SITE SELECTION

Site selection

Youth harvesting fish at Nabiswa fish pond in Trans Nzoia West.

The history of aquaculture projects all over the world has led to the conclusion that the right selection of sites is probably the most important factor in determining the feasibility of viable operations. Even though, after many years of painful efforts and of new technology, some farms on poor sites have been turned into productive units, there are many that have been abandoned after considerable investment of money and effort. So there is no gainsaying the basic importance of selecting suitable sites for successful aquaculture. At the same time it has to be recognized that compromises have often to be made, as ideal sites may not always be available, and conflicts over land and water use will have to be resolved. In many situations good, irrigated agricultural land may be the best site for pond farms for fish culture, but national priorities in cereal food production may make it unavailable for aquaculture, irrespective of economic or other advantages. On the other hand many countries, particularly in Asia, are now giving higher priority to aquaculture and farmers are utilizing rice fields increasingly for fish and shrimp culture. Although site selection will generally be based on the species to be cultured and the technology to be employed, under certain circumstances the order may have to be reversed.
If it is decided to bring under culture certain sites, selection may be oriented towards determining the species that can best be cultured there and the most suitable technologies to be used for that purpose, if indeed the site is primarily suited for aquaculture. Limitations in

any of the three factors, namely site characteristics, species and appropriate technology, obviously restrict choice of the others. However, as mentioned earlier, in the large majority of cases the species to be cultured would have been determined in advance, based on market requirements and consumer preferences.

4.1 General considerations

Although many of the factors to be investigated in the selection of suitable sites will depend on the culture system to be adopted, there are some which affect all systems, such as agroclimatic conditions, access to markets, suitable communications, protection from natural disasters, availability of skilled and unskilled labour, public utilities security, etc. (see Chapter 3). It may be possible to find solutions when these factors are unfavourable and present problems, but it would involve increased investment and operating costs and would affect profitability. In the case of small-scale aquaculture, it is necessary to determine that the selected site has easy access to materials that cannot be produced on the farm and that the necessary extension services are available.

All available meteorological and hydrological information about the area (generally available from meteorological and irrigation authorities) such as range and mean monthly air temperature, rainfall, evaporation, sunshine, speed and direction of winds, floods, water table, etc., have to be examined to assess their suitability.

In land-based aquaculture, the most commonly used installations are pond farms and hatcheries. Since most such farms have earthen ponds, soil characteristics, the quality and quantity of available water and the ease of filling and drainage, especially by gravity, are basic considerations. For fresh-water pond farms, the land available consists mainly of swamps, unproductive agricultural land, valleys, stream and river beds exposed due to changes of water flow, etc. (Land elevation and flood levels have to be ascertained. The maximum flood level in the last 10 years or the highest astronomical tide (in the case of brackish-water sites) should not be higher than the normal height of the dikes that will be constructed for the farm. It will be advantageous to select land with slopes not steeper than 2 per cent. The area should be sufficiently extensive to allow future expansion and preferably be of regular shape to facilitate farm design and construction.

The nature of the vegetation indicates the soil type and elevation of the water table. Obviously dense vegetation, particularly tall trees, makes clearing more difficult and expensive. Land under grass or low shrubs is much better suited in this respect. However, in areas exposed to strong winds and cyclonic or similar weather conditions, sufficiently tall vegetative cover around the farm can serve as an effective wind breaker. High ground-water level may create problems in farm operation, as drainage will become difficult and expensive. The use of mechanical equipment for pond construction will also become inconvenient.

Among the other important general factors to be considered are the existing and future sources of pollution and the nature of pollutants. In this connection, information on development plans for the neighbourhood areas will be necessary. It will be useful to ascertain the past use of the site, if any. Croplands that have been treated for long periods with pesticides may have residues that are harmful to fish and shellfish. If the site is located adjacent to croplands that are sprayed from air or land, there is the risk of contamination occurring directly or through run-off water. Similarly, the possible effects of discharges from the pond farms into the waterways and irrigation systems in the neighbouring area should be considered.

This can greatly influence the attitudes of the neighbourhood communities to the proposed farming and hence their future cooperation.

