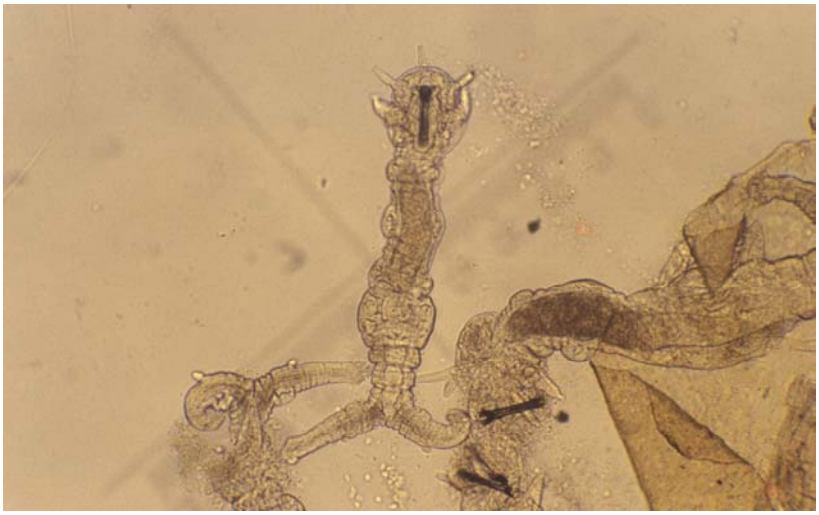


Plate 24: *Histriobdella homari* on lobster egg membranes

New groups of organisms which may cause disease in lobsters are being isolated continually. This is particularly true with the different classes of virus. How they cause disease, the signs and symptoms, and possibly the cures will be elucidated with time. This is an area where active research is underway and hatchery operators should try and keep informed about any advances that are made. This may not be easy as the generally accessible texts lag behind the research literature.

Section V TRANSPORTATION

Juvenile lobsters destined for release are generally transported in water or in air. Each method has its merits and disadvantages.

20. Wet transport

Advantage	Disadvantage
• The juveniles are immersed in water and able to respire and excrete waste products. • Air or pure oxygen may be bubbled through to maintain high levels of dissolved oxygen. • The juveniles can be packed in the same containers used for on-growing. • The damping effect of water can protect the animals from sudden impacts. • The thermal capacity of water protects against sudden temperature changes. • Juveniles generally arrive in good condition with very little mortality. • They require a shorter acclimation period, to regain normal vigour, before release. • It is seldom necessary to transfer the juveniles to fresh containers prior to release. • Can monitor water conditions.	• Water significantly increases the weight to be moved. • Water quality is difficult to maintain, especially on long journeys. • Movement of the water mass can damage the animals by forcing them into contact with the sides of the containers. • Water can transmit vibration and other disturbances to the animals, causing low-level stress. • Animals can escape and fight. • It can be difficult to secure the individual on-growing containers during transport. • Can be complicated logistically.

Transportation in water is largely a matter of common sense. At its most basic, all that is required is a tank of suitable size, a reliable source of high quality, unpolluted seawater, a means of packing and securing the containers housing the juvenile lobsters and a system to deliver either air or oxygen to the water. This type of set-up would, in most cases, be suitable for journeys up to 12 hours under benign conditions (plate 25).

Plate 25: Simple wet transport system placed on board a vessel prior to release

For longer trips or more demanding circumstances the level of sophistication would need to be increased. The first thing to add would be a mechanical filtration system to maintain water quality and prevent the build up of waste products. After that would come insulation and temperature control, to prevent overheating or, more unusually, over-cooling. A top-flight system would incorporate sensors monitoring water quality parameters, such as dissolved oxygen, temperature, pH, ammonia/ammonium concentrations, and salinity, in the tank through-out the journey; supplying real-time information to the accompanying people and automatically logging the data for later analysis. They might also be used to activate and control the life support systems built in to the tank.

Spray-bar and mist systems have been experimented with, but do not seem to be as effective as immersed transport and they tend to combine most of the disadvantages of both wet and dry transport.

21. Dry Transport

Advantage	Disadvantage
• There is no water to transport, reducing the weight and volume significantly. • Packing, handling and transport are easier. • The transportation containers are cheaper to buy and maintain.	• The animals are unable to respire efficiently or excrete waste products. • They are not protected from shocks and impacts. • Temperature can not be controlled precisely. Reduced temperatures are used to decrease metabolic rates. • Often the juveniles are removed from their on-growing containers and require repacking before release. • Pressure from packing materials can damage small or vulnerable animals. • The atmosphere surrounding the animals cannot be renewed easily and there may be legal restrictions on providing oxygen-rich atmospheres within the transport bags/containers. • The animals require a long acclimation period after re-immersion in order to regain full vigour. • Mortality levels are slightly higher than for wet transport. This becomes increasingly apparent for longer journeys. • Any damage to the exterior of the container can adversely affect the animals within. • Can not monitor the environmental conditions or the stock easily.

Various containers have been used for transporting juvenile lobsters out of the water, but, in general, the expanded polystyrene box has become the container of choice. They are light, readily available and cheap to buy. Handling and stacking is easy. Unfortunately, they are not very durable and easily damaged by careless handling. None-the-less, they are widely used and popular.

A generalised acceptable packing regime for this method of transport may be as follows:

A large plastic bag inner liner is placed within the box, to prevent leakage and help keep the atmosphere moist. On top of the base is placed the first layer of packing material. Various types have been used, ranging from wet/damp newspaper or sawdust to kelp. Animals are either removed from the on-growing containers and layered on top, or the individual containers are placed on this base. Another layer of packing is added, the next layer of animals and so on until the box is full. The final layer is of packing. The neck of the polythene bag is then drawn together and air or oxygen added before it is sealed. The lid is then placed on the box and also sealed.

When using sawdust or kelp as the packing material, put a layer/sheet of something (eg newspaper) below and above the animals to prevent direct contact and make unpacking easier.

If the juveniles are to be chilled during transport, to reduce their metabolic rate, this can be accomplished in different ways. Generally, either frozen soaked newspaper or ice packs are used to provide refrigeration. Ice packs are preferable since they do not liberate water as they thaw. In either case the cold layer should be prevented from coming in to direct contact with the animals. The frozen newspaper or ice packs are used as the first base layer and a second layer of moist, unrefrigerated material placed on top. The animals are then packed on top of this. When complete, another moist layer is placed over the final animals and this is followed by a second refrigeration level of the chosen type.

Unfortunately, the levels of packing are relatively heavy and animals at the bottom of the layers may be crushed by the weight above unless protected within their rigid rearing containers or by other spacing devices. There is also the risk of animals in the first and last layer being over-chilled, whilst those in the centre are under-chilled.

Enhancing the oxygen concentration of the atmosphere surrounding the animals is advantageous. Whilst they are unable to respire properly, limited passive diffusion of oxygen can take place across the gills and associated membranes so long as they are kept moist. However, the increased risk of fire or explosion may restrict the means of transport and some commercial carriers may not accept such consignments. It is always wise to check with them first.

No group has formally recorded or estimated the number of animals which can be packed per box using this transportation method. If removed from their containers, the animals are laid side by side in rows across the packaging, this results in very high densities being achieved, probably in the order of 2 000 – 3 000 per box. Keeping the animals within their containers would reduce the density to approximately 200 per box, but none would be crushed by the packaging.

21.1 ‘Moist’ Transport

A variation on the dry transport theme, in that it does not involve tanks or significant volumes of water, is a ‘moist’ transport method. It is particularly suited to transporting small numbers of juveniles for periods up to 24 hours.

The method is described below:

- Soak an absorbent material, tissue is OK, in seawater.
- Drain off the excess water and place the moist material at the bottom of a plastic bag.
- Place an individual juvenile on top of the material.
- Fill the bag with oxygen and seal.

- Pack the individual bags into the transport container (polystyrene box, cool box etc) and seal.

- Transport to destination, unpack the animals into suitable containers and submerge.

- Allow the animals at least 24 hours to recover from the journey.

- Cool-packs can be placed alongside the animals in the transport container, if the journey is expected to be longer than 2 hours duration or external temperatures are high.

Advantage	Disadvantage
• Simple • Cheap • Quick • Animals separated • Gills remain moist • Very low mortalities experienced • Can be transported unobtrusively • Has been used successfully with a wide variety of non-specialist carriers	• Only suitable for small numbers • Stress of handling • Animals unable to respire efficiently or expel waste products • Little protection from shocks or impacts • Moist packing material can crush animals, particularly smaller juveniles • Possible restrictions on transporting oxygen-rich atmospheres • Difficult to control temperature • Recovery period required before liberation or other use

Section VI RELEASE

Most lobster stocking programmes are agreed that the juveniles should be released directly on to the substrate in order to minimise predation. However, there are some who advocate releasing on the surface. It is easier and cheaper to do, but at certain times of the year or in particular areas the losses to predators, as the animals descend through the water column, can be high.

Release areas may be chosen for a variety of reasons: past history, location or political necessity. In all cases the seabed should be inspected visually, either using divers or remote cameras, and the ground assessed for suitability by an experienced person.

The best recovery rates have been obtained from areas where the seabed is composed of a wide variety of rock sizes; rather like an underwater scree slope or rock pile at the base of a cliff. Often these may be areas of natural erosion and rock fall or moraine deposits left by the last Ice Age. Some friable, well-fissured rock types also provide suitable habitat with a wide variety of crack and crevice sizes. Suitably designed artificial structures could also be used, but to date the costs associated with this option have prevented any exploratory work.

A degree of variety in the structure of the substrate is the key, if the ground is too uniform it often does not provide a wide enough choice of habitat for all life stages. This can lead to increased predation on juveniles or dispersal of the animals away from the area as they grow. Neither is desirable.

The animals should be released at a density of approximately one or two per square metre of suitable substrate. This is not easy to achieve in the field, but if the target density is greater there is a higher likelihood of increasing the number of encounters between the newly released juveniles. Any encounters lead to challenges or fighting, which delays them seeking and finding shelter. In turn, this increases losses to predators, particularly fish. At too high a density competition between juveniles for shelter and food may become a problem, but no-one knows where this upper limit might lie.

Once a suitable location is chosen, a choice as to release method must be made. Several alternatives are described as certain methods will suit some areas and not others. Alternatively, some systems will be too expensive for the programme to support and a less costly method will be used. Diver supervised methods are preferable because of the extra control they confer, but they tend to be the most costly option. The final choice rests with the operator, all methods work and all have advantages and disadvantages.

22. Stack or Tray Release

This method was developed by MAFF and was the mainstay of the Seafish release programme.

The on-growing trays were designed to separate horizontally (figure 4). The lower half, containing the animals was stacked in to custom-made frames. Ten trays

plus one unfilled tray as a lid completed a 'stack'. The contents were held in place by a shock-cord strap across the top (figure 5).

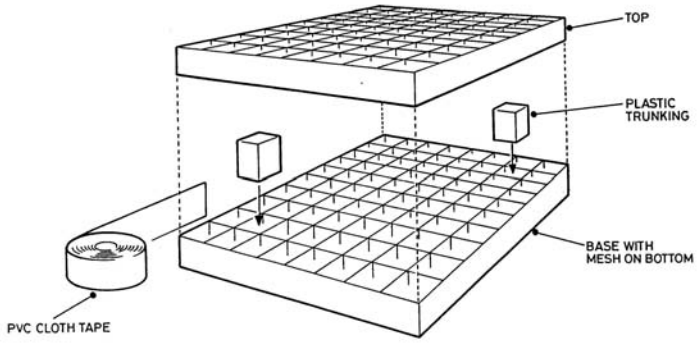


Figure 4: Construction of juvenile lobster on-growing 'trays'

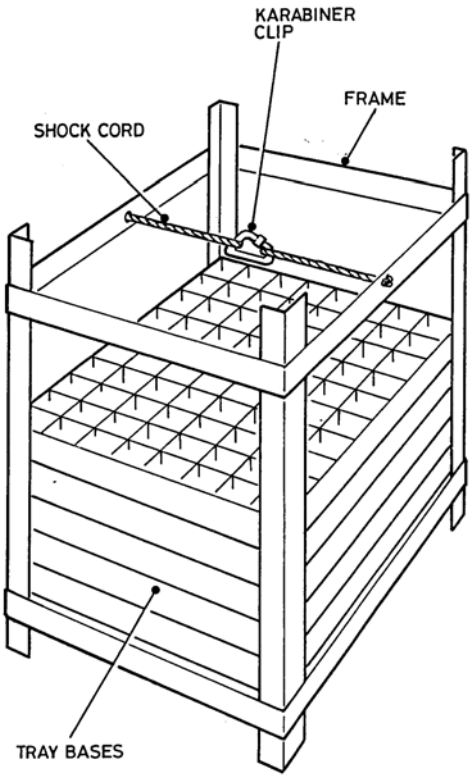


Figure 5: Arrangement of stack for release

Completed stacks were then placed in transportation tanks and the lobsters transported, in water, to the release area.

On site, the lobsters were stored in the transportation tanks until their final journey, in air, to the release location (plate 26).

