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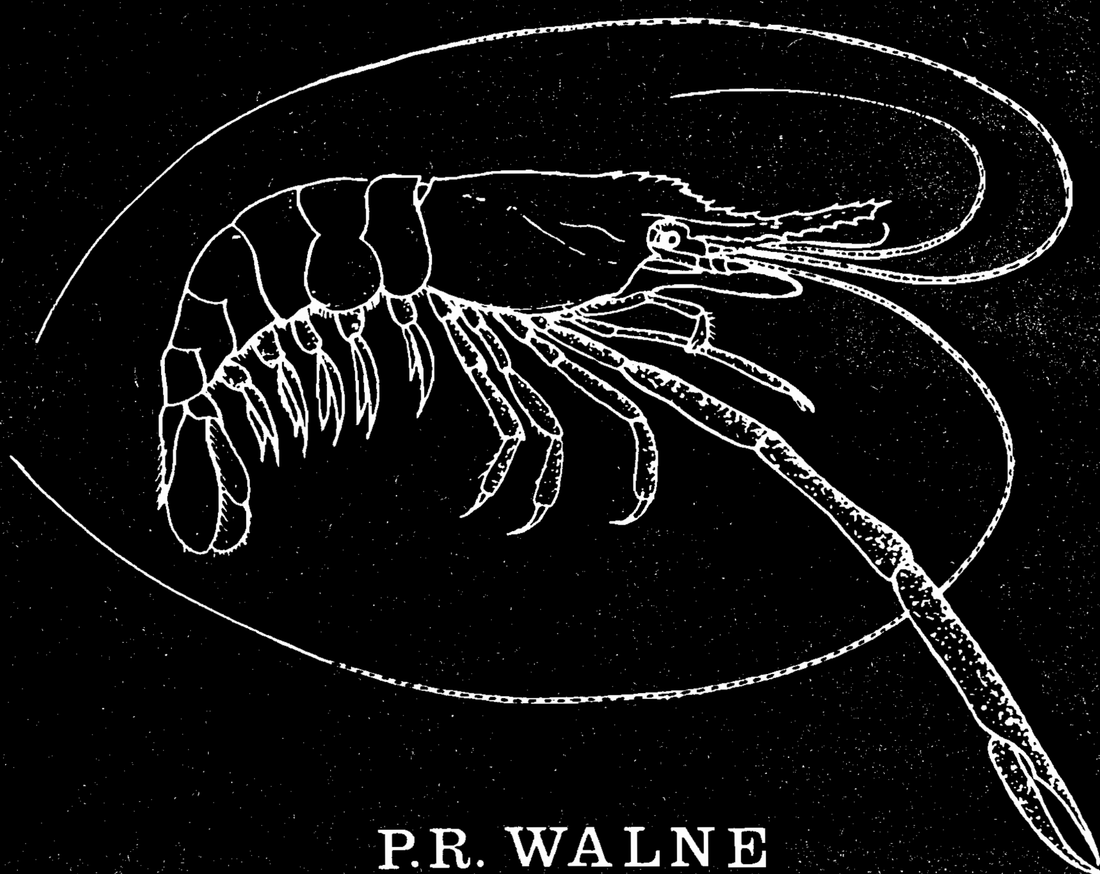
THE POTENTIAL FOR THE CULTURE OF CRUSTACEA IN SALT WATER IN THE UNITED KINGDOM



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THE POTENTIAL FOR THE CULTURE OF CRUSTACEA IN SALT WATER IN THE UNITED KINGDOM

by P. R. Walne

INTRODUCTION

There is at present (1977) no established commercial culture of Crustacea in Europe or North America, although there is very considerable interest due to an insatiable market demand throughout the world. The markets are large and the prices tend to be high compared with many other marine products. Some examples include the average annual landings of shrimps in the United States at about 172 000 tons. In addition another 91 000 tons are imported: 28% come from Asia. About 14 000 tons of lobsters are landed per year from the eastern seaboards of Canada and the United States, and about 5 000 tons of crawfish are landed in the United States. In Europe in 1975 1 841 tons of lobsters were landed, half of them in the UK. Other valuable crustacean landings in Europe were 37 400 tons of Nephrops (33% in the UK) and 504 tons of crawfish (10% in the UK). In addition to these landings about £15 x 10^6 worth of preserved shrimps and prawns are imported annually into the UK.

It will be shown below that two groups of Crustacea have some potential for cultivation in the UK - lobsters and tropical prawns. The price of lobsters varies seasonally according to supply and demand. This is illustrated in Figure 1 which shows the range of prices paid by merchants in Billingsgate market during 1976 for unselected lobsters.

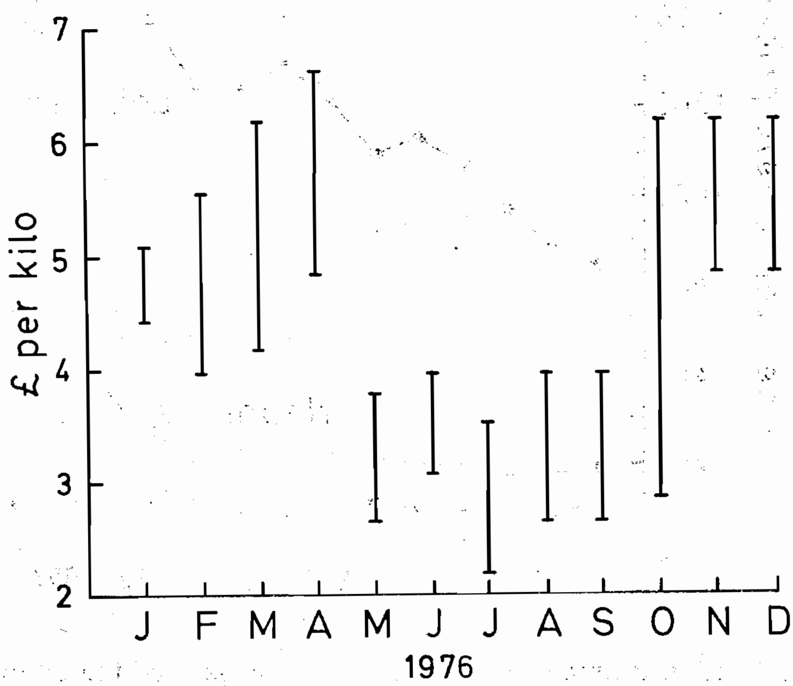

Figure 1 Range of prices for unselected lobsters in Billingsgate Market in 1976. From prices quoted in Fishing News.