When a hatchery is planned in connection with a pond-rearing facility, the selection of its site depends on the location of the nursery and rearing ponds. The more important consideration is the unrestricted availability of goodquality water, such as from springs, tube wells, reservoirs, etc. If earthen nursery ponds are to be constructed alongside the hatcheries, it is necessary to ensure the quality of the soil for pond construction and pond management. In many modern hatcheries, fry rearing is mostly done in tanks and troughs, with as much control over ambient conditions as possible. So the main consideration is the availability of essential utilities such as electricity. The situation is very similar for the selection of sites for raceway farms.When the raceways are made of cement concrete the main consideration is the availability of adequate quantities of goodquality water and essential utilities.

The choice of sites for integrated aquaculture – such as fish culture combined with crop and livestock farming – is governed by factors other than their mere suitability for aquaculture.

Land available for integrated aquaculture is generally agricultural land, even if it is somewhat less productive. A satisfactory irrigation system is likely to have been developed for agriculture, in which case water and soil management can be expected to be easier. Since integrated farming is based on the recycling and utilization of farm wastes, problems of pollution can be expected to be minimal.

4.2 Land-based farms – conflicts

Sites generally available for coastal pond farms

are tidal and intertidal mud flats in protected areas near river estuaries, bays, creeks, lagoons and salt marshes including mangrove swamps.
The traditional and, in many cases, the most economical method of water management for a coastal farm is through tidal flow, and so one of the essential pieces of information is the tidal amplitude and its fluctuations at the site.
The tidal range along the shore line may be more easily obtained from tide tables or other sources, but in estuaries and other water bodies away from the coast the figures will be different: the mean tidal level generally becomes higher; the duration of the ebb tide becomes longer and the flood tide shorter. The diurnal tidal range, that is the difference in height between the mean higher high and the mean lower low waters, becomes less. In order to determine the relation between tidal levels and ground elevation at the proposed coastal farm site, tide measurements will have to be made on the site with a tide gauge or tide staff over a period of time. The relationship of tides between the nearest port and the tide gauge placed at the site has to be determined first for this purpose. The tide curves and other necessary tidal data at the site can be calculated from the highest astronomical tide (HAT), mean high water springs (MHWS), mean high water neaps (MHWN), mean low water neaps (MLWN) and mean low water springs (MLWS).
The construction of ponds in areas reached only by the high spring tides would require excavation, leading to high construction costs and problems in disposal of the excess soil. If the dikes are made higher than necessary to deposit excess earth, the productive water area in the farm will be reduced. Excavation may also affect efficient drainage using tidal energy.
Further, the removal of fertile top soil, which is important to induce the growth and maintenance of benthic food organisms in coastal ponds, will result in the loss of much time in reconditioning the pond bottom to stimulate such growths. However, in certain mangrove areas, particularly those under the red mangrove Rhizophora, the top layer may contain peat or a very dense mass consisting of rootlets of mangroves, which in any case will have to be excavated to make the pond bottom productive.
The selection of suitable sites, based on tidal fluctuations and elevation, is shown in fig. 4.4.
A tidal fluctuation of around 3m is considered ideal for coastal ponds. However, it has to be remembered that if the tidal energy can be replaced by other forms of energy for water management, the limitations indicated would not apply. As mentioned earlier, the main consideration then would be the cost involved

and the economics of operation. Gedrey et al. (1984) estimate that the construction and operation of a farm with a pumped water supply system can be more economical than that of a tidal water farm.

4.2.1 Soil characteristics

The quality of soil is important in pond farms, not only because of its influence on productivity and the quality of the overlying water, but also because of its suitability for dike construction. The ability of the pond to retain the required water level is also greatly affected by the characteristics of the soil. It is therefore essential to carry out appropriate soil investigations when selecting sites for pond farms.