Plate 26: Stacks packed in closed transport tank at stern of boat

For the release, two stacks were usually joined together. This assembly was then fastened to a custom-made spar buoy (figure 6) and deployed over the side of the boat. When released, the drag and buoyancy from the buoy kept the stacks upright as they sank to the bottom.

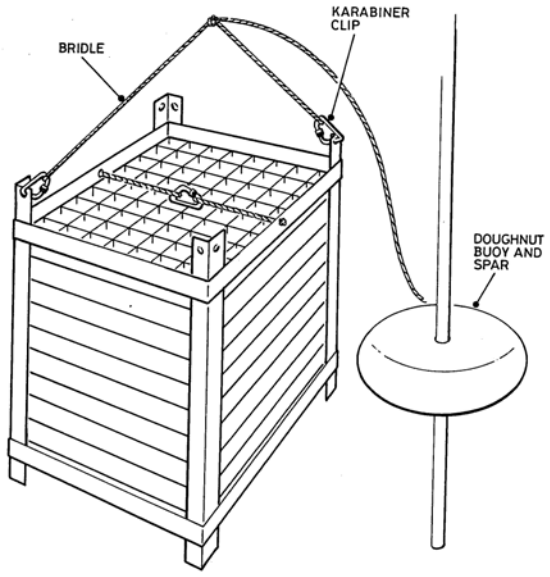


Figure 6: Stack ready for deployment

The animals were allowed to acclimate to the conditions whilst the divers prepared to enter the water.

Divers descended to the stacks, removed each tray in turn (plate 27) and liberated the juvenile lobsters at a density of 1 - 2 per linear metre of substrate (plate 28) as they swam along a transect.

Plate 27: Divers removing tray from stack

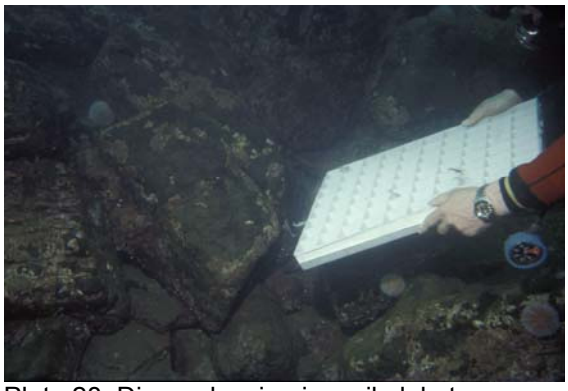


Plate 28: Diver releasing juvenile lobsters

Using this system, the animals were seen to seek shelter rapidly and predation during release was minimal. The presence of the divers discouraged some fish predators from approaching closely. Those juveniles which were eaten were usually those which were slow to shelter or
those which swam up in to the water column.

Advantage	Disadvantage
• Release supervised at all times. • Animals given the chance to recover from transport and acclimate before release. • Animals only released on to suitable habitat. • Predators discouraged. • Boat can deploy stack and divers and supervise from a safe distance.	• Full dive team required to comply with national regulations. • Limit to the number which can be released on each dive and during a day. • Expensive.

23. Pipe Release

This system was developed in the UK by the North Western and North Wales Sea Fisheries Committee and used extensively during their releases in Cardigan Bay (figure 7). Both the US and Ireland have used similar methods for release.

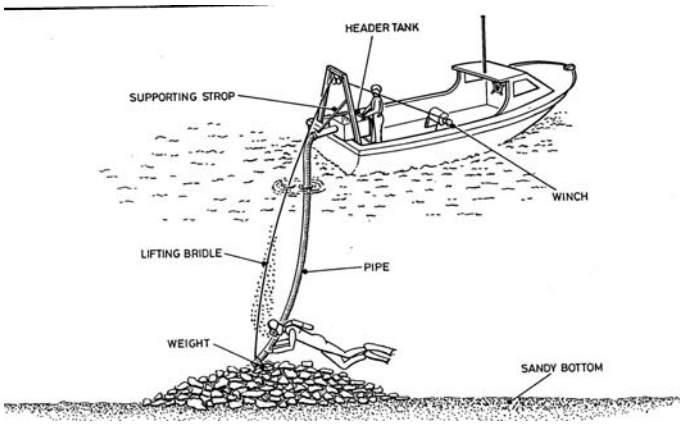


Figure 7: Diagram of the pipe release system

Juveniles from the hatchery were packed in their on-growing containers and transported in water to the release destination. The final journey to the release site was in air, but they were kept moist and protected from the elements.

For the release, a tank with a reservoir section was secured on the boat and a 4" diameter pipe from the tank lowered to the seabed by a bridle. The reservoir was then continually filled with pumped seawater which was allowed to overflow and run down the pipe. Individual lobsters were removed from their cells and placed in the exhalent water stream (plate 29). They were then conveyed down the pipe to the bottom.

Plate 29: Releasing juvenile lobsters using the North Western & North Wales SFC pipe release system

A diver, equipped with communications, was used to check the deployment of the pipe before releases commenced. Occasionally, the pipe had kinked during lowering, creating a restriction which would hinder the progress of the animals. This was easily rectified by the diver. Where the substrate was patchy, the diver remained on station, controlling the release and preventing animals being placed on unsuitable ground. If the release site covered a large area, the diver could be withdrawn and the release performed unsupervised.

From a technical point of view it may be possible to replace diver involvement completely by using fixed underwater cameras and/or surface controlled Remotely Operated Vehicles (ROV or mini-subs) to convey pictures to the boat.

Advantage	Disadvantage
• Diver supervision may be un-necessary • No limit to the number which can be released each day. • May be cheaper than stack release.	• Full dive team may be required. • Animals handled and stressed immediately prior to release. • Animals have only a very short recovery period before liberation from the pipe. • Release activity may attract predators. • System may restrict manoeuvrability of the boat.

24. Ice-cream Box Release

This method was used by Orkney Fisheries Association for its release programme in Scapa Flow.

Animals were transported in the on-growing 'cups' from the hatchery to the release site in air. Here they were unloaded from their containers into a seawater-filled vessel. Two-litre plastic ice-cream boxes were filled with water and fifty juveniles caught and placed in each.

Filled boxes were bagged together and taken to the seabed by divers, who removed each box in turn, swam to a suitable area of substrate and released the animals. Dispersal was encouraged by wafting with the hand.

Advantage	Disadvantage
• Simple system. • Release supervised. • Immediate predators discouraged. • Boat can supervise from a safe distance.	• Full dive team required • Animals handled and stressed immediately prior to release. • Crowding and fighting during packing causes stress. • Short recovery period before release. • High density released on to limited area, encourages fighting, aggression and delays sheltering. • Wafting sends animals up in to the water column, making them vulnerable to predation. • Limit to the numbers released per dive and each day.

25. Pot Release

The Irish Lobster Association has begun trials with this method in order to allow all fishers to take part in releases as part of their normal activities. It is in its early stages of development and will be refined with further experimentation. The system has great potential.

The present protocol is as follows. Animals are transported from the hatchery to the release site in air. They are either pre-loaded in to individual containers (ice-cube trays in the first instance) or they can be packed on site. The trays are then covered with fine tissue-paper and secured in to normal creels or dedicated release pots with rubber bands or shock-cord. These are then lowered to the seabed and left. The animals are released over a period of time, as the tissue-paper breaks up and disperses. The pots are recovered at the end of the day or the following day and the containers sent for re-use.

Advantage	Disadvantage
• No dive team required. • All fishers can be involved in releasing. • Dedicated release journeys un-necessary. • Pots can be left and recovered when convenient. • Simple system. • Inexpensive. • Release over time aids dispersal and may limit predation. • Time delay allows recovery and acclimation. • Pots do not appear to attract predators.	• Animals handled and stressed before release. • Release unsupervised. • Difficult to secure trays and prevent release as the pots are lowered. • Tissue-paper not an ideal cover, it does not disperse fully and can tangle and stifle animals. • Further experimentation and refinement is required.

26. Surface Release

During surface releases the juvenile animals are released directly from the boat on to the surface of the water and allowed to sink to the bottom. Whist this is extremely simple, the presence of the juveniles in the water column rapidly attracts predatory fish which can consume many animals before they reach the seabed and find shelter. The Norwegians report using this method during their trials.

Advantage	Disadvantage
• No dive team required. • All fishers can be involved in releasing. • Dedicated release journeys un-necessary. • Simple system. • Inexpensive.	• Animals handled and stressed before release. • Release unsupervised. • No recovery or acclimation before release. • Attracts predators. • Losses can be very high.

27. Mechanically-based Release Systems

The first trials of a mechanical release system have taken place. For the prototype, two ice-cube trays were mounted vertically either side of a central column. Animals were loaded into the individual cells and they were covered with plastic lids which were secured with retractable pins. The device was then lowered over the side of a boat. On contact with the bottom a central spindle withdrew the pins and the covers were pulled clear by shockcord springs. In use this appeared effective and the animals were dispersed over the seabed. Despite this promising start much development work remains to be completed.

Advantage	Disadvantage
• No dive team required. • All fishers can be involved in releasing. • Dedicated release journeys un-necessary. • Instant release, no waiting. • Reliable release. • Good dispersal. • Does not appear to attract predators.	• Animals handled and stressed before release. • Release unsupervised. • No recovery or acclimation before release. • Further experimentation and refinement is required. • Complicated • Potential expense

Section VII MARKING

Marking hatchery-reared lobsters, which are released to the wild so that they can be identified unequivocally later, is a scientific tool. It is unlikely to be of primary concern to hatcheries run on a commercial or semi-commercial basis. However, there may be occasions when there is a requirement to mark small batches for experimental purposes.

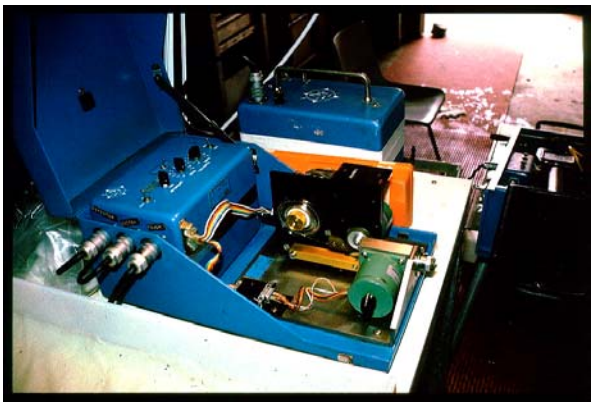
28. Coded Wire Tags (Micro-tags)

These are usually short lengths, 0.5 or 1 mm, of thin, 0.25 mm diameter, stainless steel wire with an identification code etched on the surface. The first examples carried the code in binary format and were batch coded, but later models are available with Arabic numerals and sequential numbering if required.

They were first developed for use in salmonids and experimentation extended usage to shrimps. The technology was then applied to lobsters and has now been used successfully in a number of crustacean and other species.

The tags can be implanted either manually or by semi-automatic machinery (plate 30) In either case a high level of operator training and skill is required. The actual procedures differ between makes and models of tagger. In general, the animal is positioned on its back and flexed gently at the cephalothoracic-tail joint. It is eased gently on to the implantation needle, which is then withdrawn leaving the tag behind. An illustration of the technique, using an early machine, is shown in plate 31.

The site of implantation requires careful choice, primarily to prevent tag loss but also to avoid any potential hazard to consumers. In the UK, the chosen location was internally in the thorax, placing the tag in the musculature at the base of the walking legs (to be more exact, above the coxae of the fourth pereiopods). In this location, the tag is not shed if a limb is lost and it is in a part of the musculature which is seldom eaten. With proper placement retention is very high (>90%).



Mark IIA semi-automatic tagging system

Hand tagging system (Courtesy T Scovacricchi)

Plate 30 Coded wire tagging systems

Plate 31: Implanting a coded wire tag in to a juvenile lobster

Tagging mortalities in animals which had passed stages IX or X were usually very low (< 1%), but in younger (smaller) animals at stages VI to VIII they could be higher (up to 25%). This was attributed, primarily, to actual mechanical damage to the exoskeleton.

Since the tag is internal, there is no external feature to distinguish tagged animals from untagged ones. Detection of the tags was only possible using highly sensitive metal detectors. Again, actual operational details differ between programmes, but, in general, animals to be screened were passed through or under a detection device, which registers the presence of a tag through its magnetic signature. This activates an audible signal and the animal can be separated for further investigation (plate 32).