Lobsters are more plentiful in the summer because they enter the pots more readily at higher water temperatures, and less fishing time is lost due to bad weather. Using the average price quoted in Fisheries Statistics (MAFF) and allowing for inflation it can be shown that there was a real increase in price for lobsters over the period 1962-75 (Figure 2). However, the prices for crabs and Nephrops when adjusted to take account of inflation show that there was little change in their real price over the period.

Prices for Crustacea tend to be lower in the UK than on the continent and this leads to an export trade. For example, although the statistics are imperfect it is probable that well over half the lobsters landed in the UK are exported. The average first sale price of lobsters in the UK in 1975 was £3.12 per kilo (MAFF Fisheries Statistics) while in France it was F 41.34 per kilo (~ £5.00) (Les Pêches Maritimes Françaises). Tropical prawns are more difficult to price because prawns of this type are not marketed fresh in the UK. A survey of several importers in May 1976 suggested the following prices for whole frozen prawns according to their size:

10 g - £0.95 per kg	30 g - £2.10 per kg
20 g - £1.70 per kg	50 g - £2.70 per kg

Although this paper deals with salt-water Crustacea, mention should be made here of the freshwater crayfish. These are popular in a number of European countries where progress is being made, particularly in Sweden, in the hatchery rearing of disease-resistant species from North America, and establishing the juveniles in selected waterways to form breeding populations. In 1972 Sweden imported 1 000 tons (86% from Turkey) with a value of US $1 643 200. At present good quality crayfish of the favoured species are worth £8 to £12 per kg in Sweden.

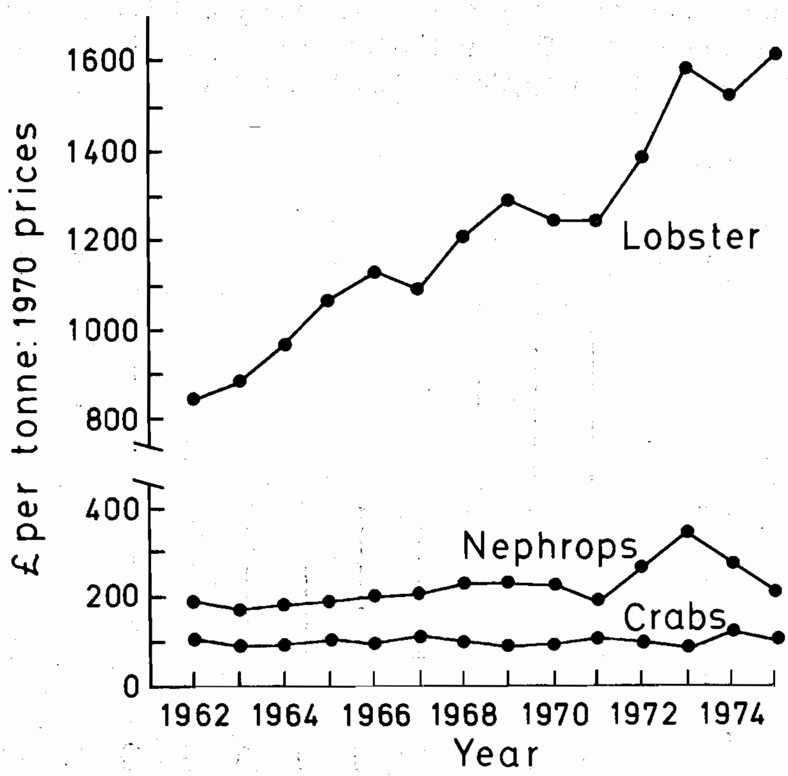

Figure 2 The deflated unit price for lobsters, Nephrops and the edible crab for the period 1962-75. Data from Fishery Statistics (MAFF) and general index of retail prices. The values shown refer to 1970 prices.

SPECIES FOR CULTIVATION

The selection of suitable species is fundamental to the soundness of any culture enterprise and since the answer is by no means clear for Crustacea to be cultured in northern Europe, it is worth examining this question in some detail. The criteria to be employed are a blend of biology and economics. About the latter the author is not particularly qualified to comment and will do no more than to stress that this could include the problems of creating a market for an unfamiliar product if the species selected is either not native to or not regularly imported into the UK. An example is presented by penaeid prawns (see below) which have considerable potential for cultivation, but as there is no market in northern Europe for fresh prawns which might command a premium price it is difficult to gauge their likely value. The selected species has to provide a product which will be readily accepted by the local population at a price which will not collapse as soon as a moderate quantity of the cultured form reaches the market. Ideally one would hope that the cultured Crustacea would be able to command a little higher price than the natural product perhaps derived from marketing out of season, or superior quality or better preservation.

To attempt to supplement the supplies of a high priced natural product by culturing may not be the way to proceed. Presumably a marine animal is high priced because it is scarce in relation to demand and to the cost of obtaining it. The market may be very limited at that price (Figure 1 may show this effect) and quite small increases in the volume available could lead to a sharp reduction in price. A medium price species may be more satisfactory for culture since the market could possibly absorb the increased volume without excessive changes in price.

BIOLOGICAL CHARACTERISTICS

Species of Crustacea of commercial interest all belong to the order Decapoda, a name describing their characteristic five pairs of walking legs. Familiar examples include lobsters, crabs, prawns, shrimps and crawfish. Biological characteristics of the group which are important for culture include:

1. Claws: The first pair of walking legs often carry substantial claws; for example, the lobster (Figure 3f).
2. Moulting: In order to grow all Crustacea have to shed regularly their hard outer skeleton and then increase in size before the new shell or skeleton is formed.
3. Aggression: Crustacea tend to be rather pugnacious and this leads to the cannibalism of moulting individuals who are not protected by a hard shell by those who are. The larger the claws the greater the damage that can be done.
4. Mobility: Crustacea move about and their commercial culture can only be envisaged in the confinement of tanks, ponds or lagoons.
5. Food: Crustacea have small mouths and all food is reduced to small particles before it is eaten. This can lead to greater waste than if the food was eaten in larger pellets.
6. Breeding: Penaeid prawns liberate large numbers of eggs freely into the sea but the other species discussed below attach their eggs to the underside of the tail.
7. Larvae: The eggs hatch into larvae which swim freely in the sea water and pass through a number of stages before metamorphosing into the adult form (Figure 4).

