market that will probably provide the cheap soft foods which fish prefer without preliminary weaning periods.

Then there is the possibility of utilizing the effluent for growing fodder foods, either culturing bivalves or fattening *Artemia*, thus simulating the real agricultural principle of growing the animal's requirements on the site.

In the future, a power station site might consist of its own hatchery unit, nursery ponds and large lagoons, as well as food preparation units and fodder ponds. This means detailed design and planning for the best use of the available ground around a power station, and therefore it is essential that all aspects of the basic research are covered so that the first fully operational unit has all in its favour to succeed.

EXPLANATION OF PLATE

Interior view of the marine fish hatchery at Port Erin, Isle of Man, showing polythene plaice-rearing tanks arranged in rows and layers.

Socio-economic aspects of fish farming

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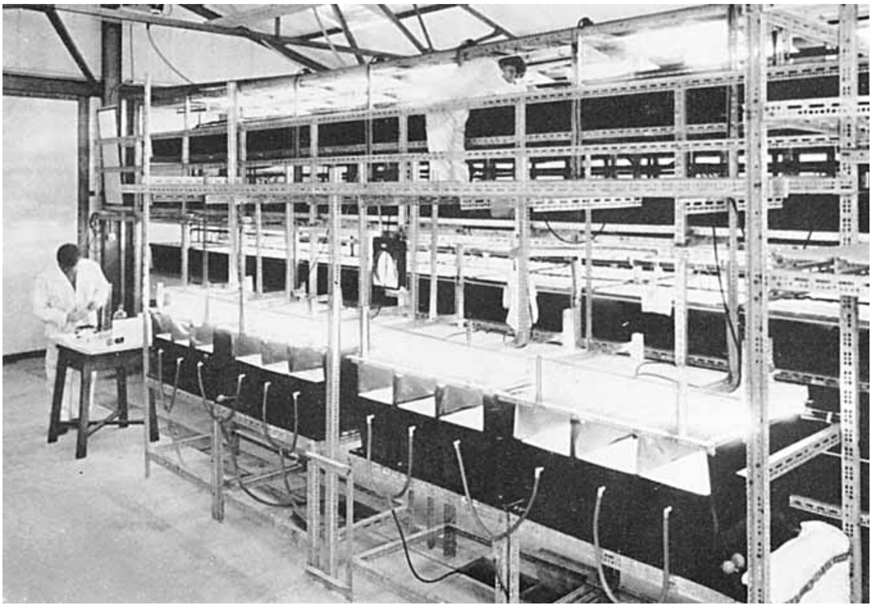
Fish farming is undoubtedly a good way of growing substantial quantities of first-class animal protein in a small area; but there are practical difficulties in its further expansion, socio-economic as well as technical.

First, there is the water supply. This may be a difficulty where there is a long dry season. In such instances, fish farming can be associated with water-impoundment schemes; and though it may there compete to some extent with irrigated plant crops, fish farming can use water which has become too saline for most plant crops, since many valuable farm fish have a notable salinity tolerance. Moreover, in warm countries, worth-while fish crops can be got even where water is available for only 6 months in the year, provided there are the facilities for restocking for the next crop. Fish farms must also not be placed where they may be liable to floods.

The best results are got in slightly alkaline water, since acid water inhibits many important links in the food chain, and also makes the fish more prone to disease.

The matter of water supply may be simpler where fish farming is done in sea water or brackish water, provided the ponds are situated at the correct levels in relation to the tides; but such ponds are liable to become very saline during a dry season. Fresh water is brought, where possible, by canal to these marine fish-farm complexes to combat excessive salinity. But salinities can vary from 0·5 to 8 % in the dry season. Obviously, such farms would grow only fish which have a great salinity tolerance. Such fish are the milk-fish, *Chanos chanos*, a herring-like fish, and the grey mullets, *Mugil* sp. Many species of Penaeid prawn are carried into the ponds as larvae, with the inflowing water, at times of filling, and these are a very valuable catch-crop. These fish are herbivorous, feeding on the algal felt which develops on the firm pond-mud; and in Formosa, where this form of fish farming is best developed, organic fertilizers are used to increase the production of this vegetable material. Hence the



J. E. SHELBOURNE & C. E. NASH *(Facing p. 140)* high rate of production of these ponds, which may be of the order of 800 to as much as 2000 lb of fish per acre and per annum. In Formosa there are over 10 000 hectares of these marine fish ponds, a substantial industry.

