

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
DIRECTORATE OF FISHERIES RESEARCH

FISHERIES RESEARCH TECHNICAL REPORT
NUMBER 92

**Techniques for the production of
juvenile lobsters
(*Homarus gammarus* (L.))**

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LOWESTOFT
1992

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Fish Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft, (92): 22pp.

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1. INTRODUCTION

The feasibility of supplementing natural lobster stocks with hatchery-reared juveniles is being examined in Britain by the Ministry of Agriculture, Fisheries and Food (MAFF), who has released them into the wild at Bridlington Bay, Yorkshire (Howard, 1982, 1988; Wickins, 1983), the North Western and North Wales Sea Fisheries Committee, operating at Cardigan Bay, Dyfed, Wales (Anon., 1984a) and the Sea Fish Industry Authority working in the Orkney Islands (Anon., 1984b). Trials involve the mass production and release of juvenile lobsters, each tagged with an internal micro-wire tag modified from salmon tagging equipment (Wickins *et al.*, 1986). Juveniles are released onto areas of sea bed which have previously been identified as being suitable habitats for juvenile lobsters.

The minimum numbers of lobsters needed to yield a useful number of returns was estimated to be 10 000 lobsters per year for five years (R.C.A. Bannister, 1983, personal communication). The size of the available rearing facilities dictated that each year the lobsters would have to be reared in two consecutive batches of 5 000 animals and this, combined with the desire to release them when sea temperatures were over 10°C, dictated that release would have to be timed for May and September of each year. The smallest lobsters which could be tagged with consistent accuracy were of 9-15 mm carapace length. Thus, the stocking and husbandry regimes were scaled to meet this release size. Following five years of releases (1983-1988), a further

five years are being spent monitoring commercial catches, analysing returns of tagged lobsters and conducting complementary experiments both in the laboratory and in the fishery.

This report describes techniques for the mass culture, tagging and transportation of juvenile lobsters, developed at MAFF's Fisheries Laboratory at Conwy, North Wales. The methods described are those used during the final year of production at Conwy; steps towards the development of these techniques are described elsewhere (Richards and Wickins, 1979; Beard *et al.*, 1985; Wickins *et al.*, 1986, 1987; Wickins, 1986).

2. SEA-WATER SUPPLY

Sea water was pumped at high tide from the Conwy estuary, to an outdoor 450 m³ concrete storage tank. A temperature-salinity monitor, linked to a chart recorder, gave an indication of changes occurring during storage. The sea water was continually recycled through each of two Lacron high-rate 1.41 m³ sand filters at up to 42.5 m³ h⁻¹.

The sea water was pumped on demand from the storage tank to a covered 6 m³ header tank (labelled H1 in Figure 1), from which water flowed by gravity through a plastic 3.8 cm diameter float valve into a 450 l glass fibre (GRP) tank in the lobster production building. This water was recycled continually through a 61 cm diameter Lacron high-rate 0.13 m³ sand filter, via a

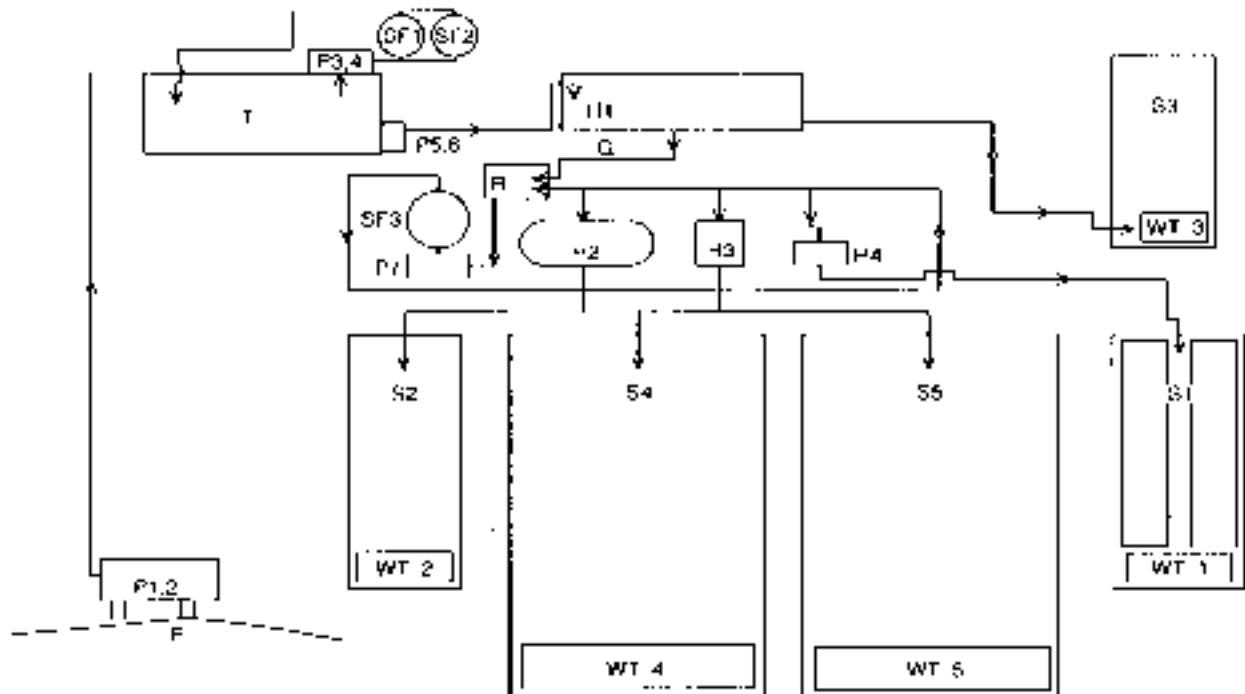


Figure 1. Plan of the laboratory sea-water supply and feeds to the lobster culture systems. **Key:** E = estuary; P1 and 2 = main sea-water pumps; T = main storage tank; P3 and 4 = recirculation pumps for SF1 and 2 sand filters; P5 and 6 = feed pumps to H1 (laboratory header tank); G = gravity feed to R (reservoir); P7 = circulating pump; SF3 = sand filter supplying ring main to header tanks H2 (heated), H3 and 4 (unheated); S1 = broodstock system; S2 and 3 = larvae culture systems 1 and 2; S4 and 5 = juvenile culture systems 1 and 2; and WT1-5 = water treatment units containing biological filter, foam column, sump and pump. Not to scale

distribution ring main at up to 14.6 m³ h⁻¹. The ring main fed three other header tanks, two of which were fitted with thermostatically controlled, titanium, electric immersion heaters, through float valves. Water from these tanks fed four separate culture systems. A fifth system was fed directly from the header tank (H1 in Figure 1).

3. GENERAL CULTURE CONDITIONS

The rearing processes were conducted in five separate open recirculation systems: one broodstock system; two larvae culture units; and two on-growing systems. All broodstock and on-growing tanks were of grey GRP; pipework, valves and fittings were of uPVC. Centrifugal pumps, incorporating plastic housings and stainless-steel shafts, were used throughout. One to three pumps, each delivering up to 11 000 l h⁻¹, were used in each system. Cylindrical, percolating biological filters were made by joining curved sections of corrugated plastic roofing sheet together with nylon bolts. The cylinders were filled with randomly packed plastic rings of specific surface area 164 m² m⁻³ (Filterpak, Mass Transfer Ltd.). Details of water volumes, filter sizes and hydraulic loads are presented for each culture system in Table 1. A 22 l capacity foam separation column, made of 110 mm uPVC

drainpipe, was incorporated into each system (Figure 2). All new tanks and fittings were leached for 14-21 days in several changes of sea water before use.

For two months prior to the introduction of animals, the biological filters in each recirculation system were 'matured' by the daily addition of a solution of ammonium citrate in fresh water. This chemical encouraged the development of microbial growths, which oxidised both organic and inorganic nitrogenous wastes. The quantity added was calculated to produce approximately 1 mg l⁻¹ of total ammonia nitrogen in the recirculating water. During this conditioning period, the addition of new sea water was kept to about 5% d⁻¹ to avoid undue dilution of dissolved nutrients. A complete water change preceded the introduction of animals.

Lobsters were exposed to a natural photoperiod at a light intensity of up to 10 lux at the water surface. During normal husbandry operations (0830 h to 1630 h daily), fluorescent strip lighting increased the intensity in exposed tanks to about 200 lux. Broodstock were kept at a lower light intensity (5-10 lux).

