About the Authors

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James Muir is Assistant Director of the Institute of Aquaculture. His professional work involves aquatic resource management, aquaculture systems and sustainable aquaculture development. He has taught, advised and worked in development projects in a wide range of tropical countries.

This manual brings together a wide array of practical knowledge as well as fundamental and adaptive research on the operation of fish hatcheries. Concentrating on catfish, carp and tilapia, within a context of appropiate technology for Africa, it reviews the opportunities for seed production and the practical needs of potential operators.

Infrastructural requirements and systems design are discussed and a guide is provided for broodstock management, egg incubation and hatching, fry and fingerling rearing, water quality, disease and transport and delivery. Common management problems, organisation, planning and marketing are also covered.

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A Fish Hatchery Manual for Africa

by
Graham Haylor
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FOREWORD

Development in sub-Saharan Africa is a process which can and must succeed. Over a decade has passed since the United Nations Economic Commission for Africa presented what it described as a 'nightmare scenario' which demanded urgent action. This envisaged rapid and increasingly unsupportable growth in the population of the continent, an acute employment problem, increasing land and water shortages, accelerated ecological degradation and increasing social and political tension. Today, the region's social, economic and environmental constraints increasingly challenge governments, investors and policy makers as living standards and environmental conditions continue to decline.

In this context, aquaculture, the farming of aquatic species, has been one of the many development hopes for the continent, offering a broad potential for managing otherwise unused resources for productive benefit. However, while aquaculture has had many apparent benefits, its uptake has been disappointing, and there have been many problems in creating a healthy and economically active sector. While national government and development agencies have made many attempts to overcome the various constraints, few have been successful to date (Harrison, 1994).

To improve processes of development of fisheries and aquaculture in poorer economies, a series of consultations (1986, 1991 and 1994) took place amongst major donors and agencies. The Study of International Fisheries Research (SIFR) was launched in 1989, funded by 18 multilateral, bilateral and private donors including the World Bank, EC, FAO, IDRC, NORAD, and UNDP. In this, a key trend in successful aquaculture development was found to be the gradual privatisation of the production of juvenile fish. A follow-up study for Africa was carried out in 1992, with 12 selected national studies, prepared by senior African scientists. These studies also recognised that a major constraint throughout the continent was the lack of juvenile fish for pond restocking.

FOREWORD

Between 1991 and 1993 The Overseas Development Administration of the UK Foreign and Commonwealth Office (ODA) supported a study entitled, *Socio-economic dimensions of aquaculture development in Africa*, a collaborative project between the School of African and Asian Studies, University of Sussex and the Institute of Aquaculture, University of Stirling. This study identified several key issues and made recommendations concerning the apparent failure of aquaculture development on the continent. Two important and closely connected issues identified in these studies related to the deficiencies of fry and fingerling supply, and the inability of extension services to meet the needs for information and other forms of support. Amongst other recommendations it was proposed that training in fingerling production be encouraged, and in areas of high density of fish farmers, support be given to economically self-sufficient fry production centres.

While recommendations such as these are important, and are essential in informing further initiatives in aquaculture development, the problems of aquaculture in Africa have led to an unfortunate, but quite widespread, loss of confidence in its usefulness and sustainability, which within a more demanding and conditional environment for development support, has severely reduced opportunities for investment in these types of change. However, aquaculture does have potential if properly developed, and change and progress must be made somewhere if aquaculture is to step out of the trap of its former problems.

One of the most effective ways to initiate such change is with information, and hence the reason for this book. Thanks to key funding from the ODA Renewable Natural Resources Programme to the principal author (GSH), support has been available to collate and develop the material for this work by the Systems Group of the Institute of Aquaculture. This has then been extended and developed by the senior author (JFM).

FIGURES

BOXES

CHAPTER 1

INTRODUCTION

1.1 Background and aims

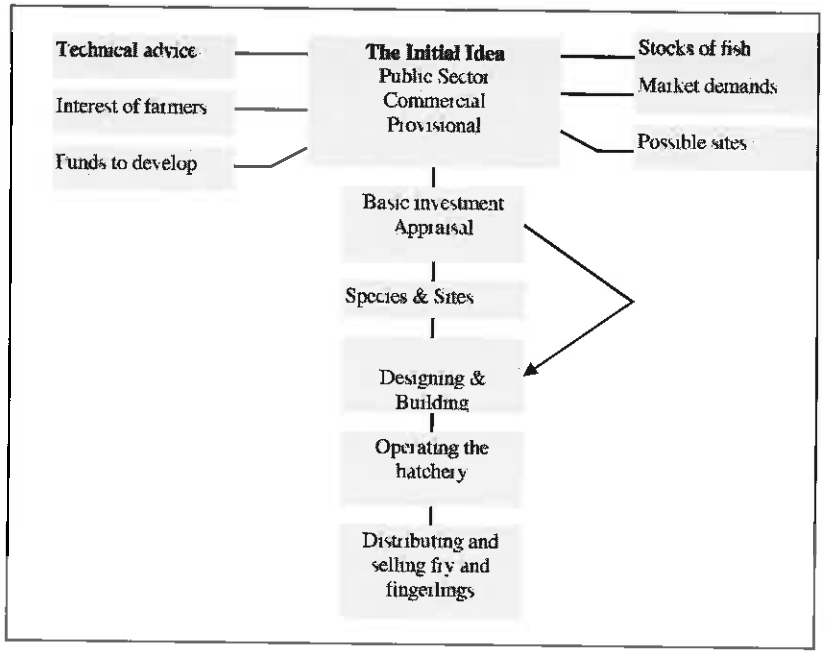
This manual has been produced with the aim of assisting individuals and agencies in achieving self sufficient fry production, and in ensuring that this supply is of a suitable quality to enhance rather than constrain local production. As a resource for the private sector, Government and Non-Government Organisations (NGOs) the manual aims to pull together a wide range of practical knowledge as well as fundamental and adaptive research findings on the operation of fish hatcheries and the essentials of producing good quality fry. The manual concentrates on catfish, carp and tilapia, aiming towards systems and methods with are appropriate for the region, and reviews the opportunities for seed production and the practical requirements of intending producers. It covers the fundamental aspects of infrastructure requirements and systems design, and provides practical guidance on broodstock management, egg incubation and hatching, fry and fingerling rearing and transport and delivery. Further sections deal with handling common problems of management, water quality and disease, as well as organisation, planning and marketing.

While it is clearly difficult to address such a text to a farmer, an extensionist, a development planner and a government policy maker all at the same time, it is to be hoped that each will find some materials of value. However, it must be recognised that different parts of the text will be more relevant for particular groups. With this in mind, while the style of the text has been pitched part way between that of a simple practical guide and an academic/technical description, it is to be hoped that neither the specialist nor the practical farmer will be unduly deterred by the result.

To offer further guidance to the different users of the manual, the first part (Chapter 2) largely covers the strategic and development-linked issues which are of most interest to those involved in policy and planning, the second part (Chapters 3-9) are concerned with technical issues of interest to the farmer and extensionist, and the final part (Chapter 10) provides information for those interested in more formal management techniques. The logical sequence of these chapters is summarised in Figure 1.1 below.

In the main text particularly, a series of 'boxes' is used to illustrate practical examples, provide checklists and offer key points of guidance. These in particular can be used as the basis for extension material, and might be used for working with interested farmers, the people to whom this manual is ultimately addressed.

Figure 1.1 Seed production - the sequence of development



1.2 A brief background to African aquaculture development

The 47 sub-Saharan Africa countries comprise 33 maritime and 14 landlocked states. The FAO Atlas of African Aquaculture (1986) divides the sub-continent into 5 agro-ecological regions, Sudano-Sahelia, East Africa, West Africa, Central Africa and Southern Africa. Further details of these regions are provided in the appendix. Table 1.1 summarises key information about these regions.

In spite of good physical resources in many locations, aquaculture in Africa is still essentially a rural, secondary and part-time activity, taking

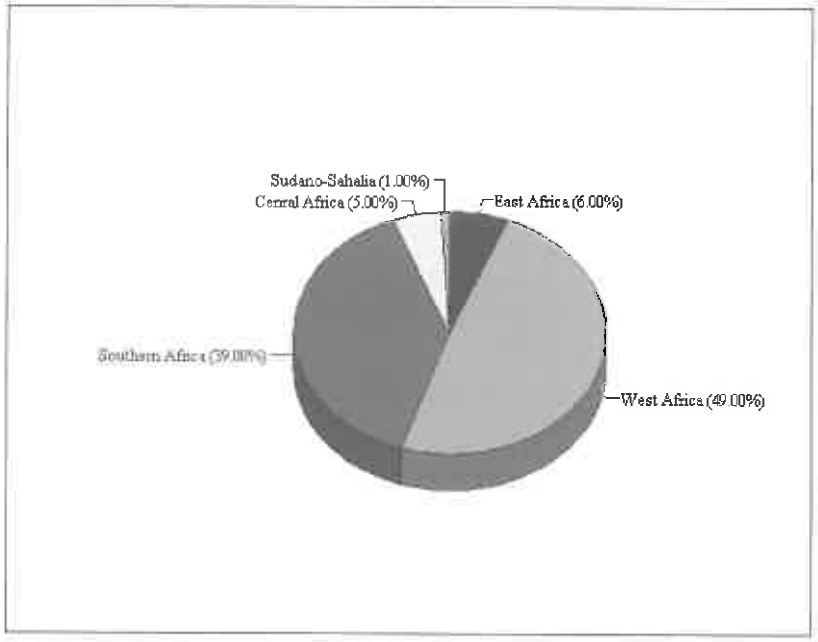
place on small farms in small water bodies. Low input aquaculture systems such as these, may be very important in local terms, but usually produce limited yields. Most of this is consumed directly, bartered or sold locally as cash crop, and very little enters the major food supply systems of the continent. Of some 20 different species known to be cultured in the region, only three; the Nile tilapia, African catfish and common carp are commonly grown. Apart from a small amount of seaweed, shrimp and oyster production, coastal aquaculture is even less significant. Production could be increased both by increasing the area used, and by improving yields. Although organic fertilisation is widely recommended for increasing fish yields, it is still far from being widely used. Supplementary feeding is also limited, often but not always restricted by the local availability of feed ingredients.

An indication of suitability for aquaculture development might be inferred from the prevailing conditions and the current status of aquaculture in different parts of the sub-continent. However, because of the early stage in the development of the sector in Africa, with total production currently in the region of 27 000 tonnes pa, a great deal of caution must be applied. For example, a single large scale commercial installation could rapidly account for 2 % of total African aquaculture production. Equally, such a general assessment may disguise localised potential within regions which might otherwise be defined as broadly unsuitable or less than suitable.

It can be seen from Figure 1.2 that according to official figures, approximately half the freshwater aquaculture on the continent currently takes place in West Africa, with Nigeria, the only significant[1] producer in sub-Saharan Africa, accounting for almost 94% of that sub-region's production. West and Southern Africa together account for over 88% of all aquaculture production on the sub-continent, while the East and Central agro-ecological regions account for just over 10% and the Sudano-Sahelian region, with some 36% of the land area, accounts for just 1.3% of aquaculture production.

[1] Producing over 10,000 tonnes per year

Figure 1.2 The freshwater aquaculture production of sub-Saharan Africa



1.3 The potential for aquaculture

Freshwater pond fish culture is the most widespread form of aquaculture production, practised in 33 of the 47 countries of sub-Saharan Africa, and *Clarias* catfish, tilapia, and carp are the most significant species. Table 1.1 summarises current levels of production of these species.

Most assessments of the strategic aspects of aquaculture development agree that pond-based culture of these three species, using semi-intensive methods (*i.e.* fertilising and/or partial feeding) hold the greatest potential for expansion. This is especially true in the warm tropics which make up 67% of Africa by area, as well as the warm sub-tropical regions with summer rainfall, a further 10% of the continent. From a strategic perspective, the most suitable areas for aquaculture are listed in Table 1.2.

Table 1.1 Current aquaculture production in sub-Saharan Africa

Country	Clarias	Tilapia	Carp	Other	Total (t)
Benin	-	25	-	50	75
Burkina Faso	3	2	-	-	5
Burundi	-	50	-	-	50
Cameroon	20	120	40	-	180
Central African Republic	1	337	-	-	338
Cote d'Ivoire	10	44	-	252	306
Congo	-	26	-	-	260
Ethiopia	-	20	2	-	22
Gabon	-	5	-	-	5
Gambia	-	-	-	50	50
Ghana	140	300	-	-	450
Guinea	5	-	-	-	5
Kenya	-	467	282	387	1136
Lesotho	3	-	23	4	30
Liberia	-	-	-	-	-
Malawi	1	30	14	178	223
Mali	17	20	-	3	40
Mozambique	-	20	10	-	30
Niger	-	10	-	5	15
Nigeria	1020	7525	800	3237	12582
Rwanda	2	45	6	-	53
Senegal	-	5	-	31	36
Sierra Leone	-	20	-	-	20
South Africa	450	55	86	2991	3582
Sudan	-	200	-	-	200
Swaziland	-	-	-	20	20
Tanzania	-	400	-	5000	5400
Togo	-	24	-	-	24
Uganda	-	30	15	-	45
Zaire	-	730	-	-	730
Zambia	-	1085	35	-	1120
Zimbabwe	-	50	-	110	160
Total	1672	11645	1313	12318	27156

(FAO, 1994)

Considering climate, population, land area, agricultural and fish production, the regions with the greatest potential in sub-Saharan Africa are humid and semi-humid west Africa and humid central Africa. In physical terms there is less scope in the Sudano-Sahelian region, with its poor soil texture and limited availability of water and production enhancing inputs. In the southern parts of the sub-continent, cooler temperatures and water shortage problems also constrain aquaculture, especially for warm water species.

Table 1.2 Areas of aquaculture potential - a regional perspective

Region	Optimum areas	Suitable areas
West Africa:	Southern Nigeria	Guinea Bissau, Guinea (except for the coastal region), Sierra Leone, Cote d'Ivoire (except central areas), Ghana (except in the north), Benin, Togo, central and most of Southern Nigeria.
Central Africa:	South CAR, N and E parts of S Zaire	Zaire (with the exception of the Central Southern area), Cameroon (except the coastal region and north of the R. Benue), CAR (except the border with Chad), Central and Eastern Congo, Gabon and Equatorial Guinea (except the coastal region).
East Africa:		Uganda, parts of the rift valley and the L.Victoria border and the south eastern border region with Tanzania in Kenya, South Western Ethiopia, Southern Rwanda, Eastern Burundi.
Southern Africa:		Tanzania-around L. Victoria the border with Burundi and north east and south east, northern and central coastal areas of Mozambique, areas in Northern and Southern Malawi, Central Northern Zambia, Central Northern Angola.
Sudano-Sahel		Southern Sudanese border with CAR, Zaire, Uganda and Southern Ethiopia.

Notes: The following data were used to assess potential: Agro-ecological regions defined by FAO Atlas of African Agriculture. [18 x 18 km at the equator]). Soils data from FAO-UNESCO Soils map of Africa (digitised at a resolution of 10'. Africa and Deichmann and Eklundh (1991). Mean annual rainfall data from FAO Irrigation and water resources potential. Other data and strategic assessment from Kapetsky (1993). Temperature data from See and Gommes (1992).

While general indications such as these are useful in describing the overall potential at a regional level, there are of course many localised variations. Within a high potential region there may be many unsuitable locations; conversely local site advantages may easily outweigh poor regional features. There is therefore still much to be done in selecting individual sites and of course there are many local social factors to take into account. For individual farmers, therefore, sites need to be carefully evaluated. Choice of potential locations should be guided primarily by the ability to grow the species considered to have most potential in the market. Then, the quality of the existing infrastructure, especially access to transport and to production enhancing inputs, may be the main factors given the

perishability of fresh products. Apart from these constraints the opportunities are likely to be comparatively open since human resources, plant and capital equipment are available in many locations.

Perhaps the most important observation to be made, already noted as the reason for this manual, is that in spite of the local suitability of resources there has been very little growth in aquaculture, particularly by comparison with other parts of the world. While many structural and economic problems can be recognised (Harrison, 1994), a major practical constraint is simply that of a regular supply of good quality fry.

1.4 The role of hatchery production in aquaculture development

As already noted, aquaculture development in Africa is at an early stage. Reported levels of production of *Clarias*, carp and tilapia imply that less than 200 million fry are currently used. This can be compared to regions in South East Asia where the sector is more mature, *e.g.* in NE Thailand alone, estimated demand in 1990 was 450 million seed. It is clear however that in Africa, even its present level of fry requirement is barely met, and the expansion of aquaculture development is amongst other things constrained by fish seed availability. Depending on the species, its market size, and the survival rate, the production of 1 tonne of fish requires ~ 2,000-10,000 fry. Thus a small pond producing 100 kg of carp may need around 300 fry, while a commercial tilapia farm producing 100 tonnes/yr might need 0.5-1.0 million fry annually. To reach even modest targets for growth will therefore require substantial increases in fry supply, particularly if some of the existing supply originates from wild catches. In sub-Saharan Africa, a regional aquaculture study (1992-1994) conducted by FAO in collaboration with the Economic Commission for Africa and the European Commission, identified the privatisation of juvenile fish production as a major priority for the development of aquaculture in the region.

However, because of the difficulties of controlling reproduction, or the inexperience of local producers, the culture of many species still remains dependent on wild populations. This has many disadvantages, including:

- unpredictable supplies due to annual and seasonal variations in the success of natural spawning ;

- supplies restricted to natural spawning areas and spawning seasons.
- possibly unsustainable exploitation of wild populations, to the detriment of aquaculture, capture fisheries and local ecology and species diversity.
- no opportunity for selective breeding.
- the potential to contaminate culture environments with other species, which may be competitors, predators or pathogens.
- difficulties in planning and expansion without security of seed supply.

By obtaining gametes[2] or fertilised eggs from captive adults, a much greater control over the spawning process is achievable. The degree of control will depend on the extent to which maturation of the gonads[3], mating (where appropriate) and gonad release will take place freely in captivity, and the extent to which these processes can be induced by an appropriate form of manipulation.

One obvious advantage of a hatchery seed supply and fry quality is that the parents of particular batches can be individually identified. This is the basis for selective breeding. Under good management in a hatchery, rates of fertilisation and survival can be improved, and it may also be possible to influence the timing of the spawning process. All of the three major species groups chosen, carp, tilapia and catfish can be produced in aquaculture, and so it can be possible to achieve all of these advantages.

Broadly speaking, there are three categories of type or size of hatchery; large government (institutional) hatcheries, medium to large commercial hatcheries and small scale artisanal hatcheries. The main features of these are summarised in Table 1.3 below.

The traditional approach to fry supply in aquaculture development had been to promote the construction and operation of large hatcheries or 'seed multiplication centres' usually Government run, capable of serving large areas of surrounding aquaculture production, and typically operated in

[2] reproductive cells - eg egg and sperm materials

[3] reproductive organs.

association with an extension service. While this approach has had the advantage of concentrating scarce skills and resources, and can offer economies of scale, and a greater potential for establishing good quality stocks, there have been many problems. Though there are more than 200 state farms in Africa's aquaculture infrastructure most of them are old and unproductive. Maintenance costs are high and management difficult. In addition, the need to distribute fish seed over a wide area from centralised facilities can be a formidable challenge when faced with poorly maintained infrastructure under tropical conditions. This is especially the case since fish spawn naturally following the on-set of seasonal rains, when transportation problems are most acute.

Table 1.3 Seedstock production - advantages and disadvantages

Institutional	**Commercial**	**Artisanal**
State, government or public body run; typically large scale, often expensive in capital and operating cost terms, may be inefficient, with poor and unreliable production records; good hatcheries however may have highly specialised techniques, excellent quality control, and the necessary resources for stock development and improvement, and new species trials.	Run as profit-making enterprises by private/ corporate entities; usually only in well developed technologies/ markets; usually efficient, quality good if in a competitive environment, however if in a monopoly position may be inefficient, over-priced. Profitable companies often invest in commercial R&D to develop new species, better products, etc.	Run as a profit making enterprise by individual, or small group, usually with simple techniques, often with poor quality control and limited genetic base of stocks, but cheap production, relatively efficient and can contribute to a diverse and competitive supply sector. May supply to wholesaler, with risks of mixing stock, spreading disease, etc.

(Source, Muir, 1995)

Largely as a result of the inefficiencies of big public hatcheries it has become increasingly common in aquaculture development elsewhere to promote the production of fingerlings by farmers themselves. Large scale state sector production, rather than supporting aquaculture development,

can discourage private sector activity and farmer-to-farmer trade in fish seed. However, in common with other industries, the informal sector in Africa (as elsewhere) is an important resource for development. While the state still has an indispensable role in providing a predictable and honest regulatory framework, efficient infrastructure and social and information services, there is growing evidence that building private sector capacity through the creation of an enabling environment can be a productive use of government and donor development efforts. In Thailand, for example, private hatchery development began in the early 1970's and within a decade contributed 50% of fish seed production.

If small scale hatchery production is to succeed, it must be fundamentally viable, and those involved in setting up hatcheries need to know which factors are important. The next chapter therefore considers the opportunities for setting up fry production in a particular area, and reviews the factors which will determine whether local fry production is feasible, and whether local farmers can participate.

Finally, it should be made clear that the process of development, perhaps particularly in a field such as aquaculture, is not a matter of science and technology filtering down to the farmers. In engaging farmers in fry production, a new range of skills develops and a new social content may arise. Experience and understanding gained by farmers, within their own cultural background, will shape how they pick up new concepts, how they adapt and develop them, how the production of fry might arise as a result, and how local communities might become more capable and independent in meeting the challenges of the future.

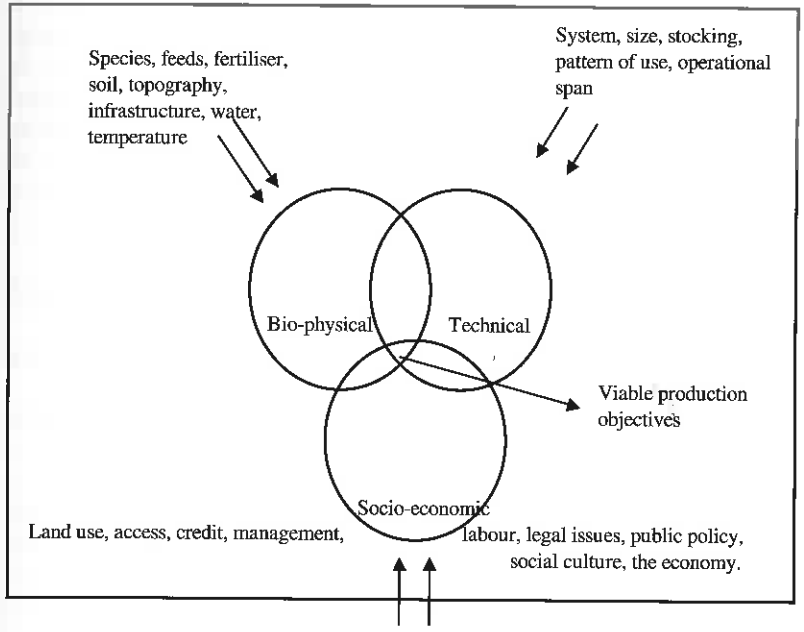
CHAPTER 2

OPPORTUNITIES FOR SEED PRODUCTION

2.1 General factors

Aquaculture in Africa will need a better and more widely distributed supply of fry if production is to develop. While this can be achieved in some areas by improving and upgrading existing facilities, there are important prospects for placing fry production into the hands of local farmers. In overall terms, successful hatchery production depends on matching up the biological and environmental requirements of the chosen fish species, the physical requirements of the hatchery facilities, and the technical requirements of the operating system in a way which is appropriate to the socio-cultural and economic situation. Figure 2.1 shows the relevant factors and outlines the key elements in hatchery production. These are discussed in more detail in later chapters.

Figure 2.1 Factors affecting fish seed production



In basic terms, of course, there is no point in producing fry unless the producer has a reasonable chance of making a profit. There is nothing to be gained by encouraging farmers to produce fry, without a clear idea of why and how they are to do so, and without a reasonable prospect that they will benefit from their involvement, and will be encouraged to continue, and develop production further.

The role of planning and technical assistance in this matter will vary. As the manual shows, there are different ways of going about the task of fry production, and there are different sizes of output, with varying levels of sophistication. There is no point in proposing a system of highly complex hatcheries requiring significant local investment and high degrees of skill amongst producers if these resources are not already there, or can not easily be established - even if in theory such a system would produce more fry of better quality. It is far more useful to look at methods of fry production which are appropriate to local conditions and to aim to build up on this with the participation of the farmers, to achieve improved levels of outputs and quality.

It is also useful to consider the overall scope for fry production within a particular area. As many examples have shown in other parts of the world, fry production can develop very rapidly, almost unexpectedly so, in favourable areas and can be associated with a rapid increase in local production and/or significant local activity supporting aquaculture elsewhere. The following factors are good indicators of the overall potential:

- good local water resources and suitable sites
- adequate local transport networks and/or an active system of distribution of small goods
- a local group of active and interested fish farmers, with some experience in managing stocks and ponds, and with a need for fry
- enough resources in the local economy to support sales of fry, and to offer beneficial returns to producers.

As mentioned earlier the main aim of the present manual is to provide information for the smaller scale hatchery developments, but clearly, the possible role of larger commercial and public hatcheries needs to be borne in mind. Too much capacity and subsidised prices will undercut the

potential for local production. A limited public hatchery capacity, and the lack of commercial ventures will improve prospects for smaller scale hatcheries. Ideally there can be some degree of cooperation, with each type of hatchery specialising in certain areas; a government hatchery can for example maintain good quality broodstock to replenish brood fish for local hatcheries, while small scale hatcheries can help test out new strains in local conditions.

It is not a good idea to try to regulate fry production amongst smaller producers, and to artificially limit their potential. It is more important to provide the right kind of advice, and to work with the producers to allow them to decide what is best for them. The following sections of the manual will help those involved in supporting aquaculture, and the farmers themselves, in deciding whether fry production will be worthwhile.

2.2 When is seed production worth considering?

Producing fish seed requires time, energy and resources, and needs careful thought before proceeding. What may be good for one person or situation may not necessarily be good for another. It is important to be aware of the opportunities and threats, and the possible strengths and weaknesses of the proposed culture. Visiting other farms, learning about the systems and hatchery processes as well as the industry in general, will be very valuable both for farmers and extensionists.

The series of questions in Boxes 2.1 to 2.3 may also help to determine whether seed production might be worth considering:

Box 2.1 Considering seed production – what opportunities exist?