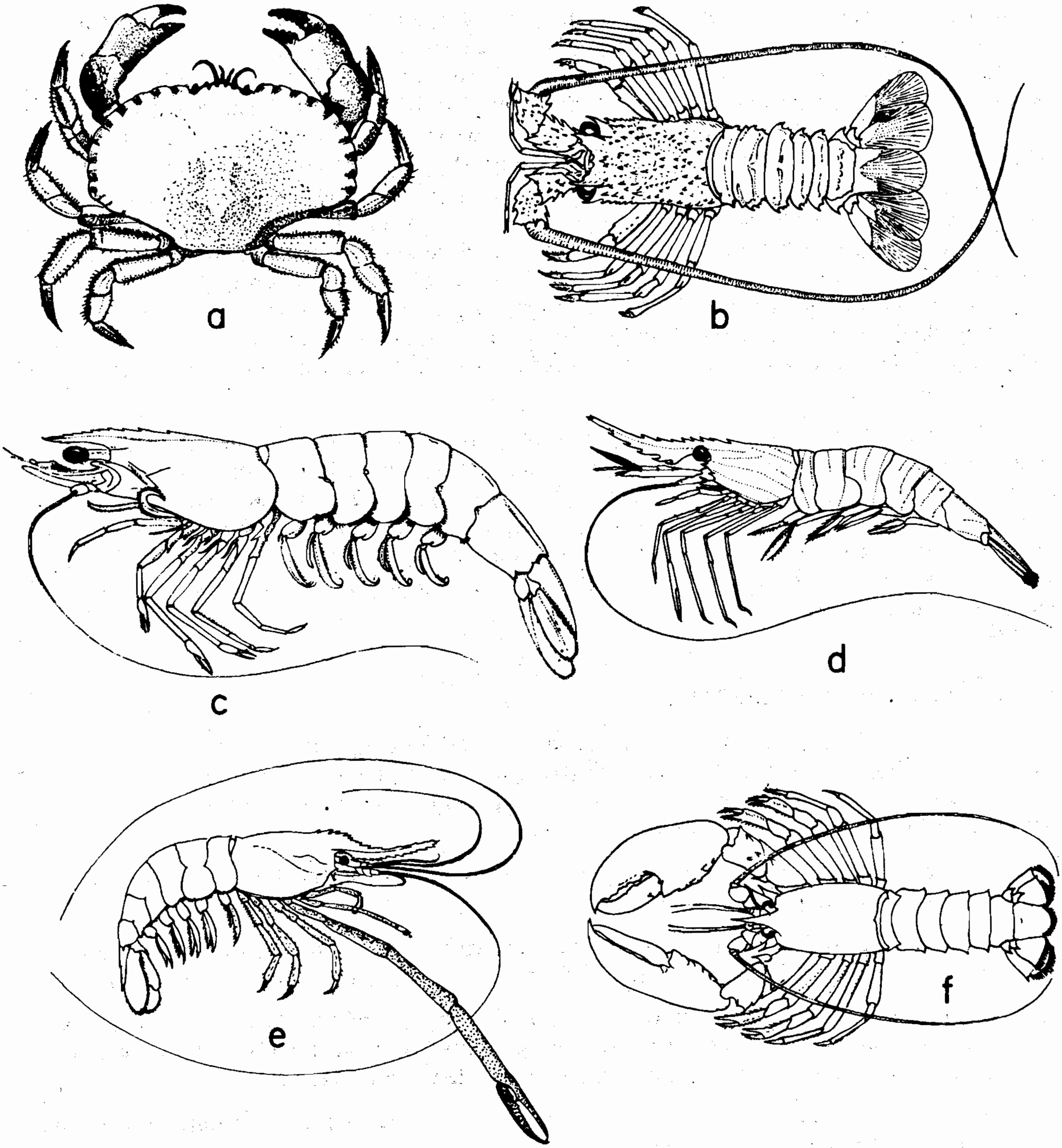

Figure 3 Representative examples of Crustacea: a. Edible crab, Cancer pagurus; b. Crawfish, Palinurus elephas; c. Penaeid brown shrimp, Penaeus aztecus; d. Common prawn, Palaemon serratus; e. Freshwater prawn, Macrobrachium rosenbergii; f. European lobster, Homarus gammarus