The larvae culture vessels were either 40 l GRP, round-bottomed, cylindrical bins (Hughes *et al.*, 1974) built in the laboratory or proprietary 100 l polyethylene hoppers

Table 1. *Details of capacities and flow rates for the five lobster culture systems*

	S1	S2	S3	S4	S5
System volume (l)	3 322	1 207	744	6 212	12 116
Culture volume (l)	3 000	800	400	1 966	1 638
Treatment unit volume (l)	322	407	344	4 246	10 478
Volume of treatment unit (%)	10	34	46	68	86
Biofilter volume (l)	122	122	122	760	747
Hydraulic load (m ³ m ⁻³ d ⁻¹)	177	443	161	114	21
Mechanical filter volume (l)	w	63	w	w	w
Number of pumps	1	1	1	3	2
New sea-water bleed (l h ⁻¹)	60	554	200	500	90
Flow per vessel (l h ⁻¹)	2 552	720	453	756	756
Flow per foamer (l h ⁻¹)	330	330	330	330	330
Flow per mechanical filter (l h ⁻¹)	-	2 300	-	-	-
Time to 50% exchange with new water (h)	36	1.4	2.5	8.5	90

Key: w = Terylene wool wadding

S1 = Broodstock holding and egg incubation

S2 = Larvae culture 1

S3 = Larvae culture 2

S4 = Juvenile culture 1

S5 = Juvenile culture 2

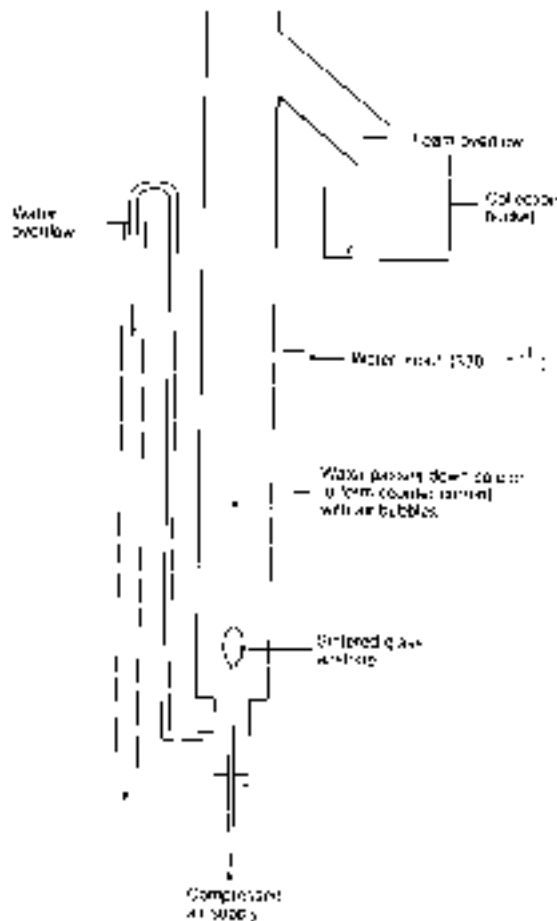


Figure 2. Simplified sketch of the foam separation column

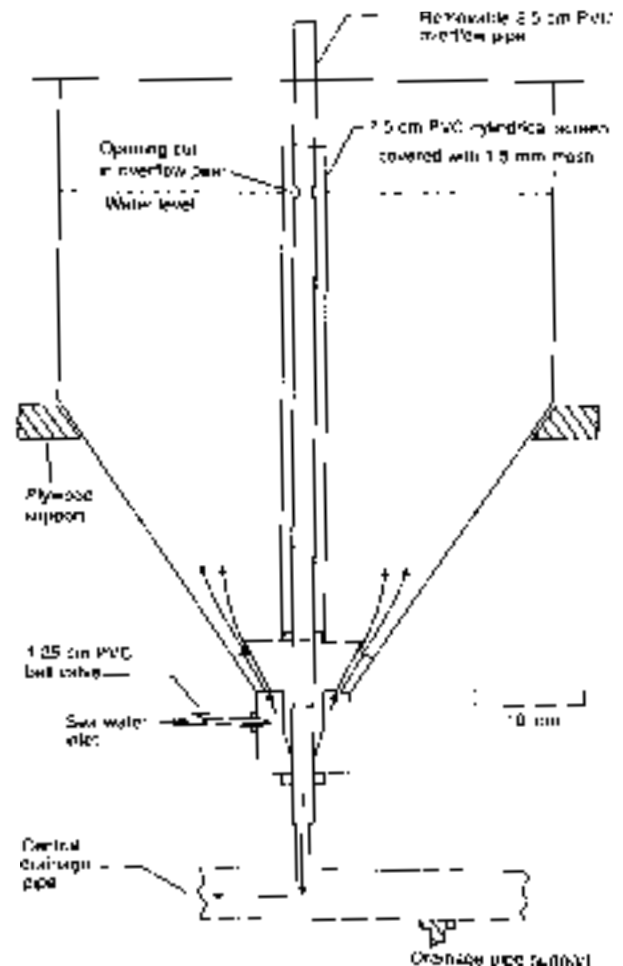


Figure 3. Section through a 100 l capacity larvae culture vessel

(Figure 3). Further details are given in Section 5, while aspects of the development and performance of these marine recirculation systems are described elsewhere (Beard *et al.*, 1985; Richards and Wickins, 1979; Wickins and Helm, 1981; Wickins, 1985; Al-Hajj, 1986).

4. BROODSTOCK

Wild-caught, egg-bearing females were purchased from merchants in February/March and again in September/October of each year. Females were purchased only from merchants who were known to have had a disease-free record. Only lobsters in good physical condition, bearing 'full' clutches of eggs, were selected. Animals bought in February/March had eggs at an advanced stage of development, which were orange-red in colour, with eyes almost circular, and of a diameter of approximately 300-450 μm . Animals obtained in September/October had newly deposited eggs, which were black in colour with no sign of eye development within the egg.

The lobsters were packed in 120 l GRP tanks, in three layers each separated by damp sacking, in preparation for the journey by road to Conwy. Ice packs were often placed on top of the sacking during the September/October shipments. Approximately 40 lobsters were purchased on each occasion. Half of these had eggs at a slightly less advanced stage of development than the others, which was seen to be a precaution against egg loss in transit or subsequent mortality occurring later in the laboratory. At the laboratory, they were housed in equal numbers in two raceways in an 'open' recirculation system supplied with a continual flow of filtered, natural sea water for between 7 weeks (February/March broodstock) and 18 weeks (September/October broodstock). Two to three females were examined each week during the incubation period to monitor egg development and to check for any egg loss.

The raceways each contained three blocks of seven uPVC shelters (Figure 4). Temperature and salinity generally ranged from 14-16°C and 28-32 practical salin-

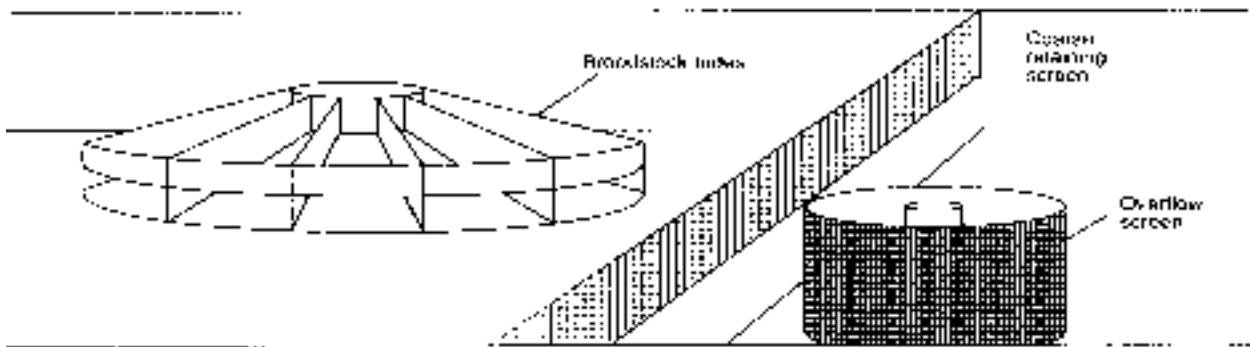


Figure 4. Sketch of broodstock holding tank showing hides (with lid removed) and larvae collection area (right)

Table 2. Maintenance of broodstock

Procedure	Duration	Frequency
Prepare food - thaw shrimps	1 h	5 days per week
- shuck mussels	"	2 days per week
Remove detritus and uneaten food	"	Daily
Feed lobsters	"	"
Clean pipes and reservoirs	"	Every 2 weeks
Collect and count larvae	Ca 1 h	Twice daily in season
Collect, count and freeze surplus larvae	"	As required.

ity units (psu) (UNESCO, 1981) respectively. The lobsters were fed at about 1% of their body weight d^{-1} . On five days of each week, sand shrimp, (*Crangon*—stored frozen but thawed before use) were fed. Fresh mussel (*Mytilus*) was provided on the remaining two days of each week. The time taken to prepare food, to remove detritus and uneaten food from the broodstock tanks and to feed the females was approximately 1h d^{-1} , and a further 1h was spent each fortnight on cleaning other parts of the system (e.g. the reservoir and pipes). A typical maintenance routine is given in Table 2.