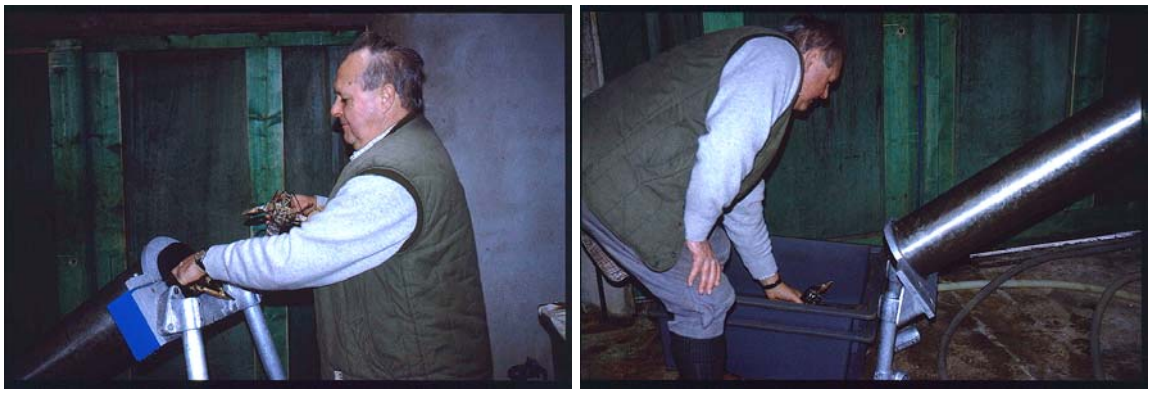


Plate 32: Screening lobsters for micro-tags using an early model tubular detector

The position of the tag is visible on X-ray, but the code can not be seen or decyphered. It has to be removed in order to be 'read'.

Extraction of the tag was by careful dissection. In some cases the tags required cleaning, using either potassium hydroxide (KOH) solutions or ultrasonic cleaning baths filled with KOH or freshwater (H_2O), before the binary digits could be read under a binocular microscope (plate 33).

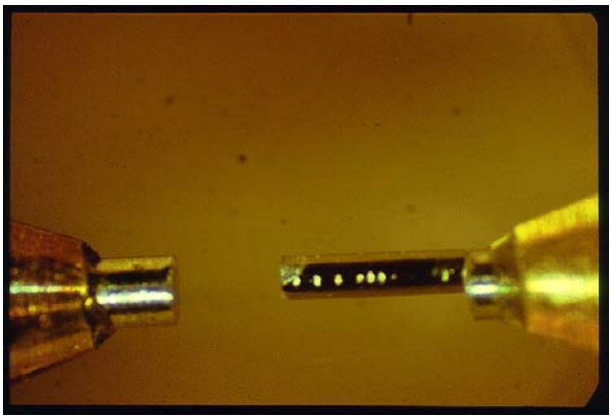


Plate 33: 1 mm long coded wire tag showing part of the binary-coded data sequence etched on its surface

Long-term tag retention in the field is very good, with documented recoveries of tags 10 and 11 years after implantation.

Advantage	Disadvantage
• Tried and tested method • Small size • Large data capacity • Good long-term retention • Low levels of tag-loss • Causes no discernible long-term harm to the animals • Internal position does no compromise the survival or behaviour in the wild • Can be positioned in areas which are not eaten	• Skilled operator required for implantation • Time consuming • Tagging mortality • Difficult to detect • Difficult to recover • Require decoding (early versions) • Expensive equipment

29. Visual Implant Tags

These are similar to the CWT in that they are implanted internally in the animal, but as the name suggests it is done in such a way that the identification mark can be seen externally. They are flat stainless steel pieces approximately 1.5 mm square with a sequential number printed in Arabic numerals on the surface. A flexible, fluorescent version of these tags also exists.

They are used successfully in many fish species, but their use in lobsters is more problematic. One of the very few areas where an internal tag may be visible from the outside is beneath the translucent membranes on the underside of the tail.

The tag must be implanted shallowly, which can predispose it to loss on moult, and if any movement of the tag occurs it can be lost from sight with nothing to indicate its presence. Undetected tags may also find their way into the consumer chain and, whilst they pose no hazard to health, they may cause concern if discovered.

This marking method has not been evaluated fully in lobsters, so no detailed information is available.

Advantage	Disadvantage
• Internal implantation • Visible externally • Recovery un-necessary • Ease of reading code	• Little experience in lobsters • Limited options for position • Skilled operator required for implantation • Time consuming • Larger size • Possibility of increased tag-loss on moult • Movement or tag migration may hide tag • Positioned in one of the prime meat areas • Expense

30. Fluorescent elastomers

Limited experiments have been conducted using flexible elastic polymer compounds which fluoresces under ultraviolet light. Once again, implantation is internal, but the size of the 'drop' injected can be varied by the operator.

In use, a biologically compatible liquid elastomer is injected through a hypodermic needle in to the tissue in such a way that it can be seen externally. The elastomer cures to form a flexible solid mark. Different colour combinations or placement in different locations around the animal provide the unique identifiers for the trial.

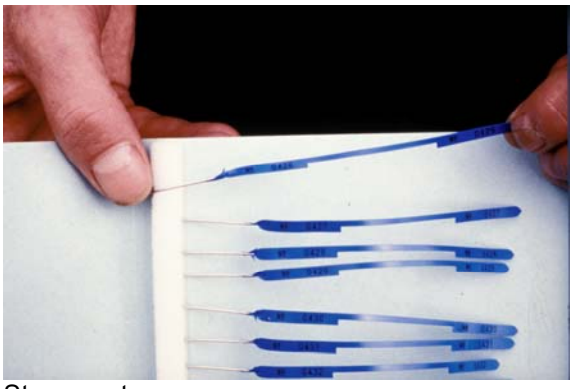
Naturally, the marks are most visible when placed beneath translucent areas of the shell, but experience has shown that a well-positioned tag can be seen through the pigmented exoskeleton when viewed under strong UV illumination. No trials have been conducted to see if the tags are equally visible under the alternative illumination source of a very bright blue light when viewed through special filters.

These marks have been used successfully in many fish species, but there are no data available about the long-term use and retention of these marks in crustacea.

Advantage	Disadvantage
• Cheap for small batches • Internal placement minimises losses • Ease of identification • Recovery of mark un-necessary • Can be viewed in the wild in ideal circumstances	• Limited experience in lobsters • Skilled operator required • Time consuming • Limited coding options • Shallow implantation may lead to loss • Mark may become obscured with time • Long-term use unproven • Use of UV light sources • Mark may be in a prime meat area

31. Other tags

Other tagging systems, such as T-bar tags, streamer tags (plate 34), archival (data recording) tags, acoustic tags etc are, by their very nature and size, only suitable for larger animals, usually greater than 35 mm carapace length. Consequently, they are unlikely to be of use to a hatchery operator who wishes to mark juveniles prior to release. They are most suited to sub-adult and adult animals.



Streamer tags

Streamer tag inserted through cephalothoracic joint

Plate 34: Streamer tags (Courtesy T Scovacricchi)

Descriptions of the use of these alternative tags in the field can be found in many scientific journals, principally those covering fisheries or ecology.

Section VIII MONITORING RELEASED STOCKS

This is unlikely to be a primary concern of any commercial or semi-commercial programme unless it has marked animals as part of a scientific study. Under 'normal' circumstances the operators and fishers are more interested in their catch rates and the price, than the origin of the animals. Monitoring programmes are costly to conduct and, depending on area, complicated to plan and administer.

In most instances, unless you want to monitor the pre-fishery animals, which is difficult using the real-world fishery, efforts will be concentrated on monitoring the commercial landings of mature animals. This may be between five and seven years after you began the first releases. Recoveries of hatchery origin animals in the first few years of the programme are likely to be small and after the euphoria of the first return has worn off it can be difficult to motivate people, fishers, merchants, even staff, and maintain their interest. Depending on the fishery, it can take many years to gather enough data to present convincing results. However, should a monitoring programme be necessary the following guidance is offered.

32. Planning

- Decide what you wish to achieve and set your goals.

- Survey the fishery and first-sale market in great detail before you start. Who is fishing where? Where do they land, to whom and how often? How many boats are involved? Are any from out of the area? Where do they land? Where and how is the catch stored before first sale? Are there any landings direct from the boats to the final consumer and what is their scale? How many merchants are there? Where are they located? Are there any merchants who collect animals from the area, but are not based there? Where do the merchants sell to, and when and how do they dispatch animals? Are any major changes to these patterns anticipated? Etc.

- Continually update the survey to identify new boats, new merchants, new landing areas or patterns etc.

- Think about the logistics of covering the fishery. Can the fishers do the monitoring? Will they be rewarded? If not, how many people can you involve? Will you monitor landings at the quayside or at the merchant's premises? Can you go for blanket coverage or will you have to target the most important sites? Are any locations more likely to yield returns than others?

- If you target sites, how will you quantify the data that you might miss from other sites?

- Try and identify factors which are likely to thwart your plans and prevent the monitoring operation running smoothly. What can be done to overcome or circumvent them?

- What detection equipment will you need? This will be determined by the type of tag used. What will it cost? How long will it last? What maintenance does it require? Will people require training/familiarisation to use it?

- What data will you collect? How will you store and process it?

- Will you have to pay for the animals you find?

- Will you have to compensate fishers or merchants in order to secure their co-operation?

- What will you do with the animals you recover? Will they continue to market or be released back to sea?

- Avoid using temporary, part-time or occasional staff if you can.

- Estimate what it is going to cost. Do you have the resources now and can you secure them for the future?

- Re-evaluate whether you can achieve your targets and goals with the resources you have.

33. Execution

- Be contactable by staff, merchants, fishers etc.

- Be reliable, turn up when arranged etc.

- Be as flexible as you can with your approach to the work, but still gather the data. Adapt protocols or procedures to met the needs of individuals as much as possible. You need their co-operation.

- Respect confidential information and commercial sensitivities.

- Keep those involved in helping with the monitoring informed about the results and progress. If anything good or unusual happens, try and get some local publicity. It helps morale.

- Make any payments due to fishers and merchants speedily.

- Keep up to date with data collection and input into the storage system.

- Evaluate progress as you go along

- Be prepared for a long commitment

34. Finding the tags

It is rare to find any of the internal tags precisely where you placed them or expect them to be (plate 35). There is usually some degree of movement, so be

prepared to look closely for them and examine unusual places, such in the vicinity of the head or within the gills.

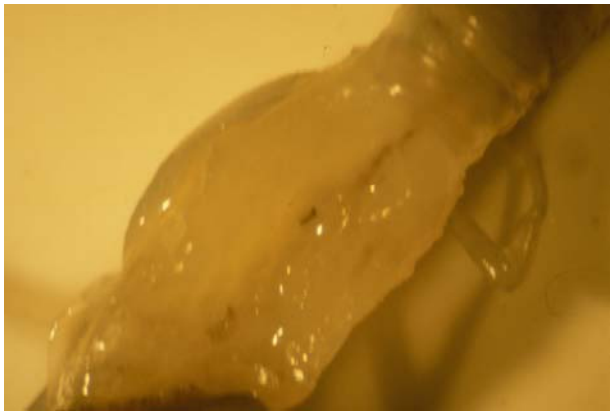


Plate 35: Micro-tag in the target position in a lobster

Animals containing metallic tags, such as CWTs and some visual implant ones if they are obscured, can be located using sensitive metal detectors. These may be fixed units (plate 32) or hand-portable 'wands' (plate 36). Both types tend to be expensive to buy. However, by progressively reducing the size of the sample that is passed through or under the detector the tags can be found.

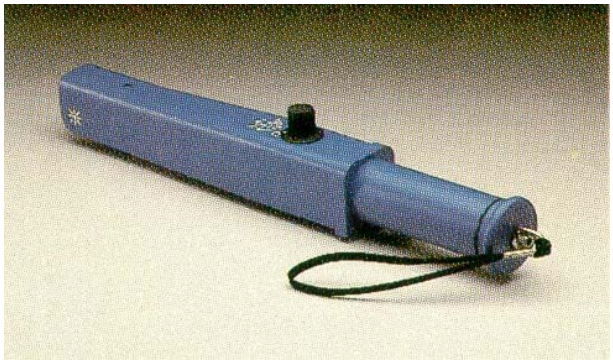


Plate 36: Hand-held 'wand' detector (Courtesy NMT International)

Concealed tags will have to be removed after the animal has been humanely dispatched. The best way to do this is place it in a domestic freezer for about 30 – 45 minutes. The tag can then be extracted, cleaned and read.

If the tags are designed to fluoresce, then a source of blue or, probably better, UV light will be required. Visible tags can be read without affecting the animal.

Section IX ECOMONICS

The costs associated with operating a lobster hatchery and/or stocking programme have been debated for a long time. Definitive costs have been hard to obtain. In the following sections, the costs quoted are valid for the year in which they were derived. An indication of the equivalent value in 2002 has been derived by increasing the original estimate in line with the movement of the retail price index (RPI) over the intervening years. This assumption is approximate and only valid for UK prices; values from the US or elsewhere remain in their original (base) form. Conversion of the currencies from £UK or $US to the new European-wide currency (Euro) were made using the approximate conversions of £UK 1.00 = 1.66 Euros or $US 1.00 = 1.20 Euros.

35. Cost per juvenile

An American study performed in 1980 estimated the cost of rearing an American lobster through to market size (454 g) to be between $US 3.38 – 9.86 (4.05 – 11.83 Euros).

A similar study in 1985, by one of the first UK commercial hatcheries, estimated the cost of producing a Stage IV European post-larval lobster to be £UK 0.15 (0.24 Euro), rising to £UK 0.60 (0.98 Euro) for an animal between stages IX – XII, culminating in a cost of £UK 2.00 (3.26 Euros) to produce a 500g adult. [The 2002 equivalent costs are: £UK 0.28 (0.46 Euro); £UK1.10 (1.83 Euros); £UK3.68 (6.11 Euros) respectively].