- Development - are there **national development goals and objectives** supporting aquaculture in general or seed production in particular?
- Markets - is there a **market** for fish seed? – What **species** is required? – What **size** and when?
- Demand - what level of **demand** is there? – How much fish seed might be required? - How frequently/at which period?
- Investment - are there any programmes or other opportunities for investment in fish hatcheries? – Where and with what conditions?

Box 2.2 What resources and skills are available?

- **Expertise/training** – have you any formal or informal training? – Do you have access to help and information?
- **Capital** - do you have any financial resources? – Access to credit?
- **Site** - do you have a site (land and water) that might be suitable? – Can you acquire a suitable site?
- **Plant** - are materials available to construct and operate a suitable system?
- **Inputs** - are production enhancing inputs available? – Are they seasonal, restricted or used for other things? – Are veterinary or chemical supplies available when needed?
- **Management** - can someone manage the development, financing and operation of the project?
- **Labour** - who will do the work? - Will someone always be required? – Will additional help be required sometimes? – Is it available?
- **Services** - are road and rail/ electricity/ post/ telephone/ advisory veterinary services available?
- **Security** - is access to the site controllable? – What effective measures are there against vandals, poachers or predators?
- **Transport** - how will the site be reached? - How will construction materials be transported? - How will inputs and fish be transported?

Box 2.3 What threatens the chance of succeeding?

- **Competition - is fish seed already widely available? - Is wild fish seed** caught, and how good is the resource?
- **Legislation** - are there rules governing water or land use? – Any dispute over ownership or access? – Are any species, systems or practices banned?
- **Environmental instability** - is there a danger of flooding or reduced water supply? – How does temperature and other water quality vary?
- **Other options** - is the **profit potential** from seed production higher than for other crops or land or water use?

Potential hatchery producers can consider these questions themselves, or if suitable, can discuss these with an extension specialist or other adviser. It may not be possible to provide answers to all the questions immediately. General resource factors and outline costs and returns may take some time to be assessed, and choices will need to be made about location and system. Ideas may have to be altered because of cost, production or other

constraints. These points are all discussed further in following sections.

2.3 Can money be made from fish seed production?

Developing a hatchery requires an investment, and therefore should only be undertaken if an acceptable financial return can be expected. Assessing the costs and returns for some projects can be a complex procedure which might need assistance from a trained professional. However, where there is access to credit there is also often access to financial advice. Even with professional advice, the quality of any appraisal will however depend on the quality of the information available. Costs and returns will be specific to the site and the project. It is important that the values used are realistic. The collection of this information is important and a little time and effort expended at this stage is well worthwhile in supplying the right decision.

Four key elements will need to be estimated, which depend on the circumstances in which a hatchery is being considered. As can be seen from Box 2.4 below, these elements can be related to produce the three fundamental relationships which can be used with suitable evaluation

Box 2.4 Important elements and relationships for investment appraisal

The important ***elements*** are:
the *unit price* for which fish seed can be sold (i.e. price per fry)
the *unit cost* of producing fish seed (i.e. cost per fry)
the total *cost of constructing* a hatchery (or the capital cost)
the *level of production* (usually number of fry per year)

The important ***relationships*** between these elements are:
Sales revenue = level of production x unit selling price
Production costs = level of production x unit cost of production
Total initial investment = total construction cost + cost of production prior to the generation of revenue

Commonly used ***evaluation techniques*** include:
Payback time = total initial investment / average annual profit
Avge annual return on investment = (avge annual profit/total investment) x 100
*Net Present Value** = future revenues (in current value) - investment costs

*See below for explanation of NPV.

techniques to determine whether the project is viable. A reasonable starting point for collecting this information is to consider the market for the fry and the price for which fish seed can be sold i.e. the unit (selling) price.

Market and selling price.
The first point is to identify in simple terms the potential market - the circumstances of the potential customers for the fry, their number, their location, and their needs. Because of the cost and difficulty of transport a hatchery will be likely to serve a specific region and this can usually be defined e.g. within groups of villages, areas around a town, or along a road, or an administrative area. The price for which fry or fingerling can be sold will depend upon supply and demand within that region. Supply will be related to the number and size of other hatcheries in the region, the wild fish supplies as well as any supply from other regions. Demand will be related to the number and size of fish farms within the region as well as price itself (see also Chapter 10).

In simple terms, if there is a good supply of fry, buyers have many choices, and prices are likely to be low, as suppliers will compete with each other to sell their fry. If supplies are poor, there is a lot of competition to get fry, and so prices will tend to rise. In practice, the farmers of market size fish also have limits for the price of fry they can purchase, as they will not be able to sell their own fish if their costs are too high. It is therefore useful to understand the position of the farmers and how much they might be prepared to pay for good fry, and still allow themselves some profit.

The price will depend on a range of circumstances and will be subject to changes. Season may also play a role, especially in relation to wild fish supplies, and the potential to spawn fish outside their normal spawning season may be important. The development of better quality, more consistent supply, and other improvements may result in a premium price, but only if these improvements are valuable to the customer. Fish farmers, seed suppliers, other hatcheries and fisheries departments may all be useful sources of market information. It is also useful to inquire whether any other factors might affect the market - e.g. other hatcheries developing or expanding, or the opening up a road or a transport service, which could improve fry supplies from elsewhere.

If the price for which a fish can be sold is low (compared with the estimated cost of production) then there may be little unfulfilled market opportunity and therefore little reason to develop a hatchery! Also, if the intended production will flood the market - for example if it doubles the local supply, prices will probably fall. Of course in the longer term, a better supply of fry in the area, at a moderate price, may encourage more people to turn to fish farming, and in turn, build up the demand.

The cost of producing fish seed (production cost) is the next element to consider, as it can be compared with the market price to see if it is possible to make a profit.

Production costs
The cost of producing fish seed will be related to the cost of providing and maintaining a suitable environment, and the required inputs of nutrients, labour, etc. A critical factor will be fry growth and development rate, and its relationship to environmental and nutritional factors. The potential growth of a fry or a fingerling is mainly determined by its age, weight and body composition and environmental temperature. The quality of the site, the efficiency of the system, and the management of the technical ability of the operator(s) will also contribute to the production cost. Box 2.5 summarises the major factors in production costs in hatcheries.

As shown these are often classified as fixed costs, which stay the same regardless of the level of production, and variable costs, which are related to the output of the hatchery. It is also quite common to include a 'contingency' - usually an extra 10-15%, to cover any unforeseen costs. In comparing production costs with market prices it is also important to make sure that they are compared on the same basis - i.e. a fish of the same size and quality available to the customer at a specific location, including the costs of transport, packing, selling fees, etc. Finally taxes may have to be included!

Construction costs
The costs of constructing a hatchery comes into the production cost in terms of the costs of the funds used to build it e.g. loan terms if money is borrowed to build the hatchery, or if someone's own funds are used, the denied opportunity to use these funds for something else, or e.g. to earn interest on the money. The construction costs also come in indirectly in

terms of repairs and maintenance, and here there is often a choice between spending on good quality construction or equipment, and having low maintenance costs, or buying the cheapest materials but having to make up later in higher repair bills.

Box 2.5 Production costs

FIXED COSTS

* Cost of funds – loan payments, interest changes, depreciation of capital loans
* Rates, Leases – e.g. for land area, buildings, use of water, etc
* Repair and maintenance - building, ponds, tanks, water supply, feeding equipment, harvesting equipment, miscellaneous equipment

VARIABLE COSTS

* Production enhancing inputs – manures, supplementary feeds, live feeds, prepared feeds
* Chemicals – prophylactic, disease treatment, disinfection
* Fuel – pumping, aeration, feeding, transport
* Labour – manager, hired full-time, hired part-time
* Other – telephone, advertising

It is useful to draw up a costed checklist for the required plant and associated costs related to the construction of a hatchery (see Chapter 4). As with production costs the choice of site, scale, system, intensity of production and market conditions will all contribute to the definition of the construction costs.

Usually, once the construction costs are identified, profit estimates (i.e. market price plus selling price x number of fry sold) can be applied to find out how quickly the costs can be returned (the pay back period) or put another way, to estimate the return on investment (ROI), the annual profit as a percentage of construction (i.e. investment rate) costs.

Level of production

There are many factors to consider in defining the best level of production. In practical terms, this could be defined by the present or expected size of the market, or by the site, the resources of the individual farmer, the amount of funds they have, the time they have available, and sometimes simply by the number of broodstock fish which might be available. The

later sections of the manual give some information on those practical issues.

Many small farmers will probably only want to produce fry sufficient for their own production, or those of their neighbours, and will base this on the stocks they have and their existing resources. In some cases, however one or more farmers or business people might want to set up a commercial hatchery, which might have to be developed as a new project, and might be run with a manager and hired staff. It is often the case that larger projects can produce at a lower cost - for example by being able to purchase materials in bulk, by being able to organise production more efficiently, but the size and efficiency of the project could also be limited by local factors such as the availability of water, or access to needed funds to develop the project properly. Also, if production affects market price very strongly, the profits may drop if the project becomes too big.

It is often better then to aim for a smaller efficient and profitable venture which can be expanded later, rather than a project which is too ambitious. In most cases therefore it is prudent to start with a modest level of production - perhaps no more than 20-30% of the existing level of supply, and build up from there if the market develops.

Assessing the investment

Even if a hatchery project is very small, it is important to assess the investment. There is no point in committing time and effort, or hard-earned funds to a project if it cannot make a sufficient return. In some cases, local development advisers can help with this assessment, and agricultural credit banks can sometimes help to determine the soundness of an investment if they are asked whether or not they can commit funds to a hatchery project. An example of a simple assessment is provided in Box 2.6

In this case, the project appears to be viable, with a good return on investment and a short pay back period. Hence the project looks like it will be worth considering. However, though these are both useful evaluation techniques, neither takes account of the change in the value of money over time, which could be quite considerable over several years. In simple terms, if the present interest rate is 10%, 1 unit of currency will be worth 1.1 units in a year's time, or conversely, the receipt of 1.1 units in a year's

time is worth only 1 unit in the present day, i.e. in technical terms the future value is discounted by the interest rate to give the present value.

Box 2.6 Hatchery investment illustration

It is proposed to build a hatchery over 6 months (during the dry season) and with the onset of rains to begin seed production on a pilot scale (30% of normal production in the first year). Production will be built up to 60% in year two and full capacity thereafter. The hatchery is expected to have a total life of 10 years. Construction costs, sales revenue and production cost profile are shown below.

Construction costs	**Currency units**
Building	20 000
Larval tanks	4 000
Fry tanks	8 000
Pump and filter	12 000
Generator	3 500
Plumbing	1 000
Fridge	500
Other	6 000
Total	55 000

Year	**1**	**2**	**3**	**4-10**	**Total**
Revenue 12 000	24 000	40 000	280 000	356 000	
Cost 13 325	16 130	18 000	126 000	183 455	
Contribution	-1 325	7 870	12 000	154 000	172 545

Pay back* = 55 000 / (172 545 / 10) = 3.19 years
Return on Investment* = {(172 545 / 10) / 55 000} x 100 = 31.4 %

* see previous box

To overcome this, it is possible to express all future revenues and costs of the project in terms of the present value of that money. An assessment can then be made to see if the net present value (NPV) of future earnings or contributions (revenue - cost) will exceed the present investment costs. If this value is positive (i.e. the future earnings exceed the initial investment, after allowing for the changing value of money) the project is worth considering; if it is negative, it will be better to invest the funds in something else. Using this method in the example shown in Box 2.7, money is borrowed at an interest rate of 12% (1/1.12) and so the present

value of 1 currency unit in 1 years time will be worth only 0.893 units and 2 years from now only 0.797 and so on. For simplicity, discount factors are available in tables for a range of interest rates. (Note that a discount rate of 12% is chosen here as an example only, it will be important to be realistic about the factors which will affect the value of the investment under consideration).

Box 2.7 Using the NPV method for the previous hatchery example

Year	**Contribution**	**Discount Rate (12%)**	**Present value**
1	- 56 325*	1.000	- 56 325
2	7 870	0.893	7 028
3	12 000	0.797	9 564
4	22 000	0.712	15 664
5	22 000	0.636	13 992
6	22 000	0.567	12 474
7	22 000	0.507	11 154
8	22 000	0.452	9 944
9	22 000	0.404	8 888
10	22 000	0.361	7 942
		Net Present Value+	**40 325**

* 56 325 = 55 000 capital + 1 325 loss in year one

A positive Net Present Value indicates that an investment has the potential to earn a better return than alternative investments which would earn money at the chosen discount rate, eg bank deposit rate of interest. Of course, it is important to choose a suitable discount rate which is appropriate for the area concerned.

So for this example, the payback period is quite short, the return on investment looks favourable and the NPV is a large positive sum - the hatchery investment therefore looks sound provided the production targets are met, the market share is maintained and the costs and revenues have been realistically estimated.

If the project does not appear to be viable, it may be worth rethinking - is it too big for the market? Too small to work well? Too expensively constructed? Are the costs accurate? Maybe it is possible to obtain a grant, or some other support, such as a low interest loan. Would these make the

project more viable? If the result is still negative, the answer is clear - it would not be worthwhile to continue. In the future, if market opportunities improve or costs can be reduced, the project may be worth re-examining, but it is important not to be tempted to try to make the project look viable - by underestimating the costs, or assuming the prospects for high priced markets - just for the sake of trying to go ahead. Invariably, such an approach will cause problems, and the goal must be to get good and viable hatcheries, rather than poor and unproductive projects which will simply drain the resources of those involved.

However, once the basic decision has been made about whether or not a hatchery project is worthwhile, and an appropriate project has been identified, it can be thought out in more detail. The first step in this is to consider the species to produce and the opportunities for finding a site. The construction of the hatchery is discussed in subsequent chapters.

CHAPTER 3

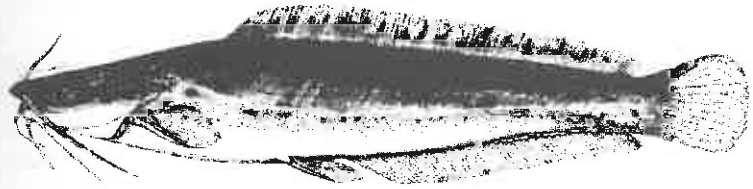
SELECTING THE SPECIES AND THE HATCHERY SITE

3.1 Introduction

This book deals with three main species of fish, the African catfish, the Nile tilapia and the common carp, as these are the most important for the region. However, many of the principles involved are equally applicable to other species, and the ideas can be adapted accordingly, provided the basic information about the species and its hatchery requirements are known. This section provides a brief description of the distribution, appearance, fecundity, eating habits, special characteristics and preferred consumption methods of the catfish, tilapia and carp. The factors to consider in selecting an appropriate site are discussed later in the section.

3.2 Species

Fig 3.1 The African catfish (*Clarias gariepinus*)

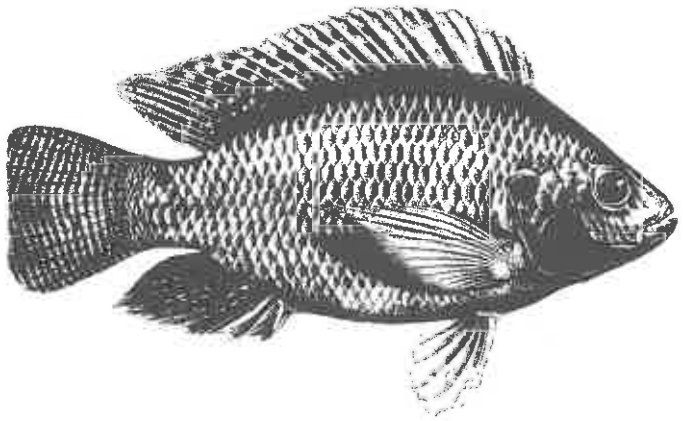


Some key facts:

- catfish are widely distributed throughout Africa from the Nile delta to the Orange River; it is the fresh water species with the widest latitudinal range in the world.
- it is very fast growing and tolerant of environmental extremes and disease, even when grown at high densities.
- after several weeks of life the fish takes on its adult form and begins to breathe oxygen from the air. This is very important because oxygen levels are low in warm water and is a big constraint to producing most species, which depend on gills for oxygen uptake from the water.

- catfish are omnivorous, commonly eating detritus (waste plant and other materials) and its associated nutritious micro-organisms, plant material, insects and their larvae, small fish and amphibians.
- the fish become sexually mature after 1 to 2 years; a female produces 20,000–1,000,000 eggs depending on its body size (60,000–70,000 per kg of body weight).
- the catfish has a long slender body and a large bony head with eight distinctive barbels. The general body colour is dark although it can tend to light brown in some fish.
- the flesh is off-white to pink in colour with medium fat levels, though these characteristics vary with feed, culture conditions and slaughter procedures. There are few intramuscular bones, the flesh is firm, the skin is robust, scaleless and slime covered.
- the catfish is usually sold whole and fresh; it can be kept alive in a market for the whole day if kept moist and shaded. The fillet yield is in the region of 50-53%; the large head which is often favoured for soups and stews represents additional yield.
- traditional smoking of whole gutted catfish adds value as well as extending shelf life, and represents a particularly flavorsome and nutritious addition to a variety of staple foods.

Fig 3.2 Nile tilapia (*Oreochromis niloticus*)



Some key facts:

- tilapia originate from Africa where they are the most widely cultivated finfish. There are many different tilapia species, and various tilapia have been introduced to many other countries where they are now very successfully cultured.

- most tilapia graze on periphyton (algal material on plants and rocks) and/or filter feed phytoplankton (algal material suspended in the water), though different tilapia species have varying feed preferences.

- tilapia are not air-breathers but when the water is low in dissolved oxygen they will gulp at the water surface, helping to increase the oxygen they can take up.

- males grow faster than females, and the production of all male populations is important for successful on-growing of larger fish, and avoiding over-breeding.

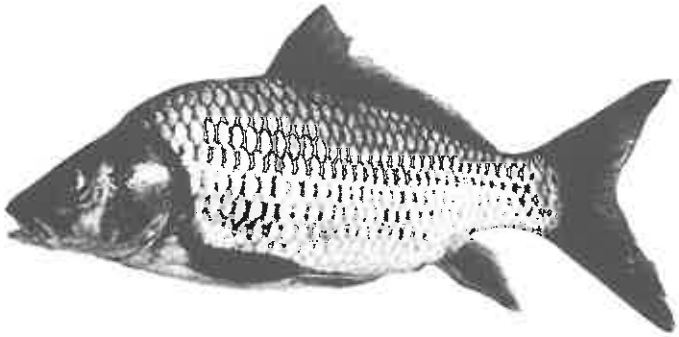
- of the tilapias, the Nile tilapia, *Oreochromis niloticus* is perhaps the most popular aquaculture species; it has a deep silver-grey, scale covered body with darker vertical bands along the body sides and characteristic vertical black stripes on the tail fin.

- the age or size of first maturity in tilapias is extremely variable. Small batches of eggs are produced in which much parental care is invested. Nile tilapia females produce and brood between 200–1,100 eggs and young in their mouth..

- precocious breeding after only a few months, in ponds containing both sexes, is a serious constraint to their culture in low input aquaculture systems.

- tilapia have firm whitish flesh; they are marketed at a few hundred grams or less and after descaling, are commonly fried when small to crispen the numerous intramuscular bones; smaller tilapia can be used in soups and stews, or can be salted or dried.

Fig 3.3 The common carp (*Cyprinus carpio*)



Some key facts:

- common carp probably originated around the Caspian Sea but spread widely into new catchments and became adapted to new conditions. Different carp species make up about 90% of the world's freshwater fish culture, of which the common carp is the most important.
- carp can grow to 80 cm and can weigh 10-15 kg. They are quite deep bodied with a greenish-brown back and yellow-white underside.
- through several centuries of selective breeding, body length, depth, colour, scale formation, and bone to flesh ratio have been altered considerably. Improved varieties have only a few scales along the back and lateral line.
- in tropical and sub-tropical regions carp reach sexual maturity after 1 year. A female produces 100,000–200,000 eggs per kg of body weight, 80,000–120,000 per litre after spawning.
- common carp are omnivorous, feeding mainly on the bottom, but are quite suitable as a pond fish.
- carp are commonly steamed, cooked with rice, fried or made into soup. Carp have a series of free floating bones within the flesh which may need to be removed, or softened through various preparation treatments.

Table 3.1 outlines the comparative features of these three species, and provides further information on the preferred culture conditions, and on the basic factors for planning hatchery production.

Table 3.1 Catfish, tilapia and carp: comparative features

Characteristics	Catfish	Tilapia	Carp
BASIC FACTORS:			
Production schedules: Spawning notes (season/ unconstrained)	Rainy season Captive broodstock induced spawning unconstrained	Regular spawner spawning must be constrained to prevent over crowding and stunting	Spawn spontaneously after ovulation genital pore sutured to prevent egg release
Fecundity	60,000-70,000/kg	10,000 /kg	100,000-200,000/kg
Breeding	Induced breeding	Broodstock conditioning	Induced breeding
Early rearing needs	Sticky eggs, cannibalistic and aggressive territorial larvae.	Mouth brooder, build hierarchies, males territorial.	Sticky egg,sticky patch on head after hatching, cannibalistic.
PRODUCTION CONDITIONS:			
Temp. range (°C)	25–35	25–30	22-26
Resultant saturated oxygenlevels(mg/l)	8.2-7.0	8.2-7.6	8.7-8.1
min. oxygen (mg/l)	3.0	3.0	3.0
Alkalinity (mg/l)	> 20	>20	>20
PH	6-8	6–8	6-8
COD (mg/l)	20-30	20–30	20-30
BOD_5 (mg/l)	8-15	8–15	8-15
Stocking density:in relation to flow/vol	8-10 l/min/kg for 20-50 mg fish	6.5 l/min/kg eggs eggs 15000/l,fry 12/l	8-20 l/min/kg
CO_2 (mg/l)	< 12	< 12	< 12
HATCHERY:			
Habitat requirements	Semi-sterile culture conditions Mesh for eggs shelter for hatchlings	Semi-sterile culture conditions.Substrate for spawning	Semi-sterile culture conditions Substrate for spawning
Feeding	Live feed initially	Sex reversal feed	Live feed initially
Water movement	Gentle flow for incubation to discourage fungal build up and maintain more constant temperature. After hatching flow to remove dissolved wastes and supply oxygen not to cause swimming,	Constant circulatory motion for incubation of eggs and yolksac larvae. Oxygen requirement to be satisfied by water flow.	Circulatory motion for incubation. After hatching flow to remove dissolved wastes and supply oxygen not to cause swimming.
Removal of wastes	Screen clearing, siphoning solids	Screen clearing, siphoning solids	Screen clearing, siphoning solids

3.3 Site selection

3.3.1 General principles

From the basic description of these species, it can be seen that a successful hatchery would require several important features:

- facilities for holding broodstock and bringing them into spawning condition
- facilities for holding eggs and hatching fry, either with the parents, or separately
- if there is a good demand, additional nursery space for holding and growing fry to fingerling size.

Hatcheries, nursery systems and their associated facilities may be land or water based, (see Chapter 4) though all systems require some land. Land based systems are more common, involving ponds or tanks constructed on the land, with water arranged to run through them; water based systems are set up - usually as floating cages or pens, within existing water bodies such as lakes, reservoirs or deeper and slow-flowing river sections.

Finding a suitable site for these hatchery and nursery facilities is crucial for technical and economic success. Though it is rare to find an ideal site, it is usually possible to select one which will be reasonably acceptable, with not too much expense required to make it suitable, and to operate it effectively. In practice the most important site characteristics can be grouped as:

- water supply, its availability and quality
- land, its layout, features and soil quality
- infrastructure and other issues.

The features which are most important will depend on the type of production units, their size, the way the system is operated and the ability of hatchery operators to overcome particular site problems. The factors are discussed as follows:

3.3.2 Water supply

Water surrounds and supports the fish; it controls the body temperature and therefore the growth and performance. It is also the medium through

which various materials are exchanged, including gases, dissolved substances and waste products from the fish themselves. Like other animals, fish need oxygen to live. They also produce carbon dioxide and ammonia; which with gases such as nitrogen, hydrogen sulphide and methane can occur in natural waters and ponds. These gases can be toxic, and need to be kept at low levels. The water surface is the site for the exchange of gases - the uptake of oxygen and the driving off of toxic gases. If this is insufficient, a certain amount of fresh water will be needed to replace the existing waters, to ensure that healthy conditions are maintained for the stock.

Water is also important for its ability to support other living organisms - particularly those which can be used as feeds for young fish, or in broodstock holding conditions. For all of these reasons both the availability and the quality of the water supplies need to be considered.

Availability

The availability of sufficient water of appropriate quality for the species of choice is one of the primary requirements of a hatchery site. The overall requirements will vary with the system, but an approximate idea can be gained from the following table.

Table 3.2 Water requirements

System	Water demands
1,000 m^2 ponds with 50-200 kg broodstock	Needed to make up for evaporation, keep water in good condition; average 0.5-2%/day, i.e. 10-30 m^3/day or ~ 7-20 litres/min
20 m^3 cage in lake, reservoir or stream with 200 kg broodstock or fingerlings	Continuous turnover needed to supply oxygen, carry away wastes; usually provided by natural mixing currents through the cage.
10m^3 broodstock tank, with 200 kg stock	Continuous turnover needed to supply oxygen, carry away wastes, 50-150 litres/m. (less required with good aeration)
1m^3 tank with 3 kg eggs or fry	Continuous or intermittent exchange needed, average 10-20 l/minute

Water sources can include:

- surface water, especially
  - perennial *lotic* systems (i.e. streams or rivers with flowing water throughout the year),
  - large or small *lentic* systems (still water bodies) such as lakes and reservoirs
  - managed water systems such as irrigation schemes, including farming sub-systems such as paddy fields.
- ground water, i.e. obtained from below the surface, particularly if it is easily available (e.g. through simple wells, boreholes or springs.)

For seed production, the constant quality and supply characteristics of ground water make it especially suitable, although many surface waters may also be utilised. If surface waters are to be used, annual rainfall can be taken as a measure of surface water availability, especially for ponds. Assessments of surface water storage potential, conducted for irrigation purposes in Africa, have indicated that a mean annual rainfall as low as 550 mm could provide some water storage in ponds. However for normal supply for aquaculture, rainfall needs would be closer to 1,100 mm, and ideally about 1,300 mm respectively.

In arid, semi-arid and sub-humid regions, evaporation losses from the open water surface of fish ponds, tanks or supply channels, as well as evapotranspiration from vegetated surfaces of pond or channel banks, can also cause significant water losses, depending on temperature, relative humidity, cloudiness and wind. These factors may all need to be taken into account. For rainfall and evapotranspiration, local farmers or their advisers are usually good sources of information. In some locations there may also be a weather recording station which can give more accurate data. Another good general indicator is the type of crop which can be grown; clearly an area which supports only sparse semi-arid vegetation is unlikely to provide sufficient local rainfall for most types of aquaculture, though if irrigation supplies or reservoirs are available, this may offer alternatives.

