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AQUACULTURE ECONOMICS AND MARKETING: AN OVERVIEW

Clem Tisdell

1. Introduction

Economics plays an important role in the survival and development of aquaculture husbandry. While technical ability to husband a species is a precondition for its aquaculture, this culture will fail to develop and survive (in any meaningful sense) if it is commercially uneconomic. The reasons for economic failure of an aquacultural project may stem from production, technical or cost problems, or from marketing problems. Therefore, those who want to have a commercially successful aquaculture enterprise must pay considerable attention to economics, including marketing issues.

Especially nowadays, aquaculture economics and marketing is a specialised subject, and its whole range cannot be covered in depth in a single chapter such as here. Therefore, the purpose of this chapter is to highlight for non-specialists in economics selected important issues that need consideration in developing aquaculture commercially and in assessing it from a community-wide economic perspective. Readers who require further in depth coverage of this subject can consult specialised books on aquaculture economics such as Shang (1981), Hatch and Kinnucan (1993), and Jolly & Clonts (1993).

Aquaculture economics can be considered from several different perspectives. It can be considered from the point of view of an individual aquaculture business, from the perspective of the whole industry or from a national standpoint. In Western countries in particular, profitability is likely to be the major economic concern in an individual business; whereas overall net national benefit should be the main focus from the national viewpoint. It should be noted that profitability does not necessarily measure net national economic benefit. For example, if an industry has adverse environmental spillovers, profits in the industry can overstate its national economic benefit because the social costs of its production may exceed the costs paid by individual firms.

In market economies, if aquaculture businesses are to make a profit, they must actively market their product and do so effectively. For established products, this may be relatively easy because it may be possible to tap existing marketing networks, making use of established food processors, transport and distribution channels. Marketing of new aquaculture products can, however, be quite difficult, especially in the absence of appropriate marketing networks (Tisdell, 2001).

Profitability is not only influenced by the market but by the costs of production, the latter will depend among other things on the types of techniques available and the costs of inputs used in the production process. For example, costs vary according to whether the business is involved in the hatchery phase, the growing-on phase or both, and whether the culture is performed in artificial enclosures requiring pumping of water or in natural water bodies.

Modelling the economics of aquaculture is complex but some insights into it can be obtained by considering simple economic models. Thus, this chapter will successively consider models analysing the profitability of a business, the market, the nature of production costs, methods by which a firm can deal with business risk and uncertainty, and the social economic evaluation of aquaculture. Economic terms used in this chapter are explained in Table 10.1.

2. The Profitability of aquaculture from a business viewpoint

For a single period of time, say a year, a firm's profits can be obtained by taking the difference between its total revenue and its total costs. Its revenue is equal to its volume of output multiplied by the price at which units of output are sold. If the market in which the firm sells its product is very competitive, the firm will need to sell at the going market price. This, for example, is likely to be the case for the sale of table oysters and for penaeid prawns on the international market. Clearly, other things being equal, the higher the price for the aquaculture product, the higher will be the profit of the business. In some cases, however, there may be few or virtually no competitors in the market for the cultured product and, up to a point, an aquaculture business selling this product will be a price-maker (as opposed to a price-taker). This has been true of the Japanese cultured pearl industry but no longer appears to be the case (Tisdell & Poirine, 2000), and is currently true in Australia for producers of pearl-oyster seed, and was so for cultured giant clams as aquarium specimens (Figs. 10.1 and 10.2).

It should be noted that the **economic** concept of costs differs from that of **accounting.** Economic costs are based on opportunity costs, that is, the economic benefit forgone by not choosing the best alternative to the choice actually made. For example, if family labour is supplied to an aquaculture business free of charge, this would not be included in the accounting cost of the business. However, if that family labour could earn an income if employed elsewhere, the highest income which it can earn elsewhere is its opportunity cost. In order to calculate economic cost, this opportunity cost would be imputed to the family labour employed.

In general, we are not interested only in the profitability of an aquaculture business in a single period of time but for an interval of time spanning several periods. Economists usually consider the firm's profitability for a planning period covering several periods of time, (e.g. for a 10-year period) covering 10 annual time periods. The appropriate planning period and horizon for planning purposes is likely to vary with the enterprise at hand. However, a very long period, say fifty years, for a planning interval is likely to be too long because discounting of the future (Table 10.1) and uncertainty will mean that events 50 years hence will have little consequence for current decisions.

The optimal business strategy from the point of view of an aquaculture business is according to standard economic theory (Tisdell, 1972, Ch. 16): that which maximises the business' net present value, that is, the present discounted value of its stream of profits over its planning period plus its discounted realisable value at the end of the planning period. Usually, the real rate of interest is used as a discounting factor since this is an indicator of the return which the business could earn on its funds if it invested them elsewhere.

If the net present value of a project is positive, it is profitable from an economic point of view because it earns more than the going rate of interest.

This principle is applied to cost-benefit analysis. If the net present benefit from investment in a project is positive after discounting using the appropriate rate of interest, it is economic. This also implies that its discounted benefits divided by the discounted costs exceed unity, or, in other words, that its benefit-cost ratio exceeds unity (cf. Shang, 1981, Ch. 7; Allen *et al*., 1984, Ch. 2).

Alternatively, but subject to some relatively minor qualifications to determine a firm's profitability or the profitability of an investment project, one may calculate its internal rate of return. The **internal rate of return (IRR)** is equal to the rate of interest which will just make the present discounted benefits from a project (or for a business) equal to its present discounted costs or outlays. IRR is an excellent measure of the profitability of a project or business. If the IRR of a business exceeds the going rate of interest, the business is profitable. It is more profitable the higher is the internal rate of return in relation to the rate of interest.

The above measures of profitability assume that the capital (finance) market is perfect and ignore uncertainties. In practice, a firm may need to give special attention to its **liquidity** (cash availability) to ensure its continuing viability. It may therefore be concerned about how quickly a business enterprise can pay back the investment in it, and about how large its debt may become during the planning period; because the larger is its debt, the greater are its risks.

It is not uncommon for economists to make estimates of internal rates of return for the culture of different species. Treadwell *et al.*, (1991) estimated the IRR from cultivating various aquaculture species in Australia. These estimates are set out in Table 10.2. To make these estimates, they considered model (or representative) aquaculture farms and specified annual operating costs and capital cost. These costs, together with predicted levels of revenue, provided the basis for estimating net benefits and subsequently the IRR values for the different types of farms. The aquaculture business' planning interval was assumed to be for a 20-year period.