Early work by Seafish during 1988/89, estimated the cost of rearing a juvenile, solely for the scientific trials, for 3 months (stage XI – XII) before release to the wild to be approximately £UK 1.25 (2.04 Euros). This was reduced to approximately £UK 1.18 (1.92 Euros) per juvenile when the holding period was cut to 2 months (stage VI – VIII) in the later trial (1990/91). [The 2002 equivalents are: £UK 2.06 (3.42 Euros); £UK 1.64 (2.72 Euros) respectively].

The semi-commercial hatchery in Orkney is run by the local Fisheries Association using the income from a levy raised from its members. It reported the costs of a juvenile for release, after approximately 6 weeks in the hatchery, to be £UK 0.30 – 0.36 (0.49 – 0.59 Euro). This included a subsidy in the form of income derived from the sale of juveniles to other interests. A subsequent joint study conducted with Seafish estimated their full production costs per juvenile to be between £UK 0.46 – 0.64 (0.76 – 1.06 Euros). [2002 equivalents: £UK 0.32 – 0.39 (0.53 - 0.65 Euro); £UK 0.49 – 0.69 (0.81 – 1.14 Euros)].

Modelling an idealised, efficient hatchery (figure 8) designed to produce 100 000 juveniles per year for release, has produced estimated costs of £UK 0.36 – 0.78 (0.59 – 1.30 Euro) for animals held for 4 weeks (stage VI) or £UK 0.54 – 1.12 (0.90 – 1.87 Euro) if they are held for 12 weeks (stage XII) before release (at 2002 values).

It is intended to subsidise most the operating costs of the National Lobster Hatchery in Padstow using income generated from tourist visitors, gift sales and

donations. Some are of the opinion that this is the only way a hatchery could be made to operate in a sustainable fashion.

36. Cost of hatchery construction and operation

In 1989, Seafish prepared a costing for a proposed hatchery cum visitor attraction. The initial design, which would produce 30 000 juveniles per year at stage XI over 10 years, had a capital cost, excluding the cost of the building itself, of £UK 47 000 – 50 000 (76 500 – 81 400 Euros). [2002 equivalents: £UK 71 500 – 76 000 (119 500 - 126 200 Euros)]. Annual operating costs were projected to be approximately £UK 35 000 (56 970 Euros) [2002 value: £UK 53 200 (88 300 Euros)]. Reducing the production capacity to approximately 16 000 juveniles (still at stage XI) per year reduced the capital cost to £UK 28 000 – 31 000 (45 500 – 50 500 Euros). [2002 values: £UK 42 500 – 47 100 (70 600 - 78 200 Euros)]. The running costs reduced to around £UK 21 000 (34 200 Euros) per year. [2002 value: £UK 31 900 (53 000 Euros)].

MAFF, in 1995, estimated the total cost of constructing a hatchery to produce 10 000 to 30 000 stage X or XI juveniles per year to be between £UK 86 000 - 130 000 (140 000 – 212 000 Euros). [2002 equivalents: £UK 100 600 – 152 100 (167 000 – 252 500 Euros)]. Operating costs were estimated to be up to £UK 185 000 (301 000 Euros) per annum for a large centralised unit or between £UK 20 000 – 50 000 (32 500 – 81 400 Euros) per annum for smaller local units. [2002 equivalents: £UK 216 500 (359 300 Euros); £UK 23 400 – 58 500 (38 900 – 97 100 Euros)].

In the real world, when Orkney constructed its hatchery, those involved set out to reduce all the costs as far as possible. They were very successful in achieving major cost savings over those projected previously. The hatchery, which has produced 30 000 stage VIII juveniles per year, but has the potential to produce up to 70 000, was constructed for approximately £UK 38 500 (62 700 Euros) [2002 cost: £UK45 000 (74 800 Euros)] with annual running costs of £UK13 900 (22 600 Euros) in 1998/9 [2002 cost: £UK15 000 (24 900 Euros)].

The most recent, idealised Seafish model (figure 8) examined various scenarios, from ‘least cost’ (using less costly styles of building and minimal investment) to a ‘high cost’ strategy (expensive building, high investment). The production life of the hatchery was set at 15 years in the model. Estimated construction costs for a ‘typical’ hatchery constructed to produce up to 100 000 juveniles at stage VIII were £UK 138 600 (231 000 Euros) in 2002. Annual running costs were estimated to be around £UK 68 400 (114 000 Euros). Releasing the same number of animals at stage VI reduces both the size of the facility required (faster turnover of stock) and the annual running costs, to approximately £UK 79 000 (127 400 Euros) and £UK 53 000 (88 300 Euros) per annum, respectively. Conversely, releasing the same number of bigger animals, at stage XII, requires a larger facility and increases the running costs. The estimated capital cost was £UK 198 000 (330 000 Euros) with a running cost of approximately £UK 83 700 (139 500 Euros) per annum.

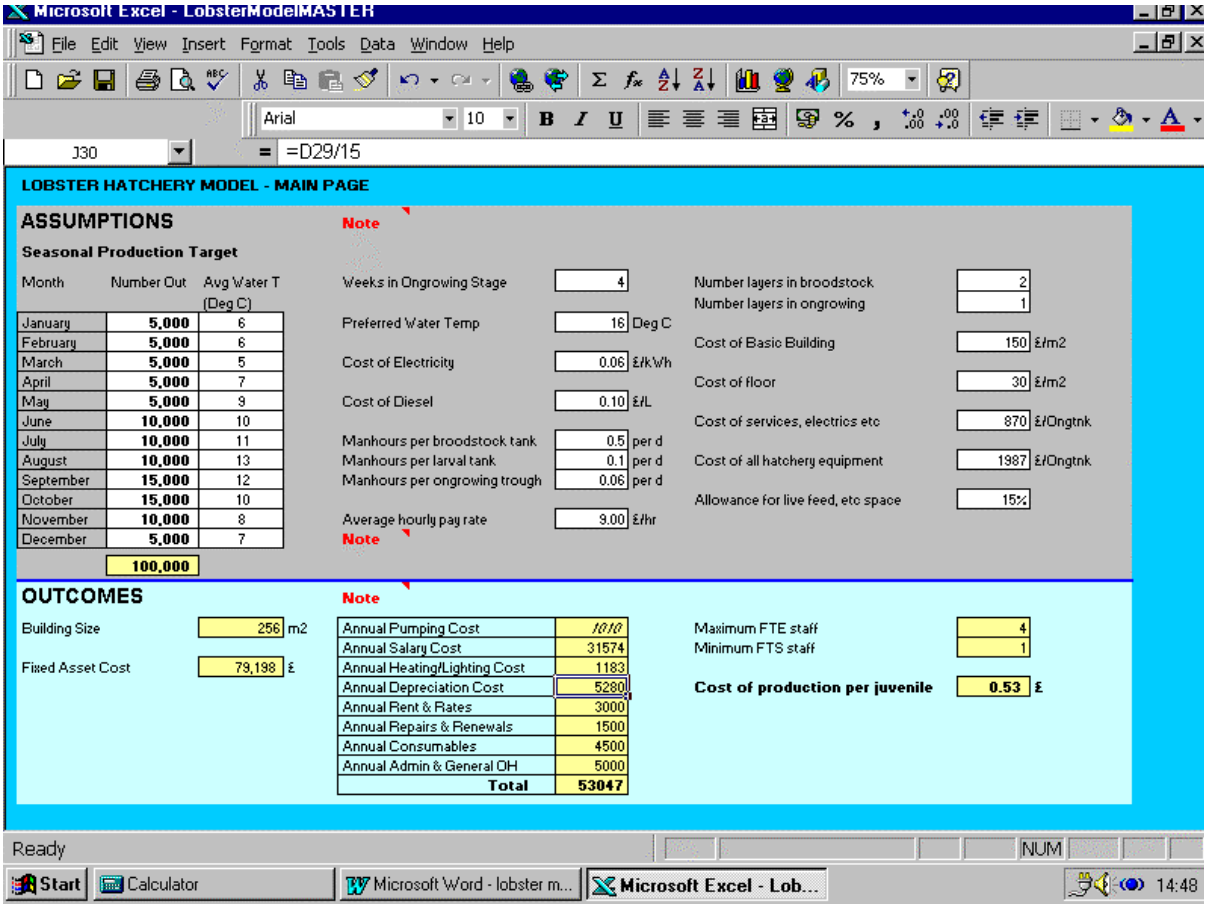


Figure 8: The Seafish lobster hatchery model as displayed on screen

Comparable capital costs for the 'least cost' scenario range from £UK 35 900 (stage VI) - £UK 105 200 (stage XII) [59 900 – 175 300 Euros] with annual running costs between £UK 36 100 (stage VI) and £UK 54 000 (stage XII) [60 200 – 90 000 Euros] per annum.

Modelling a 'high cost' scenario resulted in capital cost estimates between £UK135 600 (stage VI) and £UK 318 900 (stage XII) [226 000 – 531 500 Euros] with the commensurate annual running costs between £UK 77 900 - £UK 126 900 [129 800 – 211 500 Euros].

The costs associated with constructing the National Lobster Hatchery in Padstow, Cornwall can not be considered as typical since the requirement to provide a visitor attraction resulted in the construction of a more elaborate building with costlier fittings than strictly necessary.

Section X STOCKING AS A FISHERY MANAGEMENT TOOL

Stocking is not a panacea for the problems of the inshore fisher. Stocking is a fishery management tool, just like any other, and it should be thought of in that way.

When stocking is compared to other, more conventional, methods, such as increasing minimum landing sizes, controlling fishing effort, protecting broodstock etc, it is one of the most expensive systems to operate. However, most conventional methods are perceived to be negative by the fishing industry and individual fishers since they are considered to reduce landings, and hence incomes, in the short-term. They also contend that any benefits that accrue take a long time to become apparent. However, some fishery scientists suggest that actions such as increasing MLS only depress incomes in the first season (ie until the first affected year-class has moulted to above the new MLS), whereas other measures, such as increasing egg (and hopefully juvenile) supply by banning the landing of berried females, take longer to affect stock levels and the fishery. These factors can be crucial because when a sector is under pressure, even a modest reduction in income can be sufficient to drive many out of business and away from the fishery for good.

Stocking is seen by many as a positive step. “Man putting something back in to the sea”; “making a contribution to nature’s production”. This is as true for salmon and trout stocking programmes as it is for lobsters. In both cases it can be argued, rationally, that it is far more cost effective to control the fishery and what is taken out, than it is to spend the same amount of money putting juveniles in to the system. But that approach lacks public appeal – it is the ‘let’s do something’ factor. In the case of lobsters, the juveniles put in to the sea have been shown to survive to market size and estimates of their survival are high. They have not dispersed far and have been seen to contribute to the fisheries in a tangible way. Those that are not caught reproduce and so contribute further to future stocks. Release larger animals and you can fish them sooner, smaller ones and you have to wait longer. There are even mechanisms in place to control the fishery and who can remove the stock. It all seems to be there. This can distract many away from the costs involved and the fact that stocking alone can not safeguard the future of the stocks and the inshore industry. Additional action is needed.

Where stocking programmes have begun with the support and backing of the fishers in an area, other, positive, effects quickly become apparent. If fishers are making a financial contribution, they see the lobsters released as ‘their lobsters’ belonging to ‘their fishery’. The idea of the stocks belonging to no-one (common ownership) and therefore open to all is lost. Fishers want control of ‘their fishery’, their future livelihood. They begin to look for measures to control access to the fishery and they begin to examine the way they fish, the effort employed and the number of animals removed. The framework to control these factors now exists, largely as a result of lobbying by the industry. Invite fishers to tour the hatchery, see the reproductive effort of the females, see the various larval and juvenile stages, watch an animal struggle to moult, explain how it all works and they appreciate fully the entire basis that ‘their fishery’ rests upon. They can now see the reason for protecting broodstocks – both male and female, giving the animals a chance to reproduce before they are taken, V-notching schemes, bans on

landing berried females etc. In many cases they will actively press for their introduction. The fishers also become more aware of environmental issues affecting the seas in which they operate and many have been known to modify their own behaviour and practices.

In general, nature's efforts will always overwhelm those of man, but there are some possible exceptions. Where there are isolated stocks, as in northern Norway, which may be vulnerable or where stocks are depleted close to extinction, as in the northern Adriatic Sea, then the well-planned hatchery production of juveniles and stocking of areas may have a conservation role. Here, there are direct parallels with captive breeding programmes in terrestrial and avian biology.

There may be cheaper and easier fishery management policies to implement, but few can match the innate attraction of being seen to do something 'positive' by stocking an area with juveniles for the future. There is a natural tendency for those involved in setting fisheries policy to concentrate on the monetary costs of implementing any fishery control measures, but to be successful the policies need the support of the industry and the public. If stocking can help secure co-operation with adopting other, more conventional, measures, then it can be a price worth paying to safeguard stocks and the future of an industry which is very important to many rural communities.