Such investigations may vary from simple visual and tactile inspection to detailed subsurface exploration and laboratory tests. Because of the importance of soil qualities, detailed investigations are advisable, particularly when large-scale farms are proposed. Sandy clay to clayey loam soils are considered suitable for pond construction. To determine the nature of the soil, it is necessary to examine the soil profile, and either test pits will have to be dug or soil samples collected by a soil auger at regular distances on the site.To obtain samples, rectangular pits (1.0–2.0m deep, 0.8 m wide and 1.5m long) are recommended. If available, a standard core sampler or soil auger of known capacity (e.g. 100cm^3) can be used for collecting samples of soil from each soil horizon. Texture and porosity are the two most important physical properties to be examined. Soil texture depends on the relative proportion of particles of sand, silt and clay. The size limits and some general characteristics of the soil constituents are given in Table 4.1. By touch and feel one can roughly determine the texture. A sample of the soil should be kneaded in the hand (to make it somewhat drier, if it is wet and sticky; if the sample is dry, add some water to make it moist but not sticky). If the kneaded sample can be rolled into a bar (about 6mm thick) and bent to form a ring around the thumb, without any cracks, the soil must be clayey. If it cannot be made into a bar and remains separate with visible grains when dry, the sample is sandy. If the sample does not fall into either of these categories it can be classified as silty or loamy. Sand grains can be felt distinctly, even when not readily visible in loamy soils. Silty soils feel like flour or dough between the fingers. There are, of course, intermediate categories depending on the proportions of the constituents.

Because of their cohesive properties, the finetextured soils (clay, silty clay, clay loam, silty clay loam and sandy clay) are more suitable for pond farms.They have a greater surface area and can therefore absorb more nutrients and retain and release them for organic production in ponds;

they are also less subject to erosion and other damage. The soil structure or the arrangement of soil particles is of special importance in determining the compactness, and therefore the porosity, of the soil. Light-textured soils, particularly in close proximity to open drains can cause high seepage and percolation. Pond farms built on such soils may, however, improve in the course of time due to the blocking of interstitial pores by organic sediments produced in the pond, or introduced with the water supply or derived from manuring. Puddling is an efficient means of sealing ponds. In this process, fine particles clog the most permeable parts and in due course the bottom of the pond may be completely sealed. Compaction of soil by mechanical means during pond construction can also assist in reducing seepage. Suitable linings such as polyethylene sheets have been used on pond bottoms and water supply channels to prevent seepage with some success. But it is difficult to prevent damage to the lining and it often turns out to be too expensive for practical use. It may also greatly reduce the contribution of the pond bottom to natural productivity in the pond,even if the initial and continuing costs of the lining are acceptable.

Generally, the soil on sites selected for coastal pond farms is alluvial. It is usually porous with varying masses of fine roots of mangroves and other swamp vegetation. The preferred soils are clay, clayey loam, silty clay loam, silt loam and sandy clay loam. Sandy clay loam is the best for diking.

4.2.2 Acid sulphate soils

As mentioned earlier, one of the major problems in site selection for coastal pond farms in the tropics is the prevalence of acid sulphate soils or cat-clays. Even though such soils are also found in fresh-water swamps, the problem is more pronounced in brackish-water areas. The highly acidic conditions inhibit the production of fish and fish food organisms. Elements, particularly iron and aluminium, are released into the water in toxic quantities which render phosphorus unavailable, causing severe phosphorus deficiency for algal growth. Sudden fish kills during rains after long dry periods are a common phenomenon due to leaching of extremely acidic water from surrounding dikes into ponds built on such soils.

Acid sulphate soil results from the formation of pyrite which is fixed and accumulated by the reduction of sulphate from slat water. The process involves bacterial reduction of sulphate to sulphide, partial oxidation of sulphide to elemental sulphur followed by interaction between ferrous or ferric iron with sulphide and elemental sulphur. A sufficient supply of sulphate and iron, high concentrations of metabolizable organic matter, and sulphatereducing bacteria (Desulfovibrio desulfuricans and Desulfo maculatum) in an anaerobic environment alternated with limited aeration are the factors that give rise to sulphate soils.

In mangrove swamp areas, the most favourable conditions for pyrite formation exist in the zones between the mean high water and mean low water levels which have limited periodic aeration due to tidal fluctuation. There is less pyrite in the better-drained parts of the marshes which are aerobic most of the time.

The reclamation of mangrove swamps for pond farms with drainage results in the exposure and oxidation of pyrite and causes acidic conditions. Ferrous iron (Fe^{2+}) is released during atmospheric oxidation of pyrite under moist conditions at an optimum moisture content of 30–40 per cent. At low pH, oxidizing bacteria convert ferrous iron to ferric iron (Fe^{3+}). It can remain in solution in appreciable amounts only at pH values in the range 3–3.5 and is a more effective oxidant for pyrite and elemental sulphur than free oxygen. At higher pH, almost all ferric iron is hydrolyzed and pre cipitated as ferric hydroxide. Basic ferric sulphate is also formed during pyrite oxidation.