Table 10.2 sets out the mean probable IRR-values for the various model farms. In this case, risk or uncertainty has been specified as a probability distribution by the authors and the ranges of these distributions are shown. For some species, these ranges are very wide, suggesting a considerable degree of risk as far as returns are concerned.

To determine whether the aquaculture of a given species is profitable from an economic viewpoint, we should compare its IRR with the real rate of interest. The real rate of interest is equal to the monetary or nominal rate of interest adjusted for the rate of inflation. Treadwell et al. (1991) estimated the real rate of interest in 1991 to be 6%. That being the case, and using mean IRR values, it follows that, on average, species cultured in the following way would be uneconomic: barramundi in cages in freshwater, giant tiger prawns grown in subtropical areas, rainbow trout grown either in freshwater or in the ocean (model I), and comparatively small Atlantic salmon farms producing about 40,000 smolt per year held in 60 metre cages. The profitability of culturing the different species varies considerably. The most profitable in decreasing order are:

1. Pacific oysters on a good site;
2. barramundi farming initially involving a nursery phase and then a free-ranging phase;
3. redclaw freshwater crayfish farming on a 15 hectare farm;
4. prawns stocked at medium density in North Queensland.

Variations in the range of possible returns between species are considerable. From Table 10.1 it is evident that there is little likelihood of a low return from Pacific oysters on a good site, for freshwater crayfish farming and for large farms growing crocodiles. But there is a risk of low and uneconomic returns from rainbow trout farming, barramundi cultivation in freshwater in cages and for the culture of prawns in subtropical areas in Australia.

Similar analysis to that used by Treadwell *et al.* (1991) has been applied in the Philippines and by Firdausy and Tisdell (1991) to Indonesia to estimate IRRs for seaweed farming. This was found to be high (Fig. 10.3). Tisdell *et al.* (1993) have estimated the IRR of ocean grow-out of giant clams (*Tridacna gigas*) under Australian conditions (Fig. 10.4) and Leung *et al.* (Tisdell *et al.*, 1994, Ch.18) have done likewise for giant clam farming in Palau and various territories in the Pacific associated with the USA.

While IRR analysis is useful, it requires predictions to be made about future prices for aquaculture products and therefore about how markets for these will behave. For instance, although Treadwell, *et al.*, estimate a high economic return from the aquaculture of redclaw in Australia, this will not be sustained if many suppliers enter the industry and drive the price of redclaw down. This can happen quickly if the market is thin and difficult to expand. Therefore, let us consider markets and marketing.

3. Markets and marketing

The markets for most aquaculture products are influenced by supply and demand conditions in their industry and changes in these (Allen *et al.*, 1984, Ch. 2). For those products produced by aquaculture businesses that are price-takers rather than price-makers, the standard economic analysis of purely competitive markets is relevant (Tisdell, 1982, Ch. 3).

Normally the demand curve in such a market is downward-sloping (Fig. 10.5. D_1D_1) indicating that buyers purchase more of the product as its price is lowered. The market supply of the product is usually upward sloping indicating that greater supplies only become available if producers are paid higher prices (Fig. 10.5 S_1S_1). The quantity demanded of a product as a function of its price, all other things being constant, represents the market demand curve for a product. The quantity supplied of a product as a function of its price represents its market supply curve, all things, other than its price, being held constant. The point at which these two curves cross represents the market's equilibrium and the corresponding price is the equilibrium price and the corresponding quantity traded the market equilibrium quantity. In Figure 10.5 for instance, the demand curve D_1D_1 might represent the demand for prawns in Japan in July 2005 and S_1S_1 might represent the supply curve of prawns. (Note that economists have a convention of showing the dependent variable, in this case the quantity of the product traded, on the horizontal rather than the vertical axis when constructing demand and supply curves.) Market equilibrium would be established at point E with the equilibrium price of prawns being per kilogram with tonnes of prawns being supplied. Supplies may be drawn from cultured prawns (the supply curve for these may be as indicated by the curve marked S_0S_0) and from captured prawns, the supply function of which is the difference between curves S_1S_1 and S_0S_0. In the case shown, in market equilibrium, X_1 of supply comes from cultured prawns and $\overline{P}$ from $\overline{X} - \overline{X}_1$ captured prawns.

It is clear from Figure 10.5 that, if the demand curve for prawns moves upwards (and everything else remains constant), the equilibrium price and quantity traded will rise. It becomes more profitable for businesses to supply prawns. The market demand curve for prawns may rise, for example, if, other things held constant, (1) incomes in Japan rise and, more generally if incomes in market outlets for prawns rise; (2) the prices of prawn substitutes rise; (3) human population increases; or (4) tastes alter in favour of the product. It is important to be able to predict such trends and their influences on demand.

Sometimes the demand curves for aquacultured products are stated in terms of the average consumption per head of population or per household. Miyazawa and Hirasawa (in Liao et al., 1992) report on the basis of annual data for 1980-1989, the relationship between the consumption of prawns by households in Japan and the price of prawns (Fig. 10.6). It can be seen that a fall in price led to a substantial increase in the consumption of prawns by Japanese households. Other data also show that a rise in Japanese incomes lead to a significant rise in the per capita consumption of prawns in Japan.

A shift downwards in the supply curve (that is, increased supply for any given price), other things unchanged, tends to lower the equilibrium price for the aquaculture product, in this case prawns. The supply curve of an aquaculture product may shift downwards, other things constant, because, for example:

1. the price of one or more inputs e.g. fish food, falls,
2. new technologies are discovered that lower production costs, for instance, techniques that greatly reduce food wastage, such as have been developed for the culture of Atlantic salmon (Asche *et al.*, 1999),
3. improved methods may be found to reduce the incidence of pestilence or disease in aquaculture,
4. genetic selection and breeding may raise the productivity of cultured organisms such as tilapia (Dey, 2000), and
5. high returns in the industry may result in new businesses entering and investing in the industry thereby raising supplies.

As indicated above, most aquaculture products compete with supplies of substitutes from the capture fishery. Sometimes these are perfect or near perfect substitutes. Hence, a reduction in supplies of substitutes from the capture fishery usually raises demand for the farmed product, other things equal. A rise in supply from the competing capture fishery has the opposite effect. Nevertheless, there is evidence that increased supply of aquacultured products is not completely at the expense of sales of the capture fisheries because market segmentation exists between farmed and wild-caught products (Asche *et al.*, 2001).