37. Stocking artificial structures

Lobsters have long been known and observed to take advantage of suitable man-made structures in the sea, be they a wreck or a breakwater. In theory, it should be possible to construct a purpose-made 'reef', stock it with juveniles from a hatchery and thus create a fishery. Unfortunately, it is not that simple. There are strict regulations in the UK governing the construction of such structures in the sea and a long, complex and difficult process to follow to secure permission. As a result, the concept remains unproven and potential funding difficult to secure.

The attraction of lobsters to artificial structures or 'reefs' was first investigated in the UK by researchers from Southampton University. They studied the natural processes at work on a series of small experimental 'reef units' constructed off the south coast of England, when it rapidly became apparent that recruitment from the wild was taking place. They gathered a lot of very useful information.

Many proposals to construct purpose designed 'reefs' and stock them with lobsters have been put forward over the years, but none have come to fruition. However, recently (2001) a group from Dunstaffnage Marine Laboratory, near Oban, received permission to construct a large experimental 'reef' in Loch Linnhe on the west coast of Scotland. The declared intent is to stock the 'reef' with hatchery-produced lobsters and monitor the outcome. The progress of this experiment will be observed with interest by many groups around the globe. Construction of the 'reef' began in 2002.

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Section XII USEFUL ADDRESSES

Centre for Environment, Fisheries and Aquaculture Science (CEFAS)

CEFAS Lowestoft Laboratory
Pakefield Road
Lowestoft
Suffolk
NR33 0HT

Tel: 01502 562244
Fax: 01502 513865

CEFAS Weymouth Laboratory
Barrack Road
The Nothe
Weymouth
Dorset
DT4 8UB

Tel: 01305 206600
Fax: 01305 206601

Web site: http://www.cefas.co.uk

Department of Agriculture and Rural Development, Northern Ireland (DARD)
Fisheries Division
Annexe 5
Castle Grounds
Stormont Estate
Belfast
BT4 3PW

Tel: 028 9052 0100
Fax: 028 9052 3121
Web: www.dardni.gov.uk

The Electrical Contractors' Association of Scotland
Bush House
Bush Estate
Midlothian
EH26 0SB

Tel: 0131 445 5577
Fax: 0131 445 5548

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Agriculture Department
Fisheries Division
New Crown Buildings
Cathays Park
Cardiff
CF10 3NQ

Tel: 029 2082 5111
Fax: 029 2082 3562

National Lobster Hatchery
South Quay
Padstow
Cornwall
PL28 8BL

Tel/Fax: 01841 533877
E-mail: lobsters@hatchery.freeserve.co.uk

North Atlantic Fisheries College (NAFC)
Port Arthur
Scalloway
Shetland
ZE1 0UN

Tel: 01595 772000
Fax: 01595 772001
E-mail: admin@nafc.ac.uk
Web: www.nafc.ac.uk

North Western and North Wales Sea Fisheries Committee (NWNWSFC)
University of Lancaster
Bailrigg
Lancaster
LA1 4YY

Tel: 01524 68745
Fax: 01524 844980
E-mail: nwnwsfc@lancaster.ac.uk

Orkney Fisheries Association (OFA)
5 Ferry Terminal Building
Kirkwall Pier
Kirkwall
Orkney
KW15 1HU

Tel: 01856 871818
Fax: 01856 871919
E-mail: alan@orkney-fisheries.freeserve.co.uk

Scottish Executive, Environment and Rural Affairs Department (SEERAD)
Fisheries Research Service
Marine Laboratory
PO Box 101
Victoria Road
Aberdeen
AB11 9DB

Tel: 01224 876544
Fax: 01224 295511
Web: www.marlab.ac.uk

Sea Fish Industry Authority (Seafish)

18 Logie Mill
Logie Green Road
Edinburgh
EH7 4HG

Tel: 0131 558 3331
Fax: 0131 558 1442

Seafish Technology
St Andrew's Dock
Hull
HU3 4QE

Tel: 01482 327837
Fax: 01482 223310

Aquaculture Development Service
PO Box 68
Colwyn Bay
Wales
LL28 5WR

Tel/Fax: 01492 650884

Web site: http://www.seafish.org

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West Midlands

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Fax: 01922 643422

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Bayley Street
Stalybridge
Cheshire
SK15 1QQ

Tel: 0161 330 5577
Fax: 0161 330 5576

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Hawlaw Industrial Estate
Hawlaw Road
Inverurie
Aberdeenshire
AB51 4SG

Tel: 01467 621907
Tel: 01467 620265

Fusion Marine — Pipes and fittings
26 Hawbank Road
College Milton North
East Kilbride
G74 5EX

Tel: 01355 261218
Fax: 01355 261219
E-mail: enquiries@fusionmarine.co.uk

Capper P-C — Pipes and fittings
15 Clydesmill Place
Cambuslang Investment Park
Glasgow
G32

Tel: 0141 646 1646

Dryden Aqua Ltd — Aquaculture equipment and supplies
Butlerfield Industrial Estate
Bonnyrigg
EH19 3JQ

Tel: 01875 822 222
Fax: 01875 822 229
E-mail: howard@DrydenAqua.com
Web: www.DrydenAqua.com

Tropical Marine Centre — Aquaculture equipment and supplies
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Chorleywood
Hertfordshire
WD3 5SX

Tel: 01923 284151
Fax: 01923 285840
E-mail: tmc@tmc-ltd.co.uk
Web: www.tmc-ltd.co.uk

Lacron Ltd — Sand filters
Lacron Oasts
Teynham
Sittingbourne
Kent

Tel: 01795 512 733
Fax: 01795 522 085

Intensive Aquaculture Technology Ltd — Filtration and water treatment
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Soff Lane
Goxhill
Barrow-on-Humber
Lincolnshire
DN19 7NA

Tel: 01469 531 077
Fax: 01469 530 970

Barr & Wray Ltd — Filtration and water treatment
324 Drumoyne Road
Glasgow
G51 4DY

Tel: 0141 882 9991
Fax: 0141 882 3690
E-mail: morgan@barrandwray.com

KoolTech — Chillers
Airside Ltd
Ridgacre Road
West Bromwich
West Midlands
B71 1BB

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Fax: 0121 553 6484

Aqua-Med Ltd — Krill
14 Boxhill way
Strood Green
Betchworth
RH3 7HY

Tel: 01737 842921
Fax: 01737 842062
E-mail: info@aqua-med.co.uk

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Hoogveld 91
Dendermonde
B-9200
Belgium

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Fax: ++ 32 52 25 90 80
E-mail: inveaqua@pop.inve.be

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OX2 0EL

Tel: 01865 206079
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Tel: 01966 22257

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Glasgow
G51 1PX

Tel: 0141 427 3615

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Cambridge
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E-mail: info@camlab.co.uk
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Loughborough
Leicestershire
LE11 5RG

Tel: 01509 231166
Fax: 01509 231893
E-mail: info@fisher.co.uk
Web: www.fisher.co.uk

Laboratory supplies and equipment

Phillip Harris Scientific
Unit E6
North Caldeen Road
Calder Street
Coatbridge

Tel: 01236 437716

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IBC (Melton)
The Old Stable
Mawbrook Farm
Scalford
Melton Mobray
Leicestershire
LE14 4UB

Kick-Start / Kick-Off

Tel: 01664 444505

Hays Chemicals Distribution
61 Paterson Street
Glasgow
G5 8LF

Chloros

Tel: 0141 429 7821

Evans Vanodine International Ltd
Brierley Road
Walton Summit Centre
Preston
PR5 8AH

Buffodine / FAM

Tel: 01772 322200
Fax: 01772 626000

Sigma-Aldrich Company Ltd
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Poole
Dorset
BH12 4QE

Chemicals

Tel: 01202 733114
Web: www.sigma-aldrich.com

McQuilkin & Co
21 Polmeadie Avenue
Glasgow
G5 0BB

Chemicals and laboratory supplies

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Fax: 0141 420 1223
Web: www.merck-ltd.co.uk

ARCO Ltd — Protective clothing, equipment and industrial supplies

For regional supply centre contact:
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Waverley Street
Hull
HU1 2SJ

Tel: 01482 222522
Fax: 01482 218536
E-mail: sales@arco.co.uk
Web: www.arco.co.uk

Northwest Marine Technology — Tags and tagging equipment (European representative)
Foundary Farm
Kiln Lane
Redlynch
Salisbury
Wiltshire
SP5 2HT

Tel: 01725 512523
Fax: 01725 512964
E-mail: nmt@solomon.softnet.co.uk

Micro Mark — Coded tagging wire (fits equipment supplied by above company) and other tags.

Fish Eagle International — (UK representative)
Little Faringdon Mill
Lechlade
Gloucestershire
GL7 3QQ

Tel: 01367 252754
Fax: 01367 253406

Hallprint Pty Ltd — Streamer tags etc
27 Jacobsen Crescent
Holden Hill
South Australia 5088
Australia

Tel: ++ 61 8 261 0312
Fax: ++ 61 8 266 3816

APPENDIX I

Biology, Physiology and Life History

The European Lobster, scientific name *Homarus gammarus* (Linnaeus 1758), is a decapod crustacean. Its more precise lineage, in biological terms, is given below.

Taxonomy of the European Lobster

Phylum:	Arthropoda
Subphylum :	Crustacea
Class:	Malacostraca
Order:	Decapoda
Suborder:	Pleocyemata
Infraorder:	Astacidea
Superfamily:	Nephropoidea
Family:	Nephropidae
Subfamily:	Nephropinae (Homarinae)
Genus:	Homarus

Lobsters have 5 pairs of walking legs (10 in all), the first pair of which is heavily modified to form the large claws (chelae) at the front of the body. The next two pairs of legs also have very small claws at the end and are concerned with moving food to the mouth. The front of the animal comprises the head and thorax, together they form the body (cephalothorax) and are covered by the carapace to form a continuous shield. The abdomen (or tail) has 6 movable segments, each covered by the hard exoskeleton, and ends in a fan-shaped tail of 5 parts. The main external features are shown in figure 9 and their technical names, which are often used in the literature, are summarised below.

Common and technical names for the parts of a lobster

Body area		Feature	Technical name	Other comments
Head	Cephalo -thorax (Body)	Antennae	1st Antennae	antennules (small)
			2nd Antennae	antennae (large)
		Mouth parts	Mandibles	
			1st Maxillae	maxillules
			2nd Maxillae	maxillae
Thorax			1st Maxillipeds	
			2nd Maxillipeds	
			3rd Maxillipeds	
		Walking legs	1st Pereiopods	chelipeds (large claws)
			2nd Pereiopods	chelate (small claws)
			3rd Pereiopods	chelate (small claws)
			4th Pereiopods	
			5th Pereiopods	
Abdomen (Tail)		Swimmerets	1st Pleopods	gonopod (male sex organ)
			2nd Pleopods	
			3rd Pleopods	
			4th Pleopods	
			5th Pleopods	
		Tail	6th Pleopods	uropods
			Telson	

Adapted from a similar table in Factor J R (1995)

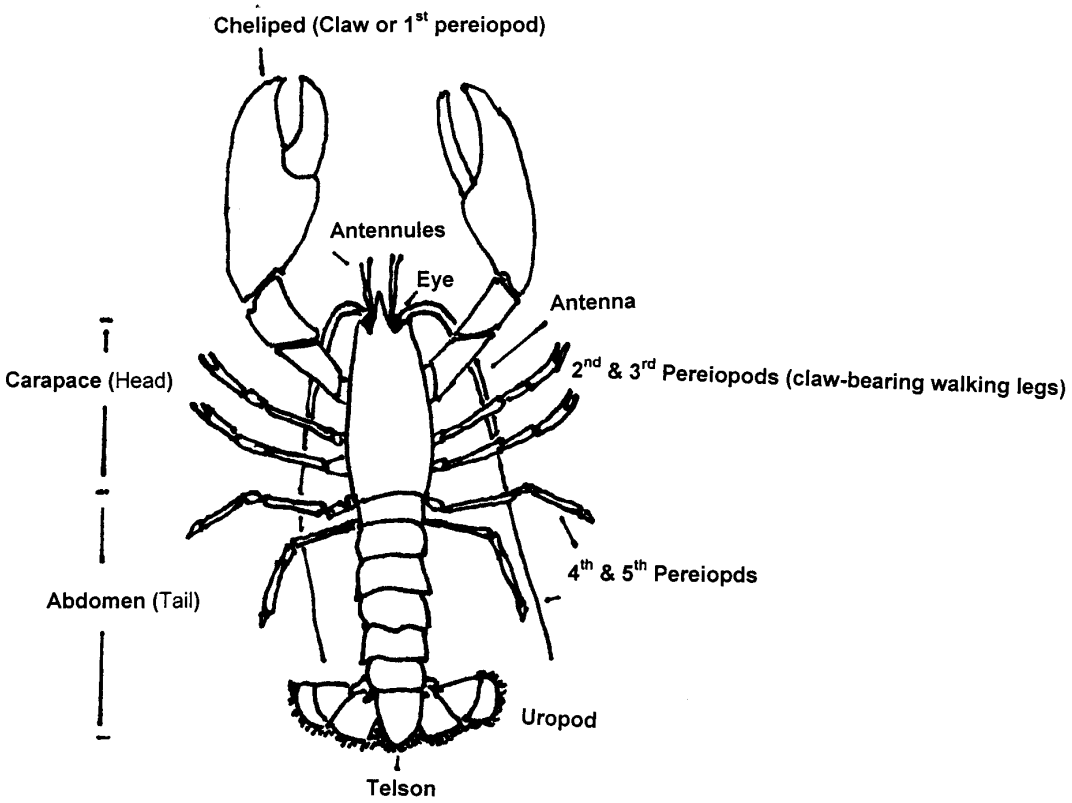


Figure 9: Principle external features of a lobster

Internally, the body contains all the vital organs: brain, heart, stomach, digestive gland/liver (hepatopancrease), major nerves, blood vessel and gonads (ovary or testis), whilst the tail normally houses mainly muscle and the gut, except during the breeding season when the gonads expand to fill up to two-thirds of the length of the dorsal (upper) cavity. The position of the organs is shown in figure 10.