Upon hatching, the larvae drifted with the current towards one end of the tank, through a 2 cm mesh screen and were collected using a small, rigid dip net. They were protected from the overflow pipe by a cylindrical 2 mm mesh screen. To estimate their numbers, the larvae were transferred to 7 l of water in a 10 l plastic bucket and mixed well but gently with a disc plunger before five aliquot sub-samples were taken and the number of larvae counted. Larvae which were surplus to rearing requirements were washed in fresh water, placed in 400 g batches in plastic tubs, covered with fresh water and frozen for use later as a dietary supplement for the

juveniles. After the eggs had hatched, each female was tested for the presence of gaffkaemia, but over the five years of trials, none was found to be positive.

5. LARVAE CULTURE

Two separate larvae culture systems, each fed from a different water supply, were employed as a safeguard against failure of a single system. The primary system of 1207 l capacity (Figure 5) consisted of 10 conically-bottomed, 100 l polyethylene hoppers (containing 80 l of sea water) fitted with a semi-tangential water distributor inside the base, a 250 l reservoir, a washable Terylene wadding filter pad, two centrifugal pumps, a biological filter (120 x 36 cm in diameter), a foam fractionation column and a 40 cm diameter Lacron high-rate sand filter (for filter flow rates and volumes, see Table 1). Flow rates were checked and adjusted daily. The secondary system contained ten 40 l GRP vessels, with no sand filter and only one pump but, in all other respects was similar to the primary system.

Each vessel was stocked sequentially with newly hatched stage 1 larvae at densities of 25 and 37 larvae l^{-1} (2 000 and 1 500 larvae per vessel) for the 100 l and 40 l vessels respectively. In order to reduce size differences,

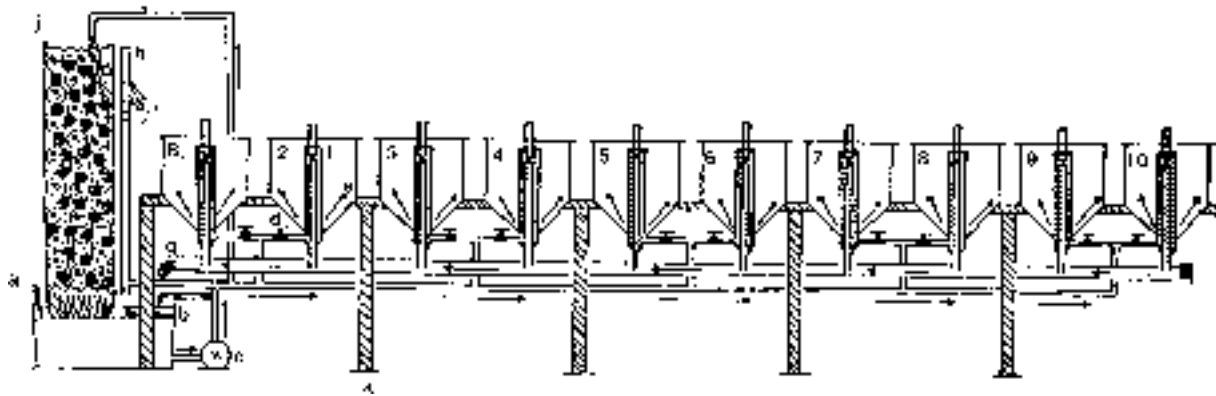


Figure 5. Section through the primary larvae culture system showing culture vessels (B1-10) and the arrangement of water feed and drain pipes. Key: (a) reservoir tank; (b) Terylene wool filter; (c) circulation pump; (d) inlet control valve; (e) upwelling water flow; (f) overflow and screen; (g) return pipe; (h) foam fractionation column; (i) foam effluent; (j) biological filter; and (k) support stand. Not to scale

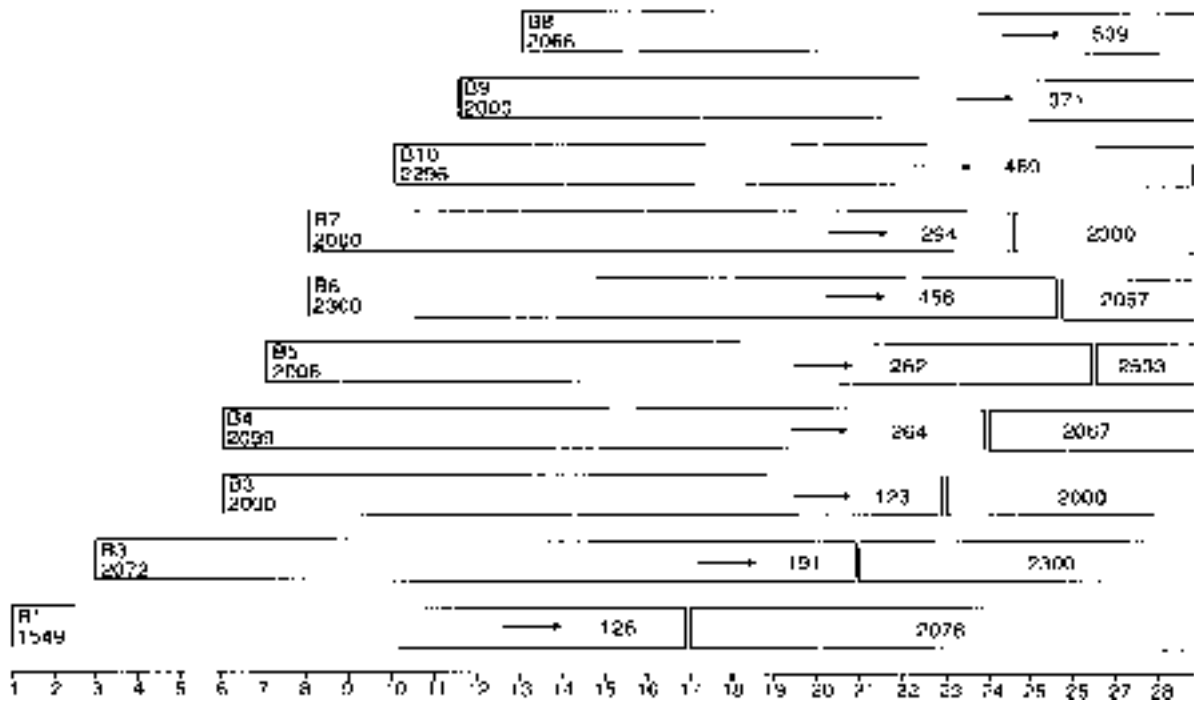


Figure 6. A typical stocking and harvesting schedule for 10 larvae culture vessels (B1-10) in the primary system. The numbers of larvae stocked are shown at the beginning of each horizontal bar, juveniles harvested are at the end. After harvesting, the vessels are restocked

and avoid cannibalism during the later stages of culture, each vessel was stocked with larvae hatched within a two-day period. A gap of one to two days was allowed between stocking the vessels, particularly during the start of each rearing season, to limit the rate at which the load on the water treatment units built up.

After about two weeks, the newly moulted stage 4 lobsters were easily distinguished from the pelagic larvae (stages 1-3) because they swam forwards with claws held out in front and with the dorsal side upper-

most. They were removed individually to the on-growing systems on the day when they first appeared to swim in this position. Vessels in which about 90% of the larvae had reached stage 4 were cleaned and restocked. A typical stocking and harvesting sequence is shown in Figure 6.

All larvae were fed twice daily with mysid shrimp (*Neomysis* sp.) purchased in frozen blocks from aquarist suppliers. The blocks were broken to provide sufficient feed for the day and thawed in sea water immediately

Table 3. Total amount of food added each day to the primary larvae culture system from the time of initial stocking with larvae. The time sequence corresponds to that in Figure 6 for days 1-25

Day	<i>Artemia</i> nauplii (x 10 ⁶)	Frozen mysids (g)
1	Not fed	50
2	0.5	50
3	Not fed	160
4	0.5	130
5	0.5	130
6	1.6	260
7	Not fed	380
8	2.1	430
9	1.8	650
10	Not fed	730
11	1.6	830
12	2.0	755
13	2.0	800
14	1.75	524
15	1.5	494
16	1.5	457
17	Not fed	546
18	1.5	381
19	2.25	336
20	1.5	375
21	2.0	366
22	1.0	446
23	1.6	420
24	Not fed	390
25	1.6	410

Total	28.8	10500

before use. This diet was supplemented three times each week with newly hatched *Artemia* nauplii of a variety known to be of good food value.

The nauplii were hatched from decapsulated eggs (see Appendix 1) at 26-28°C over a 24 h period. They were washed with clean sea water, counted and added to give an initial concentration of 5 nauplii ml⁻¹. Before being added to the larvae cultures, a 125 µm mesh screen was placed over the normal 1.5 mm outflow screen to retain the nauplii. This was removed 6 to 7 h later to prevent blockage overnight. An example of the feeding regime employed in the main system is given in Table 3.

Most larvae developed to the fourth stage within 11 to 17 days but, generally, only the first 4 to 5 days' production were transferred to the on-growing containers, while the rest were retained and frozen for use as food supplements.