Trends or expected variations in relation to all of the above-mentioned demand and supply matters need to be considered in predicting future prices and markets for aquaculture products. To do so accurately can be very difficult, especially if a 20-year planning period is being used.

Of course there are also marketing decisions to be made at the business level. These include the quality of the product to be supplied and how far to process it. In established industries, middlemen are often present to facilitate marketing and distribution but one of the difficulties sometimes encountered in developing a market for a new aquaculture product is the absence of suitable networks for its distribution and sales. The sale of giant clam for food in Australia was hampered by the absence of suitable distribution networks for this. On the other hand, the sale of Australian cultured giant clams as aquarium specimens initially progressed quite rapidly because of the existing network of wholesalers and distributors of aquarium specimens. In the absence of suitable distribution and marketing networks much more of the cost and effort of marketing activities will fall on the aquaculture business. These costs will include advertising the product, its presentation, search for market opportunities and information transfer (Tisdell, 2001).

Many cultured species progress through a typical product cycle (Fig. 10.7). In the early stages of this cycle, new production techniques are developed and the market is to a large extent uncertain. Only innovators or adventurers enter the industry at this stage. At the next stage, sorting of techniques tends to take place with the least effective ones being discarded and market penetration may proceed rapidly. The industry may go from a situation of earning low and uncertain profits to one of high profit. This induces followers to enter the industry and eventually the industry becomes well established with `appropriate' techniques relatively settled and potential markets fully tapped. This is the mature stage in which profitability falls to a level that tends to the average level of business profitability in the economy. Channel catfish culture in the USA is in the mature phase. Atlantic salmon culture is in the mature phase in Europe but in Australia is still in a relatively early stage. Redclaw crayfish culture in Australia was also in an early stage in the 1990s and, since returns in 1991 seemed relatively high for little risk, one would have expected considerable entry into the industry resulting eventually in a fall in returns due to increased supply. However, returns may not fall substantially at first because demand might also expand as consumers become more aware of this product and it gains greater acceptance. There are a number of instances in which this has occurred. For example, when tilapia culture was first introduced to Fiji local demand for this introduced fish expanded slowly. It has, however, now become a sought-after fish. Another example is the case of the farming of green turtles *Chelonia mydas* in the Cayman Islands. American conservationists blocked the sale of cultured green turtle meat in the USA using the argument that it would lead to expanded demand for turtle meat and thereby impact adversely on wild stocks. Their argument is analysed in Tisdell (1986).

When a market needs to be developed or a business plans to supply a new market, a variety of methods may be used to determine the nature of the market and foster it. These include trials of the product such as taste testing of a new aquaculture product, pilot or trial marketing, interviews and various types of surveys, and examination of the demand for substitute products Shang, 1981, Ch. 4; Meade, 1989, Ch. 4). Because giant clam farming was so new in the 1990s (see Fig. 10.4) it was necessary to use all these methods to assess potential demand for aquacultured giant clams (Tisdell, *et al.*, 1994). Photograph 10.5 shows a dish using giant clams (one of several) prepared by a Japanese restaurant in Australia for experimental taste-testing. An aquaculture business will also have to make economic decisions about how to distribute its product, promote and present it.

As a market expands, it becomes increasingly necessary to standardise the cultured product, or its grades, in order to reduce market transaction costs and increase market penetration (cf. Young, 2001). The industry may itself set standards or a government marketing body may do so. There can be an economic benefit to an aquaculture industry in imposing financial levies on its businesses in order to have its product promoted by a 'government' marketing authority. This is so even though members of the industry as individuals would not be prepared to spend so much on promotion, because others would benefit to a considerable extent by their promotion of a relatively generic product, e.g. Atlantic salmon, Pacific oysters, channel catfish.

4. Economies of scale, other types of economies and choice of production techniques

An aquaculture business' cost per unit of culturing any species is likely to vary with the size of the undertaking. There are economies of scale or decreasing costs per unit of production for many species, up to some annual volume of output. After this point, costs per unit of production may begin to rise with greater volume of output or rise after remaining stationary over a range (Fig. 10.8).

The scale (volume of annual production) at which a business obtains its minimum cost per unit produced is called its minimum efficient scale. If a business is operating below this level, it will be at an economic disadvantage compared to businesses operating at the efficient scale. Consequently, its rate of profit can be expected to be lower than that for the latter businesses.

From Table 10.2, it can be inferred that economies of scale exist in Australia for model farms producing crocodiles and Atlantic salmon. The IRR for the larger farms can only be explained by lower per unit costs of production for these (e.g. Atlantic salmon) because the businesses are assumed to be price-takers. Economies of scale exist also in relation to the farming of redclaw freshwater crayfish. The mean IRR from a 6 ha. model farm is estimated to be 9.3% compared to 19.4% for a 15 ha. model farm (Treadwell, *et al*., 1991). Available evidence also indicates economies of scale for prawn farming.

Economies of scale are likely to be marked in relation to land-based aquaculture operations involving the pumping of water to tanks, raceways or other types of containers and requiring regular water circulation. This is so mainly because of engineering relationships, e.g. volume tends to increase at a faster rate than the circumference of a container, but there may be other economies of scale for example in being able to use more effectively the services of specialised personnel who can be employed. Economies of scale can also be present for farming *in situ*, e.g. as the case of Atlantic salmon farming indicates. Minimum efficient scale (size of production operations) of an Atlantic salmon farm has tended to increase with the passage of time (see Bjørndal, 2002). Significant economies of scale in production exist for hatchery/nurseries engaged in land-based production e.g. in the supply of giant clam seed (Fig. 10.9). However, in the case of seaweed production in developing economies, economies of scale do not appear to be significant.

Apart from economies of producing a greater volume of a particular species, other types of economies may exist. These include economies of scope (or diversification) and economies of specialisation. To a large extent, these are the opposite sides of the same coin. To take advantage of economies of scope, if they exist, the firm engages in the supply of multiple products or services and this can include **polyculture**. There may be biological synergies (complementarity) in the production of more than one species so that mixed aquaculture of species is the most profitable. In land-based facilities, it may be possible to spread overheads, e.g. involved in pumping water, or the employment of specialists, by producing different species in different ponds or containers of various kinds.

Economies of diversification, however, have to be balanced against possible economies from specialisation. Frequently, if specialisation by production of species is absent, there is often specialisation by stages in the culture of a species. For example, some businesses may specialise in the hatchery/nursery stage for a species whereas others may confine themselves to the on-growing stage, or even just a part of it. This means that the industry can take advantage of maximum economies of scale at different stages in the culture of a species.