If ground water is used, specific aquifer locations must be determined and their yield estimated. For ground water supplies it is usually possible to get information from farmers or water supply specialists. A number of indigenous knowledge practices exist around the world for location of

productive aquifers. In some areas, local contractors have a lot of practical information about abstracting ground water in suitable locations without too much cost. However, many areas may simply be unsuitable.

Water quality

The water quality is fundamental to the health of fish stock at all stages. As indicated earlier, each species has its own optimum and extreme range of tolerance for the various water quality factors, although these can vary considerably through the life cycle. Water quality factors can also interact, with positive or negative results. Although there are technologies for pre-treating poor quality water, and for reusing water if supplies are limited or unreliable, these systems tend to be expensive and their costs must be judged against whatever benefits they might provide. A simple system with a gravity (free-flowing) supply of good quality water will not only be less expensive but is usually more stable.

a) Temperature

Temperature is perhaps the most important characteristic of water quality for a hatchery. Each species has a maximum and minimum lethal temperature, as well as an optimum for growth and feed conversion. This also exerts a direct effect on the activity and metabolic processes of the fish, and on their spawning and development rate, and has an indirect effect on dissolved oxygen level (see below). Temperature is difficult and expensive to manipulate and so the normal annual temperature regime is a very important factor. This determines the boundaries of areas where aquaculture is feasible, especially in relation to species choice, as well as the growth of stock and the production capacity of hatcheries and farms. Further away from the equator, water temperature tends to become lower and more seasonal and there may be periods when the growth of warm water fish species is constrained by low temperatures. Temperature also decreases by about 0.6°C for every 100 m of elevation. Levels in excess of 22°C for 12 months would provide good growth conditions for catfish, carp and tilapia, while temperatures in excess of 26°C for 12 months would support optimum growth for both catfish and tilapia. The effect of temperature on spawning, development and growth is dealt with later.

For site selection, temperature will be a function of the type and location of a water body and its origin. For surface waters, temperature varies with air temperature, solar radiation and the surface wind velocity. A daily

fluctuation in temperature is typical in standing water, reaching a peak in the afternoon and its lowest point between mid-night and dawn. If no direct information is available, the mean monthly daytime air temperature is the closest approximation to pond or other standing water temperature. The temperature of ground water will vary little over time but will need to be measured for a given supply as this can vary even within a small distance, depending on the aquifer (water-carrying rock layers) and the depth from which the water is abstracted.

The temperature of flowing water will be related to its depth, the volume of discharge, the degree of mixing and the temperature of inflows. Rivers which are supplied with large quantities of ground water have a small temperature range. However, in any river system, as water moves downstream, its temperature is more influenced by heat exchange with the atmosphere and so it becomes more similar to the air temperature. Surface water temperatures are also linked to the height and steepness of the land through which waters flow. Rivers fed from mountainous areas with seasonal snow cover may have a sudden period of cold water associated with melting snow; those running through flat lands relatively slowly, will tend to heat up more noticeably. Human interventions in the water cycle such as the creation and management of reservoirs, channels or weirs, thermal effluent discharges and the alteration of woodland cover by logging or planting will exert local effects on water temperature and other factors (see below).

b) pH and associated factors

The degree to which water is acid or alkaline is described by the *pH* scale ranging from 0 to 14, whereby 0 is very acidic, 7 is neutral and 14 is very alkaline. The pH, and the capacity of water to resist changes in pH (its *buffering* capacity), has important implications for fish health, not just because of its direct effects, but also because of its effect on other water quality factors. One pH unit represents a large change in water quality, and fish seed are particularly sensitive to acid or alkaline conditions. To avoid lethal or sub-lethal effects, the pH should ideally remain within 1 unit of neutrality (pH 6-8). Outside this range, spawning success, resistance to disease and growth will be adversely affected, fish may suffer skin damage, especially to gills and eyes, and may die. The buffering capacity of water depends mainly on the concentration of bicarbonate and carbonate in the water (referred to as alkalinity). Water with low alkalinity

(<20 mg/l as calcium carbonate) is very vulnerable to fluctuations in pH, e.g. resulting from additions of acids or alkalis or during rainfall or phytoplankton blooms). Low alkalinity can be treated by adding lime in some form to the water, though in many cases, surface waters pick up alkalinity from the soils through which they flow.

The toxic effect of water with a low pH is made worse when in contact with metals such as copper, lead and zinc, which dissolve more easily in acidic conditions. In these circumstances, galvanised water pipes should be avoided. A particularly important result of a high pH is its enhancement effect upon the toxicity of ammonia. Waters with low pH tend to affect fish gills, resulting in loss of salts and difficulties with oxygen uptake. Depending on the nature of rocks and soils in the catchment, such acid waters may also have high concentrations of toxic materials such as iron or aluminium;

- iron from borehole water may be precipitated if it becomes oxidised e.g. on contact with atmospheric oxygen, especially if pH tends towards neutral, causing coating of eggs or other early lifestages of fish with a suffocating brown iron hydroxide.
- water drained through alumina-rich soil can contain high concentrations of aluminium, especially where there is continuous contact with organic material (e.g. when there is a large quantity of vegetable matter in the soils). Some processes used in mining, industry or domestic water supply may also enrich water with aluminium. The concentration of total aluminium in filtered water samples should be below 100 µg/l (0.1 mg/l) to avoid sub-lethal toxic effects on gills or reduced hatching or spawning success.

c) Dissolved oxygen (and other gases)

Assuming temperature and pH are acceptable, *dissolved oxygen* is usually the next most important factor to consider. Most open flowing waters, should be at or near their saturation level for the temperature of supply, when saturated (i.e. the water will contain as much oxygen as it can). The amount of oxygen water contains when saturated will depend upon temperature, pressure and the amount of salts dissolved in the water. Water at temperatures suitable for carp, tilapia and catfish, at normal atmospheric pressure - (i.e. that found at sea level and containing no dissolved salts), will contain 7 to 9 mg of oxygen per litre (mg/l) when saturated. As pressure decreases with altitude, the amount of oxygen that

saturated water contains will also decrease, by about 1 mg/l for each 1,000m above sea level). Similarly as the quantity of dissolved salts increases in water its capacity to hold oxygen decreases (see appendices). Ground waters can sometimes be poorly oxygenated, and may need to be treated before use. Any activity which causes water and air (or oxygen) to come into contact and mix with one another, will help to increase the quantity of oxygen dissolved in the water, until it becomes saturated.

The most frequent cause of oxygen deficiency in water is contamination with organic substances from agriculture, industry, public sewage, etc. These substances may be broken down by bacteria which use oxygen from the water for the process. Biochemical oxygen demand (BOD) is the measure commonly used to estimate the potential for bacterial degradation and hence the prospects for the oxygen level to become lower. A maximum BOD level of 8-15 mg/l is typically recommended for carp, catfish and tilapia depending on intensity of culture and rates of re-aeration.

Dissolved oxygen is usually the first factor to limit the quantity of fish seed that can be artificially produced at a location. The amount of oxygen that fish require varies with the amount of energy they expend. Oxygen requirement in young fish is greater than in older fish, whilst all fish require more oxygen after eating and during activity. After the larval stage, catfish develop special respiratory trees (rather like primitive lungs) which allow them to breath oxygen directly from the air, liberating them from the constraints of oxygen dissolved in water, whilst tilapia, from an early age will gulp air to facilitate oxygen uptake when levels are low. Carp, catfish and tilapia can withstand dissolved oxygen levels below 3 mg/l for short periods, but for best conditions levels should remain above 5 mg/l as far as possible, and therefore saturation should be maintained above 70 % over the typical temperature ranges used.

If there are high concentrations of carbon dioxide in water this can effect the respiration of fish by reducing the blood's ability to take up oxygen, so that water must be richer in oxygen. The species described here are well adapted to oxygen poor waters and are relatively unaffected by changes in carbon dioxide levels. However where CO_2 concentrations are above 12 mg/l and associated with calcium from aquatic or dietary sources, chalky granules can sometimes become deposited in the kidneys or the stomach wall, which in severe cases can interrupt normal functioning of the organs,

and at higher CO_2 levels can cause mortalities.

Other gases dissolved in water can have an important influence, especially if the water becomes supersaturated with gases such as nitrogen, carbon dioxide or oxygen (i.e. dissolved gas levels are higher than the usual saturation level). This can occur when water is drawn from deep underground, or if air is drawn into the water supply through leaks in pipelines or pumps, or if water is abstracted from close to a high water fall or immediately below a dam. It can also be produced if water is heated up quickly (e.g. by using electrical heaters). If water becomes more than about 110 % saturated with these gases can come out of solution within the tissues of fish (especially juveniles), forming bubbles under the skin and eyes or in the fins and mouth. Supersaturation is indicated by bubbles forming and clinging to the skin of a hand placed in the water. Supersaturated gases can be 'blown off' by vigorous aeration or allowing water to splash over solid structures such as stepped weirs, or splash boards.

d) Ammonia

After oxygen depletion, the next most important water quality factor for fish is usually *ammonia* concentration. Ammonia in the incoming supply water is commonly the result of the decomposition of organic matter which may originate from urban, industrial, agricultural (arable and livestock) or other fish farming sources. Ammonia is also produced by fish as an end-product of the breakdown of proteins, and is excreted through the gills of these fish. If a large number of fish is cultured together in an enclosed body of water, this excreted ammonia can build up to high levels. Ammonia is present in water in two forms, ionised (NH_4^+) and un-ionised or free ammonia (NH_3). Only the (NH_3) is directly toxic, and its level increases with increased pH and temperature. The pH of water is the most important factor to effect ammonia toxicity, as is illustrated in Box 3.1

BOX 3.1 The effect of pH on ammonia toxicity

- un-ionised ammonia should be no more than 0.02-0.5 mg/l to avoid toxicity problems
- at 25^0C, and pH 7, only 0.05% of the ammonia in water is un-ionised
- therefore a total ammonia concentration of 36.0 mg/l would still be below the toxic level of 0.02 mg/l (i.e. 36.0 x 0.05% = 0.018 mg/l)
- however, at 25^0C, almost 15% of the ammonia in water with a pH of 8.5 would be un-ionised
- therefore a total ammonia concentration of 0.14 mg/l would exceed the toxic level of 0.02 mg/l (i.e. 0:14x 15% = 0.021 mg/l)

In neutral waters and in most ponds ammonia is eventually converted to other nitrogen compounds, normally to nitrate, which is relatively harmless.

e) Nitrite
Nitrite is an intermediate in the breakdown of ammonia and is usually found together with nitrate and ammonia in surface waters. The causes of high ammonia in water (see above) can also result in temporarily raised nitrite levels. However, the concentration of nitrite is usually low, because it is readily reduced to ammonia or oxidised to nitrate. In high concentrations, it can however be taken up by the gills of fish and becomes bound to the red coloured, oxygen carrying molecule in the blood - *haemoglobin*, forming the brown coloured *methaemoglobin*, thus reducing the oxygen transporting capacity of the blood. This can often be reversed if the fish is transferred to clean water.

f) Nitrate
Nitrate is produced from ammonia, and is also commonly introduced through agriculture or pond fertilisers. Nitrate is not well retained by soil and can be readily leached into water bodies. Its direct toxicity to fish is very low but several indirect effects of high nitrate levels are possible. If dissolved oxygen levels fall dramatically, nitrates can be converted by bacteria back into the nitrite and ammonia which are much more toxic (see above). If the productivity of the water is limited by the availability of nitrate its addition can result in excessive growth of algae and plants, which in turn will increase the diurnal fluctuation in dissolved oxygen (see above). If nitrate levels are not sustained, any subsequent die-off of the organic matter generated will rapidly deplete dissolved oxygen.

g) Suspended solids
Suspended solids are important if water is to be used for fish seed production. Fish which live in floodplains such as the species described here, are usually well adapted to turbid water with high levels of silts and other particles suspended in the water. However, the juvenile stages of all species are especially sensitive to these conditions. The effects can include silts and organic material burying eggs or early larval stages, particles causing damage or suffocation, or irritation, especially of delicate structures such as gills and respiratory trees, which can in time lead to

disease. There are also physical effects to consider: solids can reduce the flow in pipes, or can rapidly clog the fine screens and nets used to hold eggs and fry in hatcheries, causing tanks or troughs to overflow.

The level of suspended solids in water will depend upon the water source, the nature of the rocks and soils in the catchment and the ways in which land is used. Excessive rains or runoff (especially in catchments suffering deforestation), rapid reservoir draw-down, cleaning or vegetation clearance activities, drainage, etc., can all increase the suspended solids levels.

Other 'particles' in water may also need to be controlled. Planktonic organisms such as insect larvae or small crustaceans (especially cyclopids) feed on fish eggs or larvae and must be removed from the water passing to the hatchery and rearing facilities. A hatchery may therefore need a filtration system of some kind (see Chapter 4) to remove solids and plankton from the water.

h) Pesticides
Contaminants such as *pesticides* (including herbicides, insecticides, fungicides and even piscicides) can be found in an increasingly broad range of water sources. This is often a feature of agricultural areas as increased use is made of improved varieties of crops which have the capacity for higher yields but often have reduced tolerance to pests and competitors. In new settlements water bodies may also be sprayed for insect control. The consequences for fish seed production can be serious, ranging from acute toxicity to chronic long term effects (see Table 3.3).

Acute toxicity may result from discharges of large amounts of pesticide substances into the source waters of a hatchery or nursery, as a result of careless practices during application, storage or disposal, traffic accidents, factory spillage, etc. Chronic effects may arise from the washing out of recently applied pesticides, or the long-term leaching of persistent pesticides from fields and forests.

Apart from the direct effects upon fish, pesticides can kill or damage many of the sensitive organisms upon which fish feed. For example, the lethal

concentration (LC_{50})[1] for the organophosphorus insecticide 'Soldep' for common carp is 545 mg/l, while for *Daphnia magna* (an important natural feed organism) it is 0.0002-0.001 mg/l. Equally, herbicides used unwisely may rapidly destroy large quantities of plant material, and decomposition of the resulting organic matter can lead to an oxygen deficit (see above).

When a pesticide enters the aquatic environment the active ingredient may undergo chemical or biological degradation. In some cases the degradation products may be more toxic, e.g parathion is biodegraded to paraoxon which is more toxic and trichlophon is degraded to form the more toxic compound dichlorvos. Aside from the active ingredient, pesticide formulations may also contain other chemicals which may sometimes be much more toxic to fish.

Table 3.3 The toxicity of some common pesticides to fish

Pesticide	Toxicity to fish - 48 h LC50 (mg/l)
Chlorohydrocarbons(organochlorines)	< 1.0, highly to extremely toxic
Synthetic pyrethroids	0.1-10, high to extreme toxicity
Organo-phosphorus	0.1-100, very high to medium toxicity
Diazine and triazine	1-100, high to medium toxicity
Carbamate & thiocarbomate	1–1,000, high to low toxicity
Herbicides based on substituted urea	1–1,000, high to low toxicity
Based on carboxylic acid derivatives	10–1,000, medium to low toxicity

It should be noted that while many of these 'synthetic' or manufactured pesticides may be toxic, the so called 'natural' pesticides used in some areas may also be very toxic to fish and/or to their food organisms. The presence of both types of pesticide needs to be checked very carefully

3.3.3 Land Resources

Quantity and location

It was mentioned earlier that hatcheries may be land or water based. The quantity of land necessary for seed production will depend upon the system

[1] the Lethal Concentration - the concentration at which 50% of the test organisms are killed by the tested substance over a defined period - usually 24, 48 or 96 hours – e.g. LC50 (96)

and its intensity. For example, a system producing 30,000 fingerling/year at 10,000 fingerlings/ha/year would require 3 ha. for the production system, plus another 10-40% for access roadways, walls, service and storage areas, protection areas, landscaping, etc., perhaps 3.5-4.5 ha in total. In addition to the land used for the actual development land resources may also be needed to supply the necessary inputs. Table 3.4 provides a summary of typical land requirements.

Table 3.4 Typical hatchery land requirements

Stock	System	Area
100 kg broodstock	rainfed/static ponds	1,000-2,000 m^2
50 kg broodstock	flowing water ponds	50-100 m^2
50 kg broodstock	flowing water tanks	3-10 m^2
200,000 eggs	flowing waters jars or troughs	20-40 m^2
100,000 fry	flowing water tanks	15-40 m^2
100,000 fry	flowing water ponds	100-200 m^2
100,000 fingerlings	flowing water ponds	500-2,000 m^2
work/spawning area		10-40 m^2
office/work room		8 0-15 m^2

In many cases, the availability of land may simply depend on the land owned or used by the people of communities interested in developing a hatchery. In other cases, there may be the question of buying or leasing land from others. Acquiring land can be a major initial cost, but this may be insignificant when costed over the longer term. Decisions about acquiring land should be taken with care; if there is a choice, it is well worth paying more for land which is suitable, than suffering the negative effects of unsuitable conditions. Apart from local social factors - e.g. customs, traditions, local influences, the effective cost of land will vary depending on its alternative uses, the quantity of land required, the level of services locally available, access etc. In some areas, low-lying waterlogged land would be considered of limited alternative use[2], many areas of waterside land can command a premium price because of the range of competing uses.

[2] though these wetland areas are now increasingly valued for conservation - e.g. for bird and wildlife habitat

Soil characteristics

Soil is one of the most important aspects in selecting land, and includes materials with a wide variety of properties. In most areas soil characteristics change through the depth of the soil, and a soil profile, describing features from the surface to the lowest depth affected by the intended work, is used to determine the important effects. The different levels of soil with the profile are called horizons. Thus topsoil, enriched with humus, forms the uppermost horizon of the soil profile and provides the basic fertility for fish pond production. Topsoil is normally removed before constructing roads, hatcheries or other buildings, because it is usually too weak to support substantial loads and its organic content may interfere with the setting and the stabilisation of cement in concrete etc. In lower horizons, sand and gravel may be excellent as foundation materials, and will be relatively strong, but will not hold water, while clay type soils will be good for holding water, but less strong, and liable to swell and crack with changing moisture content.

Many of the properties of soils relate to the characteristics of the particles making up the soil, especially the particle size and shape (e.g. sand, silt and clay content) which can be determined from disturbed samples, (i.e. samples collected from site). However, some properties, such as permeability, relate to the properties of the soil fabric (e.g. the size and connections between spaces within the soil matrix) and must be determined in the field or from undisturbed samples (i.e. where the soils are directly in place). In addition to soil texture, chemical characteristics (especially pH, metal content, buffering capacity and the ability to 'bind' other substances) and biological characteristics (especially productivity) must be considered. Of particular interest are those properties of soils which affect:

- the support provided for hatchery and related buildings, ponds and tanks (avoiding thin coastal soils with underlying porous coral rock, abandoned termite dwellings, acid sulphate soils, etc.)
- the potential to provide building materials such as sand, protective facing material, base material for road construction, etc.
- its suitability as a construction material for ponds and roads including the stability of slopes and the lateral pressure which soil exerts against any structure, compaction characteristics and ability to retain water

- the fertility of ponds, the ability to maintain pond pH levels, and the freedom from toxic materials leaching from the soils.

Soil profiles can be cut and examined directly, or information can often be obtained from local agricultural or construction advisers. Soil characteristics can also be determined in general terms from the nature of the landform involved - e.g. floodplains with varying silt and clay areas, coastal fringes with sands and acid clays, river bed areas with gravels and sands; hilly areas with mixtures of hard rocks, eroded materials and local irregularities.

Topography

The topography of the area, that is its overall layout, its slope level and regularity, is an important feature of the suitability of land. The site should be neither too steep nor too flat. Flat areas may be associated with difficulty in providing gravity flow of water, poor drainage and slow flowing waters, which in turn are often characterised by flooding, low dissolved oxygen levels, high temperature and saline intrusion in coastal areas. In steeply sloping areas, suitable sites may be difficult to locate and flat waterside areas will be especially prone to flooding during high rainfall. Mountainous regions are associated with high rainfall and run-off, and access for transport and isolation from markets may also be a problem. A slope of more than 3-5% will tend to limit the size of pond that can be constructed.

Within the site itself, the regularity of the land surface will be important. Very irregular areas will require a lot of work to make it usable, and if soil conditions vary, may need soils to be relocated - which is usually expensive. Alternatively, fitting various constructions - ponds, buildings etc around or between irregular areas may limit their size and/or force the use of inconvenient slopes.

For water-based sites the topography of the lake, river or seabed bottom will be important in determining the position of cages or pens, the possibilities for attaching them, and in affecting the speed and direction of local currents, especially in shallow areas.

The topography of land surfaces can be measured using simple farm survey methods - surface measurements, line-of-sight estimates of relative

levels, or by using conventional surveying equipment - staffs, theodolites, survey tables, etc. For water bodies, simple surveys can be done using a weighted line to measure the depth at defined points. For small sites - e.g. < 1000 m^2, the techniques used by local builders and farmers are usually quite adequate. For larger areas, more complex shapes or more detailed assessment (e.g. if the gradients have to be measured carefully to ensure there is enough difference in water levels for filling and draining), advice could be sought from local land surveyors or engineers.

3.3.4 Other issues

Although land and water are the primary factors determining the prospects for a hatchery, a number of other issues need to be considered; any of which can make a notable difference to the suitability of a specific location. These include physical aspects such as, raw materials and other resources, road access, power supplies and connections, and social or economic aspects such as local markets, the availability of extension advice or finance. Some of the key issues are described below:

Resources/raw materials

Products from agriculture and livestock rearing, and from domestic/household activities can be very important sources of 'production enhancing inputs' for growing fish and their feed. These inputs include, livestock manures, crop residues, and wastes of various kinds. However these activities may also compete for space, labour and fertilisers or feeds. Intensive exploitation of a local ecosystem through agricultural activity and deforestation can also contribute greatly to erosion, turbidity and siltation and can significantly degrade aquatic environments with aquaculture potential. Egg and early life-stages are especially sensitive to water quality problems (see earlier).

Infrastructure and transport

The availability of appropriate *infrastructure* will be essential. Physical access via motorable roads to markets and the proximity to other farms and suppliers of seed and other inputs will be important. Transport costs may only be a small part of the cost of fry production (< 5%). However, the importance of good transport is far greater than cost alone. The inputs required tend to be bulky, and the fish seed produced are highly perishable. The potential for bulk carriage, and flexible scheduling reduces additional cost and risks involved with intermittent or unreliable transport.

Local concentration

The nearby presence of other producers commonly occurs in areas with especially good aquaculture potential. This can confer various advantages including opportunities for collective marketing, bulk buying, sharing equipment, sharing transport costs, the presence of an established market for newcomers, the opportunity for establishing 'value added' activities such as processing plants, associated industries (e.g. collection of pituitaries for induced spawning, collection of tubifex from drains as fry feed, etc.). Concentration can also be a negative factor if competition becomes too severe in which case it can be advantageous to locate at a distance from other producers.

Market and other information

Information on the proximity, type and size of markets, and present and future trends in fish production, is required to assess the best size and location for fish seed production (see Chapter 10). Information on other matters such as local developments, changes in agriculture and water management plans, and developments in infrastructure may also be important.

Credit

The availability of *credit* can vary with location, especially in relation to the location of banks and the areas in which bank loan officers, mobile credit officers, and others, are able to operate - often close to urban areas. Externally funded development projects, NGO groups, etc., with small loan financing components can be extremely useful temporary sources of funds, which may also be available only in specific locations.

Extension

Access to extension services may also vary with location. Extension services throughout sub-Saharan Africa are, in general terms, insufficient and limited in mobility, and their availability and effect is therefore also 'patchy'. In some cases, the level of knowledge and support from other farmers may therefore be very important.

Key information

While the above are all important general factors which will determine local potential for seed production, a number of specific areas of infection

will be required before a specific site and project can be confirmed, as summarised in Box No 3.2:

Box 3.2 Local information requirements

Local information must be sought and legal and administrative issues must be well considered, especially:

- local climatic information (rainfall, wind speed and direction, evapotranspiration, duration of sunshine, temperature, landslides and flooding - past record of potentially destructive events, etc.),
- availability of support and services (e.g. nearest location of power, telephone, extension service provision, etc.),
- security and predators - land and water based, poaching,
- ownership (clearing the legal status of land ownership before investing in the development of facilities),
- adjacent land uses (including the potential for expansion, origin of local run-off, location of feedlot livestock or intensive agriculture, deforestation, etc.),
- access (distance from major roads and the ownership and condition of local roadways, see transport),
- identify the future designation of land for water storage, industrial, agricultural or urban expansion,
- local or national legal constraints (regarding water and land use, development, protection, management of specific ecotypes e.g. wetlands, species introductions, etc.),
- environmental impact - local implications of development, local views of effects; particular sensitivities.

While much of this information can be obtained locally, it may also be necessary to obtain specialised information - e.g. from farm agents, credit advisors and/or fishery specialists.

CHAPTER 4

SYSTEM DESIGN AND INFRASTRUCTURE

4.1 Introduction - production planning

For most farmed fish species, the problem of poor fry supply from natural sources has been addressed by moving towards intensive fry production in hatcheries. In the design of hatcheries, the aim is to develop systems which can match the requirements of these species, to fit in with the site characteristics, to match the management approach used in production, and to meet the economic criteria for successful operation. Previous chapters have dealt with the selection of species and sites. This chapter describes the specific design features of hatchery development, with details as required for the three main species.

One of the basic steps in developing the design is to decide exactly what is to be required of the system during its normal operating conditions. Most hatcheries and fry producing systems have some periods of time which are very busy, with a lot of stock, requiring a good water supply, and a significant demand for labour and management, and other times when there may be less stock, and less need for various inputs. Obviously, the system must be designed to cope with each of these periods, and in particular, as it places the greatest demands on the system, it should be able to handle the maximum levels of stocks, hatchery activity and other factors.

A useful way to design the systems of production and sizes of facilities for different life stages of operation is to set out a production plan, which takes into account the basic biological characteristics for the species concerned (see Table 3.1 in previous chapter), and allows the intended sequence of production to be described, and fitted in with the resources available and with the system design (see Box 4.1).

Once developed, the production plan can be used as the basis for planning and designing, based on:

- the maximum biomass (i.e. the total weight of fish/fry held) which will define the physical size of the facility, taking into account the

stocking rate (number and size of units, layout, length of pipes, etc.)

- the type of stock (e.g. broodstock, fry, fingerlings of various species), their specific requirements, and the implications for holding facilities and operating procedures.
- the change in biomass over time which will define changes in inputs and requirements, e.g. feed, flow rates taking into account requirements for, oxygen, natural feed, waste removal, fish size, aeration.