Occasionally, mass mortalities occurred in one or more of the culture vessels for no apparent reason. These cultures were immediately terminated, and the vessels thoroughly cleaned and then restocked. It was found to be unnecessary to add any antibiotics or other medication to the water or to terminate neighbouring cultures even though they had received water recycled from the same source. Close attention to feeding and tank hygiene during the larvae culture phase proved to be critical. The daily maintenance tasks are outlined in Table 4, and typically took 2 persons 2 to 3 hours to complete. A considerable amount of this time was spent separating the individual stage 4 juveniles from the culture vessels and placing them in the on-growing trays.

Table 4. Maintenance of larvae cultures

Procedure	Duration	Frequency
Thaw mysids	2 persons (2-3h)	Daily
Clean filters and screens		
Decapsulate <i>Artemia</i> , hatch,		
separate nauplii and wash		
Feed larvae		
Remove stage 4 juveniles	From 0.5 day (1 person) to 1 day (2 persons) (as the numbers of larvae increase)	Up to 14 days (twice per year)
Dismantle, clean and reset vessels	0.5 h per vessel	As required

6. ON-GROWING SYSTEMS

Two independent on-growing systems were used to reduce the risk of failure of a single system. The primary system, of 6 212 l capacity, consisted of five rows, each containing four rearing troughs, two reservoirs, three centrifugal pumps, a biological filter and a foam fractionation column. A second system, of 12 116 l capacity, contained four rows, each with four troughs, four reservoirs, two pumps, two biological filters and a foam fractionation column. The differences between the two systems relate to utilization of existing facilities rather than to preference of design.

Each rearing trough (2.94 x 0.51 x 0.15 m deep) contained 4 trays which were supported 2.3 cm above the bottom of the trough on plastic 90° angle strips (Figure 7). The trays were made from two pieces of lighting diffuser material held together by pieces of 5 x 5 cm box-sectioned plastic conduit, wedged in place in two diagonally opposed corner compartments. Each tray contained 80 individual rearing compartments (5 x 5 x 10 cm deep), with a sheet of 1.5 mm bar mesh, PVC coated, GRP netting glued to the bottom.

Good water exchange to each lobster was ensured by a system of tidal flushing. A tap at each end of the trough

supplied a continual flow of sea water (378 l h⁻¹), which filled the trough until an automatic siphon was activated and the water level began to fall. At about 2 to 3 cm below the high water level, the siphon broke and filling recommenced. The rate of water inflow and the dimensions of the siphon tubes had to be adjusted initially to ensure continual operation of the cycle at 8-10 min intervals. Thereafter, siphon operation was monitored continually on two chart recorders, by a series of pens attached to solenoids each activated by a float switch in each trough (see Appendix 2).

The trays were stocked with stage 4 juveniles on the day on which they metamorphosed. As far as possible, healthy animals with a full set of appendages were selected but, occasionally, it was necessary to include lobsters with claws missing to make up the numbers. In practice, 9 000 -10 000 juveniles were stocked initially, to allow for 10 - 30% mortality between fourth and fifth stage lobsters and for 10% loss from stage 6 to tagging.

The first feed was with small pieces of *Mytilus* gonadal tissue prepared from freshly shucked, live mussels using a proprietary herb grinder. Thereafter, the animals in the trays were fed and cleaned daily according to a regular schedule (Table 5).

Two methods of feeding were employed, one for the

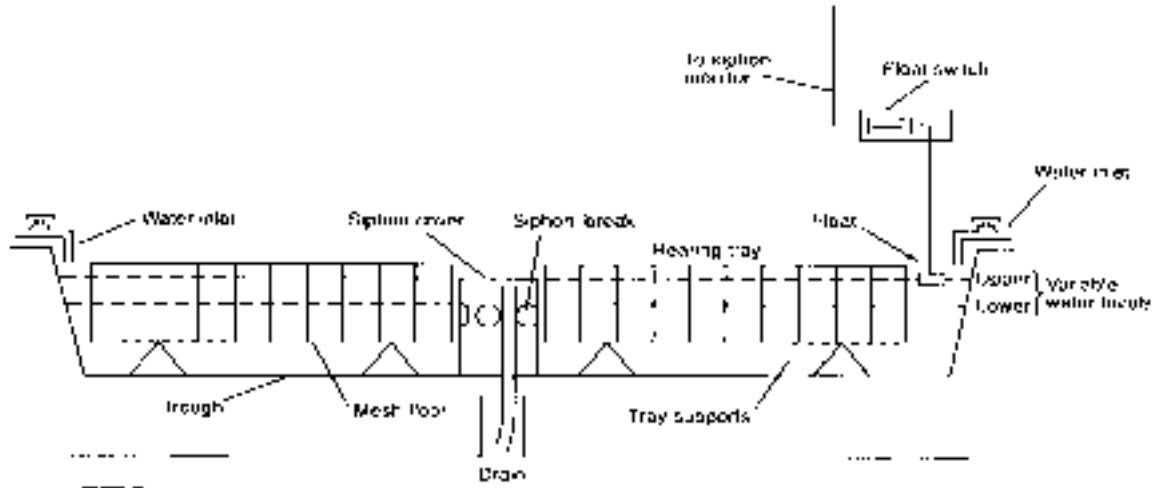


Figure 7. Longitudinal section through a juvenile rearing trough showing trays of 80 compartments, siphon and float switch arrangement

Table 5. Maintenance of juveniles

Procedure	Duration	Frequency
Prepare mussels	Max. 3 h (3 persons)	Daily
Feed mussels, clean troughs and trays	6 h per 4 480 lobsters (2 persons)	"
Feed mysids	1 h per 8 000 lobsters (1 person)	"

mussel diet which was given twice each week in the morning to lobsters in trays which had been cleaned according to the schedule (Table 5), and the other for the mysid diet which was given in the afternoon to lobsters in the trays remaining in the troughs. Food preparation was minimal with the mysid diet. It consisted of breaking frozen blocks, thawing in sea water and washing. Mussel preparation, on the other hand, took a considerable time, particularly after spawning (April/July) when many had to be opened to obtain the necessary quantity of flesh. At peak times, it would take 3 persons 3 hours to open enough mussels for 5 000 lobsters.

6.1 Feeding with mussels

After preparing and washing the small pieces of mussel flesh, 165 g were placed in an elevated hopper containing 10 l of sea water, where the pieces were held in suspension by a laboratory stirrer operating at 500 rpm (see Appendix 3). The mussel fragments were distributed to each compartment by gravity through a 2.5 mm internal diameter flexible plastic tube from the base of the hopper. The tube was passed evenly from compartment to compartment, at a rate which allowed 2-6 pieces of mussel to fall to each lobster. The hopper was replenished with sea water and mussel fragments when the level fell to about one-third of capacity. After inspection, the process was repeated to any individuals which had not received food. Using this method of feeding, 4 trays of 80 lobsters could be fed in 5 min, a rate of 3 840 lobsters h⁻¹.

6.2 Feeding with mysids

Mysids were purchased from aquarist suppliers as 1-10 kg frozen blocks and were stored in a deep-freeze until required. After thawing in sea water, the mysids were loaded into a mechanical feeding device (Wickins *et al.*, 1987) which was designed and built at the Fisheries Laboratory, Conwy (see Appendix 4). On average, this feeder delivered between 6 and 9 mysids to 73% of the compartments, with 2.1% receiving no food. The distribution of empty compartments was random so that it was unlikely that the same animals would go without food after two successive feeds. The feeding time was approximately 15 min per 1 000 lobsters, a time which included all operations except thawing and washing the mysids.

6.3 Cleaning procedures

Cleaning is an important part of the rearing process and, at Conwy, was accomplished according to a regular daily schedule (see Table 5). Trays were removed from each

trough as appropriate for the day and briefly passed back and forth over a series of 5 x 10 cm scrubbing brushes, which were fixed to the floor of a shallow tank of water in order to clean the underside of the mesh floor of the compartments. The trough was then set to drain, scrubbed clean and refilled. At the same time, the trays were placed into a service trough and the upper surfaces brushed clean. A 'pooter', powered from a laboratory water jet pump, was then used to 'vacuum-clean' uneaten food and detritus from each compartment (see Appendix 5). Cast shells were generally left in the compartments for the lobsters to eat. While the trays were in the service trough, they were supplied with the mussel diet and, in the case of lobsters of one month old, approximately 6 live oyster spat were also added to encourage the development of strong crusher claws (Wickins, 1986). After feeding, the trays were returned to their original troughs and sprinkled with water to ensure that none of the food remained floating on the surface. Each trough was subjected to this routine once per week and to the same routine (apart from the mesh scrubbing and trough cleaning operations) two to five days later in the week. The 'pootering' operation took much longer (up to 30 min per trough) when the lobsters were small than when they were over 10 mm in carapace length (about 5 min per trough), because of the risk of damaging small specimens. In general terms, it took 2 persons 6 h to clean and feed 14 troughs of small lobsters (4 480 lobsters). This did not include time taken for food preparation.