Economies of scope or of diversification seem to be very important at the hatchery/nursery stage from an economic viewpoint. Casual observation indicates that a large number of hatcheries/nurseries supply a range of aquaculture species or varieties of these, even though the mixture may be restricted to closely related species.

Possibilities for economies of scale, scope and specialisation are limited by the available techniques of production and those adopted. The appropriate choice of a technique from those available is partly an economic matter. In countries in which labour is cheap relative to capital, labour-intensive techniques are likely to be more appropriate than capital-intensive ones from an economic profit standpoint. However, in developed countries, where labour is relatively expensive, the reverse can be expected.

It should be observed that the location of an aquaculture business is likely to have a significant influence on its cost of production and profitability. The location of an aquaculture business' facilities will affect its cost of access to markets, its availability of inputs and their costs. A good location ecologically may be an uneconomic one if it is distant from markets and lacks ready availability of supporting human-related resources or services.

5. Dealing with business risk and uncertainty

Aquaculture can be a risky undertaking both due to uncertainty about economic variables, such as future prices, and production uncertainties which can arise from environmental changes, disease, etc. Most aquaculture businesses need to adapt to such uncertainties in order to survive or minimise possible losses. Some methods of adaptation include:

1. product diversification;
2. diversification in techniques used for production;
3. incorporation of flexibility or adaptability into the capital equipment or facilities used, so as to keep options open;
4. expanding cautiously into a new business area so as to leave time for learning-by-doing;
5. making sure that the business has limited liability;
6. increasing the number of shareholders or partners in the business;
7. making sure that the business' debt to equity (or ownership) ratio does not become so high as to jeopardise its ability to repay loans if its economic performance is below expectation.

8. ensuring that inescapable or fixed costs of the business are low so that a substantial economic loss can be avoided if the price of or demand for the aquacultured product is low, or if production is below that planned or the cost (e.g. price of an important input) is above expected levels.

Inescapable or fixed costs tend to be high when a production technique is capital-intensive, that is, uses a lot of equipment and fixed investment relative to other resources. When capital-intensive aquaculture techniques are adopted by a business, the business must make sure that economic conditions are favourable for this. For example, conditions are more likely to be favourable if the product is of high value or there is a high volume of demand for the business' production or the technique considerably reduces per-unit operating costs. Also, the risk of production falling markedly below planned levels should be low, for instance as a result of environmental occurrences.

Fig. 10.10 shows a relatively capital-intensive white-eel pond at a co-operative at Shenzhen in China. This type of intensive production is risky because the co-operative relies on high price fish meal (of good quality) imported from the United States and the price of this meal fluctuates considerably from year to year. Nevertheless, output is of high value and exported to Japan and California. Despite the risks, the operation is profitable on average even though in some years losses have been recorded due to sudden increases in the price of fish meal.

Fig. 10.11 shows an intensive prawn farm on Okinawa Island, Japan; Fig. 10.12 shows a semi-intensive prawn farm near Shenzhen, China; and an extensive (seasonal) prawn farm in Bangladesh involving very little capital investment is illustrated in Fig. 10.13. The Japanese business produces very high valued prawns and can operate profitably even though both its capital or overhead costs and its operating costs are high. The semi-intensive farm near

Shenzhen feeds its prawn by collecting shellfish from a nearby bay. Both its operating and capital costs are lower per hectare than in the Japanese case. The prawns are exported, but the price received is lower than for the Japanese farm. The economics of operation of the farms is hampered by the occurrence of typhoons which result in the escape of prawn stocks in some years causing an economic loss. In the Bangladeshi case, both capital costs and operating costs are extremely low because the prawns are not given supplementary feeding but rely on organism naturally present in the water which is interchanged with the nearby brackish river system. In this case the business risks are relatively low.

Diversification of production is a common risk-aversion strategy. If returns from different products are not perfectly correlated, this will tend to reduce the variability of the business firm's total returns. The same is true of production using different techniques, e.g. juvenile giant clams may be cultured in onshore tanks as well as in floating cages, so reducing the likelihood of a major loss of supply if adverse weather conditions occur. Capital equipment used to farm a range of species needs to be flexible or adaptable. It may be more sensible, taking into account business risks, to use such equipment in culturing a species, than equipment specifically designed for the culture of the species. Although specific equipment results in lower cultivation costs for the species but has little alternative use. Should the culture of the species prove to be uneconomic, flexible equipment can be used to cultivate other species and will have a higher resale value.

Businesses engaging in the culture of a species unfamiliar to them generally go through a period of learning-by-doing. With the passage of time and with the experience gained, their productivity and economic performance in cultivating the species improves. In the early stages, therefore, they might do well to proceed cautiously, e.g. use small scale or pilotplants, install flexible or cheap short-lived capital equipment. A late start can be a particular disadvantage for a new entrant to an aquaculture industry in which substantial economies of scale exist. If the new entrant starts on a small scale, this means higher cost for the entrant than for established firms. If the entrant goes immediately to minimum efficient scale of production, this involves considerable risk since it does not allow time for learning.

Institutional arrangements such as the limited liability form of company ownership can reduce personal business risks and if risk is shared amongst a large number of shareholders or partners in a business, losses are easier to bear. In addition, management needs to give continuing attention to the debt/equity ratio of the business. The higher this ratio is, the more at risk is the survival of the business in the event of unfavourable economic performance. This ratio (equity/debt) is sometimes called the firm's gearing ratio, and if equity is low relative to debt the firm is said to be highly geared. A highly geared business can have a high risk of not surviving. On the other hand, a firm with a high IRR in relation to the rate of interest may be unnecessarily foregoing profitable business opportunities if its equity/debt gearing ratio is low.

10.6 Environmental spillovers and the assessment of the economics of aquaculture from a social standpoint

While an aquaculture business may be privately profitable and an aquaculture industry may be economically thriving, this does not necessarily indicate its value from a social point of view. The social value of production by the industry will for example depend upon whether social costs of production by the industry are greater than private costs. If they are, private gains overstate social net benefits (Tisdell, 1993).