At the 8% level of salinity, these fish are not harmed, but they may cease to feed, which is a loss of earning time to the farmer.

Such brackish-water fish farms are most extensively developed in the tropics (India, Indonesia, Philippines, Formosa) but some were in use at least until very recently in the Biscay region, and all around the Mediterranean there are brackish-water lagoons in which there is a simple form of farming of grey mullet and eels. The 'valle' of the Adriatic are well-known.

Another very important economic factor in fish farming is the length of the growing season, and the temperature. Most fish seem to feed sparingly and irregularly at temperatures below about 8°, so European countries have only about 180–200 growing days a year. During a large part of the year, then, the capital invested in a fish crop at best earns nothing, and at worst may actually depreciate. Fish farming in such conditions can only pay where the fish produced can sell at a high price. Luckily, in the tropics and subtropics, where the need for animal protein is greatest, temperatures are high and the growing season long, so that large fish crops can be grown economically at a fast rate, tending to a cheaper cost of production.

It is the object of this Symposium to look at fish farming as a source of dietary protein; and from this viewpoint fish farming can be considered under three heads.

Firstly, there is the farming of carnivorous fish, chiefly trout and eels, which is usually very intensively done in small ponds. From the nutritional aspect, this is the least economic form of fish farming, since it involves feeding with animal protein to get animal protein. There may be a large net decrease in animal protein, since from 3 to 12 parts of animal protein foods are needed to make one part of fish. Eels may get a substantial part of their food from midge larvae which develop in their pond; but both trout and eels are farmed intensively chiefly on the basis of animal foods such as slaughterhouse offals and trash fish from the fish markets. The rate of fish production per unit area of pond may be exceedingly high, at a rate of many tons per acre; but, at best, such farming upgrades cheaper animal protein to financially more valuable protein. For example, in Formosa the eel *Anguilla japonica* is intensively reared on fish-market trash. The price of these trash fish is about $2 per kg, the conversion rate about 13:1, and the finished product sells at about $60 per kg. So an expenditure on food of $26 gives a product worth $60, which is very profitable.

Secondly, there is the farming of one or several species of non-predatory fish, chiefly members of the carp family (Pl. 1), on the intensive scale, growing the fish not only on the foods produced naturally in the pond, often stimulated by the application of fertilizer, but also on added fodders such as green vegetation, oilcakes such as copra, groundnut, mustard oil, and many others, and rice bran, maize residues, spoilt wheat and barley. In this instance, dietary animal protein is being created from natural production and from plant wastes themselves unsuitable for human food. It seems to be unnecessary to use supplementary fodders rich in protein, for the natural food taken by the fish contains a high proportion of protein, so that supplementary fodders can be cheap starchy materials. The food chains involved are complicated; but it is worth noting here that both a holophytic and a saprophytic process may be involved.

Unluckily, especially in tropical countries, fodders suitable for this kind of culture are becoming dearer and more difficult to get. Battery production of poultry and intensive pig rearing are on the increase, and compete for these fodders; while also there is a profitable export market for locally produced oilcakes. The small-scale fish farmer, unless he is also a pig and poultry farmer (as is often so), may find the purchase of fodders increasingly difficult and uneconomical. Nevertheless, very high fish crops are got by this kind of intensive fish farming, ranging from an optimum of about 800 lb per acre and per annum in Germany and Russia to over 4000 lb in the Far East. The rate of production is known accurately in Israel, which has a subtropical climate. In 1964, some 9990 metric tons of fish were produced, at a country average of 1860 lb of fish per acre and per annum.

Thirdly, there is extensive fish farming, relying on the food grown naturally in the ponds and stimulated by the application of fertilizers. This fertilizer is usually organic material such as pig and poultry manure, and where the fish farmer is also a pig raiser, administration of the manure may be simplified by building the pig pens over the fish ponds (Pl. 2). Human night-soil is much used, and latrines may empty into the ponds. This is known to be undesirable; but in the world's overcrowded lands, which are intensively cultivated, no source of fertility can be wasted. Treated sewage effluent is used in some European countries as a fish-pond fertilizer, and can give large fish crops.

Dung may be used directly as a fodder by the fish, for pig dung, for example, has a good nutrient value. But in any event, a large amount of organic matter containing plant nutrients goes into the ponds, and may give rise to the two types of food chain mentioned earlier, and both types may proceed at the same time.