Elemental sulphur is oxidized to sulphuric acid by bacteria.

The most harmful effect of pyrite oxidation lies in the excessive amount of sulphuric acid produced, which if not neutralized by exchangeable bases creates strongly acid conditions.

In selecting sites for pond farms, one has to take into account not only the existence of acid sulphate soils but also the potential for acid conditions to develop as a result of drainage after construction.The levels of pyrite and acid-neutralizing components such as calcium carbonate from mineral deposits and metal cations have to be considered.The use of combined criteria, as for example sedimentary relationships and sulphur sources, land form, vegetation and soil characteristics, has been suggested as a basic approach for recognition and prediction of potential and actual acid sulphate soils.Although it is desirable to have both field and laboratory investigations, it is considered possible to use certain simple criteria with confidence. Potential and existing acid sulphate soils are generally found in mangrove swamps and marshy back swamps, on the seaward side of river deltas and on marine and estuarine plains (fig. 4.5).Tidal brackish-water vegetation with dense rooting systems is usually related to accumulation of pyrite. Association with the red mangrove (Rhizophora), Nipa and Melaleuca stands is a fair indication of potential acid soils. Soils that are likely to become acidic have a high organic matter content, such as the fibrous roots of mangroves, and a

grey subsoil with dark grey to black specks or mottles of partially decomposed matter.
The detection of actual sulphate soils is easy. They can be recognized by the pale yellow mottles of the top soil, overlying pyritic subsoil. The older acid sulphate soil shows the redbrown ferric hydroxide. Their pH is generally below 4. A comparatively easy method of estimating the extent of acid and non-acid soil layers is by implanting stakes coated with redlead paint in the soil profile. Hydrogen sulphide generated in the layer with active sulphate reduction turns the red-lead marking black within about a week, leaving on the stake a record of the upper limit of the present sulphide accumulation.
It is possible to minimize the harmful effects of acid soils, but it is time-consuming and expensive. However, in many tropical areas, the available sites for pond farms may almost all have such poor soils and there may be little choice. In such cases sites that can more readily be reclaimed should be selected. Basically, reclaiming consists of removing the source of acidity by oxidizing the pyrite from the pond bottom and flushing it out of the 10–15cm deep surface soil and preventing further diffusion of acids, aluminium salts and ferrous salts from the subsoil. Acid and toxic elements are also leached and removed. If this is feasible, the farm can be made suitable for aquaculture within a period ranging from three to five years, depending on the extent of the problem.

4.3 Open-water farms

Open-water aquaculture includes mollusc culture in shallow salt- and fresh-water areas, seaweed farming in coastal seas and pen and cage culture in sea and fresh-water bodies. As is obvious, in selecting sites for such systems of culture the main considerations are the hydrographic and climatic conditions. In spite of some limited success in extending certain types of aquaculture to deeper and more exposed coasts, the most suitable and preferred areas continue to be sheltered bays, estuaries, lagoons, straits, lakes and reservoirs, protected from strong winds and rough seas. While moderate currents and water flows are necessary to maintain water quality and removal of waste products from farm sites, frequent storms and turbulent seas will make it difficult to practise most types of aquaculture. Winds will directly affect culture installations above water, whereas waves affect both the submerged structures and the animals under culture. In most cases low current velocities are preferred.
In systems like the ones for bottom culture of molluscs, the nature of the sea or river bed is important. Suitable stable substrates are needed for the attachment of the animals. Most

modern open-water culture is of the off-bottom type, where the water conditions and quality are more important.

Since mollusc culture is based largely on natural food organisms that the molluscs filter from the environment, it is essential to select sites with high primary production. Though some experimental work has been done on artificial feeding of certain molluscs, in commercial farming production is dependent on the growth of plankton or algae. In order to make natural food available to the animals the current velocity should not exceed 5 cm/s.