Social costs will exceed private costs of production by businesses if the aquaculture industry results in unfavourable environmental spillovers or externalities that impose costs on others for which they are not compensated. For example, consider prawn farming in some less developed countries. In some, e.g. in Ecuador, Thailand, the Philippines and parts of Bangladesh, wetlands are impounded to create ponds for the cultivation of prawns. Vegetation (such as mangrove trees) is lost and the breeding grounds and food supplies of wild fish stocks are destroyed with an adverse impact on local fishing communities (Fig. 10.14). When ponds are stocked with captured young prawns (Figs. 10.15 and 10.16), as in Bangladesh, this may subsequently reduce the population of large prawns available to the capture prawn industry. Furthermore, by converting coastal areas that play an essential role in the life-cycle of wild prawn populations to private prawn ponds, the aquaculture farms further reduce wild stocks. Eventually, there is a risk of the capture fishing collapsing altogether and supplies of seed prawns from the wild drying up, as happened in Ecuador (Tisdell, 1991, Ch. 6).

By contrast, in some cases aquaculture can give rise to favourable externalities and when this happens the profits of aquaculturalists understate the social economic benefits of their activity. The activity might then be on a smaller scale than is socially optimal. Waste from marine fish farms cause nutrient-enrichment of surrounding waters. Up to some level, this may enhance the growth of surrounding wild fish or benefit mollusc production. But beyond some point, this positive effect can become negative.

The economic theory underlying this matter can be illustrated by a series of figures. In Figure 10.17, curve OAB represents the private profit or benefit from farming a fish species e.g. sea bream in a region, as a function of the quantity produced annually. However, in this region the farming of the species gives rise to negative environmental spillovers so the social benefit curve is OCD. This curve is lower than curve OAB and the difference represents externality or environmental costs not paid for by farmers of the species (e.g. sea bass). In order to gain maximum profit, fish farms will produce X_2 tonnes of the farmed fish in the region annually. This is an excessive amount from a social economic viewpoint. Social net benefit in maximised when only X_1 tonnes of the species is produced each year. Therefore, because of the environmental externalities present, the market mechanism fails to ensure a social economic optimum. Hence, it may be desirable for the government to adopt policy measures to restrict production of this farmed species.

The opposite situation can arise if favourable environmental spillovers are generated by the farming of a species. This is apparent if in Figure 10.17 the curve OCD is reinterpreted as the private benefit curve and curve OAB is the social benefit curve.

It is also important to recognise that in some cases the adverse externalities generated by the aquaculture of particular species can be so great that its culture should not be tolerated. For example, in Figure 10.17 while curve OAB might represent the private benefit of producers from farming a species, the social benefit from doing so might be as shown by curve OFG. It is negative. For example, the introduction of a new species to a region can pose significant risks to wild species in the region. Escaped farmed species may compete with other wild species or become predators of them. The risks and potential costs to natural ecosystems of introduction of new species and attendant economic losses may be so great is to make it desirable from a social economic point of view to ban their introduction.

It is also possible for different methods or techniques of aquaculture to give rise to different magnitudes of external costs. It may, therefore, be desirable to introduce public policies that limit the use of some techniques, or ban these altogether. The regular feeding, for example, of antibiotics to farmed fish can give rise to a number of serious environmental externalities. These include growing resistance of disease-creating organisms to antibiotics and reduced natural resistance among the farmed stock, and possibly where there are escapees, reduced resistance of wild stock to diseases (cf. Tisdell, 1993, Ch.12). Therefore, some governments may consider it to be desirable to ban the use of environmentally 'dangerous' antibiotics in aquaculture or restrict their use.

Clearly different methods of husbandry in aquaculture can have significantly different environmental consequences. Nevertheless, it is frequently the case that technological progress reduces the magnitude of environmental spillovers. For instance between 1980 and 1997 the average feed conversion ratio (kilograms of food required to produce one kilogram of fish) in Norwegian salmon aquaculture fell from just under three to just over one (Asche *et al.*, 1999, p.24). This means that less waste per kilogram of fish produced goes into the surrounding environment than previously. Today's food, for example, sinks more slowly through the water and improved techniques are available to monitor feeding so the quantity of food supplied to the fish can be adjusted more accurately to consumption (Asche *et al.*, 1999, p.24). In addition, innovations have resulted in a substantial reduction in use of antibiotics by the Norwegian salmon industry (Asche *et al.*, 1999, p.25).

As pointed out by Tisdell (1999), adverse environmental spillovers are often the source of lack of sustainability in production and can result in an activity eventually becoming uneconomic. While they are not the only source of lack of sustainability in economic production (Tisdell, 1999), they should not be overlooked as a potentially important source.

Bardach (1997) gives particular attention to the sustainability of aquaculture and Shang and Tisdell (1997) concentrate on the economic dimensions involved.

Again, some forms of aquaculture raise income distribution questions. Large scale aquaculture, which displaces small farmers or adversely impacts on the incomes of poor fishing and subsistence communities, has an adverse income distribution effect. This has happened for prawn aquaculture in some less developed countries, for example in Bangladesh (Alauddin & Tisdell, 1998, Ch.8). On the other hand, seaweed farming in Indonesia appears, at least in some villages, to have reduced rural income inequality (Firdausy & Tisdell, 1993).

Some forms of prawn culture raise further sustainability issues (see Be *et al.*, 1999 for some examples) and, in essence, an intergenerational income equity problem. The practice has arisen in some parts of monsoonal Asia of alternating rice and prawn production in low-lying estuarine areas, e.g. in the Sunderbarns of Bangladesh (Figs. 10.13 and 10.18). Just before the wet season, rice is planted. After the rice is harvested in the dry season, the fields may then be flooded with brackish water to create prawn-rearing ponds. These ponds after raising prawns are drained before the commencement of the next wet season and the prawns are harvested. The land is then prepared for rice and replanted. So the cycle continues. This, however, does not appear to be a sustainable practice. It results in falling rice yields due to rising soil salinity and mineralisation of the soil (Alauddin & Tisdell, 1998, Ch.2).

Various forms of aquaculture can result in a variety of environmental issues including environmental health risks (Fig. 10.19) (Chapter 3). If, however, aquaculture has adverse environmental impacts, this does not mean that it should be banned from a socio-economic perspective. Instead, policy measures, such as taxes on effluent, could be adopted to ensure that aquaculture businesses take their external costs into account in their decision-making. (A tax, for example, can result in the firm's private costs of production after tax being brought into line with its social cost.) When this is done, some aquaculture businesses will no longer be economic. Optimal economic policies to control environmental spillovers are outlined in Tisdell (1993, Ch. 4), but more attention needs to be given to these specifically in relation to aquaculture. Economic theory indicates that it is not optimal as a rule to eliminate all environmental spillovers, but that government intervention to control them is sometimes justified.

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Table 10.1: Explanations of some Economic Terms

Net present value of a business

Indicates the ability of a business to operate profitably. If it is positive, the business is profitable and the higher it is, other things equal, the greater is the profitability of the business.