Box 4.1 Some notes on production planning

• for most aquaculture systems the most significant controlling factor for design is the stock biomass – i.e. the weight of broodstock, fry and fingerlings held in the system – which often varies through the production period

• a target annual production (e.g. kg fish/yr or thousands of fry per year) is usually defined from:

- the known market potential, and/or the intended output
- site constraints e.g. available water flow, land area, growing season, etc.
- availability of capital, ability to provide routine inputs - labour, feed, etc.
- the production level, which may be built up, modified e.g. with pilot stages, start-up periods, multiple cropping, etc.

• from this annual production figure the production plan throughout the year, and year to year, can be calculated taking into account the following:

- the time period for planning – e.g. weekly or monthly, in which various sequences of production can be defined;
- the spawning and early rearing stages, and the growth rate of the species concerned (this may be known from background data, for the location, e.g. from other farms, or estimated from growth formulae, e.g. based on temperature, describing increase in length or weight)
- the intended size at stocking and at harvest
- the mortality rate
- periods of brood or seed stock availability/requirement
- the optimal time of spawning, harvest, etc.
- availability of key inputs, e.g. seasonal water supplies, skilled assistance

The result of such an assessment will allow the size of the system, the water flows, feed supplies and other inputs to be defined. These in turn can define the hatchery infrastructure, e.g. numbers of pumps, blowers, water channels and weirs, if required, height of header tank, feed storage space, etc., and can define the management and labour needs and their timing.

Box 4.2 shows a partially developed production plan, illustrating these. The following sections also describe the most important of these.

Box 4.2 Outline production plan: initial assessments

This basic approach may be used for any hatchery project; the plan is usually set out daily, 5-day, weekly or 10-day intervals. For ongrowing, 20-day or monthly intervals are more common. This case is for a single crop of fingerlings in a large hatchery; for multiple crops, several such plans can be developed, and added together to show the total stocks and system needs.

Time interval (20day)	1	2	3	4	5	6
Temp °C [1]	25	26	29	32	34	34
No of stock [2]	20000	19000	18430	18060	17340	16990
Average wt g [3]	5	10	18	38	65	120
Total wt kg	100	190	330	690	1130	2040
FCR [4]	1.8	1.8	2	2.2	2.3	2.3
Food consumed kg[5]	160	250	720	970	2090	1500
Stock density kg/m^3	10	12	12	15	15	15
Water volume[6] required m^3	10	16	28	46	75	136
Volume[7] of units usedm^3	2	2	2	5	5	5
No of units	5	8	14	9	15	27
oxygen avail.[8] Mg/l	8	8	7.5	7.3	7.3	7.2
Oxygen supply, mg/l	3	3	2.5	2.8	2.8	2.7
Oxygen consumption[10] g/h	70	100	300	400	870	630
Flow rate required [11] m3/hr	23.3	33.3	120	142.9	310.7	233.3

1 for ponds, evaporation rate can be included, to define water replacement)
2 allowing for mortalities, grading out, harvesting, etc.
3 wt gain may be linked to °C, or to a growth rate equation
4 Food conversion ratio from one interval to next – expected, or from feed tables if available
5 for one time interval to next, based on growth
6 Theoretical volume needed, m^3 (in practice, this is adjusted by actual tank sizes, etc.)
7 Proposed volume of units used, m^3 e.g. defined by standard tanks, cages, ponds, etc.
8 Oxygen availability, mg/l - can be defined by temperature
9 Oxygen supply, mg/l (g/m3) = availability(12) - lowest acceptable limit for stock
10 Oxygen consumption g/hr - e.g. 0.3 times daily food fed/24
11 Flow rate required, m3/hr - based on consumption/supply

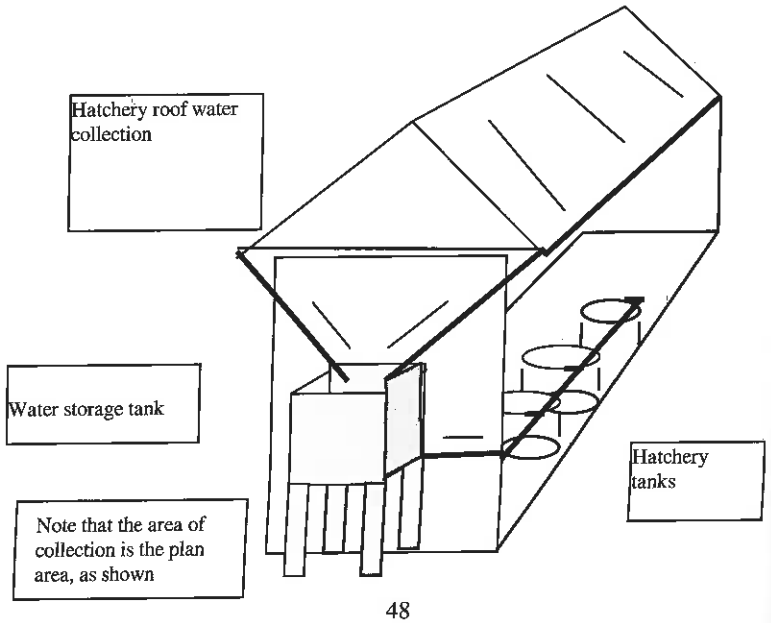
4.2 Water supply

As described in the previous chapter, water is a critically important resource, but can be scarce or irregularly available. Its supply is a key constraint to aquaculture development in Africa and elsewhere, and at the local level, will have a direct effect on the size and type of hatchery which can be established. There are three potential water supply sources for a hatchery, direct collection of rain water, surface water and ground water:

Rainwater

The potential for using rainwater varies with the local climate and with soil type and topography. It is particularly applicable where rain falls in short-duration storms with an expected annual rainfall of at least 500-600 mm. As storage is necessary areas of relatively impermeable ground (e.g. clay or rock) need to be found in small natural catchments. Direct rain water collection is also possible from other solid structures such as roadways, threshing floors and roofs. Depending on the efficiency of rainfall collection, for each 100 mm of rainfall, up to 1,000 m^3 of water can be harvested for each ha of catchment or 100 l for each 1 m^2 of roof. A typical hatchery roof rainwater collection system is shown in Figure 4.1.

Figure 4.1 Water collection direct from hatchery roof



The volume of the rainwater collection tank depends on the frequency of rainfall and the patterns of water use. Some recommended collection tank capacities are presented in Table 4.1. which is based on typical roof areas required for a range of sizes of tilapia hatcheries producing 2 million (L), 800,000 (M) and 160,000 (S) sex reversed seed per annum (see later).

Table 4.1 Recommended tank capacities for roof collected rainwater

Example/ Regions	Mean annual rainfall (mm)	Roof/water collection area (m^2)*	Maximum Collected volume(m^3)	Tank Capacity (m^3)
Ghana, NE region	800 in two wet seasons	220 L 100 M 24 S	176 80 19	88 40 10
Swaziland, Lowveld	635 with six dry months	220 L 100 M 24 S	140 64 15	140 64 15
Botswana, Francistown	470 with 7-9 dry months	220 L 100 M 24 S	103 47 11	103 47 12

Note: see further for details and hatchery water requirements.

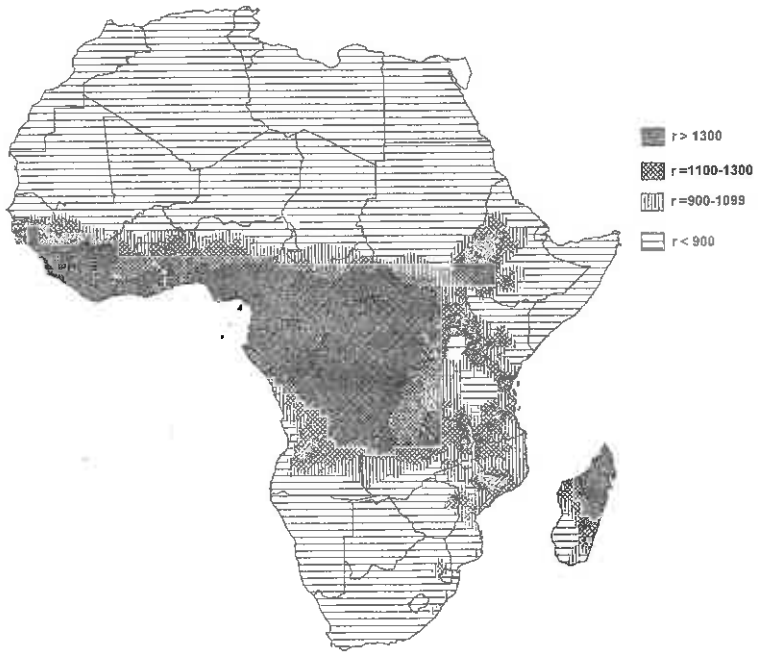
Surface water

Any water which is not immediately absorbed in the soil, evaporates from the surface or is taken up in plants, will flow over the ground surface and will collect in rivulets, streams, rivers and ponds. This is often a very convenient source of water for hatcheries, but the availability of water may vary greatly through the seasons, and this needs to be known before considering its use.

The best information about availability of local surface water is from direct observation and historical knowledge on seasonal rainfall patterns, stream flows, drinking water availability, the storage of water in local ponds, etc. Where available, local climatological or meteorological data regarding rainfall and evapotranspiration may be useful. Local information may also be found from agriculture or extension services, etc., who may keep rainfall data for advising farmers on suitable crops. Mean rainfall as low as 550 mm annually can provide some surface water for aquaculture,

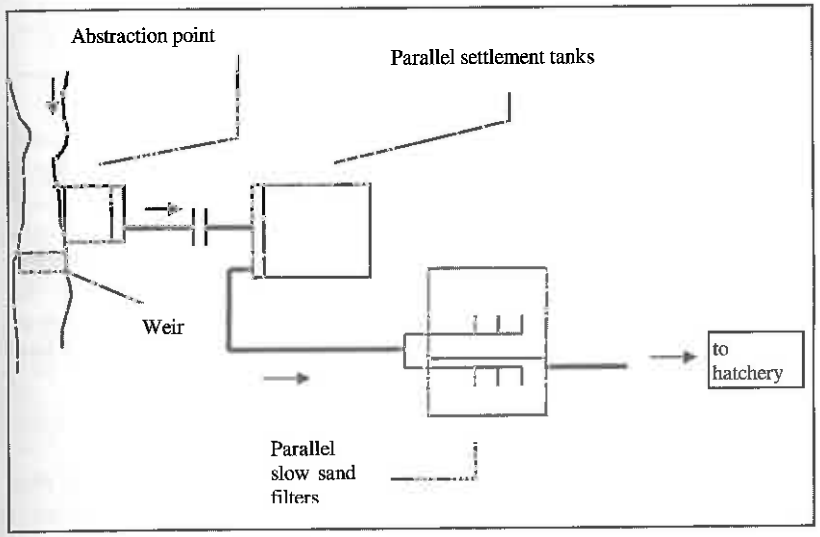
though in most areas, 900–1,200 mm would be the minimum required. Figure 4.2 shows surface availability of water as average annual rainfall for Africa.

Figure 4.2 Surface water availability in Africa, as annual rainfall (after Kapetsky, 1993)



Surface water may be taken for agriculture (irrigation), domestic use, industry, etc. A hatchery supply is best taken from a small catchment without competing users or potential contaminants upstream. Surface water often requires treatment prior to use in a hatchery. Most treatment processes work best in controlled conditions. For this reason it can be useful to build a control structure where the water is taken from the supply e.g. a weir in the source water canal to ensure that there is a continuous minimum head. Figure 4.3 illustrates some typical arrangements.

Figure 4.3 Arrangements for surface water supply



A weir system can be quite useful in that it allows a reasonably constant flow of water to be supplied, although flow rates and levels in the water stream may vary. An approximate estimate of water flow can be made based on the depth of water flowing over the top of the weir, and this is often sufficient for most supplies. A more accurate assessment can be made using a V - notch weir, provided flow is moderate - less than 70 m^3/day or 0.8 l/s. Care must be taken to ensure that all the water passes through the V notch rather than around the sides or bottom. The flow through a 90^0 V notch is given by,

$$Q = 1.37\ L_w\ (h)^{2.5}, \text{ where}$$

Q is flow in m^3/sec, L_w is the width (m) of the weir and h is the height (m) of the water flowing through the weir, measured at the bottom of the 'V'. Typical values are shown in Table 4.2. An abstraction point should be chosen so that water will flow by gravity to the hatchery. The entrance to the abstraction point should be protected by a coarse screen which may be vertical, horizontal or set at an angle (see Figure 4.3).

Table 4.2 Flow through V-notch weirs.

Width of weir	0.3m	0.5m	1.5m
h, over weir			
1 cm	0.004	0.007	0.021
2 cm	0.023	0.039	0.116
3 cm	0.23	0.38	1.15

If there is substantial change in water flow - particularly flooding, care has to be taken to ensure that flood water can be safely diverted past the hatchery site, and that the abstraction system is not damaged by erosion or by floating debris. If excessive flooding is a risk, it may be better to look for a less exposed site.

Pumping water

In some cases, including the use of groundwater supplies (see next), it may be necessary to pump water from the supply point. At some locations it may also be necessary to pump out ponds, if they cannot be fully drained. Pumps can be powered either by diesel or petrol engines, or if mains power is available, through electric motors. A range of different types is available, but centrifugal or axial flow pumps are the most common for hatchery water supplies. It is often more important simply to ensure that a certain pump is available, and can be easily maintained and repaired, than to look for an ideal pump for a particular job. In many cases, simple farm, irrigation or tubewell pumps are available locally, and should be used if possible. However, though pumps can be very useful, and can improve water flows in difficult conditions, they can be costly, need to be maintained properly, and often add considerable amounts to the operating costs of the hatchery. Though windmill pumps have traditionally been used in some areas for farm water supplies, they do not usually deliver enough water flow to be useful, except for occasional topping up of storage tanks.

The power required for a pump can be calculated simply on the basis of the flow rate of water, the pumping head (the vertical distance between the intake and the discharge, plus an allowance for friction in the pipes) and the pump efficiency. Power is calculated from:

Pump power (kW) = Q x h x g / e, where:

Q = mass flow (m^3 sec^{-1});

h = head (m); - allow 10-20% of pipe length for pipe friction

g = gravity (9.81 m s^{-1}), e = efficiency (~ 0.5 - 0.7).

A worked example is shown in Box 4.3. Table 4.3 summarizes typical pump power requirements.

Table 4.3 Pumping power, head and flow rates

	Flow rate (see units in left hand column)							
Litre min^{-1}	10.	20	50	100	200	500	1000	2000
Litre sec^{-1}	.17	.33	.83	1.67	3.33	8.33	16.67	33.33
M^3hr^1	0.6	1.2	3.0	6.0	12.0	30.0	60.0	120
Pumping Head, m	Pump power, kW, for specified flow rate and pumping head							
1	0.01	0.01	0.03	0.05	0.10	0.25	0.50	1.01
2	0.01	0.02	0.04	0.08	0.15	0.38	0.76	1.51
5	0.02	0.03	0.08	0.15	0.30	0.76	1.51	3.02
10	0.03	0.06	0.14	0.28	0.55	1.38	2.77	5.53
20	0.05	0.11	0.26	0.53	1.06	2.64	5.28	12.57
50	0.13	0.26	0.64	1.28	2.57	5.41	12.83	25.66
100	0.25	0.51	1.27	2.54	5.08	12.70	25.41	50.81
200	0.51	1.01	2.53	5.06	12.11	25.28	50.56	100.1

Notes: - head loss due to fittings is assumed to be 1.0m. – this is enough for simple systems; pump efficiency is assumed at 65%, power values are rounded up to the nearest 0.01kW (for hp, divide kW figures by ~ 0.75). For driving power, eg from a pump engine, divide the pump power by ~ 0.7 – 0.8.

If pumps are to be installed permanently, they should be securely fitted and appropriately protected – e.g. on a concrete base, with a cover, with secure pipe couplings, screened intakes, and safe arrangements for power supply - properly attached cables, secure fuel lines, fuel tanks protected so they are tamper-proof, and fuel cannot spill into the water.

Box 4.3 Example of pumping calculations

1)Pump sizes are basically defined by:

a) the *head* – the vertical distance, (usually in metres) the water has to be lifted. This is further defined as the total of:
- *suction head*, required to lift the water up to the pump
- *delivery head*, required to lift the water from the pump to the outlet
- *system head*, required to overcome frictional losses in the pump and pipe system

b) the *flow* - the quantity pumped per unit time – e.g. m3/sec, litre/minute.

2)Power required at the pump can be calculated as, e.g.:

kW = Head(m) x Flow(m3/sec) x 9.81x Water density pump/efficiency

Pump efficiency should normally be in the range of 60-75%.

Actual driving power to the pump will be: pump power/drive efficiency – typically 75%-90%

3)The *range* of head and flow required should be identified, and if possible, these can be matched to a manufacturer's or supplier's *pump performance* chart – relating head, flowrate, and pump efficiency. This should enable you to identify more closely the pump suitability, and to determine the *type* of pump. For most fish farming purposes, a low head, high flow, *axial* or *mixed flow* pump can be used: for higher head and medium flow a *centrifugal* pump is useful, and is often most easily available. Special *submersible* pumps can be used for pumping directly from wells or boreholes.

4)Other factors to consider (and to check with the supplier) include:
- the need for backup units, e.g. if a pump fails or required maintenance
- water quality, the need for strainers, and whether grit or other solids may damage the pump
- the materials used – casing, impeller, inlet and outlet flanges, etc, to ensure the is robust, and there are no toxicity problems – e.g. from copper, zinc, or other materials
- if an electric power supply: the voltage, number of phases, frequency, and the proposed power source; generator, transformer, and associated distribution
- if a diesel/gasoline power supply: the location of power units, and method of power transmission, the location of fuel tanks.

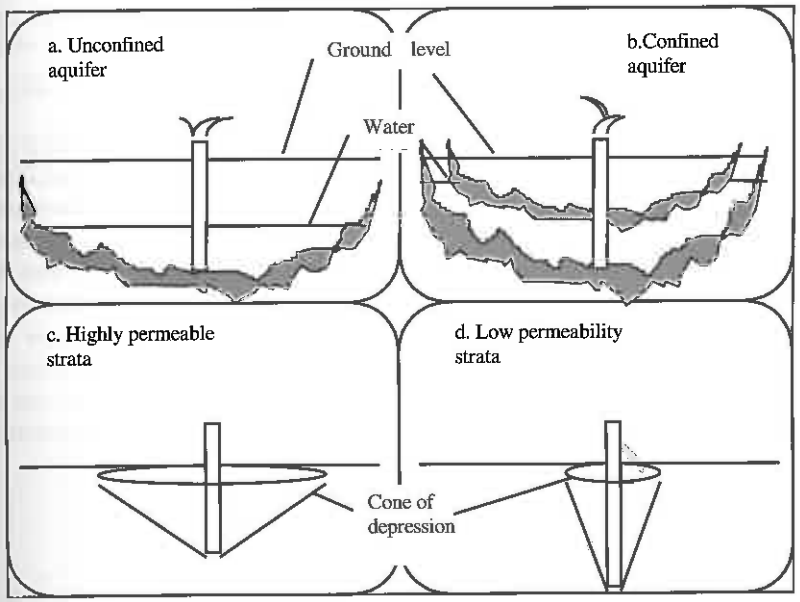
Ground water

This is often a very useful supply of high quality water for use in hatcheries. However, there may be practical problems. Before it can be used for aquaculture, ground water must first be located and its extent, quality and rate of renewal must be assessed. Ground water is obtained

from aquifers, layers of soil or rock through which water flows from other areas from which water is collected. The water table is the level at which the ground water lies. This is usually below the surface, but in some conditions, e.g. artesian springs, the level is above ground, and the water will flow out under its own pressure.

Normally, groundwater is extracted from an aquifer through a pit or tube well. Tube wells are increasingly common, and consist of a bore hole cased with screened pipe to keep out sediment, and fitted with a pump to lift the water to the surface. Unless there are local skills, a contractor is usually required to install a tubewell. Its cost to install and operate would depend on the depth of the water table and the nature of the material to be drilled or dug out (see Figure 4.4).

Figure 4.4 Groundwater development



Deeper ground water has nearly constant temperature throughout the year, usually about the same as average air temperature for a region. Depending on the conditions in the ground - the water may also be low in oxygen, and high in dissolved salts and dissolved gases such as nitrogen. Shallower groundwater is more similar to surface water in terms of temperature and quality. The characteristics of the aquifer determine the amount of water that can be withdrawn from a particular location. When water is extracted faster than it can be replenished, the water table will decline, and in some cases the de-watered aquifer may collapse. Extraction at a rate less than or equal to the recharge rate will result at equilibrium with the water level in the well slightly lower than the overall ground water level. This is the depth from which water must be pumped and depends upon the permeability of the aquifer and the recharge rate (see Figure 4.4). The 'yield' pumping rate and water depth can be tested by a contractor. The cost of pumping from a highly permeable strata (i.e. through which water flows easily) - such as coarse sand and gravel materials will be less than where permeability is low e.g. through heavy silts and clays or compacted rocks.

Conveying water

Water needs to be carried from its source to the place of use - which for flowing water requires a channel or pipe. Either of these can be used if the water is free-flowing, but only pipes can be used if the water is pressurised (e.g. from a pump). In both of these, however, the carrying capacity depends on the size (diameter), the gradient or pressure applied, and the roughness of the pipe or channel. Generally, the larger and smoother these are and the steeper the gradient or higher the pressure, the greater the flow. If bends, curves, or connections are involved, this has the effect of reducing the flow. In some cases, standard pipe or channel sizes can be suggested. Tables 4.4 and 4.5 give some examples for pipes and channels, respectively.

Table 4.4 Pipe size, flows (m^3 hr^{-1}) and applied pressures

Head loss, H /applied m	**bar**	**m pipe length,L**	**h= H/L**	**Pipe size, mm 24.00**	**50.00**	**75.00**	**100.00**	**150.00**	**200.00**	**250.00**
				Flow rate, m^3hr^{-1}						
1	.1	10	.1	2.6	16.6	49.4	107.0	318.6	690.7	1258.8
2	.2	10	.2	3.8	24.5	72.8	157.8	469.7	1018.3	1854.9
3	.3	10	.3	4.8	30.7	91.3	198.0	589.4	1277.8	2329.0
1	.1	100	.01	0.7	4.6	13.6	29.5	87.7	190.2	346.7
2	.2	100	.002	1.0	6.7	20.0	4305	129.4	280.5	511.2
5	.5	100	.05	1.7	11.3	33.5	72.6	216.1	468.5	853.9
1	.1	1000	.001	0.2	1.3	3.7	8.1	24.2	52.4	94.5
2	.2	1000	.002	0.3	1.9	4.5	12.0	34.6	77.2	140.8
5	.5	1000	.005	0.5	3.1	9.2	20.0	59.5	129.0	234.2
8	.8	1000	.008	0.6	4.0	12.0	26.0	77.4	167.9	305.0
1 0	1.0	1000	.01	0.7	4.6	13.6	29.5	87.7	190.2	346.7

Notes: based on pipe flow formula, Q m^3 hr^{-1} = k x $d^{2.69}$ x $h^{0.56}$, where k = 0.00045/3.6 (to convert flow from l sec^{-1}) ; h = head loss(applied) per length of pipe.

Table 4.5 Flowrates in open channels

Specified channel conditions:	**FLOW RATES, m3/sec FOR SPECIFIED WIDTH AND GRADIENT**						
Roughness coefficient: .03 Limiting velocity m sec^{-1} 0.30 Max channel depth, m: 0.50	Gradient	Channel width, metres					
		.10	.20	.50	1.00	2.00	4.00
	.00001	.01	02	.03	.04	.05	.06
	.00002	.02	.03	.05	.06	.07	.08
	.00005	.03	.05	.07	.09	.11	.13
	.00010	.04	.06	.10	.13	.16	.19
	.00020	.06	.09	.14	.19	.23	.26
	.00050	.10	.14	.23	.30	.36	.42
	.00100	.14	.20	.32	.42	.51	.59
	.00200	.19	.29	.46	.60	.72	.84
	.00500	.31	.46	.72	.94	1.14	1.32
	.01000	.43	.65	1.02	1.34	1.61	1.87
	.02000	.61	.91	1.44	1.89	2.20	2.65
	.05000	.97	1.45	2.20	2.99	3.61	4.18
	.10000	1.37	2.04	3.23	4.22	4.10	4.91

Note: this procedure provides for simple calculations using vertically sided channels, showing the flow rate provided for a range of channel widths under specified flow conditions. These flows are the maximum possible within the limiting velocities specified.

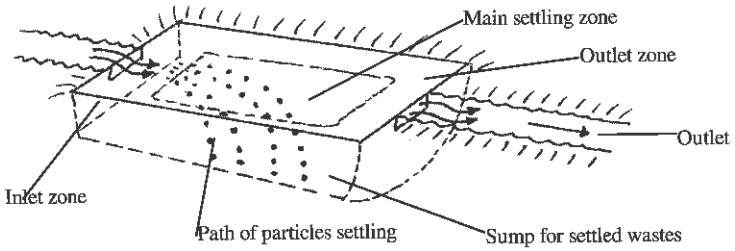
4.3 Treating water supplies

Surface waters whether streams, rivers or irrigation channels, are subject to widely varying water quality, particularly with regard to suspended solids, soil particles, small organisms and organic litter, causing high turbidity during rainy season periods. These solids can be very damaging to eggs and young fish especially since peak natural spawning for most species occurs during the seasonal rains. Solids need to be removed if possible and this can be done either by settlement (sedimentation) or filtration. For hatcheries this is usually a two stage process, with a pre-filter or settling tank to remove some turbidity, followed by a slow sand filter which further removes small suspended materials, including some disease agents (see Chapter 9).

Settling tanks

A settling tank needs to be correctly sized to effectively reduce turbidity. This can be done by considering the 'worst case' that will be encountered, often the turbid rainy season flows, (see Box 4.5). As well as size, design is important. Water should enter and leave the tank without short circuiting, i.e. so that the actual transit time from inflow to outflow should be close to the time calculated in Box 4.4. This can be achieved by ensuring that the tank has adequate capacity in relation to the rate of collection of sediment and the proposed emptying schedule. One or two baffles or fins can also be positioned in the tank to ensure that water does not short circuit between inflow and out flow. Figure 4.5 shows a settling tank.

Figure 4.5 Settling tank arrangements



As the settling tank silts up the efficiency of the tank will tend to reduce. Collected sediment may be of value as a fertiliser depending upon its origin and composition. It is particularly important to reduce the speed of the water entering and leaving the tank - large pipes or channels are better.