Even though controlled reproduction and hatchery production of seed are possible in mollusc farming, in many places aquaculturists depend on wild spat for culture. In such cases, it is advisable to select sites where there is an abundance of spat. A breeding population of the species nearby is, of course, necessary, but it does not necessarily follow that the spat will settle in the immediate neighbourhood. The larvae may be carried away by currents, so sufficient shelters and suitable current speeds are necessary to keep the larvae in the area. Field observations, supplemented by experimental spat setting, may be a necessary basis for a decision on site suitability.

In the farming of seaweed such as laver fertilizers are used to increase growth, but naturally fertile areas are still selected as in open-water situations fertilization can only be a complement to natural productivity. Movement of water prevents the increase of pH which can be caused by the consumption of carbon dioxide in seaweed-growing areas. Therefore it is necessary to select sites with an adequate current. A current of about 10–30 cm/s is considered suitable, depending on the content of nutrients in the water. Waters deficient in nutrients should have a current of 30cm/s and those rich in nutrients about 10 cm/s. Since periodic exposure of leafy thalli is important for growth in some seaweeds, it is necessary to select a place with a tidal range of 1–1.5m or more.

4.4 Water quantity and quality

The availability of water of appropriate quality is important for all systems of aquaculture, but the quantity is particularly important for landbased systems. It is therefore necessary to investigate, as thoroughly as possible, the extent and seasonality of water sources as well as liability to pollution. Since predictions of long-term water conditions have to be made, it is desirable to have data for a reasonably long period of time. In areas with controlled irrigation, reliability of supplies can generally be expected. This, together with the availability of cheap electricity, has made water management fairly easy for fish farmers in southern China, in spite of dense stocks of fish and heavy loading of manures in pond farms. On the other

hand, when rain-fed or ground-water ponds are used, as in eastern India, water levels in the ponds become dangerously low due to seepage and evaporation in summer months, when the ponds have generally the maximum biomass of fish. Access to other reliable sources of water, such as rivers, streams, lakes and reservoirs or even tube wells which can yield enough water are essential for the enterprise to succeed. Loss of water due to seepage and evaporation varies considerably. For example, the average loss in Europe is reported to be about 0.4–0.8cm per day, whereas in tropical regions it may be as much as 2.5 cm per day.When ground water is the major source of water supply, the effect of pumping on the water table and possible land subsidence have to be considered.

The need to investigate the elevation and ranges of tides for coastal aquaculture has already been referred to.This is most important when tidal movements have to be depended on for filling and draining the ponds. The constant flushing of newly constructed ponds to leach out toxic elements from the soil has also been mentioned. It is believed that if pumping were to be used for water management, the costs of construction of dikes and sluice gates would be minimized and the ponds could be constructed and operated without disturbing the acid soils, allowing a non-acidic layer of sediment to deposit on the bottom. In the long run, this may be more economical, despite the increased energy costs.However, it will be necessary to make rough calculations of the comparative costs before finally selecting the site and deciding on the system of management to be adopted.

The temperature of the water will be an important criterion when deciding whether the species selected can be cultured on the site. Although in hatcheries and in systems with a recirculating water supply the temperature can be controlled, it is extremely difficult, if not impossible, to do so at an affordable cost in large pond farms. Industrial waste heat can to a certain extent be used to raise temperatures in aquaculture areas, but very often practical problems of quality of heated water or irregularity in availability limits its use, except in wellcontrolled environments or where the animals can stand considerable variations in temperature.

Salinity and variations thereof are also important environmental factors which have to be taken into account. Some species have wide salinity tolerance limits and it has been noted that some fresh-water fish grow faster in slightly saline water and some brackish-water fish faster in fresh water. However, they still have their limits of tolerance. Even if they survive, their growth and reproduction may be affected. For example, the common carp (Cyprinus carpio) can grow well in salinities up to 5 ppt, but at 11.5 ppt the salinity becomes lethal. Similarly, the tiger shrimp (Penaeus monodon) can tolerate 0.2 to 0.4 ppt salinity, but grows well only between 10 and 25 ppt.

As will be discussed in Chapter 6, salinity and water temperature are important considerations in deciding on the sites for hatcheries. Not only do these require higher water quality but the levels of salinity and water temperature required for spawning and larval rearing may differ from those needed for grow-out to market size. This may sometimes make it necessary to select separate sites for hatcheries and grow-out farms for certain species.