Present discounted value of profits

This is the sum of profits during the firm's planning period with future profits discounted or reduced below their actual future values. The discounting of future profits reflects the fact that a dollar available in the future is worth less than a dollar available now because a dollar available now can be invested at the going rate of interest to earn more than a dollar in the future. So a future dollar is only equivalent to a fraction of a dollar now. This fraction or net present value of a future dollar is the amount which would have to be invested at the going rate of interest to earn the future dollar. The higher the rate of interest and the further into the future is a dollar available, the lower is its present value. This is because a future dollar has to be discounted by more to get its present value the higher the rate of interest and the more distant is the availability of the dollar. Economists have developed a specific formula for such discounting of future values.

Planning period

The period for which a business plans its business operations, e.g. a 10-year period.

Discounted realisable value

The sum, discounted back to its equivalent present value, which could be realised by a business selling out at the end of its planning period. A similar concept can be applied in assessing the economics of business projects.

Discounted benefits

Future benefits from a project discounted to equivalent present values.

Discounted costs

Future costs of a project discounted to equivalent present values.

Monetary rate of interest

Sometimes called the nominal rate of interest. It is the actual rate payable in monetary terms not adjusted for price inflation. The nominal rate of interests tends to rise with the rate of inflation otherwise the real rate of interest declines with a rise in the rate of inflation.

Real rate of interest

This is the monetary rate of interest adjusted for price inflation. The greater the rate of inflation, the larger the reduction in the monetary rate of interest needed to obtain the real rate.

Market transaction costs

Costs involved in arranging market exchanges, e.g. costs involved in searching for potential buyers in arranging contracts, agency costs and so on for a sale of aquaculture products.

Equity in a business

The proportion of a firm's assets or capital belonging to the owner(s) of a business.

Externalities (or spillovers) from business activity

These are spillovers or effects of the activities of a business or other businesses for which no economic payment or costs are involved. They can be favourable or unfavourable. An unfavourable case would, for instance, involve the release of a pollutant or pest into waterways by a business which is not required to pay compensation or charges but which damages other businesses. In this case, an unfavourable externality exists and the private costs of the activities of the polluter are less than the polluter's social cost. Because the cost of using the environment for waste disposal is not priced, the polluter fails to make a socially optimal decision. Such problems can be serious in aquaculture. Aquaculture may be the source or the victim of such pollution.

Internal rate of return (IRR)

Indicates the percentage rate of return on funds employed by a business or a project. It is a useful indicator of the degree of profitability of a business or a project. Estimates of IRR take into account the time-pattern of returns.

Table 10.2 Internal rates of return (IRR) for selected aquaculture species in Australia (as in 1991). Based on Treadwell, *et al.* (1991).

Species and Culture	Mean IRR%	Possible range of IRR%
1. Barramundi		
- Cages in freshwater	3.8	-12.2 to 17.5
- Nursery then free ranging	19.6	4.7 to 23.6
- Cages in the sea	13.6	-4.8 to 28.6
2. Crocodiles		
- Small breeding farm	6.1	4.4 to 7.4
- Small grow-on farm	10.8	9.1 to 12.4
- Large breeding farm	8.8	7.4 to 10.2
- Large grow-on farm	14.0	12.4 to 15.6
3. Freshwater Crayfish		
- Marron	10.3	6.7 to 14.0
- Redclaw (15 ha. farm)	19.4	15.7 to 23.0
- Yabbie	9.3	2.1 to 26.6
4. Mussels (blue)	12.3	1.0 to 22.7
5. Pacific oysters		
- Good site	31.1	28.4 to 33.8
- Poor site	10.8	8.5 to 10.5
6. Prawns (mainly giant tiger) Medium stocking density, 25/m^2		
- North Queensland	17.5	-0.1 to 29.9
- Subtropical	5.1	-8.1 to 13.8
7. Rainbow trout		
- Freshwater	5.6	3.4 to 7.8
- Ocean model I	0.0	-15.2 to 12.7
8. Atlantic salmon in 60 m cages		
- 40,000 smolt	5.5	-2.7 to 12.3
- 150,000 smolt	12.5	5.5 to 19.6

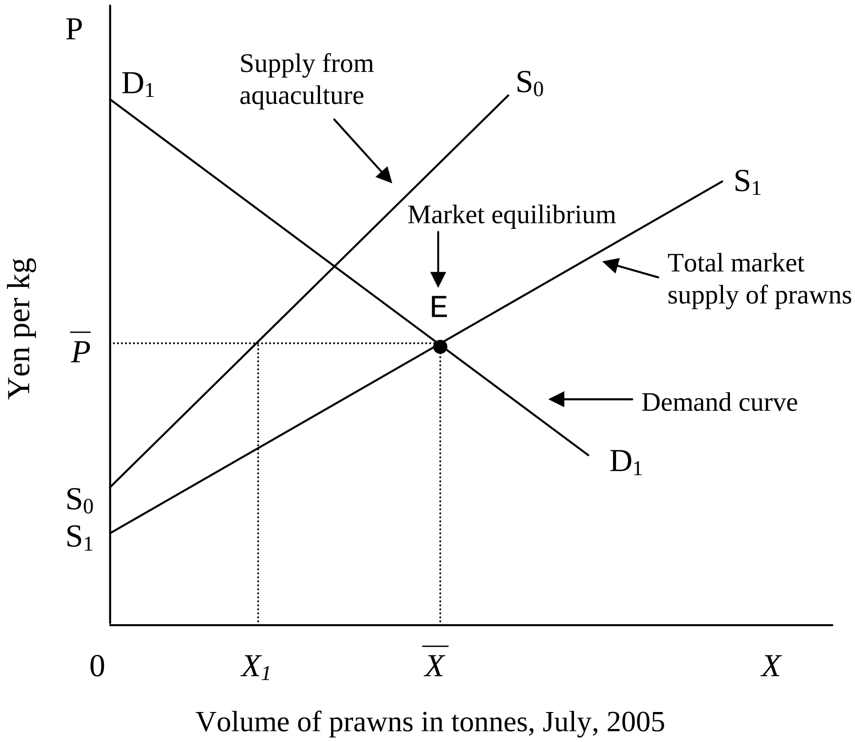

Figure 10.5

A theoretical market model for prawns in Japan illustrating market equilibrium and dividing supply into capture and culture components.