7. TAGGING PROCEDURES

All lobsters were tagged internally with small (1 mm x 0.25 mm diameter) cold-worked, type 302, stainless-steel wire microtags prior to release. Proprietary fish microtagging equipment (North West Marine Technology, Tagging Unit, Mk.2) was adapted for use with juvenile lobsters, by making a special head mould and by slightly altering the machine's injection cycle (Wickins *et al.*, 1986). The criteria for deciding the positioning of tag implantations were as follows:

- (1) the tag should cause minimum damage to the lobster;
- (2) it should not be subject to loss by autotomy (spontaneous limb loss);

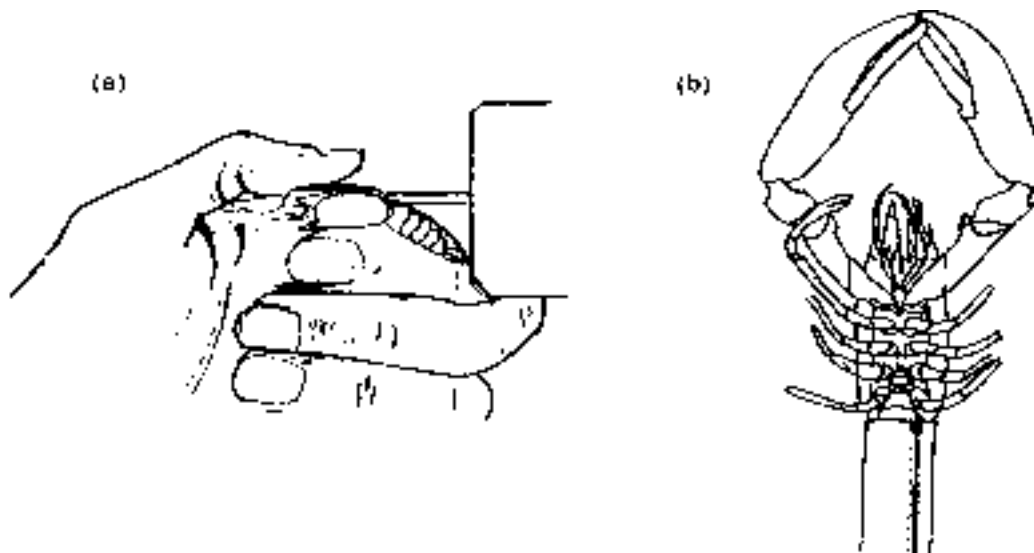


Figure 8. *Positioning the lobster against the head mould of the tagging apparatus: (a) lateral view shows the position of the inserted tag. Fingers holding the telson have been omitted for the sake of clarity; (b) ventral view shows the head mould with offset designed to place the tag under the lobster's left fifth pereopod (from Wickins et al., 1986)*

- (3) it should be placed in a part of the lobster not normally eaten but which would be large enough (in the juveniles) to accept the hypodermic needle; and
- (4) it should be placed in a plane where it would pass through the tag detection apparatus with its long axis parallel to that of the detector rather than being orthogonal to it.

Each tag was therefore placed ventrally within, and parallel to, the anterior-posteriorly oriented muscle blocks immediately dorsal to the base of the fifth pereopod (Figure 8). The depth at which the tag was placed was governed by the length at which the hypodermic needle was set to protrude beyond the head mould. This length could be adjusted to suit the size of lobster being tagged so that penetration was between 1.0 and 1.5 mm.

During tagging, the lobster was held firmly, with its ventral surface uppermost, with the thumb restraining the legs and chelae and the side of the forefinger acting as a support under the carapace (Figure 8). The thumb and forefinger of the other hand arched the abdomen slightly backwards, while the lobster was gently aligned and impaled on the needle which entered just posteriorly to the fifth pereopod. The cephalothorax of the lobster was kept level and in line with the needle so that the tag was inserted horizontally.

The width of the head mould spigot was made approximately equal to the body width of a juvenile lobster of 12 mm carapace length and the hole for the needle was deliberately offset so that, when the lobster was presented centrally to the mould, the needle automatically entered under one leg. In practice, two head moulds were made, each with an opposite hole offset in order to tag lobsters in either their right or left sides, thus distinguishing between those released in May and September.

Experience showed that, whenever a new operator was employed, it was desirable to inspect tag positioning in two or three lobsters from each batch after the first 20 or so had been tagged. These inspections were made under a low-power, binocular microscope to see if the tag was correctly aligned within the muscle block, or protruded outwardly or internally beyond the muscle block. The former observation was made from the dorsal surface after removal of the carapace and internal organs. As a further precaution, a tray of 80 lobsters was retained from each batch and tag loss monitored after three months. Most tag losses occurred within the two moults following tagging (see Appendix 6).

Experiments had previously shown that tag retention was 85-100% as the animals grew through up to 22-29 moults (90-102 mm carapace length) in captivity. The studies also showed that tags could be accurately placed and retained in lobsters as small as 9 mm in carapace length. As experience was gained, claw loss during handling was reduced from 4% to less than 1% at a tagging rate of 240 lobsters h^{-1} (Wickins et al., 1986).

8. TEMPERATURE ACCLIMATION

After tagging, and approximately 7 to 14 days prior to release, the temperature of the rearing water was lowered by increasing the rate at which new, cold sea water was bled into the system. Since no refrigeration equipment was available, the lowest temperatures obtained varied from batch to batch according to the weather. They were generally around 16°C and some 3 to 6°C warmer than the sea at Bridlington.

9. TRANSPORTATION AND HOLDING FACILITIES

On the day of transportation to Bridlington Harbour, the top portion of each individual rearing tray was removed so that the lower sections, containing the lobsters, could be stacked up together in columns of 8. An empty tray was placed at the top and bottom of each stack to prevent escapes and damage to the mesh of the bottom tray. The whole stack was bound together with two straps. Plastic angle strips along the top and bottom edges of each stack prevented damage as the straps were tightened (Figure 9). Each stack was placed inside a plastic box which was open at the top and bottom. Two plastic angle strips, fastened to the inside lower

edges of the box, supported the stack approximately 2.5 cm from the bottom of the tank to allow adequate water circulation. Boxes containing stacks of lobster trays were positioned in pairs within 450 l capacity GRP tanks. Sea water was pumped from the bottom of each tank to the top of each stack by a 12 V submersible pump connected to a pair of heavy-duty batteries. The box walls ensured that a continuous downward flow of water was maintained through the stack of lobsters throughout the 5 h journey. Polythene sheets were fastened as lids over the tanks to prevent splashing, while sacking provided protection from sunlight.

On arrival at the harbour, the tanks were off-loaded into a quayside net store to await transfer to the chartered vessel and subsequent release. During this period of 4 to 10 days, the sea water was circulated by a submersible 240 V AC pump in each tank. As a safeguard, aeration was also provided to each tank system. New sea water was added daily an hour or two after the lobsters were fed.

Typically, only one or two tanks (1 200-2 400 lobsters) were taken on board for release on any one day, because of limitations of tide and daylight. Battery-powered pumps were used again to provide water circulation during the 2-4 h spent steaming to the release grounds, while clean sea water was flushed through the tanks at intervals during the journey to further acclimate the lobsters. When time and weather conditions permitted, lobsters were also fed during the journey.

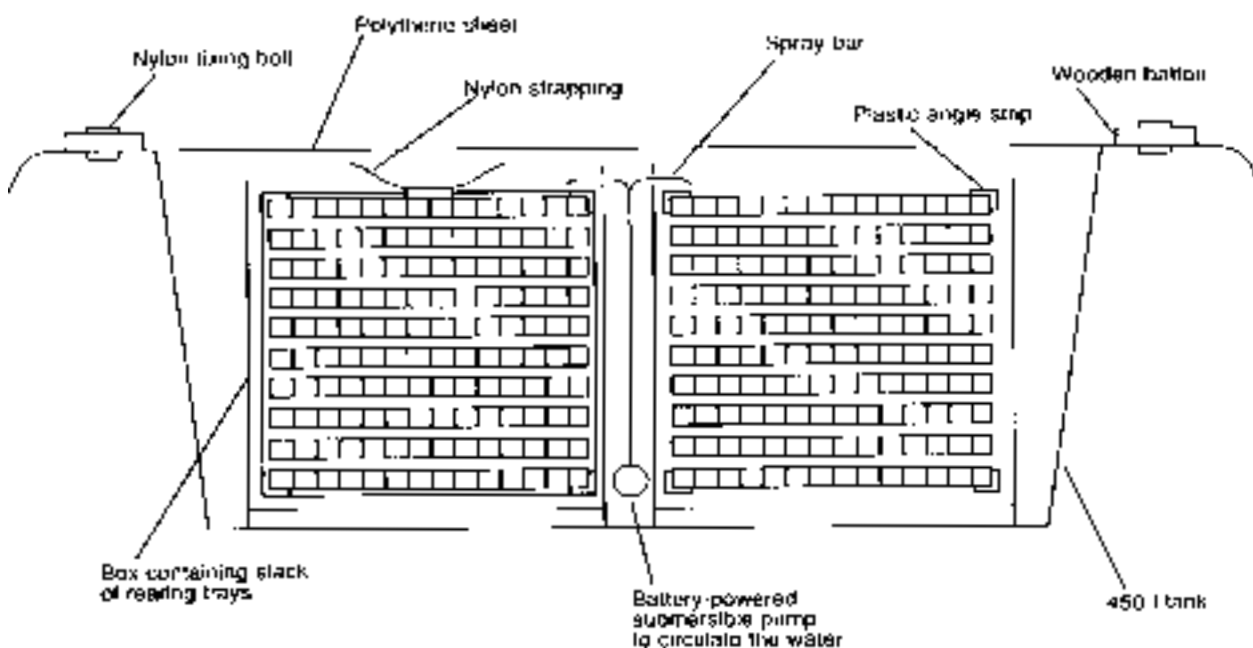


Figure 9. A transportable recirculation system capable of holding 1 280 individually confined three-month-old lobsters. The nylon strapping on the right-hand stack of trays has been omitted