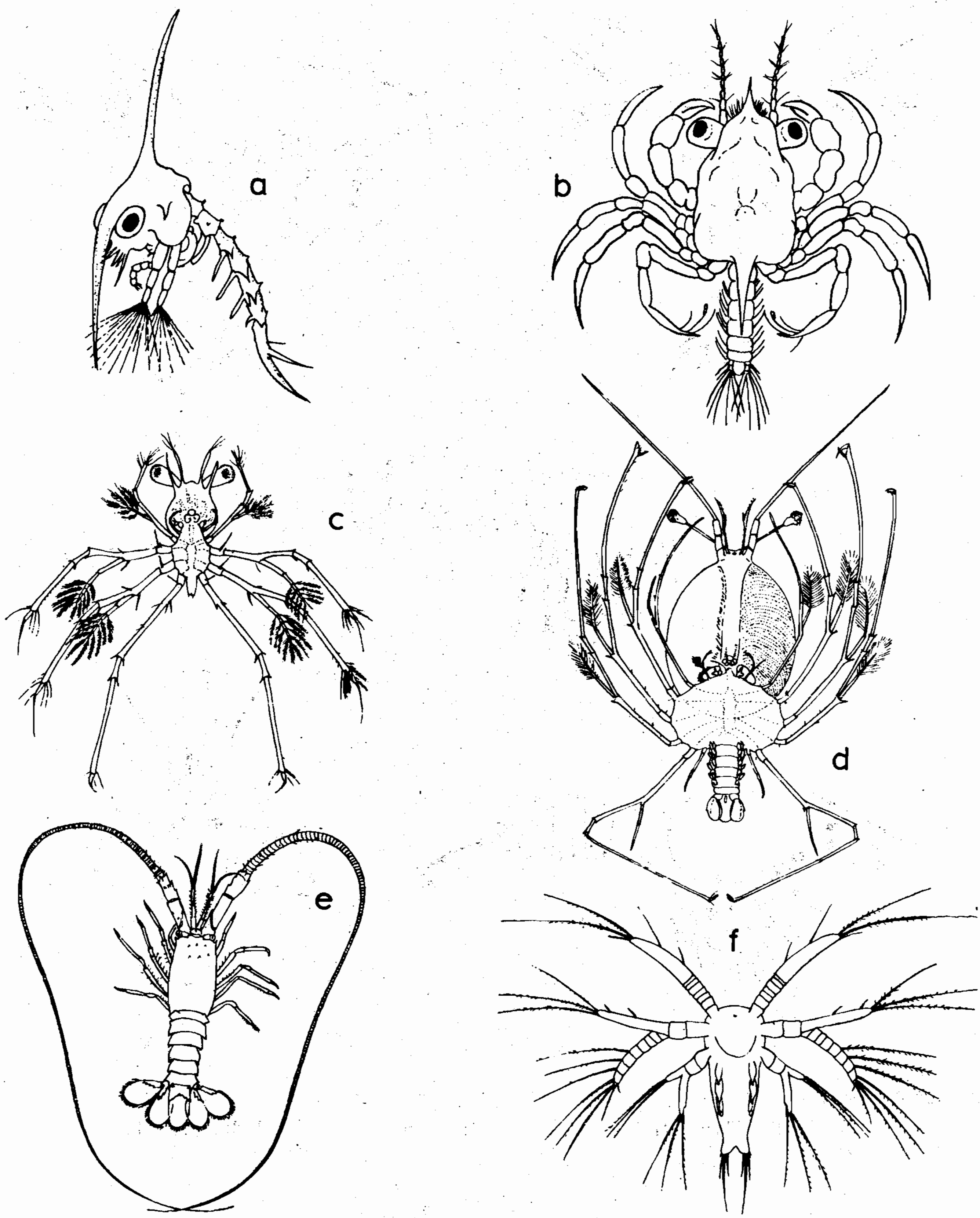

Figure 4 Larval development of Crustacea: a. Edible crab, 5th zoea; b. Edible crab, megalopa; c. Crawfish, phyllosoma larvae, early; d. Crawfish, phyllosoma larvae, late; e. Crawfish, puerulus larvae; f. Penaeid shrimp, late nauplius.

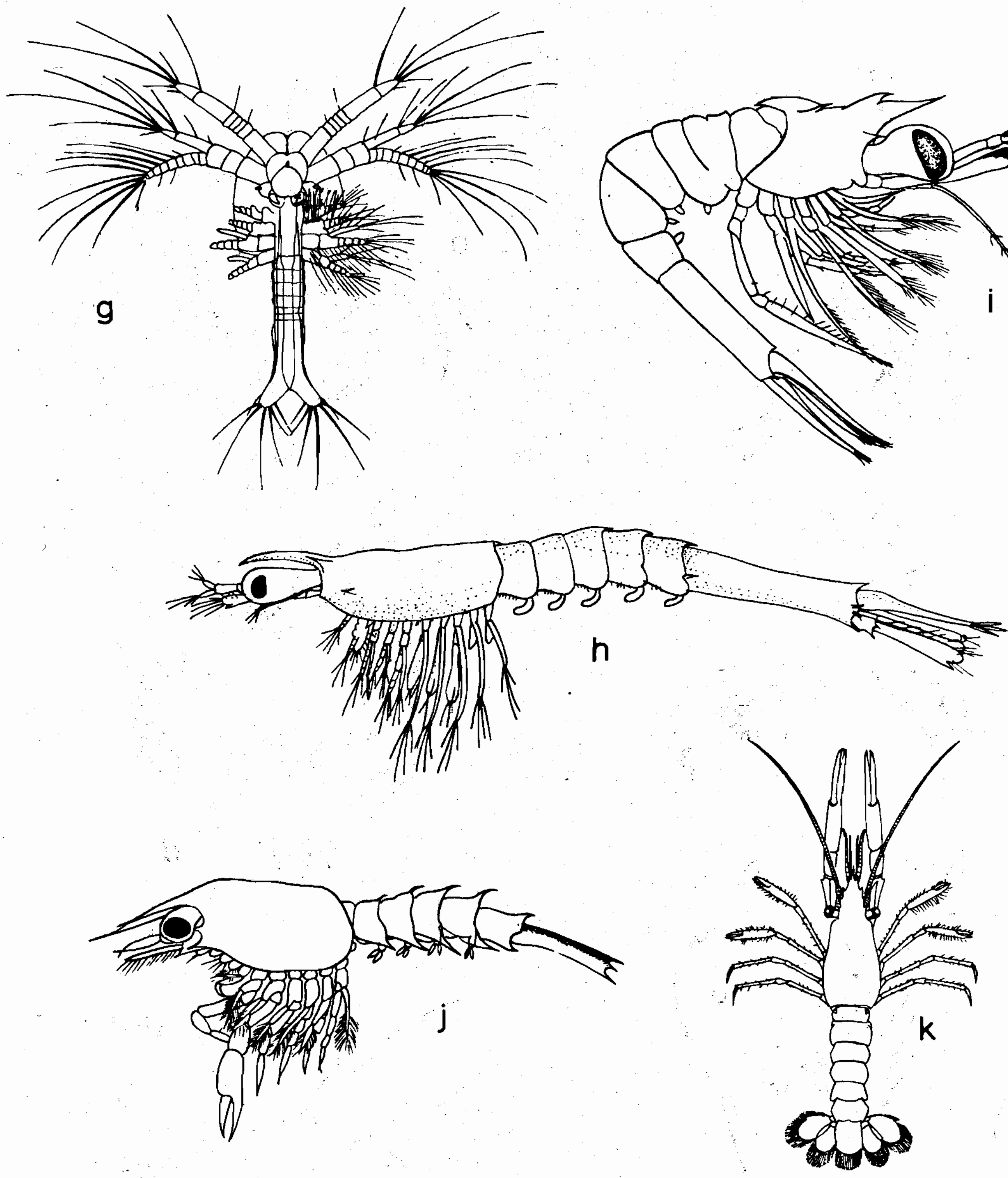

Figure 4 g. Penaeid shrimp, 1st protozoea; h. Penaeid shrimp, 2nd mysis; i. *Macrobrachium*, larva; j. Lobster, 2nd stage; k. Lobster, 4th stage.

The following five biological groups comprise the commercially important Crustacea from which the candidates for culture must be selected.

1. Crabs (Brachyura)

Only one species, the edible crab (Cancer pagurus), is marketed in the UK and there is a small fishery for spider crabs in south-west England for export to France and Spain. In northern Europe small numbers of various species of swimming crabs are also marketed. Crabs are generally rather low priced per unit weight (the edible crab averaged £231 per tonne in 1975) and have no particular advantages over the other crustacean groups. The pelagic larvae pass through five zoeal and a megalopa stage before developing the adult form (Figure 4a, b).

Subsequent growth is fairly slow. It takes about four years for a crab to reach 4½ inch carapace width, the minimum legal landing size in England and Wales.

2. Crawfish (Palinura)

The British species (Palinurus elephas, Figure 3b) had an average first-sale price of £2 505 per tonne in 1975. Foreign species of this group, which may be better known as spiny lobsters or rock lobsters, support substantial fisheries, especially in Australia, New Zealand, South Africa and the Caribbean. They are attractive due to their high market value but, unfortunately, as a group they have a long and rather elaborate larval life cycle (Figure 4c, d, e). The egg hatches into a phyllosoma larva characterized by extreme flatness, very long divided legs and weak mouthparts. This goes through about 12 moults while drifting in the ocean before changing into a puerulus larva. This swims actively and gradually approaches the coast where in some parts of the world it can be trapped in mesh bags containing seaweed. This stage subsequently moults into the juvenile form of the adult. It has been estimated for the Californian spiny lobster (Palinurus interruptus) that it is then about 12 months old.