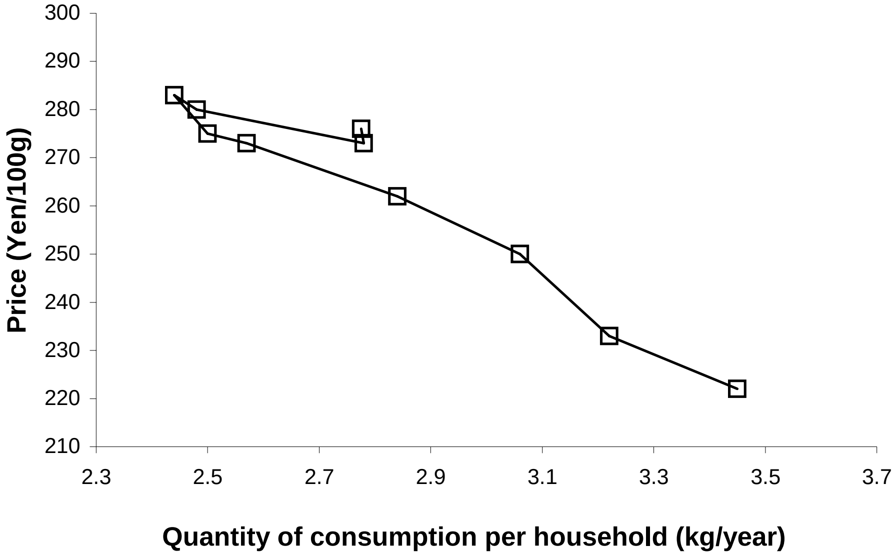

Figure 10.6

Quantity of consumption per Japanese household of shrimp related to the purchase price of shrimp in the 1980s based on Liao *et al.* (1992).

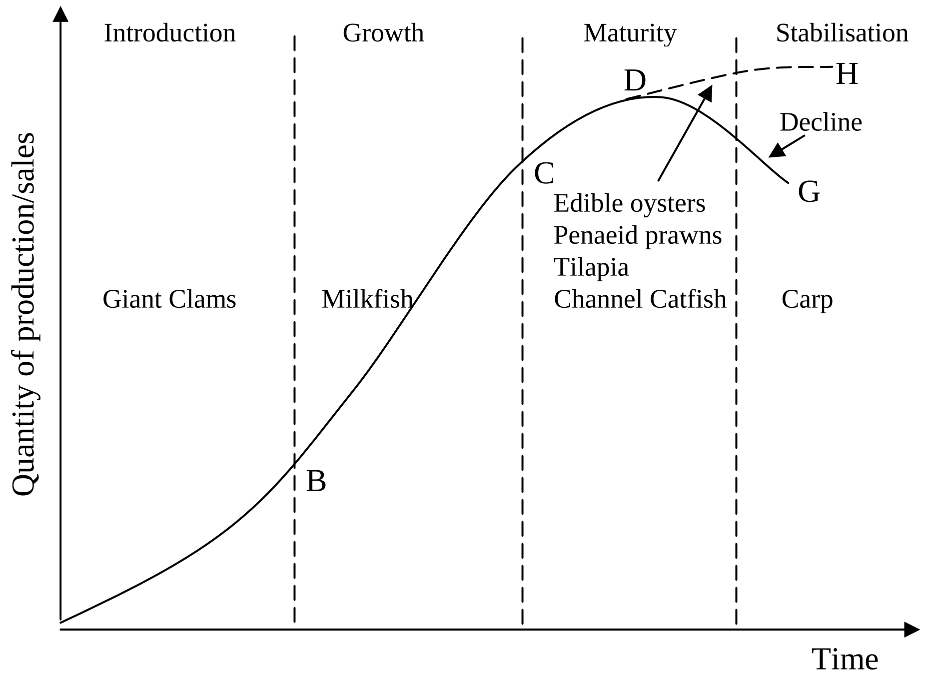

Figure 10.7

Product cycle showing typical stages which aquaculture industries pass through if they succeed economically and the approximate stage in which some of these industries are now. The demand and volume of supply for all these industries does not decline but stabilises for some as upper limits to production and demand are approached.

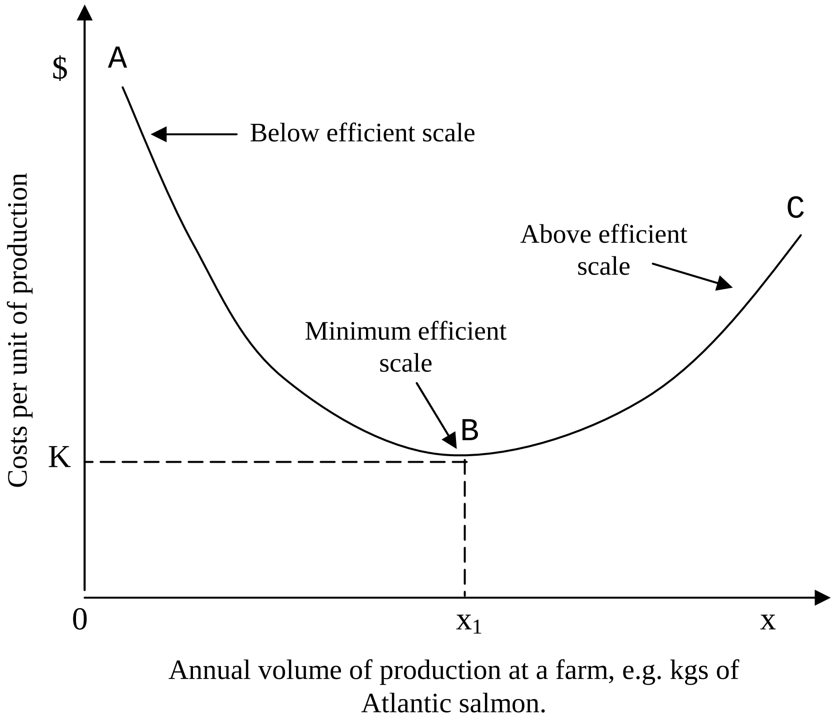

Figure 10.8

U-shaped average cost of production curve. Businesses having a level of production less than the minimum efficient scale could reduce their costs per unit of production by expanding their level of production.