10. LOBSTER RELEASE

Areas suitable for release were located initially by side-scan sonar or echo sounder, but more accurate surveys were made by drift diving. The chosen areas were reefs formed of cobbles and boulders which provided plenty of crevices and thus initial protection for the juveniles while they began to burrow. Suitable reefs were marked by anchors and dans placed by divers and a ground line was run at right angles to the tide along the up-tide edge of the reef. When the surface tidal flow had fallen to 0.5-1 knot, diving began. The stacks of rearing compartments were unstrapped, the top and bottom empty trays were removed and the remainder were clamped into the diver's release cage (Figure 10). A perforated plastic sheet was used as a lid over the top tray. A loop was tied from the release cage around the dan rope and the cage of lobsters was carried down to the anchor by a diver. Trays were removed sequentially and the lobsters released up-tide of the ground line. Although a few animals escaped from the open trays, most remained in place until shaken out by the diver and carried by the current onto the reef. The rate of release was intended to deliver a maximum of 2 lobsters m^{-2} , but lobsters were often seen to land at much higher densities. Empty trays

were accumulated near the cage until all lobsters had been released. The cage was then restacked and returned to the surface.

Some of the releases were made using a method developed by the North Western and North Wales Sea Fisheries Committee during their operations in Cardigan Bay. Essentially, the lobsters were sent down a pipe trailing from the surface to the sea bed as the vessel drifted over the chosen release site. In Bridlington Bay, the lobsters were picked out of the trays on deck one by one and released down a weighted 30 m x 75 mm diameter flexible pipe extending from the vessel to the sea bed. A flow of water ($12 l s^{-1}$) was maintained down the pipe to ensure the rapid and smooth passage of lobsters to the sea bed (Figure 11). The juveniles took approximately 80 s to be discharged. On arrival, they emerged tail-first with their claws extended in line with the body and were ejected some 20-30 cm from the end of the pipe. Then, they immediately swam tail-first to the bottom.

A summary of lobster production and release is given in Appendix 6.

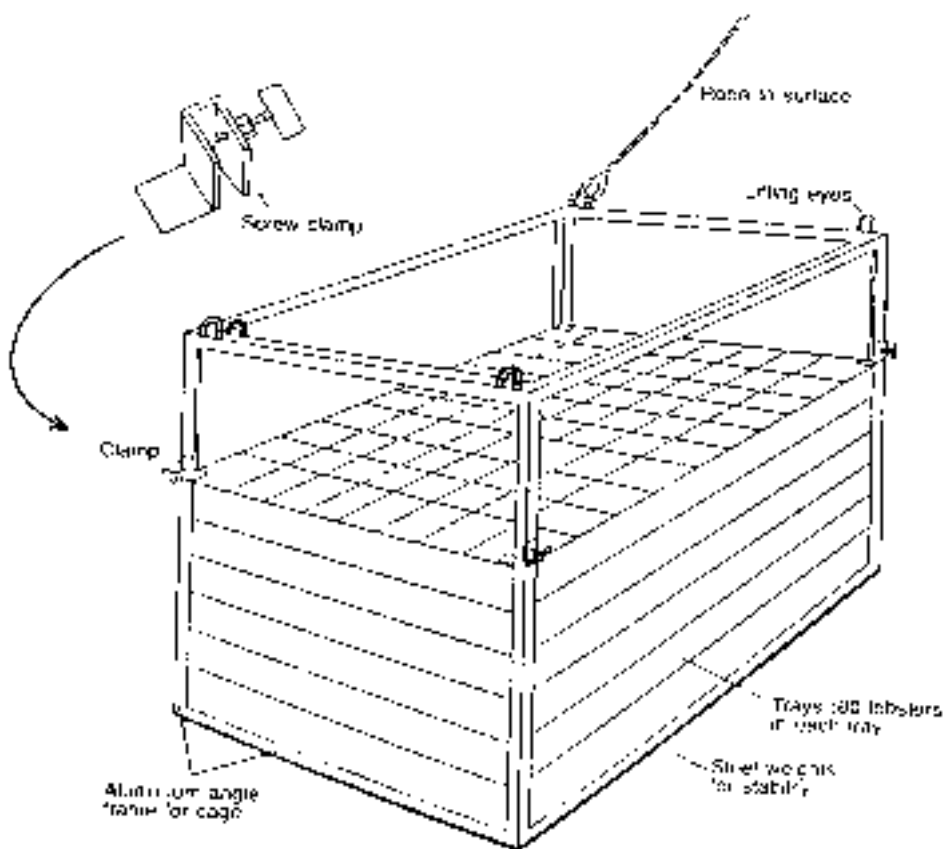


Figure 10. The cage used by divers to carry trays of lobsters to the sea bed

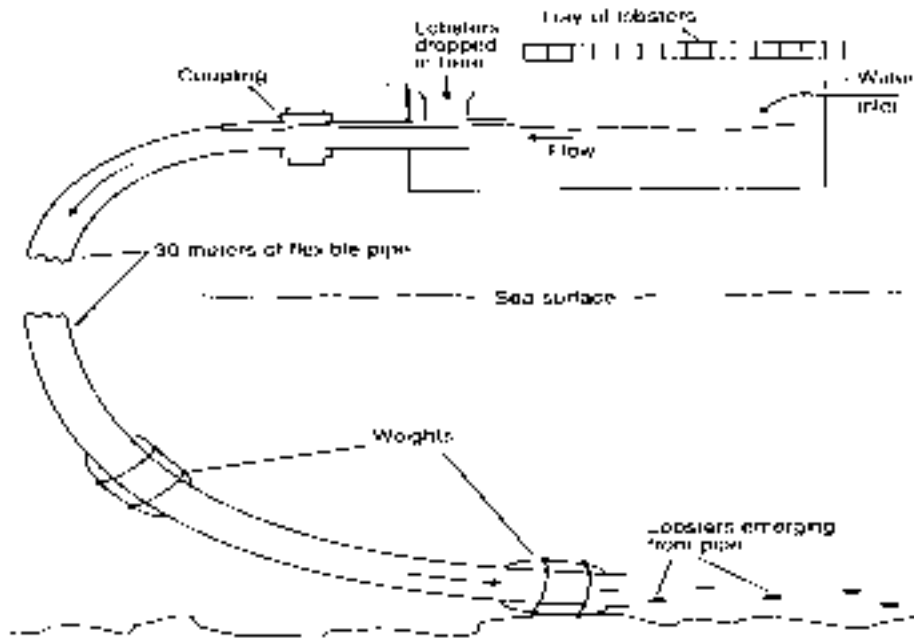


Figure 11. The arrangement used to release lobsters through a 30 m length of pipe

11. SPECIAL CONSIDERATIONS

- (1) Within the culture buildings, air conditioning would have been preferable to using immersion heaters for safety reasons and because of problems with condensation and corrosion of the fabric of the building.
- (2) Titanium thermostat and heater casings are judged to be preferable to stainless steel because of corrosion problems, sometimes experienced even with best quality (316 grade) stainless steel. No other metal components should be in contact with the sea water.
- (3) Thorough leaching, (3 changes of sea water per week for 3 to 4 weeks) of all new materials used in rearing, especially polyethylene larvae rearing containers, is strongly advised.
- (4) It is recommended that biological filters are properly conditioned with regular additions of ammonium citrate, sufficient to maintain a circulating concentration of around $1 \text{ mg nitrogen l}^{-1}$ (after allowing for a 5% daily exchange of new water) for 3-4 weeks before a complete water change and subsequent addition of animals.
- (5) Regular daily back-flushing of all high-rate sand filters, regardless of particulate load, is recommended. Monthly inspection of the sand is also advised, so that any solidification and channelling can be rectified. Daily inspection of all flow rates, siphon operations, temperature and salinity measurements are essential.