The larvae can only be cultured with extreme difficulty and it is doubtful if the puerulus larvae can be collected anywhere in sufficient quantities to form the basis for culture. In Britain the larvae and young stages of crawfish have rarely been recorded. Crawfish as a group are not promising candidates for culture.

3. Penaeid shrimps

Species of this group (Figure 3c) reach their greatest abundance in warm water and particularly in tropical areas. Some species occur as far north as the deep water off western Scotland but not in commercial quantities. The eggs, which are more abundant than in other decapods, are laid freely in the water. They hatch into a nauplius larva but this stage does not feed although it moults several times. The next stage is the protozoea larva (Figure 3) which moults three times before changing into the final mysis larva. This stage again moults three times before metamorphosing into the juvenile form of the adult. Although this sounds elaborate, in practice the entire larval stage is passed through in two to four weeks and present techniques give a good survival. The average survival for a number of batches of Penaeus merguiensis reared at Conwy was 58% of the nauplius larvae through to the juvenile stage.

The claws of penaeid shrimps (Figure 3c) tend to be small and their behaviour is less aggressive compared with many other decapods. Their growth rate (Figure 5) is usually rapid, up to 25-30 g, and a number of species readily reach 100 g or more. This group includes the following species which support notable fisheries: the Kuruma shrimp (Penaeus japonicus, Japan), the sugpo (P. monodon, the Philippines) and three species from the Gulf of Mexico, the brown shrimp (P. aztecus), pink shrimp (P. duorarum) and white shrimp (P. setiferus).

In the UK the interest in this group lies in intensive culture in tanks with continuously recirculated water. Although the cost of heating and the high technology required are disadvantages, they are the only group of Crustacea which offers the possibility of 2.0-2.5 crops per year.

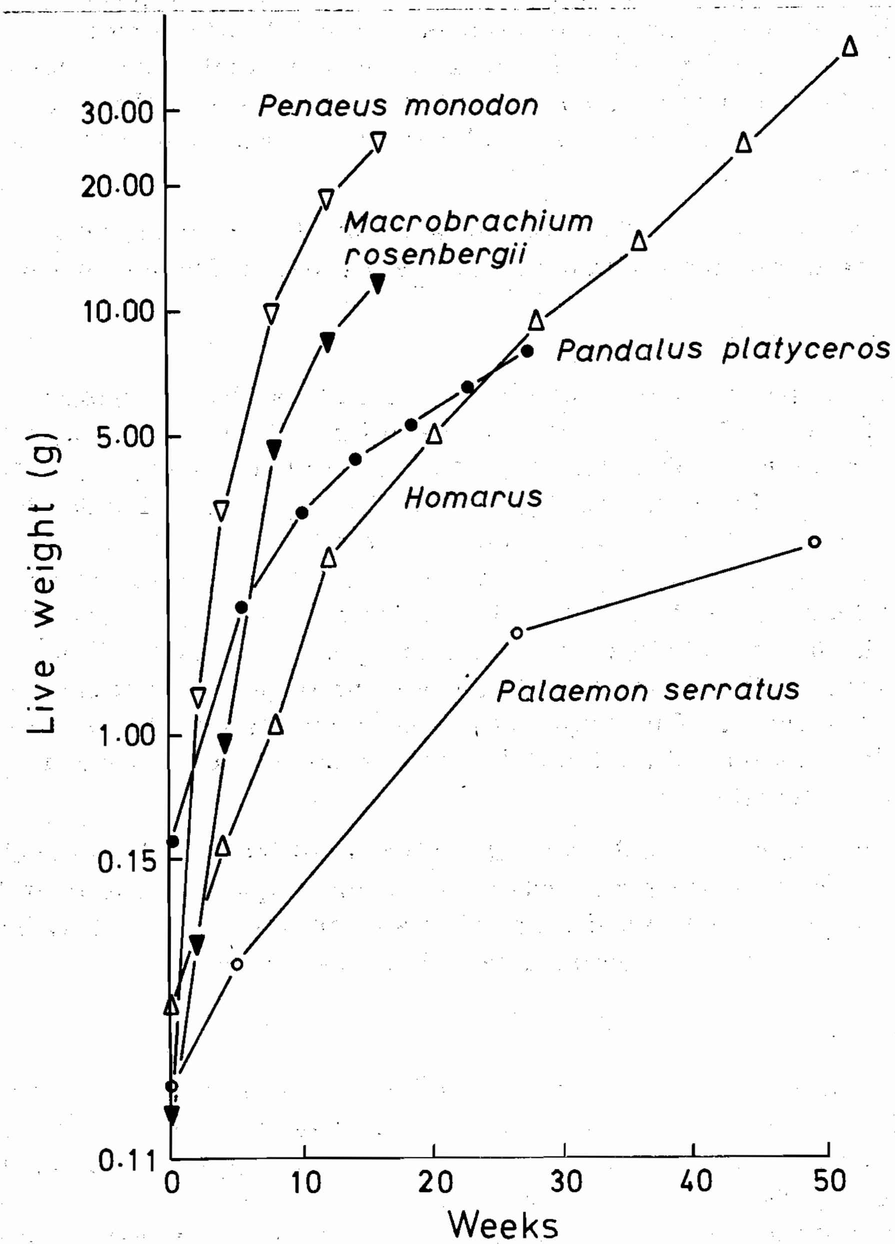

Figure 5 The growth rate of various Crustacea cultured at Conwy.

4. Caridean prawns

Caridean prawns are superficially similar to penaeid shrimps but a clear difference is their habit of carrying their eggs under their tail until they hatch into free-swimming larvae (Figure 4i) which are more advanced in development than early stages of penaeid larvae. The group includes Palaemon serratus (Figure 3d) which is caught commercially in very small quantities on the south coast of England. Studies at Conwy showed that, although this species could be successfully cultured intensively, it was not a promising subject for commercial exploitation. As it does not survive for more than a few days at water temperatures below $4^{o}C$ it could not be overwintered in unheated ponds in the UK.

Only the females reach the optimum commercial size of 6-8 g and both males and females will breed before reaching market size. This causes a check in the growth rate and extends the culture period. Even under optimum conditions P. serratus takes at least a year to reach market size (Figure 5). Other temperate-water species of caridean prawn include members of the genus Pandalus. Some of these support substantial fisheries, for example the pink shrimp P. borealis in the North Atlantic. This genus characteristically is in cooler offshore waters and, with individuals breeding as males before changing to female, does not offer special advantages for culture. Pandalus platyceros from the eastern North Pacific grew reasonably well at Conwy (Figure 5) but the larvae are less easy to rear than those of some other species.