Box 4.4 Sizing a settling tank

Solid particles with a greater density than water will eventually sink. The speed at which these particles sink depends on their size and density, where larger and denser particles settle most quickly. The size of the settling tank is defined by the settling speed of the particles to be removed, as follows:

$A = Q/v_s$ where;
A = area (length x width) of tank;
Q = flow rate, m^3/sec; v_s = settling speed, m/sec

Therefore, where particles of a settling speed of 0.001 m/sec (1mm/sec) (or more) are to be removed, with a flowrate of 100 lpm (= $0.0016 m^3$/sec), the tank area, A required = $0.0016/0.001 = 16 m^2$.

Normally, settling tanks are rectangular in shape with their lengths typically 3-4 times their breadth. This tank could be set up for example as 8m long x 2m wide. The particular settling speeds can be estimated from the Table 4.6, or can be calculated directly from (at 30°C)

$v_s = 0.7 \times (\rho_d - 1) \times 10^6 \times d^2$

where ρ_d = particle density
d = particle diameter, m

Thus, for silt with $\rho_d = 2.62$, = 50 microns = 50×10^{-6} m

$v_s = 0.7 \times (2.62 - 1) \times 10^6 \times (20 \times 10^6)^2$
= 0.003 m/sec

Table 4.6 Typical particle settling velocities – effect of density and size

Particle diameter	Settling velocity (m sec^{-1}	
	Rock	Faeces
1 mm	0.82	0.027
100µ	0.0082	0.00027
10µ	0.000082	0.0000027

Notes: rock density 2,300 kgm^3 and faecal density 1,050 kgm^{-3}

The next issue to consider is how quickly the settling tank or pond will fill up with sediment. This can be defined either by the concentration of sediment removed e.g. in mg/l or by the sediment delivery rate in tonnes of sediment per km^2 of catchment per year. This will vary with the characteristics of the catchment, season and land use e.g. activities which disturb vegetation cover. Box 4.5 shows an example.

Box 4.5 Solids collection

E.g. considering a 10 km^2 catchment, with a sediment delivery rate of 100 tonnes/km^2/month. During the season, rainfall of 200 mm per month would give a monthly runoff of:

10 km^2 x 200 mm = 10 x 10^6 m^3 x 0.2 m = 2 x 10^6 m^3

Silt delivery = 100t/km^2/month = 100 x 10 km^2 = 1,000t/month

Average silt concentration = 1,000t/10^6 m^3 = 1000 x 10^6g/2 x 10^6 m^3
= 500 g/m^3 or 500 mg/l

If 50 l/min of this water flows through the settling tank, that equates to:

50lpm x 43,200 (mins to month) x 500 mg/l/10^6 (mg to kg)
= 1083 kg per month, on average

Where the density of the collected solids = 2.62, this occupies

1083/2.62 = 413 litres, i.e. 0.41 m^3

If a settling tank as in Box 4.4 is used, this would compound to 0.41/16 m^2 = 0.026 m depth (2.6 cm). From the value for silt density above, this will occupy 1.28 m^3. From this value the cleaning frequency schedule can be estimated.

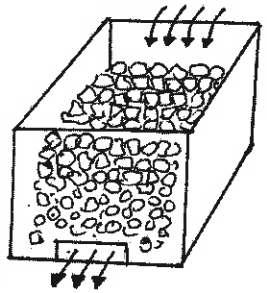
Calculations of this type are able to give some estimate of the approximate size of tank required but should only be used as a rough guide to planning.

Filtration

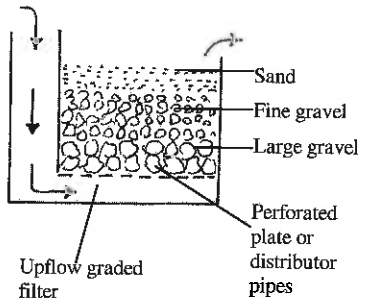
If a settling tank is insufficient to clean the water, a further stage of treatment is to use a filter of some type. Usually it is better to clean up the water as much as possible with a settling tank, and use a filter only for 'polishing'. Here, the aim is usually to use small particles in the filter - usually sand, so that the smallest particles in the water can be removed. However, if there are too many solids in the water, the filter will block up too quickly. In a typical sand filter, water enters over a wide area at the top and solids pass through until they become trapped in the spaces in the filter bed, allowing the cleaner water to pass out of the bottom of the filter. As more solids become trapped in the filter it becomes more efficient as

the spaces fill up and reduce the gaps through which solids can pass. Eventually, however, the filters will block up and will need to be cleaned. Slow sand filters with a minimum depth of 60 cm of well graded sand will effectively remove small particles but will rapidly become clogged if there is no settling sank or pre-filtration system. It is important that the water is well distributed over the filter surface (it can also be arranged to flow upwards through the filter), and ideally, the bed should be graded in the direction of the flow (i.e. big particles - gravel or coarse sand, as the water comes in and small particles - finer sands, as the water leaves the filter. If incorrectly graded, short circuiting and short filter runs occur, which can also seriously affect the performance of the filter (see Figure 4.6).

Figure 4.6 Filter arrangements



Simple, ungraded coarse mesh



4.4 Hatchery Systems

4.4.1 Introduction

The following sections describe the features of typical hatchery units - the buildings, water supplies and other features involved. Whichever species is to be produced, it can be seen that there are many common elements within these hatcheries, including:

- the buildings themselves; these need to cover the most sensitive areas - places where skilled work is to be carried out, places where stock need protection, and places which need to be secure such as feed or equipment stores. Buildings do not need to be too elaborate, but need to be suitable for the job.

- holding units for the stocks involved - broodstock, eggs, fry, fingerlings - not too complicated or expensively made, but a suitable size and quality for the stocks held.
- working/access areas - to allow people to carry out the necessary working duties of handling the stock, producing the fry and fingerlings moving materials and stock in and out, getting access to important controls and equipment.
- water systems - including channels pipes, settling and filter tanks, header tanks, and various gates, sluices, valves etc. needed to adjust flows to suitable levels.

These hatchery systems are described in turn for tilapia, catfish and carp, and show typical arrangements and dimensions for hatcheries of different sizes, ranging from very simple farm-based hatcheries suitable for individuals to more specialised units suitable for commercial production. While these descriptions provide guidance for the layout and development of working hatcheries for the species involved, the importance of the earlier sections on site selection and water supplies remains, and hatcheries should not be developed unless a suitable site and water supply is identified, and means defined for making these available for the hatchery.

While various suggestions are made for building layouts and forms of construction, there are no absolute rules for these, and it is more important to ensure that capacity is adequate, that the system can operate effectively, that workers can carry out their tasks without too much difficulty, and that suitable construction methods are used to meet local conditions. It is therefore usually better to use locally proven building types and construction methods, rather than to try to develop complicated and possibly expensive alternatives.

4.4.2 The tilapia hatchery

Objectives and major constraints

The principal objective of a tilapia hatchery is the mass production of fry for on-growing with suitable, species type, quality and at the times required by farmers. Because tilapia breed very early and rapidly in farm ponds single sex fish are often preferred - usually all male, as these grow faster. The major constraints to routine production concern the behaviour

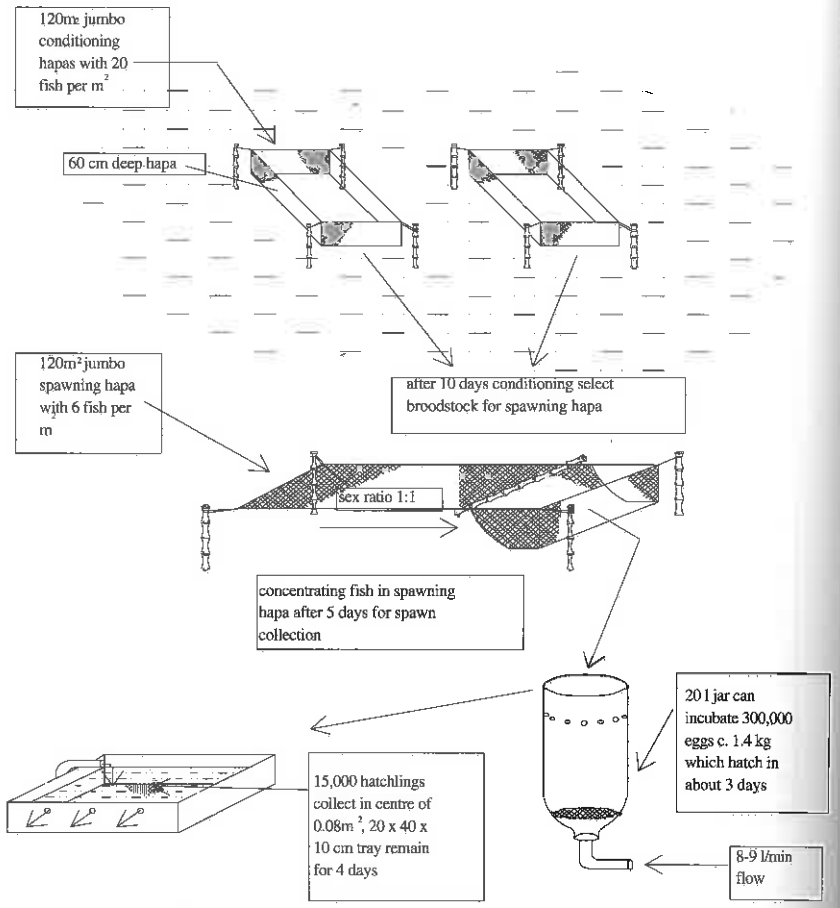
of the fish - the very territorial behaviour of male tilapia, with a lot of fighting as fish try to become dominant in the group, the irregularity of natural spawning, and the relatively low levels of fry produced per sperm per female fish (fecundity). However the fish do breed readily and repeatedly. More regular production can be achieved by pre-spawning '*conditioning*' and productivity of a spawning stock can be improved by *broodstock exchange* and *artificial incubation* (see further). Controlled spawning of tilapia is covered in Chapter 5. Box 4.6 summarises the key processes.

Box 4.6 Tilapia fry production

- Broodstock are held in hapas(1) - net cages in ponds for conditioning, then moved to spawning hapas (2), from which eggs are collected and incubated (3) in single round.-bottomed cylindrical jars.
- Hatched fish are then transferred to a single collecting tank, where they absorb their yolk sacs. At the end of yolksac absorption fish can be introduced to first feeds – either in green ponds or using artificial diets.
- If fish are to be sex-reversed, which is often preferred, they are transferred to hapas in 3 x 2 x 0.5 m tanks at a stocking rate of 30,000 per tank (equivalent to 12 fry/l.).
- They are then fed finely sieved fish meal with a vitamin C supplement and 60 ppm of 17 alpha methyl testosterone. Survival is about 70%; over 21,000 fish attain about 0.2 g and almost 100 % are functional males.

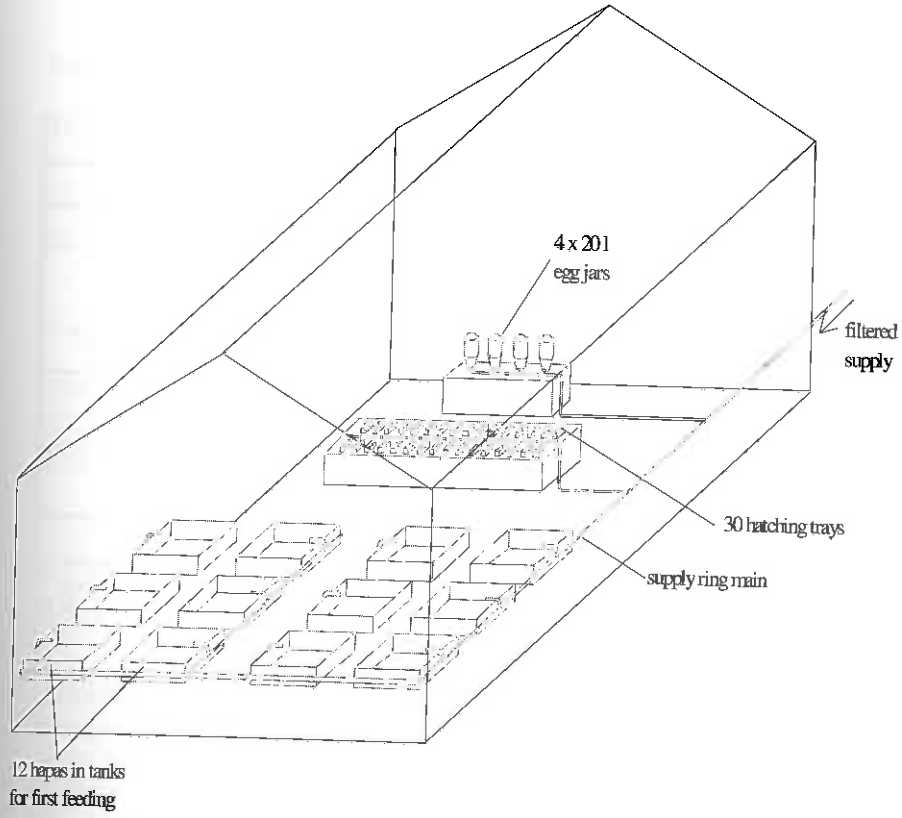
Box 4. 6 (continued): - Tilapia fry production

Box 4.3: Tilipia fry production



Chapter 7 provides more details. These early rearing stages, particularly for sex reversal are usually carried out inside a simple hatchery building, holding the hatchery jars and fry tanks. Figure 4.7 shows a typical tilapia hatchery layout for medium-large scale production.

Figure 4.7 A tilapia hatchery for 2 million fry per year production



Small-scale tilapia hatchery production

Table 4.7 shows a typical production plan for tilapia fry using this system of hapas for broodstock and jars or tanks for fry production. This shows each step in the production cycle, the time required, and the water and feeds. The table is based on production levels of 5,000 and 10,000 per cycle. These systems would produce 40,000 and 80,000/yr, based on 8 cycles of 40 + days per year, or rather less if a smaller number of cycles were used (e.g. because of seasonal effects). These can be considered as micro-scale and small-scale hatcheries. Using simple low-input farming

techniques, 5,000 fry would be sufficient to stock 5,000 m^2 of ponds, or with slightly more intensive methods, perhaps about half this area. Table 4.8 shows a similar production schedule for slightly larger hatcheries, for 20,000 and 40,000 fry respectively, using broadly similar methods.

Table 4.7 Infrastructure requirements for smaller tilapia hatcheries

Stage	**5,000**		**10,000**	
Spawning (5 days)	20M + 20F	10 m^2 hapa	40M + 40F	20 m^2 hapa
Eggs (3 days)	18,000	5l jar *	36,000	10l jar
Hatchlings (4 days)	9,000	1 tray**, 0.08 m^2	18,000	1-2 trays, 0.08 m^2
Fry (21 days)	7,200	1 tank***2 m^2	14,400	1 tank, 3 m^2
Total water flow required		5l/m		10l/m
Approx. holding area		4-10 m^2		8-20 m^2

Notes: * Jars can be specially made, or based on plastic soft drinks bottles of 0.5-2l capacity. ** Trays of plastic, aluminium or wood, with plastic mesh floor, typically 40 x 20 x 10 cm deep. *** Tanks are typically ~0.5 m deep; fry are held in hapas in these; non sex-reversed fry can be transferred directly to ponds, or hapas within these.

These tables exclude the conditioning and supply of fresh broodstock. Around 4-8 times the spawning stock numbers would be required, depending on the condition of the stock, temperature and feeding levels. Thus if 20 broodstock fish are used per cycle, 120-160 fish would be needed in reserve. If stock can be captured regularly from local ponds, and are of known quality, these can be used as needed. Otherwise, and particularly if certain stock lines are to be kept, it will be necessary to hold and condition broodstock. These can be held directly in ponds or in 'jumbo' hapas - larger nets, at about 20 fish/m^2. For the micro-hatchery therefore, perhaps 100 of each sex would be required, i.e. 2 nets of 5 m^2. The small-scale hatchery would require ~ 400 brood fish of each sex; 8 nets of 5 m^2, or perhaps 2 nets of 20 m^2. The decision about broodstock holding will depend on the local conditions, and on the security of keeping broodstock, which could be susceptible to theft or poaching, particularly if

they are kept together. In many cases it may be simpler and safer to select broodstock from harvested stocks, or keep them only for a short time before using them.

Table 4.8 Infrastructure requirements for medium tilapia hatcheries

Target production	**Stage**	**Quantity**	**Infrastructure**
100,000 per cycle*	Broodstock eggs hatchlings early fry sex reversed fry on growing	180 M x 180F 360,000 180,000 144,000 100,000	60 m^2 spawning hapa 2 jars 10 trays 4 tanks 40-50 l/min flow 5 - 10 ha ponds
Total		40 l/min	850,000 fry/y
20,000 per cycle*	Broodstock eggs hatchlings early fry sex reversed fry on growing	90 M x 90F 72,000 36,000 28,800 20,000	30 m^2 spawning hapa 1 jar 2 trays 1 tank rainwater tank ** 1 - 2 ha pond
Total		20 l/min	170,000 fry/y

* one cycle lasts 43 days

Larger-scale tilapia hatcheries

Table 4.9 describes the production plan for a larger hatchery, capable of producing 2 million fry in 8 cycles, i.e. on average 125,000 fry/cycle. Such a holding uses similar facilities to those described in Table 4.7, and would be an appropriate size for a rural centre, serving a wide range of farms, and would normally produce sex-reversed fry. If security was acceptable it might also be able to hold and select broodstock over a larger period of time, and therefore aim to improve the quality of fry using known broodstock sources. All these tables are based on the use of sex reversed fry, but can also be used for ordinary fry, without the use of special feeds.

Table 4.9 Production plan for a larger tilapia hatchery producing 2 million sex reversed fry in eight cycles

Phase	System	Numbers	Survival	Water	Other inputs	Output
Conditioning (10days)	Jumbo hapas in ponds	2,400 females and 2,400 males in separate 120 m^2 hapas	-	-	Fertiliser, supplementary feeds	Approx 50 % of broodstock will spawn synchronously
Spawning (5 days)	Jumbo hapas in ponds	360 females + 360 males in 1 x 120 m^2 spawning hapa	-	-	fertiliser, supplementary feeds	4 kg of seed after 5 days
Egg incubation (3 days)	Round bottom upwelling incubater jars	Up to 300,000 eggs (1.4 kg) in 3 x 20 l incubation jars	50 %	3 x 8-9 l/min	-	450,000 hatchlings
Early rearing (4 days)	Plastic or aluminium tray 40 x 20 x 10 cm	15,000 in 30 x 0.08 m^2 trays	80%	30 x 3-4 l/min	-	360,000 early fry
All male fry production (21days)	Hapas in 3 x 2 x 0.5 m tanks	30,000 in 12 x 5.4 m^2 tank (12/l)	70 %	12 x 4.2 l/min	fine sieved fish meal, vitamin C supplement and 60 ppm of 17 alpha MT	250,000 all male fry of ~ 0.2 g
Total				120 l/min		2 million fry/year

The building areas defined are simple guidelines. The buildings therefore can be made very simply - either with local wood/netting construction, or using basic timber or concrete posts and fibre or corrugated metal (iron)

roofing, with a packed earth, gravel or simple concrete floor. Water flows can be provided, and water can be settled/filtered as described earlier.

4.4.3 The catfish hatchery

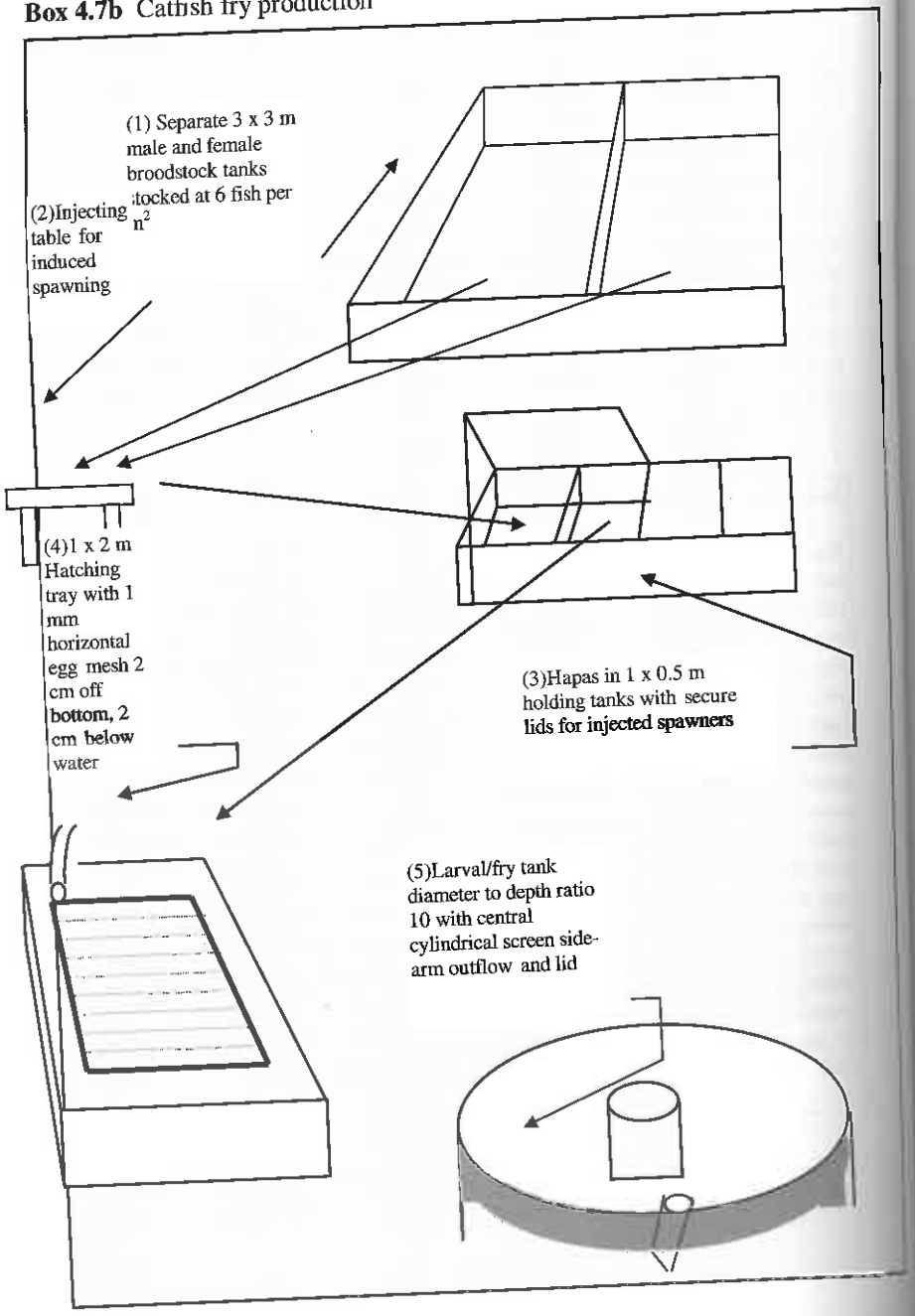
Objectives and major constraints

The principal objective of a catfish hatchery is the mass production of good quality airbreathing fry for on-growing. The major constraints are: the induced spawning of broodstock, territoriality and cannibalism in populations of larvae and fry, the requirement for a live first feed (prior to weaning onto a prepared diet) and the management of the onset of airbreathing. Controlled spawning and early rearing are dealt with in Chapters 5, 6 and 7. Boxes 4.7a,b gives the basic outline for catfish fry production.

Box 4.7a Basic outline for catfish fry production

The sequence commences with the selection and stocking of broodstock (1) in separate tanks, hapas, or small ponds) at around 6 fish/m^2. Once individuals are selected for spawning, broodstock are injected with hormones (2) to induce them to spawn, and injected fish are transferred to smaller covered holding tanks with very secure lids!– suggested 1 m x 0.5 m x 0.4 m deep (3) for each individual until the females ovulate. Once ready to be stripped the females are removed and eggs stripped into a dry container. The males can not be stripped of milt and are therefore killed, the testes removed and milt squeezed over the eggs. A small amount of water is then added and after about 1 minute the fertilized eggs begin to swell and develop sticky egg cases. At this stage they are spread in a single layer on a horizontal 1 mm mesh to which they adhere (4). The submerged mesh rests above the bottom of a tank. After hatching the meshes (and any unhatched eggs and adhere egg cases) are removed and the larvae swim freely (5). Any current at this stage should be gentle and fine meshes over the out flows should be regularly cleaned. After 48-72 h of yolksac absorption depending on temperature (see further) feed can be offered. The larvae grow rapidly and after several weeks develop into fry (miniature adults) that can breath oxygen from the air. Fry are transferred to a circular flow hapas/fry tank with a cover to protect stock. Such tanks are wide and shallow with slow flow rates.

Box 4.7b Catfish fry production



The rate of mortality from territoriality and cannibalism can be minimised by appropriate stocking density and appropriate feeding (in terms of quantity, quality and timing of presentation).

Small scale catfish hatchery production

Table 4.10 provides a survey of the basic requirements of small catfish hatcheries. This is based on using the broodstock several times. Note that broodstock can be used again after three months. Typical times for each production stage are: injecting to stripping (latency period) 12 h, spawning to hatching 24 h, hatchling to larval stage 48-72 h, larval to fry stage 14 days on-growing 4-12 months, this depends on temperature and development will proceed more rapidly at optimal temperatures of 28 to 30°C.

Table 4.10 Infrastructure requirements for smaller catfish hatcheries

Target production	**Stage**	**Quantity**	**Infrastructure**
6,000 per cycle*	Broodstock Eggs Hatchlings Larvae air-breathing fry on growing	from pond 20,000 10,000 7,500 6,000	fenced pond 1 trough 1 tray 1 tray 1-2 trays 2- 3 ha ponds
TOTAL		13 l/min flow	100,000 fry/yr
12,000 per cycle*	Broodstock Eggs Hatchlings Larvae Air-breathing fry On growing	from pond 37,500 18,750 15,000 12,000	fenced pond 1 tray 1 tray 1 trough 4 tanks rainwater tank ** 1 - 2 ha pond
TOTAL		20 l/min flow	200,000fry/yr

- one cycle lasts 14 - 28 days depending on temperature

For smaller quantities of fry, broodstock fish can be collected from local ponds, kept briefly in hapas in the hatchery, injected and held in a hapa or

tank, one at a time. A small hatchery sufficient to service 1-2 ha of ponds would have a target production of 12,000 air-breathing fry and might be possible even where water appears limited. A rain water collection volume of 200 m^3 would be required for one cycle. If a pond greater than 200 m^2 is constructed above the site of the hatchery, water can flow via a filter (see section on surface water supply) to the hatchery by gravity. Additionally, a roof 12 m long with two 3 m faces subjected to more than 600 mm of rain could collect sufficient water for egg incubation and hatching.