The first type is holophytic, and depends on the production of green plants, both aquatic weeds and phytoplankton, in sunlight. Phytophagous farm fish feed on these directly; other farm fish take this material indirectly from a food chain which passes through phytophagous crustacea, insects, and other animals.

In the presence of much organic matter, the plants which develop may contain a high proportion of blue-green algae. An increasing number of blue-green algae have been shown to be fixers of atmospheric nitrogen, and I have been shown Indian work on paddy fields inoculated with blue-green algae, which gave crops equivalent to those got with a substantial application of nitrogenous fertilizer. Therefore such a fish pond tends to produce its own nitrogen requirements from the atmosphere.

At all events, when inorganic fertilizers are used, the addition of nitrogenous fertilizers, whether as nitrates or as urea, will not ensure fish crops better than without them. Phosphate is the key fertilizer; and, in a series of fertilizer trials in the tropics, each lb of P_2O_5 gave an additional 15 lb of fish. The addition of potash fertilizer is seldom necessary, except possibly in some peaty soils.

In the second, saprophytic, food chain, organic matter in the pond nourishes bacteria, which feed infusoria, which are food for rotifers and some crustacea and worms, which in turn feed the fish. An interesting example of this occurs in Tripur State in north-east India, where, in spite of acid conditions, there is a high rate of fish production. It has been found that a very rich zooplankton, chiefly Cladocera, develops without the intervention of phytoplankton, and all the major Indian carps grow fast on this diet.

With phosphate fertilizer alone, fish ponds at the Malacca research station have given crops of fish at the rate of from ¾ to 1 ton per acre and per annum. This is about the same as the country average in Israel, where the fish have supplementary feeding. The high and steady temperature of the tropical ponds has the same effect on fish growth as massive supplementary feeding in Israel. But labour costs would be much less, for inorganic fertilizers are cheap to buy, to transport and store, and to spread in the ponds.

This kind of fish farming is the most economical of all, for here new protein material is being synthesized. I consider that one of the most important pieces of extension work is the propagation of the use of inorganic fertilizer in place of animal manure as fertilizer for fish ponds. Animal manure has valuable soil-conditioning properties, which are badly needed on the land, but are unnecessary in waterlogged pond soils. Better fish crops can be got with much less material in artificial manuring, for dosages of the order of 40–60 lb P_2O_5/acre are easily handled.

But the use of artificial fertilizers involves a cash transaction, in communities where self-sufficiency is often preferred. And this brings us to a number of socio-economic factors which handicap the extension of fish farming. First there is the conservatism of farmer folk everywhere. The second is a general lack of capital in the underdeveloped countries, especially for a newcomer such as fish farming. The third is land-tenure. Where, as so often happens, land is held by people on an insecure short-term lease, there is no incentive to put in the work needed to build a fish farm. Many peasant fish farmers are squatters with no title at all, and they may use ready-made ponds such as sand- and gravel-pits, borrow-pits, and opencast mining pools. None of these are satisfactory fish ponds, but better than nothing.

The situation is better with brackish-water fish farming, since reclaimed foreshore and mangrove swamps are usually state land for which long leases can often be got. But considerable capital is needed; for example, in Sarawak a Chinese business man is spending £30 000 in clearing mangrove swamp for prawn culture ponds. Where plenty of capital is available, and land can be bought, fish farming can be as much big business as other kinds of farming, with all the economies of large-scale working.

For the man of small means, however, fish farming is probably best associated with pig, duck, and poultry raising, as is done among peasant people of Chinese origin, and with fruit and market gardening. The fish ponds are then reservoirs for the gardens, as well as for growing fish. Waste materials from the gardens and livestock feed the fish, and at intervals the pond-mud can be scraped out to fertilize the gardens. A good rate of production of fish, chickens, ducks, eggs, pork, fruit and vegetables is possible from such a smallholding, with the fish as often the best money-earner.

Fish farming fails to appeal where the people have no tradition of livestock husbandry. Nomadic populations and those who still practice shifting cultivation are unlikely recruits for fish farming. Even where livestock is kept, the animals may be left to shift for themselves with the minimum of care; and people who treat their land livestock in this way are unlikely to give farm fish any better husbandry. This is probably the most serious socio-economic handicap in propagating fish farming.

EXPLANATION OF PLATES

Pl. 1. Catch of fish at Killa Fish Farm, Cuttack, India. Fish species; Indian major carps *Labeo*, *Cirrhina*, *Catla*, and hybrids.

Pl. 2. Fish farm pond in Malaya; pigsties and buffalo shed on banks.

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