This group also includes the genus Macrobrachium (Figure 3e) which occurs in fresh water in the tropics. The eggs are carried under the tail of the female and while these are developing she descends the river to the mouth so that the larvae hatch in brackish water. They, in turn, ascend the river after completing larval development. One of these species, the giant freshwater prawn from Malaysia (Macrobrachium rosenbergii), has been the subject of considerable research and is now being successfully reared in extensive culture in ponds in India, Pakistan, Malaysia, Thailand, Mauritius, Hawaii and elsewhere in the tropics. It has been successfully reared through a number of generations at Conwy. The disadvantages of this species for intensive culture are its large claws, aggressive nature and the relatively small proportion of the total weight which is represented by tailmeat (35% compared with 60% in a penaeid). Although the growth rate is reasonable (Figure 5), a wide variety of sizes develop in both ponds and tanks, perhaps due to dominance by more aggressive individuals. It is therefore advisable to have repeated harvesting in which the larger individuals are culled off.

5. Astacura

This group includes the commercially important lobsters (Figure 3f). These are confined to the North Atlantic Ocean where there are two species: one is found in North America (Homarus americanus) and one in Europe (Homarus gammarus). Their larval life (Figure 4j, k) is simplified and they reach the adult form and adopt a bottom-living habit by the fourth stage. Although lobsters have a low fecundity, are distinctly aggressive and will probably take two years to reach market size, they are receiving increasing attention because of the size and value of the market. Additional cultural advantages are the low temperature required compared with penaeid prawns (20°C compared to 28°C), many fewer juveniles required per ton produced, and the large European and North American market for fresh lobsters. The group also includes Nephrops (the Norway lobster), but this species does not seem to be a likely candidate for cultivation due to its preference for offshore environments, its burrowing habit and probably aggressive nature.

METHODS OF CULTIVATION

There are two basic types of cultivation available for Crustacea: extensive in ponds and lagoons, where the population is relatively low, or intensive in tanks where populations are relatively dense. These will be discussed separately.

Extensive cultivation

Prawns

Simple culture of penaeid prawns has been practised in the tropics for a long time, but the methods rely on juvenile prawns being available in the local sea and hence are not applicable to the UK. The development after a long period of investigation of a more controlled system of culture of the Kuruma prawn (Penaeus japonicus) in the temperate waters of Japan has stimulated considerable interest. The yield in Japan of cultured prawns was 1 300 tons in 1974 - about equal to that from the wild. Large numbers of larvae are reared in controlled conditions through to juveniles which are then planted into large salt-water lagoons. These are often constructed from old salt ponds. The grow-out phase, which starts in April and May, is assisted by feeding a variety of fresh diets and the prawns reach market size (20-25 g) in late autumn. The cycle has to be completed in less than one year because survival over winter cannot be guaranteed except in the south of Japan. When considering the Japanese development, however, it is essential to remember that it is predominantly catering for a special live prawn market used in the traditional 'Tempura' dishes, and prices are correspondingly high (up to £15 per kg).

The controlled culture of penaeid prawns has been subsequently tried in a number of countries. The most recent development has been in the Philippines where extensive development of Government-operated hatcheries for the culture of the larvae of Penaeus monodon is taking place. The juveniles produced will be supplied to the owners of coastal lagoons. The development of hatcheries and lagoons in the US now seems to have come to a halt with most of those companies which have retained an interest having moved to Central America.

The culture of either caridean or penaeid prawns outdoors in the UK does not seem to be practicable. The possibility of obtaining a suitable site at low cost is unlikely in view of the pressure on the coastline for industrial, residential and recreational use. Our own species of caridean prawns would, even if they survived the winter, take two or three years to reach market size; our waters are too cold for penaeid prawns. Further south, for example, on the north coast of the Mediterranean it should be possible to reproduce the Japanese system, but unless the annual yield can be increased above the 2-3 tons per hectare obtained in Japan, it would seem unlikely to be profitable.

Lobsters

A variant of extensive culture is the continued attempts being made to ranch lobsters. The larvae and juveniles are cultured for a period in a hatchery and then the juveniles are released on to the sea-bed on the assumption that the shortage of lobsters in a fishery is due to inadequate survival of the larval stages. This type of stocking was begun by the US Fisheries Commission in 1885 and rather later in northern Europe. It has yet to be demonstrated that artificial restocking has had any measurable effect and no doubt for this reason hatcheries for this purpose are reduced to one in the USA and one in France. Similar releases are being made of hatchery-reared prawns in Japanese waters. If it can be so demonstrated, then it is possible that either industry on its own, or in conjunction with public authorities, could adopt this type of culture.

Intensive culture

Since temperate water Crustacea grow rather slowly, intensive culture appears to offer the main way forward to crustacean culture in the UK provided warmed water is used as it allows the culture of tropical species or temperate species at optimum conditions. The commercial feasibility of using elevated temperatures probably depends on the development of closed circulation systems in which the water is continuously recycled. The assumption is made that it is probably cheaper to purify the water rather than heating a fresh supply. An intensive system need not be closed. If a continuous supply of water heated to a suitable temperature is available recirculation would not be required and the intensive system could be operated on open flow. Recirculation systems do have a number of advantages other than conserving heat. These include:

1. Optimum growing conditions in respect of water chemistry can be permanently maintained.

2. Stock maintenance is greatly simplified and close control can be kept over feeding, harvesting and disease.

3. Systems are amenable to automation.

4. There are no predators.

5. The reliance on large quantities of water from natural sources is considerably reduced.

6. A developed system can be used for the cultivation of other species.

The disadvantage of intensive systems arises from the high density of stocking. The survival of the stock is completely dependent on the proper functioning of the equipment and its failure is liable to have catastrophic consequences unless it is quickly detected.

Prawns

It has been a common experience among research workers throughout the world that it has been difficult to obtain mature female penaeid prawns in captivity. For reasons which are not yet fully understood the ovary does not readily develop in captive animals although mature females from the sea will spawn normally. In the UK this difficulty has handicapped progress with non-indigenous species. Most of the reported experimental work, notably from Japan and the US, has taken place where mature fertilized females could be caught locally. Even this had disadvantages since not only do they have to be captured in good condition when required, but work is limited to their natural breeding season. It is only in the last few years that success has been achieved in obtaining ovarian development and fertilization in captive penaeid prawns. It is reported in tanks, ponds and cages with P. monodon (Philippines and Taiwan), P. merguiensis, P. japonicus (Tahiti), P. japonicus (France). P. merguiensis has also been reared and subsequently spawned through several generations in a closed recirculation system in the UK at Conwy. Recently success has been obtained in spawning P. japonicus in France where, by careful control of feed, photoperiod and temperature, 18 females have spawned 150 times. There would seem to be no fundamental difficulty, after some further research, in obtaining the regular breeding of a number of desirable species. Although it is vital that complete control of seed production is obtained before capital intensive methods of culture are attempted on any scale, it is thought that the techniques which will be required will not add significantly to the cost.