High turbidity of water caused by suspended solids can affect productivity and fish life. It will decrease light penetration into the water and thus reduce primary production. This would naturally also affect secondary production. In certain cases, oxygen deficiency has also been reported as a result of a sudden increase in turbidity. The suspended solids may clog the filterfeeding apparatus and digestive organs of planktonic organisms. The gills of fish may be injured by turbid water.Although the effect will depend on the species and the nature of the suspended matter, pronounced effects are seen when the water contains about 4 per cent by volume of solids. The use of turbid water in hatcheries should be avoided, as it can greatly affect the hatching and rearing of larvae.

If it becomes necessary to select sites with highly turbid water, which the candidate species cannot tolerate, suitable methods of reducing turbidity have to be adopted.The use of settling tanks, different types of filters and repeated application of gypsum (200 kg per 1000m^3 initially, followed if necessary by an additional application of 50 g per 1000m^3) have been recommended. All these will involve higher capital or operational cost, but in cases where there are no alternatives the possibility of absorbing the costs will have to be examined in feasibility

studies. Improvements in drainage from catchment areas, often the cause of high turbidity, may also be considered.

Among other water-quality criteria of importance in site selection are acidity and alkalinity. The most suitable pH of water for aquaculture farms is considered to lie in the range 6.7–8.6 and values above or below this inhibit growth and production, although the extent of their effect will depend on the species concerned and environmental conditions such as the concentration of carbon dioxide or the presence of heavy metals such as iron.

The prevalence of low pH in brackish-water areas and the problems of improving soil and water quality in farms built in such areas have been described earlier.Water of low pH is also common in fresh-water areas with soils low in calcium and rich in humic acids. Acid water with a pH range of 5.0–5.5 can be harmful to the eggs and fry of most fish and the adults of many. Acidity reduces the rate of decomposition of organic matter and inhibits nitrogen fixation, thereby affecting the overall productivity.

The most common method of correcting low pH is by liming to neutralize the acidity. The dose will depend on the pH value and the chemical composition of the water, especially the concentration of calcium bicarbonate [$Ca(HCO_3)_2$]. It will also depend on the type of lime applied. The relative quantities of quick lime (calcium oxide, CaO), slaked lime or agricultural lime (calcium hydroxide, $Ca(OH)_2$) and limestone (calcium carbonate, $CaCO_3$) required will be in proportions of 1 : 1.5 : 2 respectively.The actual dosage has to be determined by titrating the water to neutrality and calculating the equivalent amount of lime to be added. The additional costs involved will have to be taken into account before selecting sites with acid water.

High pH, indicating excessive alkalinity, can also be harmful. However, it should be noted that in productive water pH may reach higher values of 9 to 10 due to the uptake of carbon dioxide during photosynthesis in the daily pH cycle. This is why it will be better to take pH measurements before daybreak to determine suitability for aquaculture. A pH level of 11 may be lethal to fish.

Toxic substances in water supplies can affect aquaculture, particularly in hatcheries.

Table 4.2 Threshold of toxicity and maximum permissible concentration of toxic substances in the water supply of indoor fish hatcheries.

Substance	Threshold concentration (mg/l)	Maximum permissible concentration (mg/l)
Ammonia	0.2–2.0	0.05
DDT	0.02–0.1	absent
Calcium bisulphate	30–60	
Calcium chloride	7000–12 000	
Potassium chloride	700–5200	
Potassium sulphate	800–1000	
Magnesium chloride	5000–15 000	20
Magnesium nitrate	10 000	15
Magnesium sulphate	30 000	50
Manganese (nitrate, chloride, sulphate)	75–200	5
Copper (compounds)	0.08–0.80	0.005
Sodium bicarbonate	5000	
Sodium carbonate	200–500	
Sodium chloride	7000–15 000	
Cadmium	3–20	0.003
Ozone	0.02	
Mercury	0.1–0.9	
Rotenone	0.01–0.012	absent
Sulphides	0.4–4.0	0.1
Hydrogen sulphide	1.0	0.1
Iron (compounds)	0.9–2.0	0.01
Phenol	6–17	0.0005
Formaldehyde	15–30	
Tannin	15	5
Paraquinone	0.1–10	
Chlorine	0.05–0.4	absent
Carbolineum	7	
Zinc (compounds)	0.1–2.0	0.005