12. FURTHER RESEARCH

The rearing programmes conducted at Conwy, and elsewhere in Britain, over the past 5 years have shown that, with meticulous husbandry and selection of diet, few problems are encountered during rearing of the juveniles from about stage 6 through tagging to transportation and release.

Erratic survival during incubation, larvae rearing and in the first one or two juvenile stages has resulted in serious losses in all hatcheries at one time or another. It seems likely that mortality of early juveniles is but a reflection of the quality or culture history of the larvae and that the causes of variable performance arise earlier.

Further research is being conducted at Conwy, on factors leading to egg loss from females incubating while in captivity. Special attention is being given to the effects of low and fluctuating salinity on egg attachment and lipid content.

Relationships between the rate of utilisation of egg food reserves following exposure to different salinity regimes, temporal position in the hatching hierarchy and subsequent larval viability are also being investigated.

The reference to proprietary products in this report should not be construed as an official endorsement of these products, nor is any criticism implied of similar products which have not been mentioned.

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APPENDIX 1. The decapsulation of *Artemia* cysts

Complete separation of *Artemia* nauplii from their cystic shells after hatching is not always possible. The shells can cause bacterial contamination of larvae. Removal of the shell with hypochlorite solution solves this problem and often improves the hatch rate. The steps in the process are as follows:

- (1) The cysts are first placed to hydrate in aerated sea water for 1 to 2 h (25°C, 35 psu salinity) in a conical-bottomed vessel.
- (2) After hydration, they are washed over a 120 µm screen to remove debris.
- (3) The cysts are then held in suspension in an aerated decapsulation solution maintained at 20°C in a water bath or with ice. (Cooling is necessary because the decapsulation reaction produces heat which could kill the *Artemia*).
- (4) The decapsulation solution may be made using liquid sodium hypochlorite solution or bleaching powder. The requirement is for 0.5 g of active chlorine and 14 ml of decapsulation solution per gram of cysts. If bleaching powder is used, it must be well dissolved by aeration and allowed to settle to remove undissolved material before use. Some authorities recommend the addition of alkali in order to increase the pH of the decapsulation solution.

Below are some practical examples of the composition of decapsulation solutions, made up with either NaOCl or Ca(OCl)₂ as active agents for the treatment of 100 g dry cysts (from Sorgeloos, *et al.*, 1986).

EXAMPLE 1: Use of concentrated liquid bleach

Concentration of active product in NaOCl-solution
= approximately 156 g l⁻¹.

Amount of active product needed for decapsulation of 100 g cysts: 100 x 0.5 = 50 g.

Volume of liquid bleach needed: 50 x 1 000/156
= 320 ml.

Amount of NaOH needed: 0.15 x 100 = 15 g or 0.33
x 100 = 33 ml of 40% solution.

Total volume of decapsulation solution: 14 x 100
= 1 400 ml.

Volume of sea water needed: 1 400 - 320 - 33

= approximately 1 050 ml.

Decapsulation solution is thus made up of:

320 ml of liquid bleach;
33 ml of 40% NaOH solution; and
1 050 ml of sea water.

EXAMPLE 2: Use of bleaching powder

Activity of product (70% (by weight) of active ingredients).

Amount of product needed for the decapsulation of 100 g cysts: (100 x 0.5) x 100/70 = 71 g of bleaching powder Ca(OCl)₂.

Amount of Na₂CO₃ needed: 0.67 x 100 = 67 g (or 0.4 x 100 = 40 g CaO).

Volume of decapsulation solution (= volume of sea water needed): 14 x 100 = 1 400 ml.

Decapsulation solution is thus made up of:

1 400 ml of sea water;
71 g of bleaching powder; and
67 g of Na₂CO₃ (or 40 g CaO).

- (5) Within 10-15 min, the solution will change colour as the shells dissolve (grey with bleaching powder, orange with liquid bleach).
- (6) When decapsulation is complete, the cysts appear to be almost translucent and multifaceted when viewed under the microscope. At this point, they are washed thoroughly with sea water or tap water until there is no smell of chlorine. Any toxic residues still attached to the cystic surface are removed by dipping them twice in a 0.1 normal solution of hydrochloric acid or in dilute sodium thiosulphate solution for 10-15 s and washing again in sea water.
- (7) Properly treated cysts will now sink in sea water; those that float can be treated again if required.
- (8) Hatching may now be conducted in the normal way.

Reference

SORGELOOS, P., LAVENS, P., LÈGER, P., TACKSERT, W. and VERSICHELE, D., 1986. 'Manual for the Culture and Use of Brine Shrimp, *Artemia*, in Aquaculture'. State University of Ghent, Belgium, 319 pp.

APPENDIX 2. The siphon monitor

The diagrams below show the siphon monitor, drawn isometrically, including only one of the eighteen-channel pens, (Figure A2.1) and the circuit diagram of the siphon monitor (Figure A2.2).

The monitor consists of two eighteen-channel pen recorders, each channel being activated by a float switch in one of the rearing troughs.

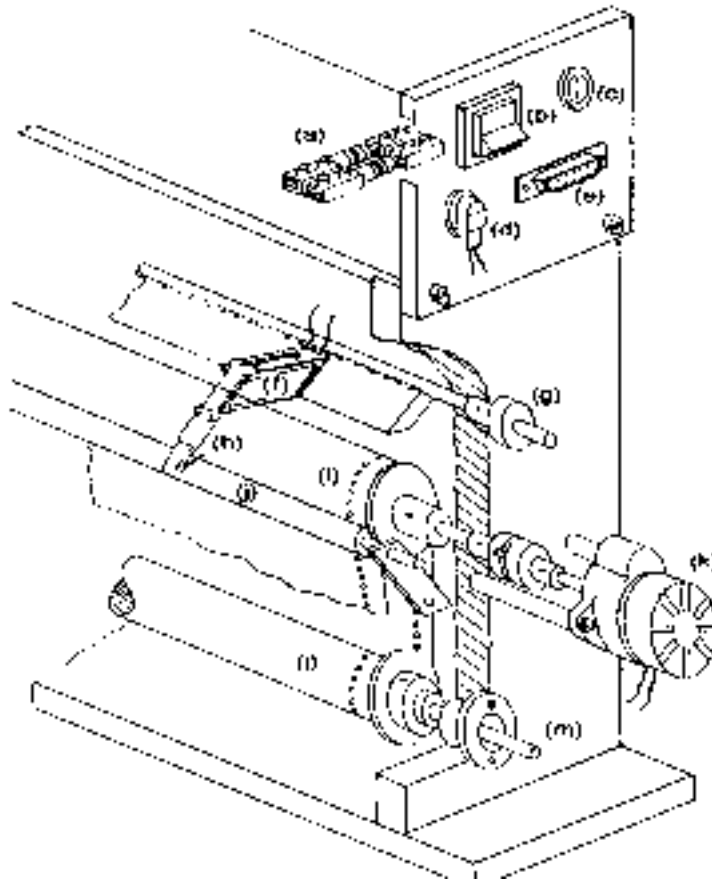


Figure A2.1. *The siphon monitor. Key: (a) resistor and terminal blocks; (b) on/off switch; (c) low-voltage input to solenoids and float switches; (d) 240 V AC input to drive motor; (e) input connector from float micro-switches; (f) solenoid; (g) pen lifting arm; (h) pen; (i) chart recorder paper passing over drive roller; (j) spring-loaded rubber retaining roller; (k) drive motor geared to give a paper speed of 4.5 cm h^{-1} ; (l) roll of paper and (m) part of the Perspex mounting frame*

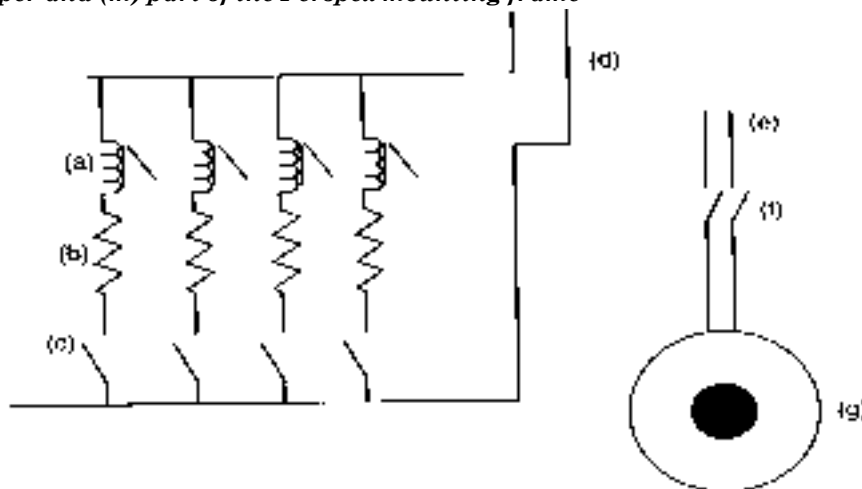


Figure A2.2. *Circuit diagram. Key: (a) solenoid 12 V DC 53 ohm; (b) 100 ohm 2 W high stability carbon resistor; (c) micro-switch lever; (d) supply from 13 V DC 4 A power pack; (e) 240 V AC mains supply; (f) on/off switch and (g) geared electric motor*

APPENDIX 3. Mussel feeding equipment

The diagram below (Figure A3.1) shows the arrangement of the hopper, stirrer and distribution pipe. The equip-

ment is used to dispense pieces of mussel tissue to juvenile lobsters.