Larger scale catfish hatchery production

Table 4.11 provides a more detailed description of the production process, based on a larger hatchery, with similar production systems. Figure 4.8 illustrates a typical layout for a larger hatchery, with 2 broodstock tanks, 12 larval and fry rearing tanks, suitable for 1-2 million fry per year.

Figure 4.8 Layout of catfish hatchery for 1-2 million air-breathing fry/yr

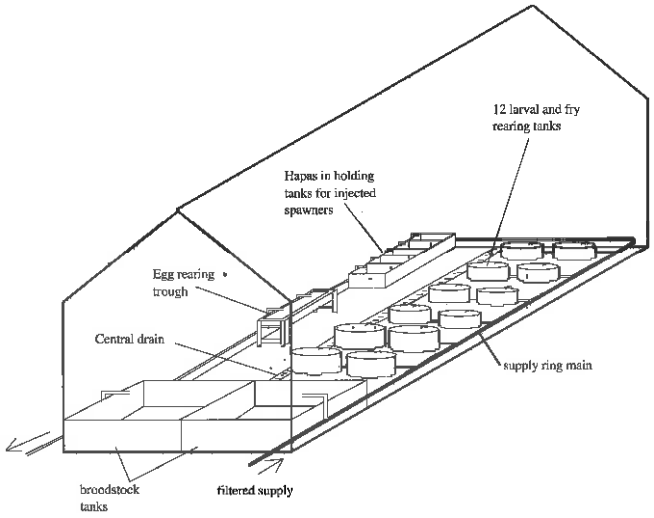


Table 4.11 Production plan for catfish hatchery producing 1-2 million air-breathing fry in 24 - 48 cycles

Phase	System	Numbers	Survival	Water	Other inputs	Output
Selection & injection (1 day)	Hapas in tanks	54 females (up to 1 kg) and 54 males in separate 9 m^2 hapas *	100 %	2 x 1.6 l/min	feed 2 % body weight day cease 2 days before broodstock selection	all broodstock with post vitellogenic oocytes will spawn
Latency (1 - 0.5 days)	Hapas in small tanks with lids	at least 2 F and 2 M in individual holding tanks	100 %	4 x 0.25 l/min	-	134,000 eggs (67,000 per kg body weight)
Egg incubation (1 - 2 days)	On horizontal mesh in hatch'g trough	up to 134,000 eggs in 1 x 2 m trough	50 %	4-6 l/min	-	67,000 hatchlings
early rearing (2 - 4 days)	In hatching trough	67,000 in 1 x 2 m trough	80%	4-6 l/min	first feeding with decysted unhatched *artemia*	53,600 early larvae
Airbreathing fry production (12 - 24 days)	Round tanks; diameter/depth ratio 10	53,600 in 12 x 1.4 m diameter 0.2155 m^2 tanks (25/l)	80 %	12 x 1.75 l/min	Decysted un-hatched *art-emia* substituted >5 days with finely sieved fish feed	42,000 air-breath-ing fry of about 50 mg
Total				32 l/min		1 - 2 million/yr

* females can be spawned again after 3 months (female broodfish should be tagged for identification),males are killed and the testis removed depending on temperature, see further

The hatchery size can be adjusted according to requirements (see Table 4.11). Details on the care and management of the stock, and the selection and use of suitable feeds are given in Chapter 8.

4.4.4 The carp hatchery

Objectives and major constraints

The principal objective of a carp hatchery is the mass production of good quality carp fry for on-growing. The major constraints are: the induced spawning of broodstock, cannibalism in populations of larvae and fry and the requirement for a live first feed (prior to weaning onto a prepared diet). The rate of mortality from cannibalism can be minimised by appropriate stocking density and appropriate feeding (in terms of quantity, quality and timing of presentation). Controlled spawning and early rearing are dealt with in Chapters 5, 6 and 7. Box 4.8 provides all of the key stages in outline carp fry production.

Box 4.8 Key stages in carp production

Selected broodstock are held in separate hapas/tanks for males and females at a density of 6 fish per m^2. Individuals are taken for injection (via careful handling in net carriers and following mild anaesthetic) with pituitary extract and transferred to holding hapas/tanks for approximately 12 h. At this stage (following mild anaesthetic) the genital opening is sutured and the females receive a second injection of a pituitary extract. The males also receive an injection of pituitary extract at this time. After a further period of around 10 h (depending on temperature) ovulation occurs. At this point the females are stripped of eggs and the males of milt. After fertilization the eggs are treated for stickiness and placed in incubation jars with up welling water. After hatching the larvae are transferred to larval rearing containers.

Small-scale carp hatchery production

Details of system requirements for small scale carp hatchery production are given in Table 4.12, based on production levels of 100,000 to 350,000 fry per cycle, with up to three cycles per year.

Table 4.12 Infrastructure requirements for smaller carp hatcheries

Target production	Stage	Quantity	Infrastructure
350,000 per cycle*	Broodstock Eggs Larvae Advanced larvae on growing	2 - 3 F, 2 M 560,000 532,000 375,000	2 x 4.5 m^2 tanks 4 jars 1 jars 4 tanks 6- 10 ha ponds
TOTAL		18 l/min flow	1,000,000 advanced larvae/y
100,000 per cycle*	Broodstock eggs larvae advanced larvae on growing	1-2 F, 1-2 M from pond 140,000 133,000 100,000	Fenced pond 1 x 40 l jar same jar (2-3 l/min) 1 tank rainwater tank ** 2- 4 ha pond
TOTAL		10 l/min flow	300,000 advanced larvae/y

* one cycle possible 4 time annually

**A small hatchery sufficient to service 1-2 ha of ponds would have a target production of 100,000 advanced larvae and might be possible even where water appears limited. A rain water collection volume of 173 m^3 would be required for one cycle Therefore if a pond of 200 m^2 is constructed above the site of the hatchery, water can flow via a filter (see earlier) to the hatchery by gravity. Additionally, a roof 12 m long with two 3 m faces subjected to more than 600 mm of rain could collect sufficient water for egg incubation and hatching.

Medium-large scale carp hatchery

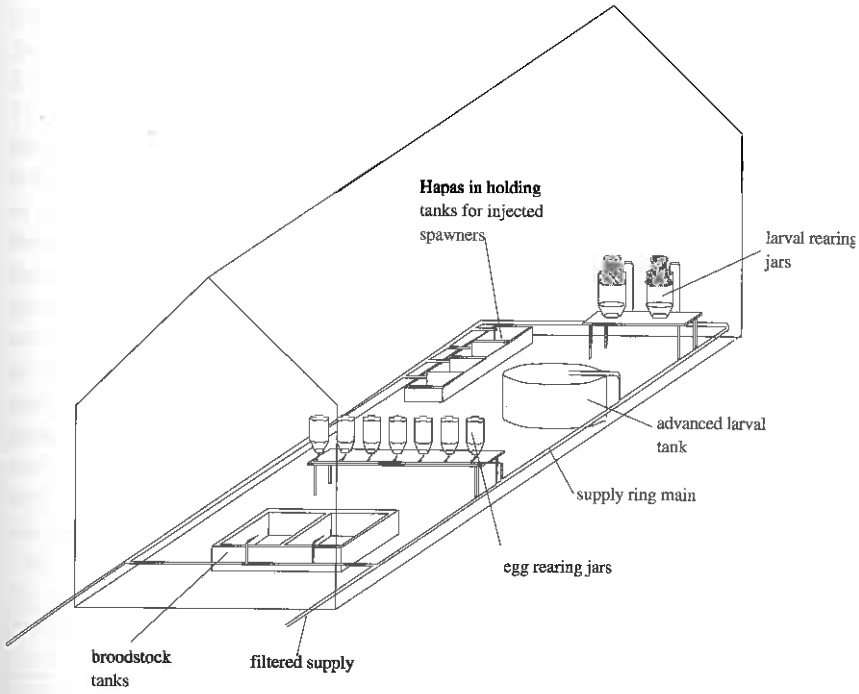
Figure 4.9 shows a typical layout of a medium-large sized carp hatchery, while Table 4.13 outlines a production schedule. The hatchery size can be adjusted according to requirements (see Table 4.12).

Table 4.13 Production plan for carp hatchery producing 1-2 million fry in 3-4 cycles in a year

Phase	System	Numbers	Survival	Water	Other inputs	Output
Selection & injection (1 day)	hapas in tanks	54 females (1 kg up to 4 kg) and 54 males in separate 9 m^2 hapas *	100 %	2 x 1.6 l/min	feed 2 % bodywt/day cease 2 days before broodstock selection	all broodstock with post vitellogenic oocytes will spawn
latency (1 - 0.5 days)**	hapas in small tanks with lids	at least 5 females and 2 males in individual holding tanks	100 %	4 x 0.25 l/min	-	1 million eggs (200,000 eggs/kg body weight)
egg incubation (2 - 6 days)**	7 x 7 l egg incubator	up to 140,000 eggs per incubator	95 %	0.5 - 2 l/min	-	931,000 hatchlings
early rearing (3 - 4 days)**	in 2 rearing jars	500,000 per jar	75 %	12 -15 l/min	can be first fed in jar decysted unhatched *artemia*	750,000 early larvae
early feeding (if larger fish required for stocking) 5 dys	in 7 x 1.4 m diameter tanks	100,000 per tank	75 %	1.2 - 4 l/min	first feeding with decysted unhatched *artemia*	562,500 advanced larvae
TOTAL				34 l/min		1 - 2 million/y

* spawning condition may be reached 3 - 4 times each year
** depending on temperature, see further

Figure 4.9 A carp hatchery for producing 1-2 million advanced larvae/yr



4.4.5 Multiple use of hatcheries

There is considerable overlap in hatchery specifications for different aquaculture systems, as will be apparent from comparing the hatchery infrastructure outlined above for the 3 species. If a mature broodstock population of any of the species is available to a hatchery then a range of possibilities for using any one of the above designs for multiple production of species exists. Each of the fish species has broadly similar water quality requirements and broodstock holding tanks with secure lids can be made suitable for tilapia, carp and catfish. Trays can be constructed that are suitable for egg and larval rearing of catfish (see Box 4.7) or for rearing

hatchlings of tilapia (see Box 4.6 and Fig 4.8). Similarly incubation jars or round hatchery tanks may be used for carp, catfish or tilapia rearing.

Well fed, mature, conditioned broodstock of each species under suitable conditions can be spawned as required. Following a short recovery period, females can be spawned more than once.

Hatcheries may be designed in relation to a production plan involving all of the species described. A guide to species infrastructure requirements is given in Table 4.14 to facilitate planning. When scheduling production in order to make best use of hatchery facilities a number of other factor should be considered. This will include the size of fish to be produced and its relation to the system into which they will be stocked (considering, predation, cannibalism, disease susceptibility, polyculture, etc.) and the time at which they will be required (e.g. for tilapia-catfish polycultures catfish should be stocked 1 month after stocking 5g tilapias). Piscivores (fish eating fish) such as catfish should therefore be spawned later than carp or tilapia.

Table 4.14 Guide to infrastructure requirements for planning multiple use of hatchery facilities

Species	Tilapia	Catfish	Carp
Type of Infrastructure	1 x 120 m^2 hapa* 3 x 20l jars 30 trays 12 tanks 5.4m^2	9 m^2 tanks 4 small holding tanks 1 x 2 m trough 12 tanks1.5 m^2	9 m^2 tanks 4 small holding tanks 7small incubation jars 2 large rearing jars 7 15 m^2 round tanks
Production	250,000 0.2 g all-male fry	42,000 x 50 mg air breathers	560,000 advanced larvae
Time period	43 days	17-32 days	12-20 days

* suspended in pond or water body outside of hatchery

CHAPTER 5

BROODSTOCK MANAGEMENT

5.1 Introduction

This chapter provides a guide to the acquisition, holding, feeding and care of broodstock, and gives specific information on the sexing, selection and spawning of Nile tilapia, common carp and African catfish.

Broodfish may be caught from natural waters just prior to the spawning season or may be selected for spawning (see further) from the stock of fish raised on the farm. Although collection of wild broodstock may be cheap or convenient, it is often less predictable, and so planning and production of a reliable seed supply can be more difficult. There is also little opportunity for selective breeding or the use of special broodstock diets or prespawning conditioning to maximise egg quality and survival. In some cases the excessive use of wild stocks will also risk depleting local fisheries and may reduce the strength of local fish stocks.

The establishment of a captive, farm held broodstock population removes the reliance on wild fish. It reduces the risk of introducing disease (brought in with wild fish) and the potential for negative impacts on wild stocks. Because the choice of broodstock will determine the total range of characteristics (e.g. shape, size, growth) from which the hatchery can select, stocks should as far as possible be selected from a variety of different genetic origins and should include a wide array of genetic variability. Unless well managed, (unintentional) selection pressure on cultured strains can lead to rapid genetic change and an unacceptable decline in genetic variation for commercially important traits (see further).

Before spawning, male and female broodfish are held separately, in manageable ponds (50 m^2 to 1 ha), which should be rich in natural food. Security is especially important where large well maintained fish are kept in manageable ponds! Ponds might be positioned close to homesteads or where protection from poaching can be provided. Carp, and to some extent catfish, respond well to stocking at low density (e.g. 300-400 fish or <1,000 kg/ha). Conversely, tilapia spawn readily in ponds or enclosures,

and the control of unwanted natural spawning, and synchronisation of spawning for mass fry rearing, is facilitated by stocking the broodfish at high density prior to release into spawning hapas (see Chapter 4 and further).

5.2 Basic requirements

The area of broodstock ponds required depends on the size of the breeding population. This depends on the method of spawning, the method of ongrowing in the ponds or farms to be supplied and the area of ponds or quantity of fry to be supplied. Thus, semi-intensive carp, catfish or tilapia ponds are often stocked at 3 fish per m^2, and therefore to stock each hectare of pond, 30,000 fry are required. One million fry is sufficient for around 30 ha of ponds. Box 5.1 illustrates the typical requirements for broodstock.

Box 5.1 Broodstock requirements for fry production

Producing one million fish by induced spawning in a hatchery requires:

- At least 10 female carp of around 2 kg each and about 5 males. Fry production where spawning is induced by manipulating environmental conditions is less productive and requires correspondingly more broodstock (about 200 females of about 2 kg and 200-300 males).
- At least 32-40 female catfish of around 1 kg each and around 25 males. Fry production where spawning is induced by manipulating environmental conditions is very variable and can only be advocated as a small scale low input option producing around 500–1,000 fry per female.
- Tilapia are much less fecund and much larger stocks of broodfish must be accommodated (see further). Fry production in jumbo hapas (120 m^2 with 3 males and 3 females/m^2) would require 5 hapas with a total of at least 1,800 males and 1,800 females.

In addition capacity is required for ripening males and females and for allowing spawned fish to recover and regain condition. For carp and catfish, additional ponds are normally used, while for tilapia in hapa systems, broodstock are held in conditioning hapas at densities of around 20/m^2.

Inbreeding

The calculations for broodstock numbers used earlier have been based on

the practical matter of ensuring that enough fry can be produced. However, if there are only small numbers of broodstock, although they may produce the right numbers of fry, there may be a risk of inbreeding - that is breeding between small numbers of stock which are too closely related to each other. This can result in poor quality stocks, and reduced overall viability, and may increase the incidence of physical abnormalities. For small hatcheries it may not be practical to hold large numbers of broodstock, or to separate and log different family lines and individual stocks, and it may be simpler just to attempt to replace broodstock regularly, and to try to avoid close breeding of selected stocks of the same parentage over several generations. In any case it can be useful to monitor the average level of inbreeding for hatchery stock from year to year, so that the risk of the negative consequences of inbreeding can be weighed against the potential danger of introducing new stock into the breeding population.

The degree of inbreeding per generation can be calculated as:

$$R = \frac{1}{2N_e}$$

where N_e = the rate of inbreeding per generation = $4x(N_f \times N_m)/(N_f + N_m)$
where N_f = No. of females actually breeding, N_m = No. of males breeding

The males and females concerned are those contributing to the next generation, and the larger the numbers involved and the closer the sex ratio is to 1:1 the lower the level of inbreeding will be. Table 5.1 shows some examples, the higher the 'R' value the greater the inbreeding problem.

Table 5.1 Examples of the rate of inbreeding

Females	2	5	10	20	20	20
Males	2	5	10	20	12	6
Ne.	4	10	20	40	30	18.5
Degree of inbreeding per generation	0.175	0.05	0.025	0.013	0.017	0.027

Broodstock nutrition

Nutrition is one of the key considerations in the management of broodstock and the production of good quality seed. While carp, catfish

and the control of unwanted natural spawning, and synchronisation of spawning for mass fry rearing, is facilitated by stocking the broodfish at high density prior to release into spawning hapas (see Chapter 4 and further).

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Broodstock nutrition

Nutrition is one of the key considerations in the management of broodstock and the production of good quality seed. While carp, catfish

and tilapia can be held in broodstock populations and spawned by the farmer, surprisingly little is known about the detailed nutrient, metabolic or husbandry requirements of either broodstock or larvae, or about the precise ways in which these factors may best be managed to improve the numbers, the continuity and quality of seed supply. However, enough is known to establish basic principles, and to provide overall guidance for good practice.

The nutritional status of broodstock can significantly affect broodstock reproductive physiology as well as the egg and larval quality. Gross nutrient availability, along with fish size (and to a lesser extent age) and genotype (i.e. inherited characteristics) are important in determining fecundity, ability to mature and egg size. It is clear, therefore that special attention should be paid to the diet of broodstock, where feasible this is often in the form of specially prepared feeds. Box 5.2 outlines some of the important issues.

Box 5.2 Key factors in broodstock nutrition

- The ratio of protein to energy in broodstock diets might be similar to those fed to growers. However as excess energy tends to be stored as fat in the body cavity and around the gonads, too much energy in broodstock diets might interfere with optimal reproductive function.
- Increasing attention is now paid to the role of individual components, in particular micronutrients such as water soluble vitamins e.g. **vitamin C**. These break down quickly, are not stored, yet need to be passed on to the eggs to ensure adequate egg quality.
- Of the fat soluble vitamins, **vitamin E** should be an important dietary component due to its action in preventing membrane oxidation.
- **Astaxanthin** also appears to reduce damage caused by oxygen species (such as singlet oxygens or hydroxy radicals), fulfilling a protective role similar to vit. E. In addition, astaxanthin which is a pigment, absorbs ultra violet light at wavelengths which might cause damage to unprotected eggs.
- **Phospholipids** may be significant in view of their important role in bio-membrane structure and function and their predisposition to oxidation, lethecin for example is believed to be important in larval nutrition.
- Finally, **carnatine** which is a co-factor in the biochemical breakdown of fatty acids for energy may be important in egg development and sperm motility (both of which are fuelled by fatty acid catabolism). Little work has been undertaken with fish, but carnatine has been shown to improve egg and sperm quality in some mammals.

Dietary components such as these may have an effect upon aspects such as: fertilisation rate, hatch rate, survival to different development stages, quality of reproductive products e.g. sperm motility, egg histology and larval deformity. Where (as is often the case) sophisticated diet formulation and feeding is not an option, efforts can still be made to support the nutritional needs of broodfish. One highly successful carp hatchery uses the following regime (Box 5.3).

Box 5.3 Practical broodstock nutrition

- broodfish between 1 and 5 kg can be kept in medium sized ponds of around 3,000-6,000 m^2 at low stocking density, with abundant natural feed supported by regular addition of fertiliser
- throughout the year fish receive supplementary feeding with single feeds such as mustard oil cake (40%) and rice bran (60%)
- as fish become mature nearer the spawning season, it is better to improve the diet, and if available, dried ground fish meal can be incorporated increasingly into the feed, up to a maximum of 15% just prior to spawning. However, unless fish meal is of good quality and has been stored properly (e.g. smells fresh, not burnt or rotten) it may be better not to include it.
- Feeding is carried out every second day at a rate of just less than 5% of body weight. Weekly cast net sampling can be carried out to assess the size and condition of the fish, the quantity to feed and the quantity of fish meal to include.

General care

Broodfish are easily stressed by poor conditions and careless handling. All aspects of the maintenance, holding, handling and transport of spawners should be carried out with this in mind. If a net is used in a broodfish pond the aim should be to catch small numbers of stock with unhurried movements, to avoid crowding. Holding in hapas is especially appropriate for broodfish as this allows frequent examination of their state of ripeness without undue disturbance, and ideally without having to remove the fish from the water. Transportation over short distances can be accomplished using wet cloth sacks or a simple stretcher.

Fish introduced into hatcheries for induced spawning (see later) are usually placed into isolated tanks which have separate water supplies from

the rest of the hatchery. These tanks should be aerated, shaded and covered with netting to prevent the fish jumping. It is good practice to control parasites at this stage, to keep the stock in good condition and avoid contaminating other stocks. After several hours, allowing the fish to become used to the hatching tanks, a parasite treatment can be administered. A commonly used disinfectant contains 0.2 ppm malachite green and 30 ppm formalin (37%), applied for 4-5h. Chapter 9 gives more details. The fish are unfed at this stage, and a further 12h is usually allowed without feeding prior to starting spawning, to reduce the potential for contamination of the eggs with wastes from the broodstock.

5.3 Sexing and selection of broodfish

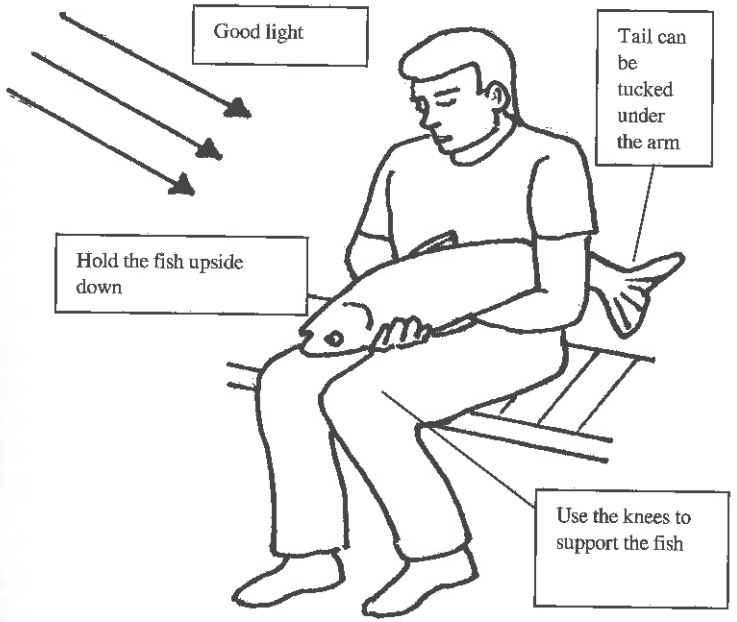
The advantages of controlled hatchery production of fish seed have already been described. However, many species do not spawn in captivity, and those which do, often spawn in an irregular manner, or at a time which is inconvenient for the management of the hatchery or for the needs of customers. To obtain seed consistently for on-growing or stocking it is therefore preferable to control spawning, which in turn requires some understanding of spawning and its means of control. This involves an appreciation of the characteristics of the separate sexes, the selection of suitable spawners and the control and manipulation of spawning.

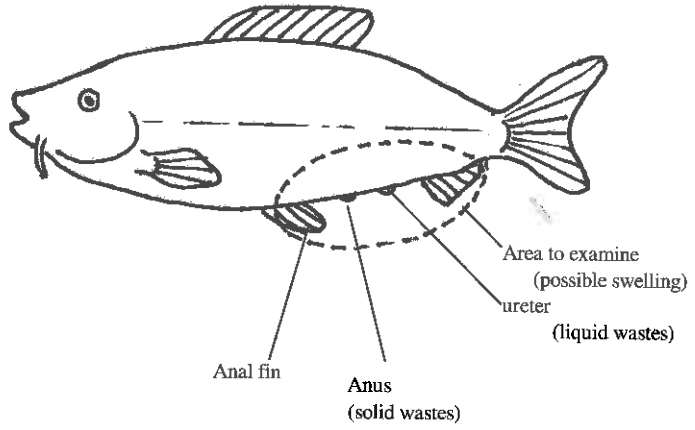
Of the three species, catfish and carp are highly fecund (spawning many eggs at one time) and are commonly induced to spawn, producing large numbers of fry at one time. In contrast, tilapias spawn readily in captivity but individuals produce relatively few eggs, and so to produce large numbers of tilapia, fry breeding behaviour must be synchronised. In addition, to overcome the problem of unwanted natural spawning by tilapia in on-growing ponds, single sex stocks are preferred (see further).

Sexing

All three species can be distinguished by their external appearance - in some cases simply by size, colour or behaviour, or else by netting out the fish and examining their underside in the body area between the belly and the tail. Fish should be handled carefully, but firmly, with wet hands and/or a wet cloth or plastic sheet to hold the fish, to avoid damaging the skin and stressing the fish. Figure 5.1 shows the basic points.

Figure 5.1 Handling and examination of broodstock



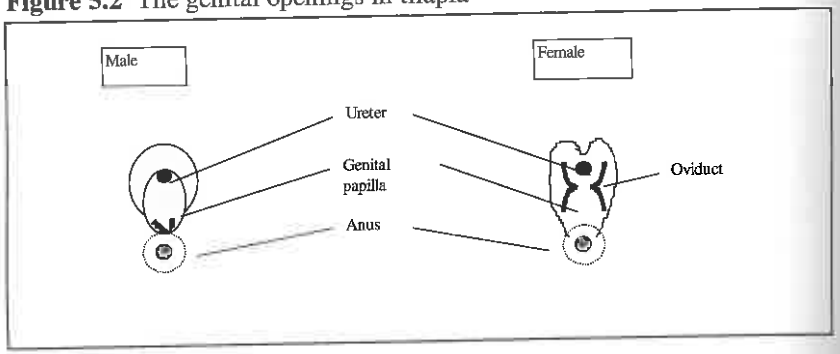


The distinguishing features to look for are, for the female, the oviduct, from which eggs are released, and for the male the genital papilla, a small protruding organ from which the sperm or milt is obtained. The next paragraphs and figures describe the features of each of the three species.

(1) Tilapia

Female and male tilapia can be distinguished with care when the fish mature. Figure 5.2 shows the essential differences. The females posses an oviduct posterior to (i.e. behind) the anus and just behind the ureter, which is tiny and difficult to distinguish. The males possess a small urogenital papilla posterior to the anus, and sometimes develop distinctive breeding coloration. This varies with species. *Oreochromis niloticus* can develop a blanched silver white appearance over the body and a black coloration on the fins. *O. mossambicus* can develop a jet black body colour with red on the fins, whilst *O. aureus* tend to become light in colour with iridescence over the body. A species from a different genus *Tilapia zilli* develop very red bellies. Females can become lighter during courtship and tend to become darker especially around the mouth when brooding.