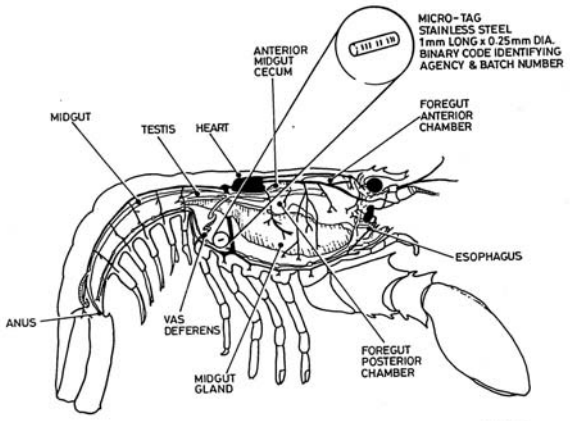
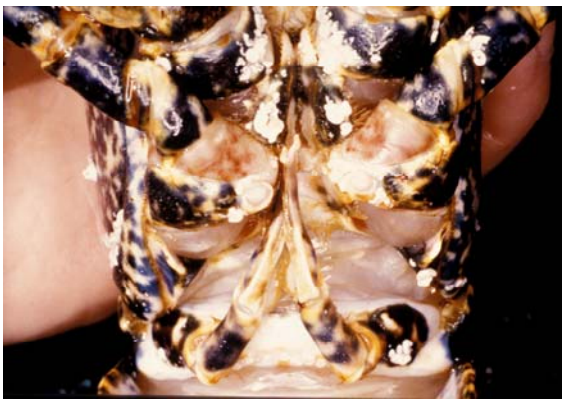


Figure 10: Arrangement of the internal organs of a lobster with the target position for the implantation of a coded wire tag indicated.

As they are enclosed in a hard, rigid exoskeleton or shell, lobsters can only grow in size by moulting or shedding the old shell after growing a new one underneath. A newly moulted animal is very soft and vulnerable, so they seek shelter, and may even block themselves in, before casting. The new exoskeleton is expanded and stretched when it is still soft by the animal taking in water from the outside and

excreting it into the body tissues; hence the watery appearance of the flesh of a newly moulted lobster. The shell hardens over a period of days and the fluid is gradually replaced by extra body tissue as the animal grows and gains weight. The old, cast shell is eaten progressively, starting with the softer elements, by the animal in order to recycle minerals and nutrients. The frequency of moulting varies with size, age and nutrition. Larvae can moult every week and juveniles once or twice per month during the summer. Things slow as they mature, those which are almost adult may moult twice in a good year, whilst mature animals moult, on average, once per year. Males tend to moult in early summer, whilst females moult in late summer, early autumn, after their eggs have hatched.

The sexes, male and female, are separate and the distinguishing external features are shown in plate 37. Both mature around the same size. In the UK this is about 85 mm carapace (body) length (CL), although there are reports of sexually mature animals as small as 75 mm CL. On average, it takes approximately 6 - 7 years for wild animals to reach 85 mm CL. This corresponded with the previous UK minimum landing size (MLS), but in 2002 the MLS was increased to 87 mm CL, thus allowing the animals at least one breeding season before they enter the fishery. Some Sea Fisheries Committees in England and Wales are planning further increases (to 90 mm CL) for their local areas.



Male lobster genital organs

Female lobster genital organs

Plate 37: External diagnostic features of male and female lobsters
(Courtesy of T Scovacricchi)

Mating takes place between a hard-shelled male and a freshly moulted, soft-shelled female. The female is turned on her back with the male above. Copulation is penetrative and brief. The spermatophore from the male is deposited in the seminal receptacle (also called the thelycum or spermatheca) on the underside (ventral surface) of the female. Here it remains until it is used to fertilise the eggs as they are laid.

The sperm themselves are cylindrical in shape and have three rigid spines at the base. The sperm have no flagella and are non-motile. They are large and can be

seen easily under light microscopy. Their structure is very complex and has been the subject of detailed research, particularly in *H. americanus*.

The eggs are laid once the female's shell has hardened. Once more, she rolls onto her back and extrudes the eggs from the opening of the oviducts, across the spermatophore, to fertilise them, and then cements them onto the swimmerets (pleopods) underneath her tail. Newly laid eggs are bottle-green in colour and can be seen, in the UK, beneath females from August to October. A female of 85 mm CL can hold up to 12 000 eggs and the numbers increase as the animals get bigger.

The female tends the eggs under her tail, removing diseased or dead material, providing protection and ensuring a good supply of oxygenated water to the developing brood. As the eggs mature their appearance and colour changes, until shortly before hatching they are a brown-blue colour and the dark eye-spot of the larva can be seen clearly (plate 13). When close to hatch the eggs are approximately 300 – 450 μm in diameter. The speed of embryo development depends upon water temperature. Hatching can begin in the south in March/April, whilst in the north it commences in April/May and continues into September. Many authors report that the peak hatching each day coincides with dawn. During the hatching process, the female adopts a head-down, tail-extended almost vertically (about 70^{o} from the horizontal), posture and fans vigorously with the pleopods (plate 17). A cloud of free-swimming larvae are liberated into the water in short bursts.

Newly hatched larvae are approximately 7 mm in total length (TL) (figure 11.I) and they swim up into the plankton, where they remain and feed for the next 30 days. At this stage they a positively phototaxic (ie they are attracted to light) and negative for geotaxis (ie they swim away from the bottom). During the larval phase, they moult 3 times (figures 11.II and 11.III), finally metamorphosing into a juvenile lobster approximately 12 mm long (TL). This stage is often referred to in the literature as a post-larva (plural: larvae) or Stage IV (being the 4^{th} moult stage) (figure 11.IV).

At this point, they begin to settle on to the bottom, but they do not become truly benthic (bottom-dwelling) until after the next moult (Stage V, sometimes referred to as an Early Benthic Phase or EBP lobster). The juveniles shelter within cracks and crevices in rocky substrates or construct burrow systems in soft sediments beneath stones, where they live, feed and grow for the next 4 years. This hidden or cryptic lifestyle means that very little is known about their habits at this point in their life history. There are observations from the closely related American Lobster (*H. americanus*) and aquarium studies, but there are crucial differences apparent when trying to repeat the results in the field using our native species. Divers report seeing 'small' (estimated 50 - 60 mm TL) juveniles in rock crevices at shallow depths (<5 m) around some coasts.

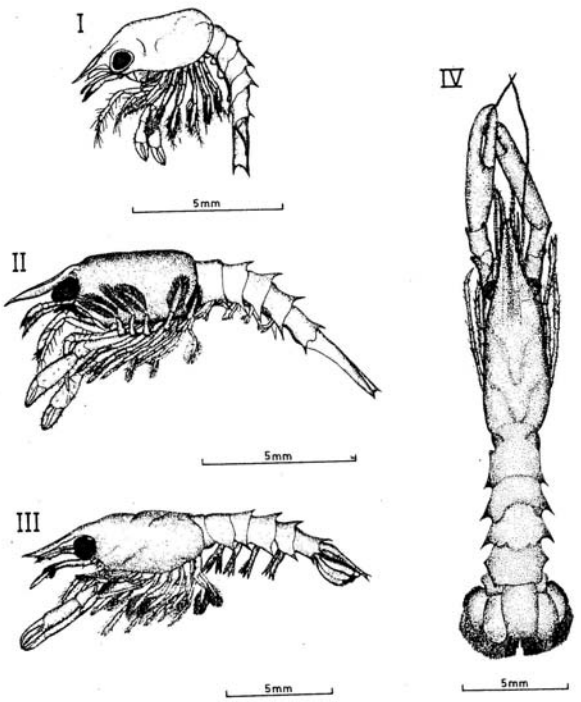


Figure 11: Free-swimming larval stages of the lobster
(from Nichols & Lawton 1978 with permission from ICES)

An increasingly emergent lifestyle for juveniles between 15 - 50 mm CL has been reported for the American Lobster, but this has not been corroborated for its European cousin. However, once our native animal has grown to 40 mm CL (approximately 150 mm TL) it has been shown to begin to emerge from the burrow and forage more openly. They may be seen during such forays and captured in suitable traps for the first time. Commercial fishing gear seldom captures animals below 55 mm CL, but this is a result of their design and construction. At some point, it is not known precisely when, the animals vacate the burrows and begin the adult lifestyle.

An adult lobster of 85 mm CL is approximately 247 mm long (TL), weighs around 450 g and is in moult Stage XXIV (stage 24). They can be found on all types of bottom, but have a preference for rocky substrates which have lots of holes, cracks and crevices. Those captured on soft muds and silts are thought to be in transit to another area. When crossing this type of bottom lobsters are known to dig shallow depressions in which to shelter temporarily.

Once established in an area an adult lobster will have a territory extending approximately 250 m either side of a central point. They will have several lairs within the area and will move freely between them. Territories overlap with those of others and encounters between animals lead to threat displays and trials of strength by pushing and shoving until one backs away. Actual fights, which inflict substantial damage, are thought to be rare in the wild. If conditions are favourable a lobster is thought to spend a majority of its adult life in a relatively small area. However, for unknown reasons, some animals can suddenly undertake extended excursions covering long distances; movements up to 25 miles (40 km) have been recorded. Equally strangely, animals have returned to their territory after several

months away and covering unknown distances. This behaviour seems to be most prevalent in the autumn, but it appears to be unpredictable and the triggers are unknown. Much remains to be discovered about this aspect of their life.

A wide range of food items are eaten, from algae to fish. They are skilled predators, but also take dead material, hence the attraction to bait in traps. Food that can not be eaten immediately is often taken away and stored by burying to be consumed later.

The maximum size and age of a lobster has been the subject of debate for some considerable time. The largest taken in recent times weighed 9.3 kg (20 lb 8 oz) and measured 1 260 mm overall (claw-tip to end of tail). It was caught in Fowey, Cornwall in 1931. Herrick writing in 1895 reports examining a preserved specimen of the European Lobster, of total length 485 mm, (tip of body to end of tail, excluding the claws), calculated to weight between 9.5 - 10.4 kg, and writers from the 16 th Century speak of even larger examples occurring around Orkney and Shetland. There are claims of a 10 kg specimen being taken off Norway in 1988. However, since there is no terminal (or final) moult in this species, it can, in theory, continue to grow until death. Until very recently it was impossible to age wild lobsters. All previous assumptions were based on observations of the growth and size of captive or hatchery-reared specimens and then applied to wild stocks. More accurate ageing may now be possible by measuring the concentration of a pigment (lipofuscin) found in the nerve tissue of the brain. To date, the oldest animal examined by this method was a female estimated to be approximately 72 years old (± 9 years) with a length of 151 mm (CL) and weighing 2.069 kg. Whilst promising, this method has still to be accepted fully by all fishery scientists.

Adult lobsters have few natural predators although both large Cuttlefish (eg *Sepia officinalis*) and Octopus (eg *Octopus vulgaris* and *Eledone cirrhosa*) are known to eat them. The juveniles are eaten by a variety of different animals, mostly fish or other crustacea. They are most vulnerable during the planktonic phase and as they first settle on to the seabed. The following species have been observed predating on juvenile lobsters in Scottish waters, the list is not exhaustive as many others are likely to have done so unobserved. Other species will be important on other coasts.

Cuckoo Wrasse	*Labrus mixtus*
Ballen Wrasse	*Labrus bergylta*
Goldsinny Wrasse	*Ctenolabrus rupestris*
Rock Cook	*Centrolabrus exoletus*
Corkwing Wrasse	*Crenilabrus melops*
Poor Cod	*Trisopterus minutus*
Bib	*Trisopterus luscus*
Pollack	*Pollachius pollachius*
Saithe	*Pollachius virens*
Cod	*Gadus morhua*
Five-bearded Rockling	*Ciliata mustela*
Three-bearded Rockling	*Gaidropsarus vulgaris*
Sea Scorpion	*Taurulus bubalis*

Butterfish	*Pholis gunnellus*
Velvet Crab	*Necora puber*
Green Crab	*Cacinus maenas*
Blue Squat Lobster	*Galathea strigosa*
Long-clawed Squat Lobster	*Munida rugosa*

Gobies of the following species have been observed to 'attack' juvenile lobsters when they are seeking shelter after release. No successful 'kills' were recorded, but larger specimens are undoubtedly capable of taking smaller juveniles.