Spawning penaeids produce large numbers of eggs and the culture of the larvae, using first phytoplankton (Tetraselmis at Conwy) and subsequently Artemia as food, is well understood and good yields of juveniles can be obtained.

Prawns are essentially bottom dwellers and many species can be grown in shallow tanks containing 15-30 cm of water. This leads to expressing prawn density as weight per square metre of tank rather than using tank volume. Results so far obtained at Conwy indicate that a routine yield of 1.5-2.0 kg/m^2 is a realistic target. This corresponds to 100 20 g prawns. We have used shallow rectangular tanks but these are expensive in terms of area, and deeper tanks, containing perhaps a number of false floors, would be more economical and perhaps essential for the larger prawns. It will also be necessary to include self-cleaning devices.

In an intensive recirculation system the water continually overflows from the culture tanks and passes to a treatment system where it is reconditioned before being re-used. A settlement tank removes large pieces of debris such as uneaten food and a filter may be required to remove smaller particles. Aeration removes surplus carbon dioxide and restores the oxygen level; some chemical adjustment of pH may be required. The water also contains the soluble excretory products of the prawns as well as an organic load which has leached from the food. Ammonia is the main excretory product and this is toxic in low concentrations. It is the unionized fraction which is highly toxic to prawns and there is about 10 times more unionized ammonium nitrogen at pH 8 than at pH 7; a low pH is therefore beneficial. Ammonia can be removed from the system using algae but such a system requires light. More convenient is the use of a trickle or biological filter in which the circulating water passes through a large volume of gravel or plastic. Bacteria and other organisms growing on the surfaces remove organic material and successively oxidize the ammonia to nitrite and to the relatively harmless nitrate. More intensive systems, such as the activated sludge process, will also carry out the same function. The selection of a suitable economical system belongs to the field of chemical engineering, but most of the information in the literature refers to freshwater systems and little of it to salt water at tropical temperatures.

The continual recirculation of the sea water may lead to other changes. We know that there is a continuous loss of inorganic carbon which must be replaced. At present changing 50% of the water per week has proved satisfactory, but the biological loads have been light. Systems at Conwy have approached 1 kg of prawns/100 litres but some fish systems are reported to operate as high as 10 kg of fish/100 litres.

Comparative trials at Conwy using low stocking densities in a standard culture system and Mytilus and Crangon as food showed that in a grow-out period of 16 weeks Macrobrachium rosenbergii grew to 11.9 g with 73% survival, while P. monodon grew to 25.4 g with 100% survival (Figure 5). Other species of penaeids grew as well but did not appear to be as robust in culture. P. monodon appears to be outstanding in its general hardiness and adaptability to culture and more recent trials show that it should be possible to reach an average size of 25 g in six months.

In the wild mature female P. monodon weigh 120-220 g, and in grow-out ponds in the Philippines the average individual weight can exceed 50 g after six months. Clearly, there is a considerable potential for growth awaiting exploitation with this species. No doubt the biological difficulties will be overcome in due course but, in the meanwhile, we need to attempt to establish a commercial judgement of the economics of recirculating systems operating at tropical temperatures.

Lobsters

From a number of biological aspects the lobster looks a less encouraging subject for cultivation than penaeid prawns. It has a low fecundity, it is more ferocious and territorial in behaviour, it has to be grown to a larger size to be commercially acceptable and this will take a relatively long time. On the other hand, it shows some advantages: the larger size suggests that smaller numbers of juveniles will be required, 20°C and not 28°C is the optimum rearing temperature and, most important, it enjoys a good and well-established market at a very high price in northern Europe and North America. This latter feature suggests that there will be fewer marketing problems with fresh lobsters compared with fresh prawns. In recent years interest in lobster cultivation has increased considerably, and both species are the subject of additional research in North America and Europe.

Most investigators have studied relatively short stages in the life cycle because of the slow growth rate of lobsters and there have been few attempts to grow a reasonable number from larvae to market size. Many of those that have been reared resemble laboratory pets rather than random individuals and it is not clear if their growth rates are about average or are those of exceptional individuals. However, a study of the literature shows that most investigators agree that a 450 g (1 pound) lobster should be obtainable in approximately two years.

The larvae (Figure 4) can be reared through to the bottom-living stage 4 in about three weeks using brine shrimps, other chopped crustaceans, and chopped mussels as food. Although the methods are reasonably standardized (Figure 6), further study is required to improve survival. After the larval stage the juvenile lobsters are transferred to plastic boxes with a mesh base (Figure 7).

Our studies at Conwy have shown that maximum growth is obtained in normal salinity sea water at 20-22°C (Figure 5). It prefers tranquil conditions; less activity and better growth is shown in dark or dim conditions rather than in a day-night cycle. Shelters in which to hide also improve growth. For example, juvenile lobsters after 12 weeks culture without shelters had a wet weight of 1.2 g, but if a shelter was present in each container the weight was 1.4 g. A good diet is provided by a mixture of the blue mussel, Mytilus, and the shore crab, Carcinus. This is not practicable on a large scale but after a number of trials we have been able to show that a diet largely based on fish meal and reclaimed haddock flesh, and bound as a jelly in agar, gives reasonable growth. If it is supplemented with fresh food once a week then the diet is as good as a fresh diet. This supplementation presumably supplies vitamin and other trace nutrients which are lost in processing. Although this diet is uneconomic as it stands, it is a basis from which further developments can come.