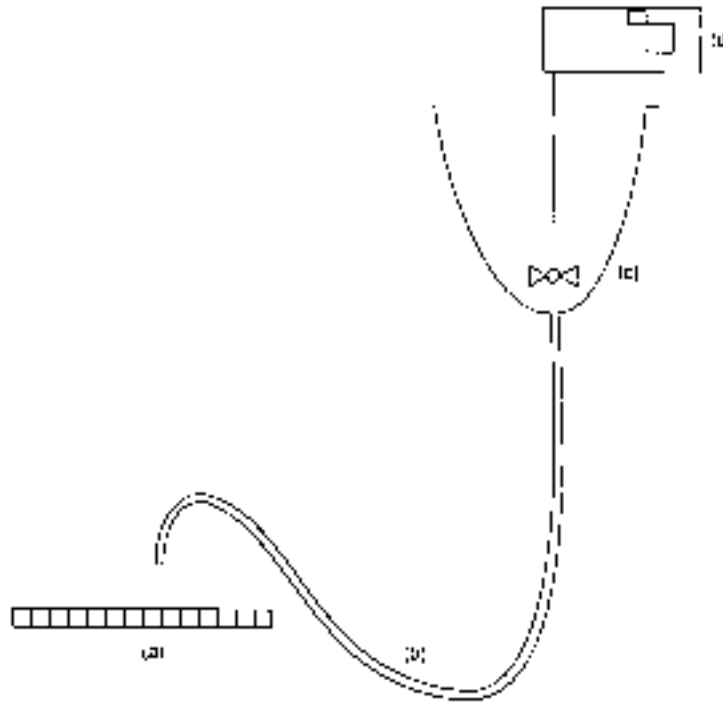


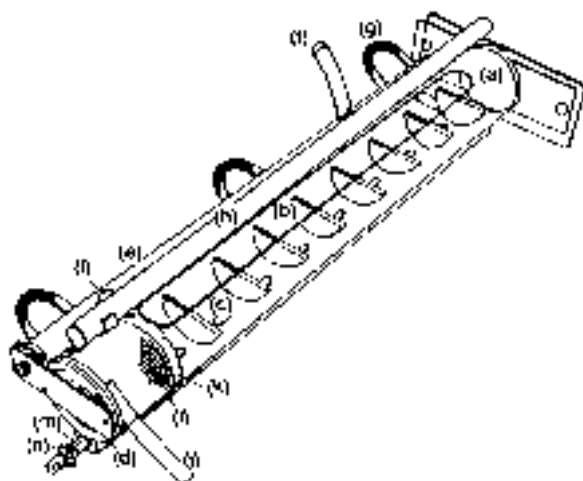
Figure A3.1. Mussel feeding equipment. Key: (a) tray of juvenile lobsters; (b) flexible 5 mm tube; (c) polyethylene hopper and (d) variable speed stirrer

APPENDIX 4. The general arrangement of the wet (mysid) feeder

The device shown below (Figure A4.1) consists of an elongated hopper which spans the width of the rearing troughs. A shaft along the bottom of the hopper is bored with a number of longitudinal slots. The shaft rotates as the hopper is pushed from one end of the trough to the other and, at each revolution, food is transferred from within the hopper to successive rows of

rearing compartments below. A toothed wheel at each end of the shaft locates into tracks fastened to the edges of the troughs to ensure uniform rotation. The mysids are kept in suspension in the hopper by a series of water jets, while baffles within the hopper help to maintain a uniform suspension and distribution of food organisms.

Figure A4.1. The wet mysid feeder. Key:



- (a) hopper tube; (b) baffles;
- (c) slots in hopper; (d) shaft housing tube; (e) water distribution manifold; (f) water inlet pipe; (g) water feed to shaft housing (one of three);
- (h) water jet manifold;
- (i) feed to water jet manifold;
- (j) overflow from hopper;
- (k) retaining ring for screen;
- (l) screen; (m) spindle and
- (n) toothed drive wheel

APPENDIX 5. The apparatus used for cleaning individual rearing containers ('pooters')

The diagram below (Figure A5.1) shows details of the 'pooter' apparatus, which is used to suck uneaten food from individual rearing compartments.

Control of suction is achieved by exposing or occluding the top of the 'T' piece with the thumb.

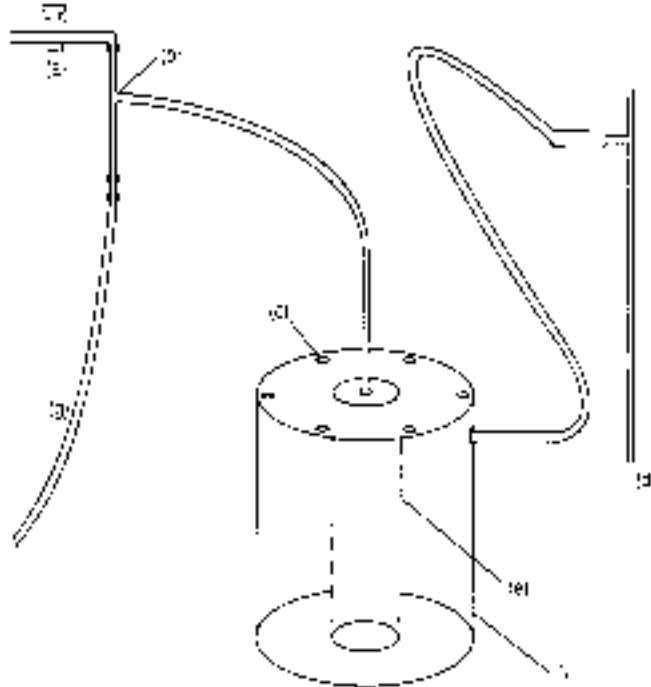


Figure A5.1. The 'pooter'. Key: (a) mains fresh water; (b) vacuum pump; (c) removable lid; (d) suction orifice; (e) mesh screen; (f) sealed vessel and (g) waste water

APPENDIX 6. Production summary and numbers of tagged lobsters released

Broodstock performance (No records for 1983)

Year	1984		1985		1986		1987		1988	
Release number	1	1	2	2	1	2	1	2	1	2
No. of females	31	20	40	15	32	37	38	46	31	
Days captive (to 50% hatching)	100	101	62	105	59	129	64	113	47	
Larvae hatched	198248	102693	341580	118289	120965	206471	492954	38217*	282216	

* = Unusual egg loss

Larvae culture (No records for 1983)

Year	1984		1985		1986		1987		1988	
Release	1	2	1	2	1	2	1	2	1	2
No. 80 l cultures	9	12	10	15	7	13	12	7	0	9
Mean survival (%)	12.4	21.7	23.7	<10	26.8	15.4	30.3	25.3	0	23.9
Range	2-28	13-37	11-41	-	10-49	6-27	13-56	20-32	0	19-32
No. 40 l cultures	17	15	10	19	18	17	12	10	0	8
Mean survival (%)	14	18	30	<10	25	18	30	25	0	34
Range	1-32	5-29	18-45	-	7-70	8-32	13-53	16-41	0	22-45
Total reared	4160	8960	11500	3000*	10730	8780	11204	10346	0**	8060

* = Poor survival, many populations combined

** = Severe egg loss, no larvae culture records kept

Juvenile culture (No records for 1983. Not all lobsters were released — some were retained for experimentation)

Year	1984		1985		1986		1987		1988	
Release No.	1	2	1	2	1	2	1	2	1	2
No. at start	4160	8960	9234	3000	8250	8239	7689	9095	2669	8060
No. at 3 months	2601	6378	6160	2080	5560	7156	6327	7804	1920	6770
Survival (%)	62	71	67	69	68	87	82	85	72	84

Effective numbers released

Year	1983		1984		1985		1986		1987		1988	
Release no.	1	2	1	2	1	2	1	2	1	2	1	2
No. released	268	3120	2480	6198	6080	2000	5480	7240#	6400#	7780	0	8690#
Tags retained after 3 months (%)	100	68	97.5	100	99	98	100	84	94	85	-	80
Effective no. released	268	2122	2418	6198	6019	1960	5480	6082	6016	6613	0	5952

Animals added from a previous rearing

Note: Total no. released = 54 810; effective total released = 49 128