Black Goby	*Gobius niger*
Common Goby	*Pomatoschistus microps*
Painted Goby	*Pomatoschistus pictus*
Sand Goby	*Pomatoschistus minutus*

Blennies, which occur on suitable substrates, are also likely to encounter and predate juvenile lobsters, although this has never been confirmed. Likely candidates include Shanny (*Lipophrys pholis*), Tompot Blenny (*Parablennius gattorugine*) and the unrelated Yarrell's Blenny (*Chirolophis ascanii*), which is, in fact, related to the Butterfish (above).

History of stock enhancement in the UK

The first well documented attempts at hatchery rearing lobsters began at the end of the 19th Century. Williamson in a paper published in 1905 and other authors of that time attribute the first attempts in the UK to Saville-Kent during 1883, but Fullerton in a paper from 1896 records possibly the first release of '700 000 young lobsters' (probably larvae) from ponds in Brodick Bay, Scotland. He also refers to similar work being done in America by Herrick on behalf of the American Fish Commission. A larval release scheme also ran in eastern Canada from 1891 - 1917.

Further work in the UK was carried out in the 1930s by Smith and co-workers in the Isle of Man, but the most recent developments were begun in the early 1970s by Wickins, Beard and Richards at the MAFF laboratory in Conwy, North Wales. Initially, they drew upon the experience of Hughes, and others in America, who had been studying hatchery techniques and stocking the seas off Martha's Vineyard, New England, with larvae and juveniles since the late 1940s. Methods and equipment were adapted to suit the needs of the European Lobster and by 1983 a small-scale, reliable system had been devised.

Intensive culture was not economically viable and attention then focused on extensive rearing or stock enhancement. Consequently, a partnership was formed between MAFF, the Sea Fish Industry Authority (Seafish) and the North Western and North Wales Sea Fisheries Committee (NWNWSFC) to examine stocking at different sites around the UK. MAFF performed their experiments on

the moraine deposits in the North Sea off Bridlington, Yorkshire; NWNWSFC chose the moraines of Cardigan Bay off Aberystwyth; whilst Seafish worked on the rocky shores of Loch Ceann Traigh, Argyll (Ardtoe) and Scapa Flow, Orkney (figure 12).

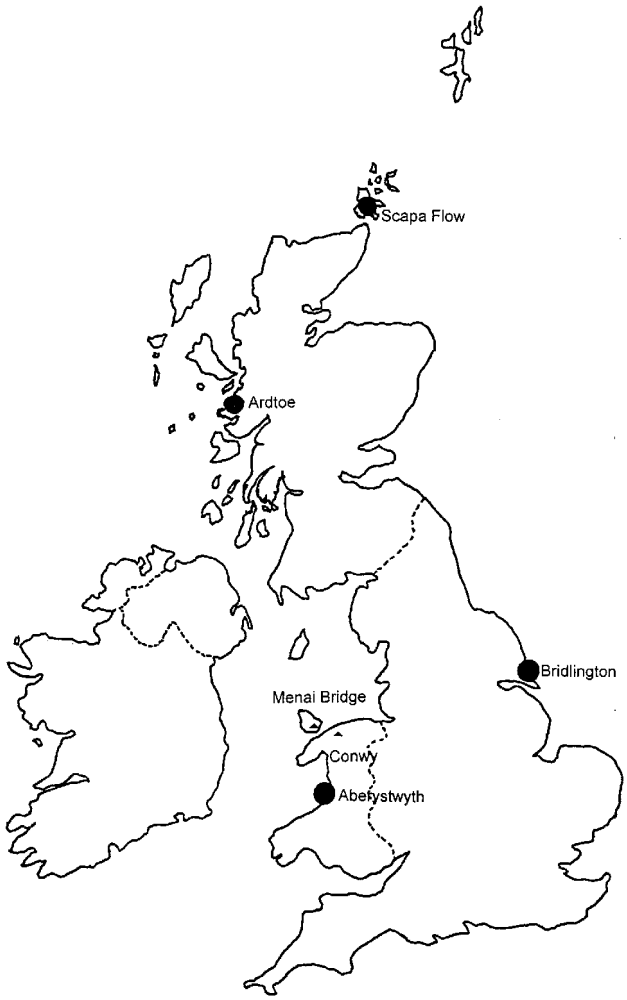


Figure 12: Release locations for the UK lobster stock enhancement trials
(▲ hatchery location)

A unique feature of this programme was that each juvenile released was tagged internally with a small (1 mm long x 0.25 mm diameter) coded wire tag (CWT). This enabled the unequivocal demonstration that any animals recovered were of hatchery origin and also allowed the year and season of release to be identified. Until these trials, all previous stocking had been done as an 'act-of-faith' - a 'we have added more so it must do some good' scenario. A smaller (0.5 mm x 0.25 mm) CWT was implanted during the later trials (phase II).

The main releases took place between 1983 and 1989 and the liberated stocks were monitored until 1996 when all funding ceased. In total, MAFF released approximately 49 000 animals; NWNWSFC just over 19 000; and Seafish 3 000 in to Loch Ceann Traigh and 19 500 in Scapa Flow. A further 8 500 'small' juveniles were released during a second phase of the programme in Loch Ceann Traigh from 1989 - 1992. Funding for all monitoring ceased finally in 1997.

Take-up by industry and other groups

Even before the experimental trials were complete sections of the UK inshore fishing industry were keen to take advantage of the research results. Some elected to wait until the legislative changes described in the introduction were made before proceeding, but others pressed on regardless. The change in the law has also made it easier for prospective programmes to access potential sources of grant aid.

The first non-scientific UK hatcheries, in the early 1980s, were private enterprises, intending to supply juveniles for the pet trade or stocking. They were generally ahead of their time and found the market reluctant to purchase their output. Some converted to tourist-based display aquaria, with the lobster hatchery forming part of the exhibits, whilst others closed.

Later, a successful shellfish merchant in Orkney began very small-scale trials of hatchery rearing along side his holding ponds. He received support from Seafish staff who routinely visited the premises during the course of their experiments in Scapa Flow. Over time the hatchery grew, until, with backing from Orkney Fisheries Association (OFA), the Islands Council and development grants, the first non-scientific release programme began. Today (2001) the expanded hatchery is run by the Fisheries Association. During the 1998/99 season approximately 20 500 juveniles were released around Orkney and animals were also provided for other stocking experiments. A second OFA funded hatchery is planned, the eventual target is an output of 60 000 juveniles per year. The Council and OFA have together applied for a Regulating Order to control the waters around Orkney.

Shetland were not far behind in wishing to have a hatchery of their own. The first small, experimental unit was constructed, with Seafish assistance, at the North Atlantic Fisheries College (NAFC). To increase output, they decided to explore a more mechanised production system and, with an industrial partner, have been developing a semi-automated unit. To date this has met with limited success. A purpose built marine hatchery, which incorporates a new lobster facility, has been constructed and plans for a full-scale stocking programme are in progress. A consortium comprising fishery interests and the Islands Council became the first in Scotland to be granted an extensive Regulating Order covering all their waters in October 1999.

Groups in England and Wales also plan to use the technology. The National Lobster Hatchery, supported by the Cornwall Sea Fisheries Committee and local fishery interests, has opened in Padstow, whilst the two SFCs in Wales are discussing a similar programme for the Principality. Other Committees are examining the prospects for their areas and some have begun initial experiments using juveniles sourced from the existing hatcheries.

The UK trials have had far reaching consequences further afield. The Irish were able to draw upon the results and experience when setting up their hatchery and release programme which was funded by generous support from their government, the US and EU. Spanish researchers requested information in support of two regional stocking initiatives. In Italy, the techniques may be used to repopulate the northern Adriatic, where native stocks are almost extinct. Even

Norway, which had its own very large-scale lobster stocking programme running at the same time, received advice on micro-tagging stocks prior to release and drew support for its own programme from the UK results. Many other countries continue to approach the UK researchers in pursuit of their valuable knowledge and expertise in this field.

APPENDIX II

Eye Index for assessing egg development

The *eye index* is used to estimate the rate of embryo development within the egg. The increase in size of the developing larval eye is measured from a small sample of eggs using a low-power microscope (x 20 – x 50) fitted with a graduated eyepiece. Perkins (1972) established the relationship between the weekly increase in eye size and water temperature (10 – 24 ^{o}C) for American lobsters (*H. americanus*) and Richards & Wickins (1979) applied the same formula to the European lobster (*H. gammarus*) at 13 – 15 ^{o}C.

The larval eye is not apparent within the egg for approximately 9 weeks after spawning.

The *eye index* (*E*) is defined as half the sum of the greatest length (l) and breadth (b) of the eye, measured in microns (μm).

ie. $E = ½ (l + b)$

The time to hatch was then estimated according to the formula:

Time to hatch (weeks) = $\frac{\text{Eye index at hatching – Initial eye index}}{\text{Increase in eye index each week (at each temperature)}}$

$$T_h = \frac{E_h - E_i}{\delta E}$$

The results of the calculations for the European lobster are tabulated below:

Relationship between *Eye Index* and time to hatching for *H. gammarus* eggs at 13 – 15 ^{o}C

***Eye Index(E)* (microns, μm)**	**Time to hatch (T_h) (in weeks ± 2 weeks)**
50 – 100	15
100 – 150	14
150 – 200	13
200 – 250	12
250 –300	10
300 – 350	8
350 – 400	7
400 – 450	5
450 – 500	4
500 - 550	2
600 - 620	Hatch imminent
640 - 680	Hatch imminent

Adapted from Richards & Wickins (1979) and Charmantier & Mounet-Guillaume (1992)

Increasing the incubation temperature will shorten the time to hatching; reducing the temperature will increase the time.

APPENDIX III

Example dosage regimes for chemical therapeutants

These are intended solely as examples. YOU MUST CONSULT THE DATA SHEETS, A VET OR THE CURRENT SCIENTIFIC LITERATURE FOR DEFINITIVE INFORMATION **BEFORE** STARTING A TREATMENT

Chemical	Disease	Stage	Treatment method	Quantity of chemical	Quantity of water	Target concentr-ation	Exposure time	Frequency
Malachite Green *	Shell disease	Larvae‡	Dip	20 mg	1 litre	20 ppm	8 min (max)	
	Microbial epibionts	Eggs		5 mg		5 ppm	10 min	Once
		Larvae‡				5 ppm	2 min	Every 2 days
	Langenid-ium	Eggs				5 ppm	10 min	Once
		Larvae‡				5 ppm	2 min	Every 2 days
	Haliphth-oros	Larvae‡ and Juveniles	Bath	0.25 mg		0.25 ppm	Indefinite	
		Post-larvae and Adults	Dip	2.00 – 4.22 mg			25 – 60 min	
			Dip	67 mg			10 – 30 sec	
Furanace	*Haliphth-oros*	Larvae and Juveniles	Bath	2.5 mg	1 litre	2.5 ppm	Indefinite	
Acriflavine				0.02 – 0.05 mg	1 litre			
Methylene Blue				2.11 – 8.71 mg	1 litre			
Kick-Start		Eggs	Dip	4 ml	996 ml	1:250	30 – 60 sec	Once
Buffodine		Eggs	Dip	10 ml	990 ml	1:100	10 min (max)	Once
Betadine	All	Female with eggs	Dip, excluding gills and mouth parts	10 ml	990 ml	1%	7 min (max)	Once
Freshwater	*Pseudo-carcino-nemertes homari*	Eggs	Dip				4 min	Once

*** Important Note**: The use of malachite green is no longer permitted under EU legislation and its use is severely restricted in many other parts of the world. At present there are no alternative permitted products on the market. UK hatchery operators are advised to consult CEFAS Weymouth or FRS Aberdeen for advice. In all other areas, operators must consult a qualified vet or the relevant national legislation to establish whether and under what circumstances it can be used.

‡ Where the use of malachite green is permitted, as a general guide for the larval stages **do not exceed** exposures of 8 ppm for 16 min or 20 ppm for 8 min.

Antibiotics that have been used in lobster culture

The use of antibiotics in a lobster hatchery can seldom be justified. They should be the treatment of last resort and only used under extreme circumstances. Their disadvantages often out-weigh their perceived advantages. In the UK, they can only be used under the supervision of a Vet. No UK hatchery has resorted to any of them to date.

Agent	Organism
Streptomycin	*Leucothrix mucor* *Aerococcus viridans* var *homari* Epibionts
Oxytetracycline	*Aerococcus viridans* var *homari*
Vancomycin	*Aerococcus viridans* var *homari*
Penicillin	*Aerococcus viridans* var *homari* *Leucothrix mucor* Epibionts
Neomycin	Epibionts
Sulphonamides	Bacterial diseases in general

APPENDIX IV

Dissolved oxygen concentrations

The solubility of oxygen in seawater varies with temperature and salinity. Meters that measure dissolved oxygen concentrations often present the result in term of milligrams per litre (mg l^{-1}) rather than percentage saturation. The table below presents values for dissolved oxygen (mg l^{-1}) that represent 100% saturation for the temperatures and salinity ranges likely to be encountered by the hatchery operator.