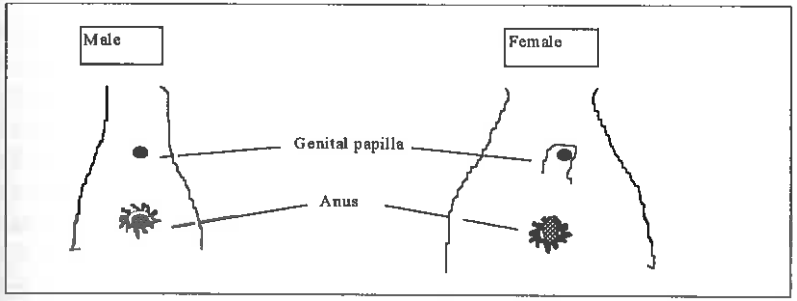
Figure 5.2 The genital openings in tilapia



(2) Common carp

Female and male common carp broodfish can be easily distinguished by their body shape and the characteristics of the genital pore (Figure 5.3).

Figure 5.3 The genital opening of common carp

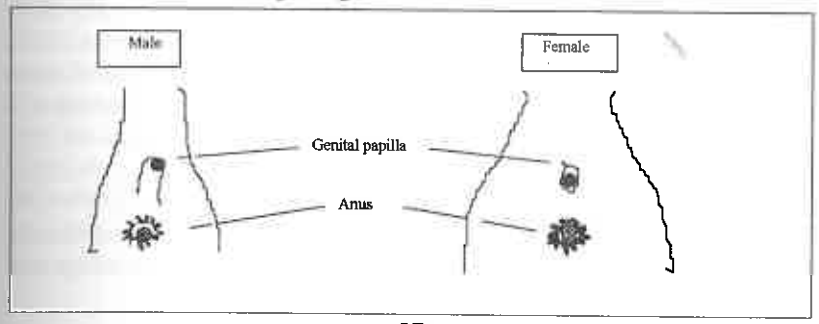


Mature female fish have larger more rounded bodies with a large genital papilla, which is erect and tinged red. At this time the anal pore is enlarged and protruding. The mature male body is slender, the belly is not rounded and the genital opening which is found behind the genital papilla will release white milt when the abdomen near to the papilla is gently squeezed. Sometimes mature males develop small nodules around the head and gill covers when in breeding condition.

(3) African catfish

Female and male African catfish can be distinguished from their external appearance by the time they reach about 10cm in length. The male possess a genital papilla several mm in length, located between the anus and the anal fin (Figure 5.4). In the female a genital pore is found in the same position, posterior to the anus. A female catfish in breeding condition also has a rounded abdomen filled with developing eggs, whilst the underside of the male remains more flat-sided and angular and its pale appearance may become marled with grey.

Figure 5.4 The genital opening of African catfish



The selection of suitable broodfish

(1) Tilapia

As mentioned earlier, the term tilapia is used as a common name to describe a group of African cichlid fish. Although there are over 70 species, belonging to four genera, most species used in aquaculture belong to one genus, *Oreochromis*. The species differ in appearance, and also in their tolerance and response to different environmental conditions. The suitability of a particular species or strain for different locations can therefore vary. However, one species, *Oreochromis niloticus*, is especially popular.

Unlike carp, tilapias do not have a centuries-long history of selection. However, they have been extensively hybridised by crossing different tilapia species. A common reason for this is to produce all-male offspring, to overcome the widespread problem of early and excessive breeding in on-growing ponds. Thus, crossing female *Oreochromis niloticus* or *Oreochromis mossambicus* with male *Oreochromis hornorum* will produce 100% males, provided pure parent strains are available. A high proportion of males also result from crossing *O. niloticus* females with *O. aureus* males, with the possible added advantage of thicker body shape compared with the other hybrid. While these can be useful and effective techniques, hybridisation has become less popular in recent years because most hybrids are fertile and readily back-cross when in contact with pure strains. If this is not managed, this can produce hybrid-contaminated stocks whose performance in breeding programmes is unpredictable, and often poorer.

Efforts are currently underway to develop and test improved strains of tilapia, selecting for faster growth or delayed onset of maturation. In recent years, strains of red tilapia have become popular, especially in East Asia, where they command a higher price. Some of these are crosses such as certain strains of *O. mossambicus* x *O. hornorum* which may show improved salinity tolerance, whilst some red tilapia are believed to be *O. niloticus* or *O. aureus* of varying degrees of purity. The supply of stocks which reliably produce a red colour, or other required characteristics, is still uncertain, unless stocks are from highly reputable producers.

Tilapia of 1 year age and about 200 g will tend to produce 1,000-1,500 eggs whereas 3 year old fish weighing 600 g to 1 kg may produce around 3,000 eggs. The yield of eggs per weight of broodstock is therefore greater

for younger fish. Younger fish also tend to have a shorter inter-spawning period (see further) and therefore produce more eggs per unit time. However, the first few spawnings from a female tend to be poor quality and should be discarded.

(2) Common carp

Common carp have been mass selected over many years, resulting in the development of improved varieties, and now many different races and lines exist. The aim of selection has been to produce a fish good for eating and culture which grows rapidly, has few scales and a thick set body. There are four principal phenotypes: (i.e. body types)

- fully scaled - the traditional type
- mirror carp, with scales of different size along the sides and a row of scales along the back
- carp with a single row of scales of the same size along the side
- "leather" carp which are practically scale free.

Fish for spawning should be in good health with no deformation to the spine, tail or fins, no body wounds and no parasites (mainly lice and leeches). The body should be supple and have normal curves and no flat areas, the underside should be wide, the fish should be neither excessively fat or excessively thin. The lateral line should be consistent, in the middle of the body and not change direction. It is common to use fish of 2-4 kg for spawning.

If early season spawning is required and a simple laboratory area is available, the selection of females ready for spawning can be ensured by sucking out a small sample - 40 to 50 oocytes using a 4 mm internal diameter tube gently inserted via the genital duct about 6 cm into the ovary. The opaque oocytes are placed in a solution of ethanol, formalin (40%) and acetic acid in the ratio 6:3:1 which will cause them to become translucent within about 3 minutes and remain so for another 5 minutes. The position of the germinal vesicle is determined in each of 40 oocytes. If 65% have migrated from the centre then induced spawning is likely to be successful.

(3) African catfish

The culture of African catfish (*Clarias gariepinus*) has been developed

over the last 25-30 years and a small amount of selection has been undertaken. Hybrids between Asiatic and African catfish are currently being investigated in Asia, especially crosses between female *Clarias batrachus* or female *Clarias macrocephalus* with male *Clarias gariepinus*. In both cases African catfish crosses seem to give faster growth and larger size, whereas appearance and flavour follow maternal characteristics. The fertility of the hybrids remains to be determined. In general, the import of exotic species, with the risks of disease transmission and unknown ecological consequences, is undesirable. In Africa, where the local species is a popular food fish, fast growing and tolerant of culture conditions, there is little convincing case for hybridisation with imported species.

Fish selected as broodstock should be healthy with no deformation to the spine, tail or fins, no body wounds or parasites and a thick slime covering. Barbels should be large and complete. The body should be supple, with normal curves and no flat areas, the underside should be wide, and the fish neither excessively fat or thin. The lateral line should be consistent, in the middle of the body and not change direction. Fish of 1-3kg make good broodstock, as larger fish are difficult to handle without the use of anaesthetics. Spines on the pectoral fins of large catfish are particularly dangerous to handlers, and cuts can lead to painful and unpleasant infection.

5.4 Spawning, its biological basis and control

Natural spawning

Spawning in wild populations occurs in sexually mature fish during the season most suitable for the development of young fish. In carp and catfish, natural spawning is discontinuous i.e. there is a breeding season. The breeding season of African catfish varies with location but correlates with periods of maximum local rainfall. In carp, a range of environmental cues, especially water temperature, are important stimuli, i.e. starting spawning. These reproductive cycles are regulated by annual changes in the activity of a large gland at the base of the fish brain called the pituitary. The pituitary releases chemicals - hormones which control spawning and levels of these hormones change throughout the spawning season. These are in turn regulated by the hypothalamus in the brain (see Box 5.4 and Figure 5.5). Hormone levels rise prior to spawning and

decline afterwards.

Box 5.4 The biological basis of spawning and its control

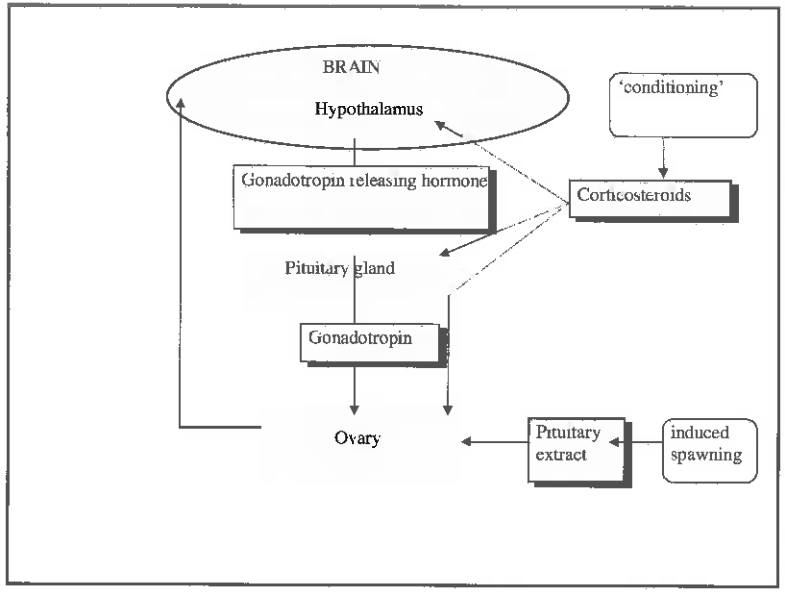
- Spawning occurs in mature fish when gonadotropic hormone (GTH) released by the pituitary gland causes maturation and ovulation of oocytes in the ovary.
- In seasonal spawners the release by the hypothalamus of gonadotropin releasing hormone (GnRH) which stimulates the release of GTH is inhibited by a gonadotropin release inhibitory factor (GRIF).
- Environmental cues which trigger spawning act on the hypothalamus to reduce production of GRIF, eventually allowing oocyte development.
- Figure 5.4 describes the pathway for control of maturation and ovulation and indicates the opportunities for inducing spawning in catfish and carp, and conditioning broodstock of tilapia.
- African catfish or common carp containing oocytes with yolk can be induced to spawn by manipulating environmental conditions or by intervening at several levels of the hypothalamic-pituitary-ovarian axis (see further) which controls reproduction.
- Tilapia kept at high density cease spawning activity (sometimes referred to as 'conditioning). This may be the result of elevation of corticosteriod levels depressing ovarian activity. Spawning is resumed (and synchronised) when the fish are returned to less dense conditions.

Natural spawning in carp and catfish takes place at night, usually after heavy rain in recently flooded pond or river margins. The fish aggregate before spawning and courtship is preceded by aggressive encounters between males, until spawners pair off together. Mating between separate pairs takes place in shallow water amongst inundated terrestrial or semi-aquatic grasses and sedges. There is no parental protection of the young except by careful choice of a suitable spawning site followed by splashing which disperses the eggs to adhere to vegetation.

The natural reproductive cycle of *Oreochromis* (tilapia) species is a little different. Pressures from predation and competition may be most important in controlling the timing of spawning. Normally, spawning takes place in an area where an assemblage of mature males excavate and defend shallow 'nests' in the substrate. A mature female responds to the courtship display of a male and enters its nest. Spawning and fertilisation

occur over several hours, after which the female leaves the area for nursing grounds to incubate the eggs (over 6-10 days) and then nurse the fry (over 10-30 days), brooding them in her mouth. Following incubation the ovary develops during a period of feeding and recovery lasting 14-30 days, after which a female will re-enter into the spawning area.

Figure 5.5 The hypothalamic-pituitary-ovarian axis, its control of maturation and ovulation and opportunities for controlled spawning.



Controlled spawning

As discussed in previous chapters, the control of spawning through various means offers particular advantages for hatchery production and for aquaculture in general. While natural spawning continues to contribute to production in many areas, the reliability and quality available from controlled spawning makes it a worthwhile approach for most hatcheries. The following sections describe a range of techniques which has been developed for the three species of concern, starting with the synchronising of spawning of tilapia, then describing the various means of stimulating and controlling spawning in catfish and carp.

5.5 Synchronised spawning in tilapia

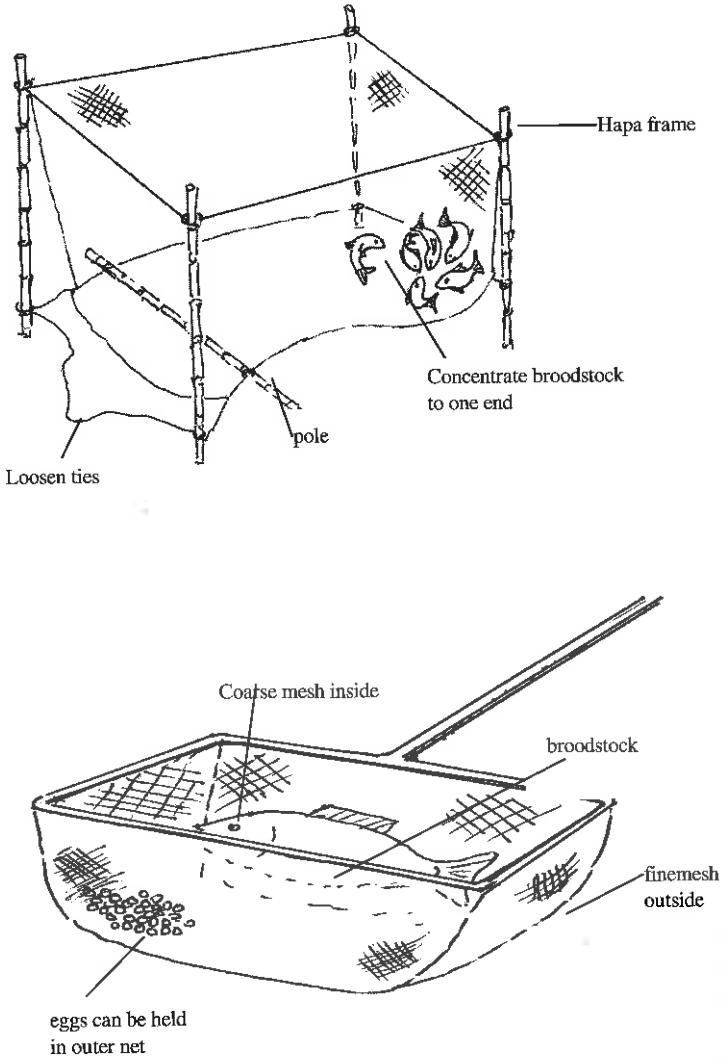
As already mentioned tilapias spawn readily in earthen ponds, or in fine-mesh net enclosures (hapas) suspended in ponds or small tanks and aquaria. They are unique amongst important commercial species in that seed can be produced easily without externally induced spawning. However the breeding behaviour and biology of the mouth brooding tilapias (*Oreochromis* species) make the synchronised production of large numbers of fry problematic. However, high production of eggs and fry has been achieved by spawning fish in hapas, which helps to ensure broodstock purity and enables easy collection of eggs and fry. The method maintains broodstock condition, reduces fry losses from cannibalism and predation, and provides the opportunity for improved fry production planning.

A system developed by the Asian Institute of Technology[1] in Thailand involves pre-spawning 'conditioning' and selective broodstock exchange, and has been particularly effective, and is as follows:

- male and female broodstock are sexed and placed into separate 120 m^2 hapas suspended to a depth of 60 cm in earthen ponds at temperatures of 23-32 °C. The fish are kept at high density (20 fish/m^2) as a further measure to prevent spawning during conditioning.
- after 10 days, fish are transferred to spawning hapas at a lower density (6 fish/m^2) and a sex ratio of 1:1, after which spawning usually occurs in up to 50% of females.
- after 5 more days, the bottom strings of the hapa are untied and the broodfish are concentrated at one end of the hapa using a bamboo pole slid underneath the hapa from one end toward the other (Figure 5.6).
- all broodfish are removed individually. A double hand net is used, the fish being held in a large mesh net inside a fine mesh net of similar size positioned to collect any eggs expelled from the fish mouth.

[1] The system was developed by Dr David Little and his co-workers - see references.

Figure 5.6 Management of broodstock in hapas



- the mouth cavity of each fish is checked for eggs or yolksac larvae which are removed by washing the seed from the mouth into the fine mesh net. A simple plastic "squeezy" bottle of water can be used to rinse out the mouth, taking care in holding and handling the fish.
- individual seed clutches can then be held in plastic bowls for inspection prior to artificial incubation (see next chapter).
- spawned females and unspawned/unripe females are removed at harvest and replaced with females selected for ripeness from fish in the conditioning hapa. Females will tend to spawn more frequently if males are all exchanged after 5 days in the spawning hapa, with 10 day or even 5 day conditioned males.

5.6 Induced spawning of African catfish

African catfish do not release a large amount of gonadotropin, even under favourable husbandry conditions and so oocyte (egg cell) maturation and ovulation must be induced. In the wild, the presence of oocytes ready for induction corresponds to the period of maximum rainfall and therefore induction will be restricted to that period. Broodstock transferred from outside tanks to the hatchery maintain their annual reproductive cycle for about one year, after which time spawning can be induced monthly. However broodstock raised entirely in captivity mature precociously at the age of 6-9 months, and can be induced at any time. The following techniques can be used.

Manipulating of environmental conditions

A process can be used which mimics the conditions in the wild, but allows timing to be chosen and brood fish to be selected. This can produce 5-11 fingerlings per m^2 by the following method:

- the process starts 2 weeks before the new moon.
- a pond is left empty over at least a 7 day period of strong sunlight - to sterilise it, and kill off parasites - and is then partially filled.
- ripening females (check by redness and fullness of belly - see earlier), and males of the same or smaller size and are stocked early in the day e.g. ~ 0700 h (waste fish are fed for at least a week).
- the pond is filled completely in the evening with an application of about 50 kg dry cattle manure, 25 kg sun-baked red laterite soil, and 25 ml of phosphoric acid per 100 m^2.

- the same treatment is repeated every day for 3 days when the pond is topped up. The first filling is always done one week before new moon.
- the fish should start spawning during the new moon period.

Hormone manipulation

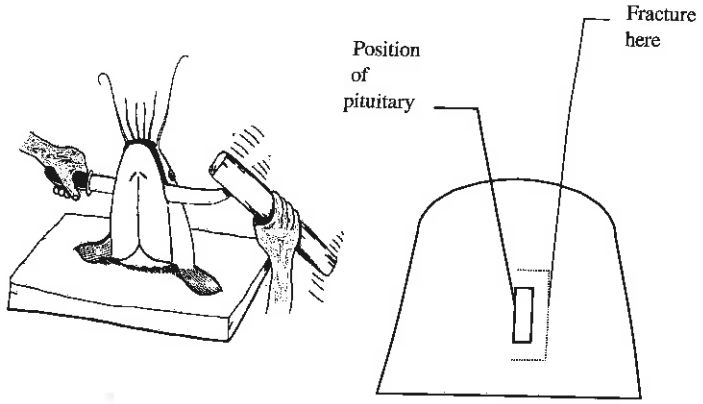
Spawning can also be stimulated artificially; various chemical preparations are available to induce spawning, but their availability and cost can limit their use in many situations. While it may be possible to purchase materials their use and effectiveness may need to be checked in local conditions. The method described here uses fresh catfish pituitary extracted from mature catfish "donor fish", of similar size to the fish to be spawned. This requires a clean working area, some basic tools, chemicals, storage containers, and simple (e.g. plastic) syringes. The process involves the following steps.

- extraction of pituitary gland from donor fish; donor catfish can be killed rapidly by holding firmly and cutting through the spinal cord just behind the bony head plate using a sharp knife (Figure 5.7). The lower jaw can then be removed revealing a rectangular bony capsule in the center of the underside of the upper jaw, beneath a thin membrane.
- this capsule must be carefully fractured or cut away on 3 sides and gently prised open to reveal, in the center of the underlying tissue, a small white pituitary gland.
- the gland can be used immediately or may be stored in pure (absolute) alcohol or dried after desiccating in acetone. Stored pituitaries can be kept in jars or other small containers, labeled to indicate the date of collection and weight of the donor fish.
- preparation for injection; the dose required to induce ovulation is 1 gland from a fish of similar size to the recipient, if taken during the spawning season, and 1.5 glands if taken at another time. Glands can be taken from male or female donors.
- male and female spawner fish receive a single injection, but males receive half the female dose. The pituitary is injected into the fish in a 0.9% salt solution carrier (made by dissolving 9 g of salt in 1 litre of fresh clean water[2]). About 1 ml of this salt solution is required per gland to prepare a homogenate for injection. The homogenate is

[2] This solvent can be stored in sealed bottles if surplus to immediate needs.

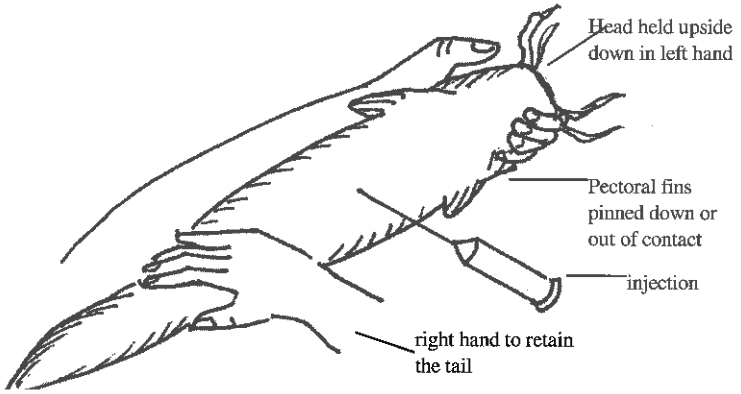
prepared by pounding down the dry pituitary in a dry bowl (or e.g.mortar and pestle), and adding the solution - usually with a simple syringe.

Figure 5.7 Removing the catfish pituitary



- injecting; selected broodfish are removed from holding areas and placed individually into broodstock containers. Where feasible, each container receives a small quantity of flowing water and must be very tightly secured. Small tanks or basins, with heavy and/or securely closable lids or net frames can be used.
- several males and females are spawned at once to improve the chances of successful spawning. Two persons are required to inject fish.
- broodfish are removed from the holding container one at a time, using a hand net. The net with the fish is placed on a nearby table with a wetted surface and the eyes covered with a damp cloth. Firmly but gently the thumb and index finger of the left hand are used to turn the fish's head so it is lying on its back, and the fish's body, held between the arm and the table, holding away pectoral fins and their sharp spines. The right hand is used to prevent the tail of the fish from moving (Figure 5.8).

Figure 5.8 Handling and injecting catfish broodstock



- a second person with the syringe injects the restrained fish. A sharp, short (2-3 cm), wide gauge (0.6-0.7 mm) needle is attached to the syringe. Air is pushed out prior to use by holding the syringe, needle up, and gently pushing out a little liquid. With great care the needle is then eased through the skin of the underside of the fish at an angle of 45 degrees pointing towards the tail. The needle should be only just through the skin, so as not to damage any of the body organs, before gently and slowly pushing down the plunger.
- after injecting, an index finger is placed against the needle and the fish's skin and the needle is gently and slowly removed. The small hole left by the needle is gently massaged and the fish replaced in the holding container.

5.7 Induced spawning of carp

The general principles of induced spring are broadly similar to those for catfish; as with catfish, there are two major options, which are described below.

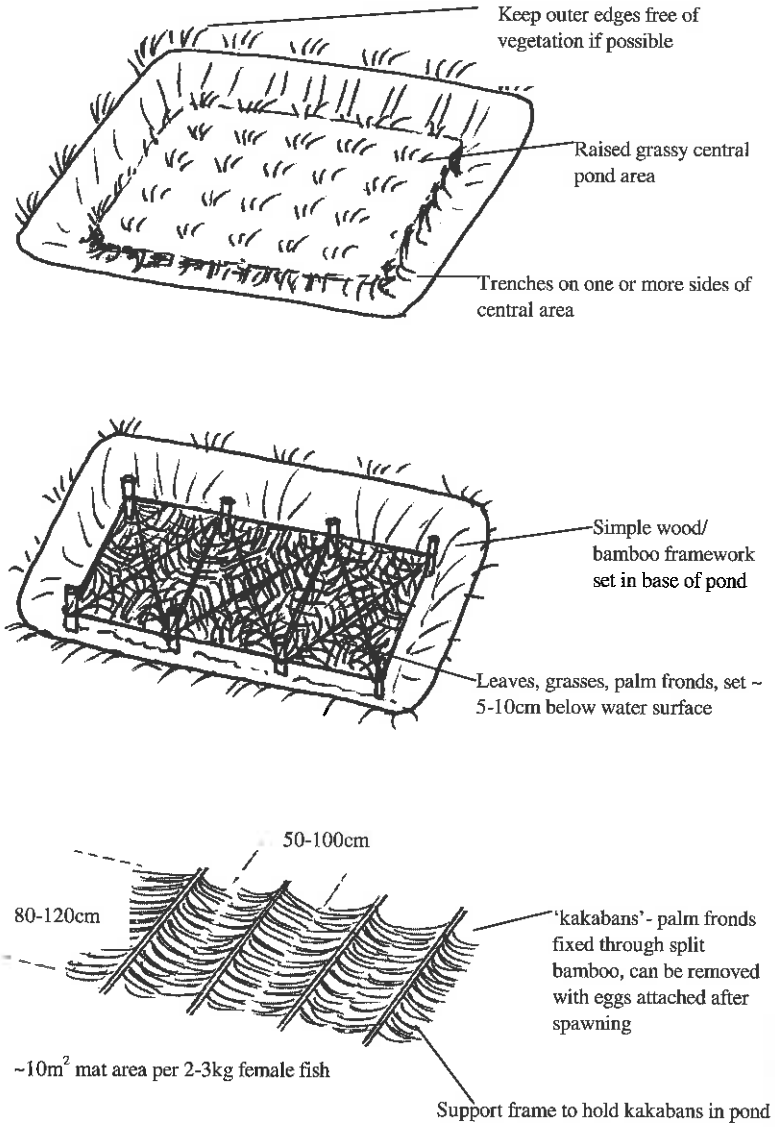
Manipulating environmental conditions

Common carp can also be induced to spawn by manipulating

environmental conditions, as follows:

- select good quality males and females and stock them in separate ponds or tanks. A spawning pond containing egg collectors will be necessary; this pond may be around 50-200 m^2, 0.5-1 m deep.
- egg collectors can be made from a variety of local materials. Bamboo poles and oil palm fibres are commonly used The aim is to provide a good area of material on which the sticky carp eggs can be attached. The oil palm fibres are combed with a wire brush, the bamboo is split in half lengthways and rough edges are smoothed. The fibres are arranged between two split bamboo pieces which are then pinched together with nails. The egg collectors rest on trestles made from bamboo poles (or similar) so that the collectors rest 2 cm below the surface of the pond when filled. Of the types of leafy or fibrous material can also be used, provided they do not release toxic materials into the water. (Figure 5.9):
- place the carp in the spawning pond at sunset. For every 1 kg female put 2-4 males with a corresponding total weight of 1 kg. Each 1 kg female requires four egg collectors. A 50 m^2 pond might contain 20 collectors and 5 breeding sets of carp.
- Common carp spawn during the hours of darkness. Early in the morning if the collectors contain eggs, transfer these to previously prepared nursery ponds for hatching.