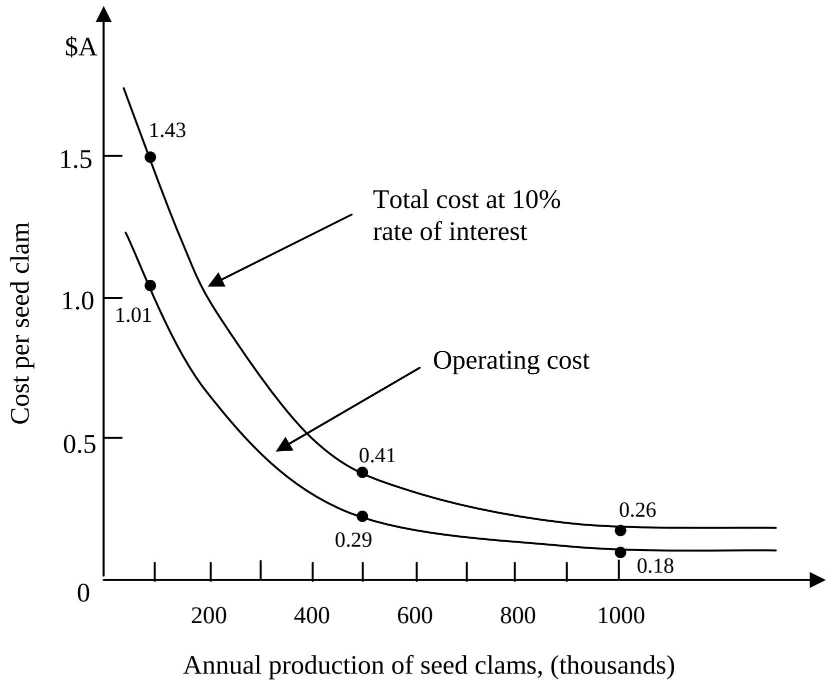

Figure 10.9

Estimated cost of production curves for a producer of giant clam seed in Australia (Tisdell *et al.*, 1993).

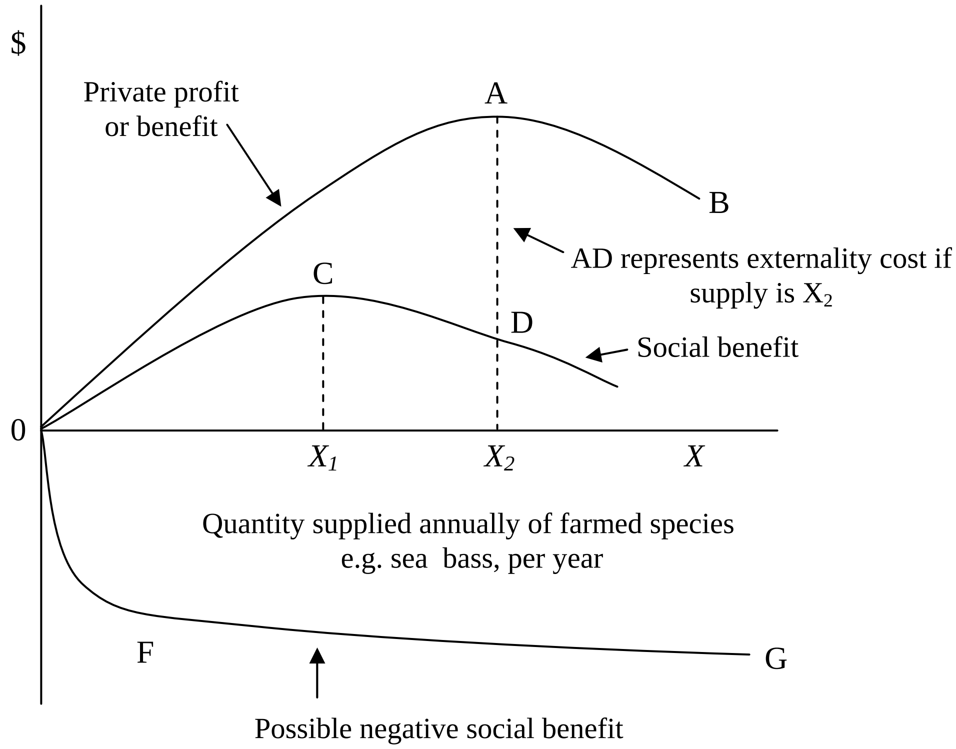

Figure 10.17

Environmental spillovers from fish farming sometimes result in private decisions being at odds with social economic benefits from these decisions.

Captions for Photographs[*]:

Fig. 10.1

Pearl oysters at a hatchery/nursery on Fitzroy Island, North Queensland. Because the number of registered suppliers of the seed of pearl oysters is limited in Australia, suppliers have some market power.

Fig. 10.2

Giant clams (*Tridacna crocea* and *T. maxima)* at a nursery on Fitzroy Island, North Queensland, being used as broodstock to supply the aquarium trade with specimens. The number of suppliers worldwide for this cultured product was low in the 1990s. The industry was at the beginning of its market product cycle (see later).

Fig. 10.3

Experiment in progress with the culture of a *Echeuma* species at the Marine Laboratory, Silliman University, Dumuguete, The Philippines. Seaweed farming shows a high level of economic returns in Indonesia and The Philippines.

Fig. 10.4

Giant clams *Tridacna gigas* being grown out experimentally at Orpheus Island, North Queensland.

[*] Photographs not included with this Working Paper but will appear in the book.

Fig. 10.6

A pond producing white eels under intensive conditions at Shenzhen, China, for export. Production is risky but the product is of high value.

Fig. 10.11

An intensive prawn farm on Okinawa Island, Japan. Costs of production are high but the product is of very high value and production is well controlled by intensive management.

Fig. 10.12

A semi-intensive prawn farm near Shenzhen, China.

Fig. 10.13

The harvest of the wet-season rice crop is finished and soon the rice fields in the Khulna region of Bangladesh will be flooded by brackish water to produce a crop of prawns during the dry season. This practice raises questions about sustainability.

Fig. 10.14

Banks being built for a prawn farm near a coastal village on Los Negros, The Philippines. The natural wetland will be destroyed and the mangroves in the distance lost.

Fig. 10.15

Juvenile prawns being captured near the Bay of Bengal in India to stock extensive prawn farms.

Fig. 10.16
Juvenile prawns being traded at Chalna in the Sundarbarns, Bangladesh. They will be used to stock extensive prawn farms.

Fig. 10.18

'Remnant' crustacea taken from a dry-season waterhole on the farm shown in Fig. 10.13. The hole was soon to be flooded as the cycle of dry season production of prawns was about to commence.

Fig. 10.19

Intensive ocean floating pen culture of fish near Kagoshima, Japan. Under such conditions fish diseases can spread rapidly amongst stock owned by different operators.

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