Dissolved oxygen concentrations (mg l^{-1}) at different salinities and temperatures:
values for 100% saturation.

Temperature (°C)	Salinity (°/oo)		
	25	**30**	**35**
10	9.621	9.318	9.024
11	9.412	9.117	8.832
12	9.210	8.925	8.648
13	9.017	8.739	8.470
14	8.830	8.561	8.300
15	8.561	8.389	8.135
16	8.478	8.223	7.976
17	8.311	8.064	7.823
18	8.151	7.910	7.676
19	7.995	7.761	7.533
20	7.846	7.617	7.395
21	7.701	7.479	7.262
22	7.561	7.344	7.134
23	7.426	7.214	7.009
24	7.295	7.089	6.888
25	7.168	6.967	6.771

Adapted from Spotte (1992) and Parsons *et al* (1984)

Intermediate values can be extrapolated by interpolation between the values given.

APPENDIX V

Salinity measurement

Some hatcheries will be unable to afford electronic salinity meters which provide a direct read-out of the result. They are more likely to use the most affordable method – the hydrometer. This measures the specific gravity of the liquid. The result then has to be converted to salinity using the formula below. To assist hatchery operators, the readings for specific gravity and their salinity equivalents, for values most likely to be encountered, are tabulated below.

Conversion of specific gravity (SG) to salinity ($^{o}/_{oo}$) at different temperatures

	Temperature (^{o}C)															
SG	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
1.019										25.8	26.1	26.5	26.8	27.2	27.5	27.9
1.020					25.7	25.9	26.2	26.5	26.8	27.1	27.4	27.8	28.1	28.5	28.9	29.2
1.021	26.1	26.3	26.5	26.7	27.0	27.2	27.5	27.8	28.1	28.4	28.8	29.1	29.4	29.8	30.2	30.6
1.022	27.4	27.6	27.8	28.0	28.3	28.5	28.8	29.1	29.4	29.7	30.1	30.4	30.8	31.1	31.5	31.9
1.023	28.7	28.9	29.1	29.3	29.6	29.8	30.1	30.4	30.7	31.0	31.4	31.7	32.1	32.4	32.8	33.2
1.024	29.9	30.1	30.4	30.6	30.9	31.1	31.4	31.7	32.0	32.4	32.7	33.0	33.4	33.8	34.2	34.5
1.025	31.2	31.4	31.7	31.9	32.2	32.4	32.7	33.0	33.3	33.7	34.0	34.3	34.7	35.1	35.5	35.9
1.026	32.5	32.7	33.0	33.2	33.5	33.7	34.0	34.3	34.6	35.0	35.3	35.7	36.0			
1.027	33.8	34.0	34.2	34.5	34.8	35.0	35.3	35.6	35.9							
1.028	35.1	35.3	35.5	35.8	36.0											

Adapted from Spotte (1992) and Parsons *et al* (1984)

Intermediate values can be extrapolated by interpolation between the values given.

Lobsters should not be subjected to salinities of less than 27 $^{o}/_{oo}$ or greater than 35 $^{o}/_{oo}$ for prolonged periods.

The equation for converting specific gravity to salinity is:

$$\text{Salinity } (^{o}/_{oo}) = 1.1 + 1300\ (SG - 0.999)$$

Readings taken directly from a hydrometer may require a correction factor to be applied depending upon the temperature. See the manufacturer's instructions for the specific make and model.

Glossary

Aerobic A process taking place in the presence of oxygen.

Anaerobic A process taking place in the absence of oxygen.

Artemia See Brine Shrimp.

Berried Refers to females bearing eggs under the tail.

Betadine Aqueous Providone Iodine solution. Used for in medicine for preparing (sterilising) operation sites. Similar to Buffodine.

Brine Shrimp A small shrimp-like crustacean which occurs naturally in many highly saline inland environments. It forms very resistant egg-carrying cysts when the lakes dry up during the summer. These can be harvested, stored and then incubated and hatched at will. The scientific name is *Artemia salina*.

Buffodine A preparatory iodine-based solution used for disinfecting fish eggs. Together with similar iodine-based compounds they are often referred to as *iodophores*.

Carapace The covering of the front half of a lobster – the 'body'.

Carapace length The distance between the rear of the eye socket and the back of the 'body', measured along the centre-line.

Catch-per-unit-effort (cpue) The average number of animals caught for a given level of fishing effort. Effort can be measured in terms of the number of traps fished, or per hour, or for any other unit defined by the author. For crustacean fisheries *cpue* is usually measured in catch-per-100-trap-hauls.

Cephalothorax The 'head' and 'thorax' of a lobster, which together form the 'body'.

Chelae Claws

Chloros Trade name for Sodium Hypochlorite (NaOCl) solution (available Chlorine 14 / 15%).

Cohort A year-class of animals all spawned or recruited in the same year.

Creel See Pot.

Crustacean Animals belonging to the Phylum Arthropoda, subphylum Crustacea. A diverse group usually taken to mean lobsters, crabs and shrimps, but it also incorporates others, such as barnacles and many less well-known types.

Denitrification Generally taken to mean the aerobic process of converting ammonia (NH_3)/ammonium (NH_4^+)-based waste products to nitrite (NO_2^-) and finally nitrate (NO_3^-). More correctly, the process continues by firstly reducing nitrite or nitrate to their gaseous oxides (Nitrogen oxide [NO] and Dinitrogen oxide [N_2O]) before a final reduction to gaseous Nitrogen (N_2) which can be liberated from solution.

Dorsal Back or upper surface of the body.

Early Benthic Phase Also written as EBP. A juvenile lobster which has settled to the bottom and is living within a burrow system in the substrate.

Exoskeleton The hard, ridged exterior shell of a lobster, crab, or shrimp, which provides protection and support for all the internal organs.

Eye Index A method of assessing the time until a batch of eggs will hatch. Derived by measuring the length and breadth of the eye of the developing larva in the egg (see Appendix II).

Flow-through system Also known as Flow-to-waste. A rearing system where the water passes through the tanks once before flowing to waste.

Geotaxic Deliberate movement in response to gravity; movement towards is described as *positive*, away is described as *negative*.

Gonopod Modified swimmerets on the first tail segment, forming the male sexual organ.

Gonopores The external openings of the reproductive ducts. These are the oviducts in the female and the vas deferens in the male.

'Green-water' system A system of rearing marine larvae in tanks containing high concentrations of micro-algae. Pioneered in Japan. The algae do not necessarily form part of the nutrition of the larvae, but are thought to help to maintain water quality by consuming waste products from the larvae.

Instar See Moult stage

Iodophor See Buffodine.

Ion In water chemistry: when some compounds are dissolved in water they split into a positively-charged and a negatively-charged fraction. These are the *ionic* forms.

Kick-Start® Preparatory solution of Peracetic Acid (CH_3COOOH) [5%], Hydrogen Peroxide (H_2O_2) [20%], Acetic Acid (CH_3COOH) [10%], Ethoxylate Alcohol ($C_2H_5OCH_2CH_2OH$) [1.2%] and Water (H_2O) [63.8%].

Krill — Shrimps from the family Euphausiacae. Usually from Polar regions.

Lipofuscin — A naturally occurring pigment found in the neural tissue of many animal groups, including humans. Its concentration appears to increase in a predictable fashion with time.

Metamorphosis — A point in the life-history where the appearance of the juvenile form is transformed in to that of the adult – usually a large change (eg tadpole to frog etc).

MLS — Minimum landing size. It is illegal to retain or sell animals below this size and they must be returned to the sea speedily after capture.

Moult — The act of replacing an old shell with a new one which can accommodate growth.

Moult stage — A numeric value, usually given in roman numerals (but can also be Arabic), used to describe the developmental point in the life cycle. It is usually one more than the number of moults undergone (eg Stage I = 1^{st} life form, no moult [just after hatch]; Stage IV = 4^{th} life form, 3 moults [I $\Rightarrow$ II $\Rightarrow$ III $\Rightarrow$ IV]). Also called *instar* in some literature.

Mysid — An esturine shrimp from the family Mysidae. Many different species. Also known as Possum shrimps.

Nauplius — The name for the larval forms of many shrimps (plural: Nauplii).

Overall length — The length of the animal measured from the tip of the claws (extended to full extent) to the end of the tail.

Ovigerous — Egg-bearing, the same as *berried*.

Ozone — A highly reactive form of oxygen (O_3) produced by electrical discharge under controlled conditions. Ozone spontaneously decomposes to form gaseous oxygen (O_2) and an oxygen free-radical (O^{2-}). It is the oxygen free-radical that is toxic to biological life, disrupting the biochemical process of the cell, thus giving ozone its sterilising effect.

Pecking order — A hierarchy whereby the stronger animals dominate the weaker. Each individual knows its position in relation to the others. (First described in chickens, hence the name).

Pereiopod — A walking leg

pH — A scale to measure the acidity of a liquid. pH 7 = neutral, less than 7 = acidic, more than 7 = alkaline. The further from 7 the greater the strength of the solution (ie pH 1 = very acid, pH 14 = very alkaline).

Phototaxic Deliberate movement in response to light; movement towards the light is described as *positive*, away is described as *negative*.

Pleopod A paddle-shaped swimmeret under the tail.

ppm Abbreviation for *parts per million* = mg l^{-1}

psu Abbreviation for *practical salinity units*. A measurement of salinity. Almost identical for practical purposes to *parts per thousand* ($^{o}/_{oo}$, see below)

Pot A passive, baited trap used to catch lobsters, crabs and shrimps. Designs vary around the country and around the world.

Recirculation A rearing system where the same water passes round the system many times. There may be limited top-up with new water.

Recruitment The size or age when animals enter a particular phase, eg. the fishery.

Regulated Fishery Order An order granting the right to regulate molluscan or crustacean fisheries in a designated area to a named body or individual. These operate over and above national controls.

Rostrum The spine at the front of a lobster, which begins between the eyes.

Sea Fisheries Committee A body established in England & Wales to control and regulate fisheries on a local scale. They have the power to make by-laws with the agreement of the Secretary of State.

Seminal receptacle A small pouch on the ventral surface of a female, just behind the opening of the oviducts (*gonopores*), designed to receive the *spermatophore* from the male during mating.

Several Fishery Order An order granting the sole right of harvest for a named species (can be more than one) of mollusc or crustacea within a defined area to a named individual or group for a set period of time.

Spermatheca See Seminal Receptacle

Spermatophore The sperm-containing package transferred from the male to the female during mating.

Spp Abbreviation for species, where there is more than one with the same generic name, but they are generally known by the same common name.

Stock In the wild: A self-sustaining population of a particular species. In the hatchery: the animals within the various hatchery areas.

Telson Middle segment of the tail fan.

Thelycum — See Seminal Receptacle.

Total length — The length of the animal measured from the tip of the *rostrum* to the end of the tail along the back.

Trap — See Pot.

Uropod — An outer segment of the tail fan (4).

Ventral — Front or lower surface of the body.

V-notching — A fishery management scheme whereby a V-shaped notch is cut in the tail (preferably the *uropods*, do not cut the *telson*) of an egg-bearing female when she is caught in the wild. She is then returned to the sea so that the eggs can hatch. The notch disappears progressively with each succeeding moult. Whilst the notch is still visible, the animal can not be landed for sale, even if she has no eggs. If the animal is caught again with eggs, then the notch is renewed. In this way a standing stock of reproductive females is created.

X^x — Scientific notation for *square* or *cubic*. Eg. m^2 = square metre, m^3 = cubic metre etc. [Also a number to the power ^{x} Eg. $2^2 = 4$, $3^2 = 9$ etc]

X^{-x} — Scientific notation meaning *per*. Eg. m^{-1} = per metre, m^{-2} = per square metre, m^{-3} = per cubic metre, min^{-1} = per minute, h^{-1} = per hour etc. [Also the ^{x} Root of a number Eg. 9^{-2} = square root of 9 = 3]

X_x — Scientific notation denoting the number of molecules of an element in a compound. Eg. N_2 = two molecules of nitrogen = gaseous nitrogen; H_2O = two molecules of hydrogen plus one of oxygen = water.

$X_x^{x-/+}$ — Scientific notation used to show the electrical charge of the ionic form of a compound when in solution. Eg. NO_3^- = the nitrate ion which has a single negative charge; SO_4^{2-} = the sulphate ion which carries a double negative charge; H^+ = the hydrogen ion which has a single positive charge; Ca^{2+} = the calcium ion with a double positive charge.

<X — Scientific notation denoting *less than* the value given.

>X — Scientific notation denoting *greater than* the value given.

$^o/_{oo}$ — Scientific notation denoting *parts per thousand* (Eg. 35 $^o/_{oo}$ = 35 g per 1 litre). Commonly used when giving the salinity of seawater.

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Over the years that the lobster stock enhancement trials were conducted many, many people played important parts. I trust that those I forget to thank by name will forgive me and accept my thanks in any event.

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