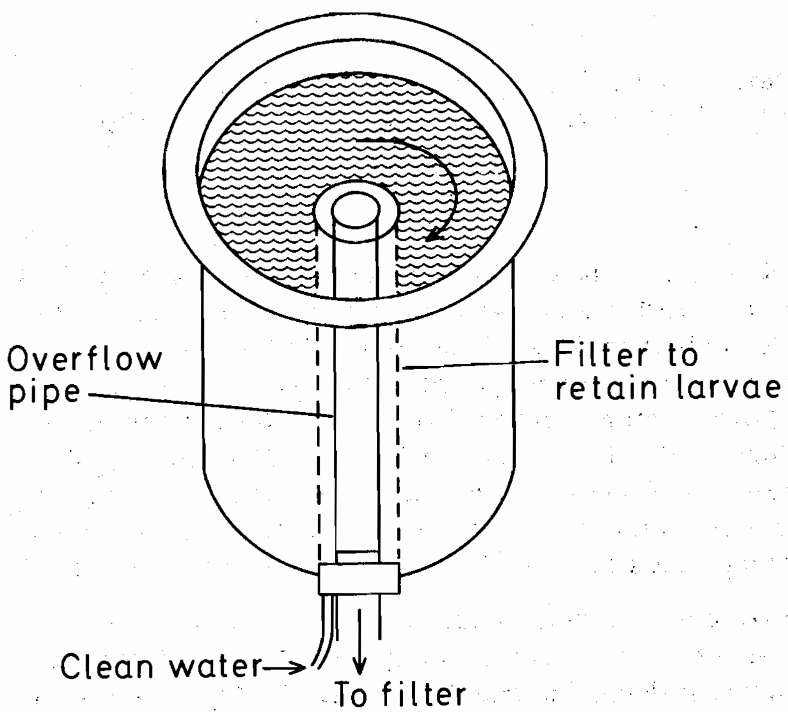

Figure 6 Bin with circulated sea water for the culture of lobster larvae.

A major question mark for lobster cultivation arises from the requirement to keep the animals in individual compartments (Figure 7). It has been shown that the compartments need to be only a little bigger than the animal. But will it be possible to devise a system in which huge numbers of individual compartments can be checked, cleansed, fed as required, and all at reasonable cost? There are projected estimates from groups working in California that this can be done, but clearly there is a requirement to develop such methods of culture to a scale where realistic estimates of cost can be made.

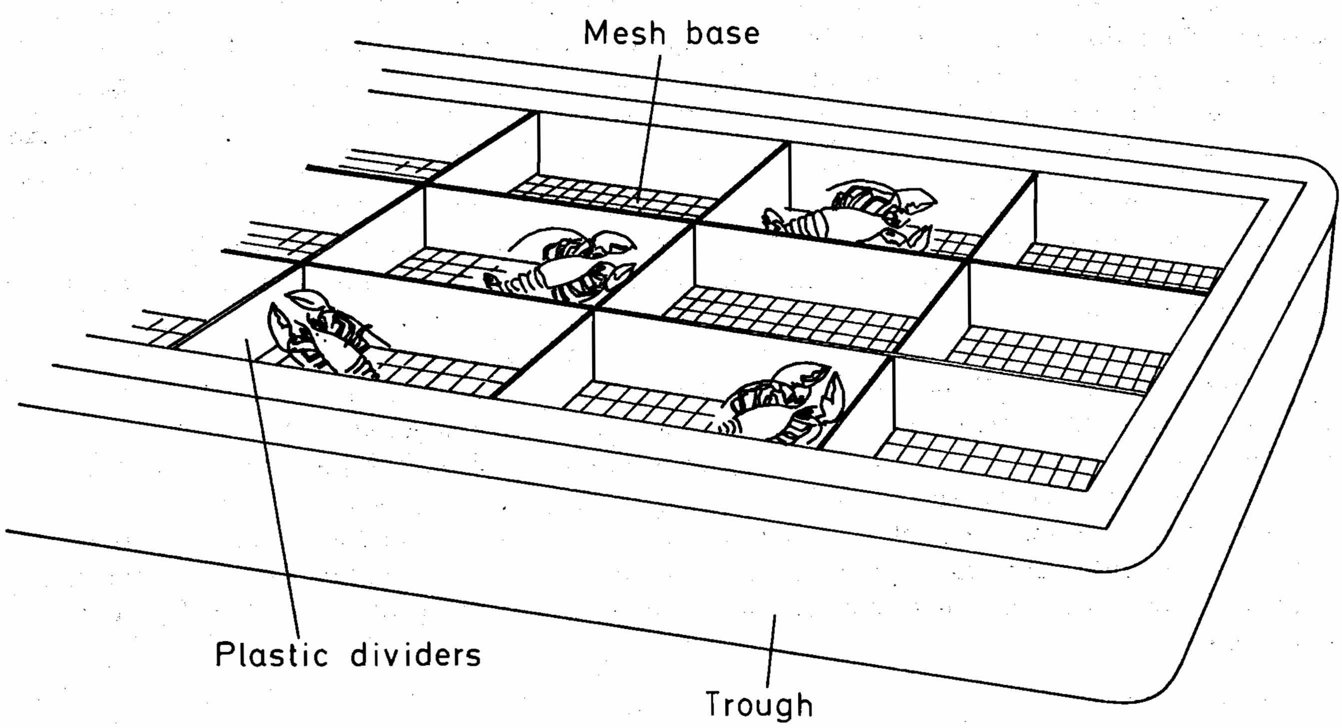

Figure 7 Lobsters in individual compartments with mesh bases. The compartments stand in a shallow trough through which sea water flows.

DISCUSSION

Sufficient studies have now been made of the relevant basic biology of Crustacea to suggest methods and species which warrant further consideration for commercial application in the UK. It is clear that the choice is limited by the biological characteristics of the various species, by the climatic regime and by the pressure on the use of land adjacent to the sea. The latter factors suggest that the way forward is by intensive culture rather than by semi-natural extensive culture, although the possibility of a combination of the two should be remembered. It may be feasible to cultivate the young stages intensively at elevated temperatures in the winter months and utilize the summer months for the grow-out period in outdoor ponds into which perhaps some waste heat is injected.

In the culture of any marine animal it is desirable to have rapid growth which leads to a commercial size before sexual maturity. Rapid growth ensures the maximum use of capital resources and reduces the running costs. It also reduces the time at which the population is at risk from accidents such as abnormal environmental changes and equipment breakdown. These and other factors favour the warm-water penaeid prawns.

The culture of warm-water species in the UK implies that either waste warm water is used or that the water is heated for the purpose and continuously re-used after purification in a biological filter. Purification of both fresh and sea water in aquaculture systems has been receiving attention in a number of countries primarily for use with freshwater and marine fish, and is able to draw on the extensive experience of the waste water treatment industry. Since the waste products that have to be treated are similar a system using a biological filter could be used for any species of marine animal.

The proposal to culture lobsters goes against the conclusions reached in the preceding paragraphs in that it is a relatively slow-growing species taking at least two years to reach market size. The main force of the argument for lobsters is market orientated. There is a good local market for fresh lobsters. For prawns the fresh local market is a matter for conjecture, otherwise the cultured product is in competition with frozen prawns from many parts of the world.

Over the last five years considerable strides have been made in narrowing the choice for crustacean cultivation in the UK. The next stage is to establish the feasibility, particularly in economic terms, of the concept in the UK. If this looks promising and the areas of high cost and major difficulty are identified then the stage is set for further investigations which may well include engineering and water treatment studies as well as biological investigations.

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