Figure 5.9 Egg collectors for carp spawning



Hormone manipulation

Induced spawning of common carp by manipulating the hypothalamic-pituitary-ovarian axis (see Figure 5.5, earlier).

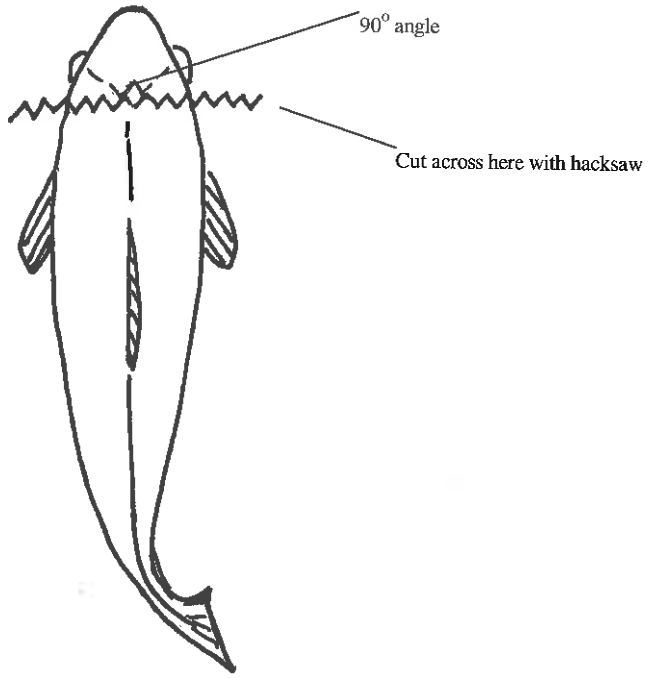
Various chemical preparations are available to induce spawning but their availability and cost can limit their usefulness in many situations. The method described here uses fresh carp pituitary extracted from mature carp of similar size to the fish to be spawned.

- extraction of pituitary gland from donor fish; where possible, pituitaries should be collected from mature, freshly killed fish. Hold the head of a freshly killed carp firmly in a vertical position. Select a position on the head by drawing a line on the head backwards from each of the eyes so that the lines meet forming a 90^0 angle at a mid point on the head posterior to the eyes (Figure 5.10).
- using a hack saw cut through the skull at this point, then carefully remove the underlying brain tissue (including the hypothalamus) lying at the base of the skull and pick out, with a forceps, the pituitary gland. Use or store as for catfish above
- preparation for injection; as for the catfish, the pituitary is injected into the fish in a 0.9% salt solution carrier (made by dissolving 9 g of salt in 1 l of fresh clean water). The pituitary solution is also made in the same way.
- the dose required to induce ovulation is 1 gland (approximately 3 mg) from a fish of 1 kg, per kilogram of recipient fish, if taken during the spawning season and of known origin and quality.
- female fish receive a "priming" injection equivalent to 1/10 the total dose in 1 ml of salt solution followed after 8-10 hours by a second injection, equivalent to 9/10 the total dose in 1.5 ml of solution, with males receiving 2 mg per kg at the time of the second injection.
- thus if the female is 2 kg and the male is 1 kg, the female receives 2 x 3 = 6 mg of pituitary (~ 2 glands) of which ~ 1/10th - 0.6 mg is given in the first injection, 9/10th - 5.4 mg in the second injection stage. The male will receive 2 mg at the second stage (a bit less than 1 gland). However, these amounts can be increased, if handling small amounts is very difficult.
- in areas where there are many hatcheries, people may specialise in collection and storage of pituitary glands. Glands from such sources are often from fish of unknown size and in some cases unknown carp

species. Commercial hatcheries operating under these conditions often use 8-10 mg per kg depending on the weather and time of year (with higher doses used early and late in the spawning season). Females receive 4 mg followed by a second injection of 4 mg after 8 hours. The males receive a single 4 mg dose at the time of the second injection.

- injecting; selected broodfish are removed from broodstock tanks, ponds or enclosures and placed (males and females separately) into hapas in tanks. Several males and females are taken at once to increase chances of successful spawning. Two persons are required to inject fish.
- broodfish are removed from the holding tank by concentrating them in half of the hapa and lifting them out one at a time using a hand net. The net with fish is placed on a nearby table with a wetted surface and the eyes are covered with a damp cloth. Firmly but gently the fish is rotated on to its back. The right hand is used to prevent the tail end of the fish from moving.
- a second person with the dosed syringe injects the restrained fish. A sharp, short (2-3 cm), wide gauge (0.6-0.7 mm) needle is attached to the syringe. Air is pushed out prior to use by holding the syringe, needle up, and gently pushing out a little liquid. With great care the needle is eased through the skin of the underside of the fish at an angle of 45 degrees pointing towards the tail. The needle should be only just through the skin, after injection, an index finger is placed against the needle and the fish's skin, and the needle is removed.
- the fish is then replaced into the vacant half of the hapa. At the time of the second injection the genital opening of the female should be sutured (stitched up) with strong cotton thread or monofilament nylon. This will prevent egg loss prior to stripping.

Figure 5.10 Removing the carp pituitary



CHAPTER 6

EGG INCUBATION AND HATCHING

6.1 Introduction

This chapter deals with the collection and intensive rearing of eggs in a hatchery. The previous section has dealt with the process commonly referred to as 'induction of spawning' i.e. the stimulation of the fourth and final phase of the development of oocytes in the fish ovary (Box 6.1).

Box 6.1 Oocyte development phases:

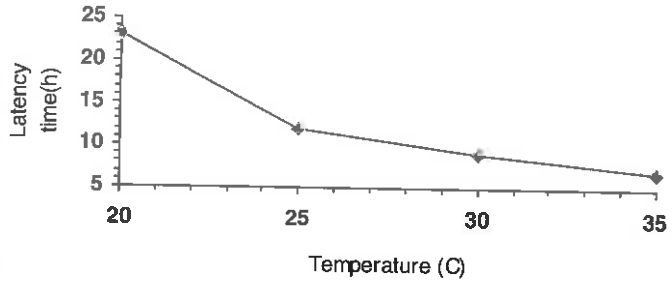
1. Initial growth of oocytes
2. Oocytes develop vesicles to store yolk to nourish the hatchlings, in their early life
3. The yolky substances are accumulated in the liver of the mother fish and transferred to the oocytes via the fish blood
4. When yolky eggs are present they can be induced to mature, which is accompanied by the uptake of water which causes them to swell and then ovulate
5. Ovulated eggs are expelled naturally or can be stripped.

The following sections consider the process from ovulation through to hatching in carp and catfish as well as artificial incubation and hatching of tilapia eggs. The practical aspects of egg incubation and hatching of the three species are dealt with separately.

6.2 African catfish

Several female and male catfish need to be held individually in secure containers after injection and prior to stripping. The period between injecting fish and stripping eggs, when maturation and ovulation take place, is commonly referred to as the latency period. The most important determinant of its length is the temperature of the water (see Figure 6.1). The sum of the hourly water temperatures over the latency period for African catfish is usually at least 300-360 degree-hrs, e.g. 25°C x 12-14+ hrs, or 30°C x 10-12hrs.

Figure 6.1 The time between injection with pituitary extract and stripping of African catfish in relation to temperature



Source: Haylor, unpublished

Stripping

Male catfish cannot be reliably stripped of milt, and so the testes are removed from a mature male and stored in a refrigerator (normally ~ 4°C) until the female is stripped. The testes can be removed by carefully slitting open the belly of the fish forwards from the genital area. Storage is possible in this form for 24 h. As the male is sacrificed, the pituitary can also be removed and stored for use in induced spawning - (see previous chapter). A small sample of milt can be tested for motility (i.e. activity and hence effectiveness) if a microscope is available (see Box 6.2). Motility is not a guarantee of viability, however, but if swimming activity cannot be activated another source of milt should be sought. When the approximate time has elapsed following injection of the fish (see Figure 6.1), the females are removed one at a time and held as before with the head covered with a damp cloth. If eggs run freely from the genital opening the female is ready for stripping. No force should be required. If eggs do not run freely the female should be returned to her container and checked every half hour.

Box 6.2 Observing motility of catfish milt

- A tiny drop of milt is squeezed from a small incision at the edge of the testes onto a microscope slide and covered with a cover slip.
- The slide is irrigated with a little water and sperm motility is observed at x 400 magnification.
- Swimming activity continues for about 30 seconds after activation.

Two people are required to strip the female. The head, covered by a damp cloth, is held gently but firmly in one hand. The thumb and index finger hold the pectoral fins (with spines) against the fish's body. The other hand is free to apply gentle pressure to the belly of the fish in order to help out the last of the eggs. This can be done by gentle stroking movements from the belly towards the tail, first on one side and then the other. The second person gently restrains the tail, without gripping tightly or bending it, whilst ensuring that the eggs fall gently into a dry bowl held in the other hand.

Excessive rubbing along the underside of the fish will cause its protective skin slime to be removed and may result in the female becoming infected, e.g. with fungus. The whole process should be completed as quickly and quietly as possible, away from direct sunlight. The female is then returned to her container where she can recover until she resumes feeding and can be released into a broodstock tank or pond.

Several drops of the creamy milt are now added to the eggs in their dry bowl, from the testes, which are cut along their edge and squeezed between dry fingers and thumb. The bowl is then gently swirled to mix the eggs and milt and a little water is added (about half the volume of the egg mass) from the source of water which is used to feed the incubation equipment. Water is added down the inside of the bowl causing gentle movement of the eggs and activating fertilisation. After 45 seconds to one minute, no further fertilisation can take place as the sperm are no longer motile. The egg bowl can now be filled to the top with more water, which together with the excess milt is tipped away. This process is repeated until the washing water runs clear and no milt remains around the eggs. The eggs of African catfish become sticky between 1 and 4 minutes after contact with water, depending to some extent on the temperature. The eggs must be washed and/or placed into the incubation system before they become sticky (see later).

Egg incubation

Like those of other catfish, the eggs of *Clarias gariepinus* are fairly large (~ 1.5 mm diameter). The eggs become sticky shortly after they come into contact with water. This stickiness can be removed by washing the eggs in a urea/salt solution or by continuous stirring in a full cream milk powder mixture (see Box 6.3).

Box 6.3 Dealing with sticky eggs

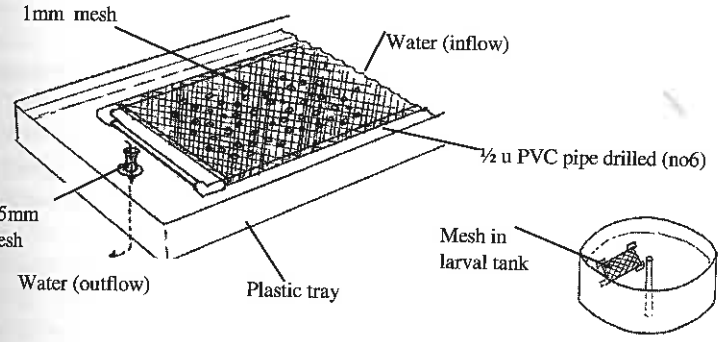
1. Urea/salt solution for removing stickiness of eggs
   mix 3 g of urea + 4 g of NaCl in 1 litre of water
   wash eggs for 45 minutes in this solution

2 Milk-powder for reducing stickiness of eggs
   mix 15–25 g milk powder/litre water and immerse eggs at a milk:egg ratio of 20:1 stirring continually for 35-40 minutes

Following either of these treatments the eggs can be placed in hatching systems, in which they will be held until they hatch. At this stage they are called yolk-sac fry or larvae, as the yolk sac from which they were nourished while in the egg is still attached, and continues to provide the food for further growth. As the yolk sac is absorbed, so the fry become dependent on external food, and this is usually the stage at which they need to be removed to a different system.

One way of holding the new eggs is to incubate them in funnels or in jars in which water rises upwards through the egg mass (Figure 6.2). However, the use of these systems requires additional expense in time, labour and chemicals and is not without risk of mechanical or chemical damage to the eggs. If water flow reduces or stops during incubation, the eggs may sink and stick together, which is potentially damaging. A funnel of 10 litres volume would typically need ~ 1 litre/min of water flow.

Figure 6.2 Systems for rearing catfish eggs



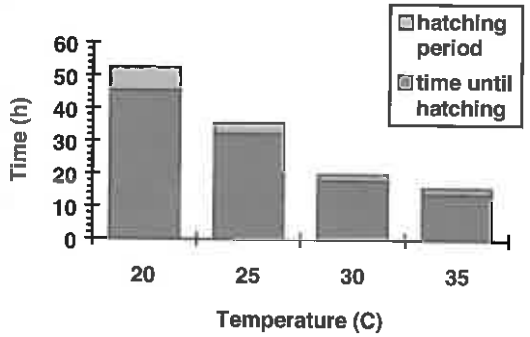
A more efficient method is to distribute the fertilised eggs in a single layer on a horizontal 1 mm mesh screen (such as nylon mosquito netting) set inside a suitable tank, fitted with a lid. Eggs should be placed ~ 1 to 4 minutes following contact with water (see above). Tank lids should then be closed to exclude light and only raised occasionally to check for blocked screens or water flows.

The 1 mm mesh restrains the eggs, which adhere to it, but allows the yolk sac larvae to pass through. If the mesh is suspended in water a few centimetres above the base of the tray or trough, then following hatching the hatched larvae seek shelter beneath the mesh, which at the end of the hatching period can be removed. The outflow end of the tanks or trough should be screened to prevent the young larvae from being swept out. This simplified approach is particularly useful for *Clarias gariepinus* which are reported to be much more sensitive to disinfection and prophylactic treatment than, for example, carp.

The optimum temperature for egg incubation is between 27-30°C, but eggs can be incubated successfully from 17-35°C, especially where incubation temperature closely matches the ambient temperature from which the female is taken. Water should be as clean as possible and the temperature should not be allowed to vary too rapidly during incubation. The oxygen requirement of the eggs is quite low, as is the release of wastes into the water. Low flow rates which do not disturb the eggs are therefore preferable. Actual flow rates will depend on the incubation container used - as an approximate guide, 4-5 litres/minute is needed for every kg of eggs, where 1 kg of eggs requires ~ 2-3 litres volume, or around 1-2 m^2 of trough area.

The time taken for the eggs to hatch is very variable, and is principally affected by temperature, as well as other conditions such as the pH* of the water, oxygen levels, and egg size. Hatching has been recorded between 18 and 57 hours after spawning in hatcheries throughout Africa. Figure 6.3 shows the effect of temperature on the time until hatching and the hatching period.

Figure 6.3 The effect of temperature on the time until hatching and the hatching period of African catfish



Source: Haylor and Mollah (1994)

Apart from periodically checking on temperature, water flows and the general operation of the system, the main activity at this time is in keeping the fine screens over the outflow as clean as possible to prevent overflows. This is especially important during hatching. The hatching period (the time between the onset of hatching and the point at which no further hatching takes place) is also affected by temperature. The cooler the water temperature, within the viable range, the longer it takes for the eggs to hatch. Hatching continues over 7 hours at 20°C but is complete within 2 hours at temperatures over 30°C.

On hatching, the larvae immediately seek shelter, dropping through the 1 mm mesh and resting beneath. Dead eggs, egg cases and the common fungus (*Saprolegnia*) that rapidly grows on them (see Chapter 9) remain attached to the screens which should then be removed. These should be cleaned disinfected if possible (see later) and stored dry.

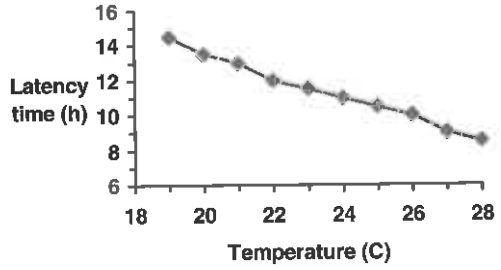
6.3 Carp

Several females and males need to be held individually in tanks or covered hapas for stripping. In contrast with African catfish, common carp spawn spontaneously after ovulation and immediately scatter their eggs, which in natural conditions or semi-natural spawning (see earlier), adhere to vegetation or spawning mats. If eggs are to be incubated in jar type

incubators in the hatchery, scattering must be avoided, so that the eggs can be stripped and the stickiness removed. To prevent this, as mentioned earlier, the genital pore can be sutured at the time of the second injection.

The sum of the hourly water temperatures during the latency period for carp should reach 240-260^{0}C. As with catfish, the most important determinant of the length of the latency period is the temperature of the water (see Figure 6.4). After the latency period, the females are tested in the water for ripeness. Timing is important because carp eggs rapidly become over-ripe (within 50-80 minutes), when they can no longer be fertilised. The female is ready for stripping if the belly is very soft.

Figure 6.4 The time between injection with pituitary extract and stripping of common carp in relation to temperature



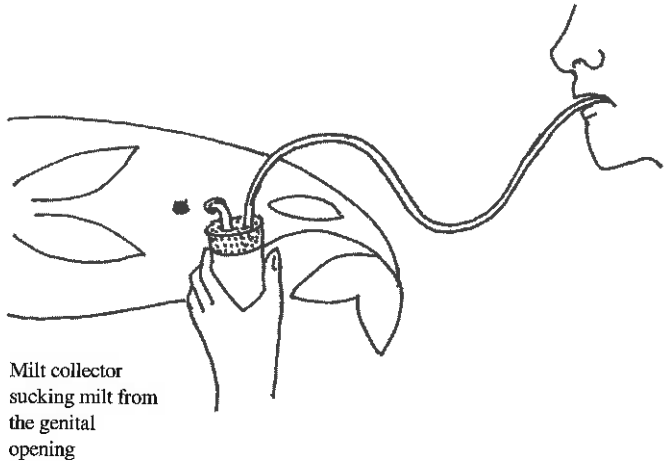
Source FAO, 1985

Two people are required to strip the female. The part of the body around the vent is dried and the suture of the genital opening is cut and the thread gently removed. Whilst the pore is held closed with a finger, the fish, in a damp cloth, is secured by the tail area, usually in the left hand, whilst the right hand cradles and gently massages the soft belly of the fish from the pelvic fins to the vent. No force should be required. The second person ensures that the eggs fall gently into a dry bowl.

Larger fish can be stripped by two people, by lying the fish near to the edge of a softened, moist surface and stripping into a bowl held below the genital pore. Spawned females are returned to a recovery hapa or tank until they resume feeding, when they can be returned to a pond.

The male is ready for stripping 6 hours after the injection of pituitary extract. Again, the part of the body around the vent is dried and milt collected in a small dry plastic or glass tube, (preferably with a screw top), by applying gentle pressure to the belly. Milt can also be sucked into a milt collector from the genital opening. A 4 kg male might produce about 20 ml of milt (see Figure 6.5).

Figure 6.5 Direct collection of milt from carp



If scales are available, the dry eggs are weighed and milt is added in the ratio of 1:100 (e.g. 10 ml of milt to 1 kg of eggs). Milt from several males should be added to each batch of eggs. Fertilising solution (20 litre water mixed with 60 g salt and 80 g urea) is added to the eggs and milt, which are gently but thoroughly mixed and then left in the solution for 90 minutes before rinsing in fresh water and treating with milk (see Box 6.2).

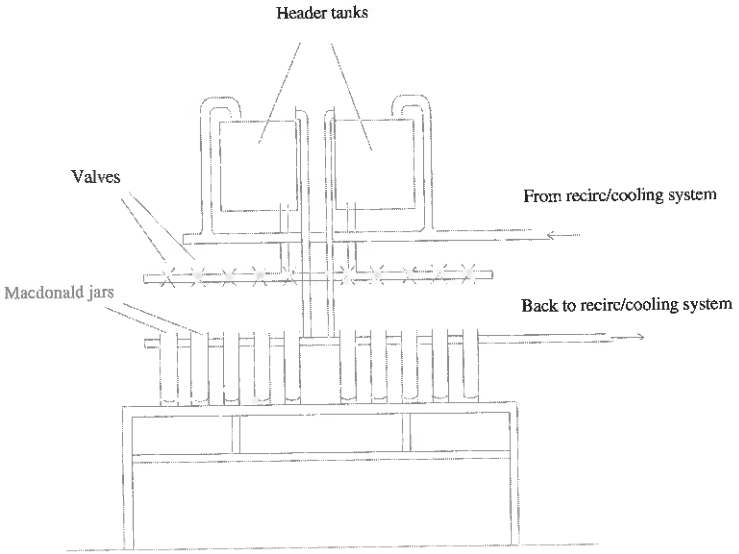
Egg incubation

Carp eggs are normally raised and hatched in glass or plastic incubation jars (Macdonald jars). The size of jars varies from 7 l to 750 l accommodating from several hundred kg of eggs. Water from a borehole or other suitable source (after passing through a slow sand filter) enters the jar from the bottom, passes over a supporting mesh then washes through

the eggs to overflow through a fine mesh at the top.

Several such jars can be set on a simple stand or table, all supplied from a single water source. Flow rates need not be high but should keep the eggs moving.

Figure 6.6 Egg incubation systems for carp

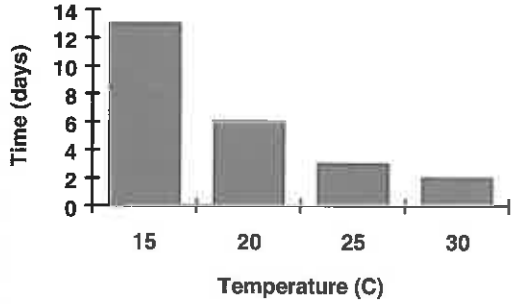


Flow rates of around 0.2-0.3 l pm for a 10 l jar, in the initial stages can be gradually increased to 0.5-1 l pm by the time the body shape of the young fish can be detected within the egg[1]. When the eyes and pigmentation of the embryos are visible flow can again be increased by 20-30%. An adequate water supply can also be judged by the slowly revolving eggs. The optimum temperature for incubation of carp eggs is from 22-26°C but eggs can be incubated from 15 to 30°C, especially if incubation temperature closely matches the ambient temperature from which the female is drawn. The time taken for the eggs to hatch is again principally

[1] * Technically , the closing of the blastopore; the head and the long spine/tail of the fish can be seen under a microscope, coiled all around the yolk mass in the egg.

affected by temperature (see Figure 6.7).

Figure 6.7 The effect of temperature on the time until hatching of common carp



Source: FAO (1985)

The emergence of the first free swimming larvae signifies the onset of hatching. At this stage the eggs can be transferred into bowls of static water in order to facilitate rapid hatching. The level of dissolved oxygen in static water will gradually fall stimulating the embryos to swim free of the egg cases, this process should be monitored to avoid asphyxiation and would not normally exceed 10 minutes.

6.4 Tilapia

Though induced spawning is possible with tilapias using various hormone-related chemicals, the feasibility of these more complex and labour intensive techniques is questionable for a species producing so few eggs. Stripping tilapia also appears to substantially delay subsequent spawning, thus reducing broodstock productivity and opportunities for synchronisation.

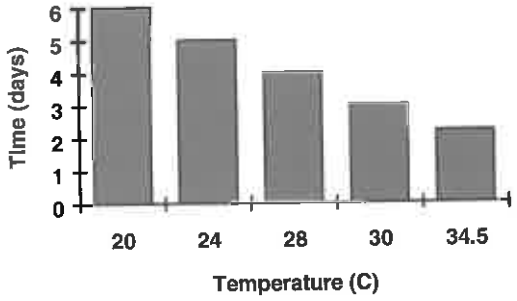
The method for spawning tilapia on a large scale as outlined in the previous section is therefore usually most practical. Females and males are stocked separately and at high density for 10 days to condition (inhibiting spawning), followed by 5 days at low density and a 1:1 sex ratio in a

spawning hapa. This appears to promote early and synchronised spawning without causing any deterioration in egg quality (see Chapter 5). Large (120 m^2) hapas stocked in this way with conditioned fish (360 females and 360 males) can maintain seed yields of 350 seed/female/day for 200 days. This is equivalent to 3-4 kg of seed collected after each 5 day period. The next section deals with incubation and hatching of the collected seed.

Artificial incubation and hatching

As with other species, the time taken for eggs of tilapia to hatch is strongly affected by temperature. Hatching in *Oreochromis niloticus* has been recorded at between 17 and 35°C. Figure 6.8 shows the effect of temperature on the time until hatching in *O. niloticus*. In practice, seed is collected after 5 days in spawning hapas (see Chapter 5). The buccal (mouth) cavity of each fish is checked for eggs or yolksac larvae, which are removed by washing the seed from the mouth into the fine mesh net. Individual seed clutches can be held in plastic bowls for inspection prior to artificial incubation.

Figure 6.8 The effect of temperature on the time until hatching of tilapia (*O.niloticus*)



Adapted from Muir and Roberts (1988)

Four people can collect 4 kg of spawn from a large hapa of 120 m^2 in a single morning. The eggs are then removed to the hatchery for incubation.

Artificial incubation of eggs and fry is more productive than natural spawning (i.e. producing greater numbers and weight of fry per unit

weight of female tilapia broodstock). This is partly because females from which eggs have been collected are ready to spawn more quickly than naturally incubating females. The average period between spawning is ~ 15 days with artificial incubation, compared to 37-40 days with natural incubation. Survival of fry during artificial incubation can also be greater.

For artificial incubation a clean water supply is required. This can be provided using a slow sand filter, which is easily constructed and maintained (see Chapter 4 earlier). The preferred temperature is 25-32°C, ideally 28°C. A single large incubation jar, 20 cm in diameter and 30 cm high (volume 20 litres) requires around 8-9 lpm. This can incubate 1.4 kg of eggs (~ 300,000) which hatch after 3-4 days at 28°C. Smaller jars (e.g. up-ended plastic bottles) can also be used, with approximately similar flowrate: volume (~ 0.5 lpm per litre of egg volume). In practice the upwelling water should be sufficient to keep the eggs and then hatchlings moving and circulating slowly; the motion of eggs and yolksac fish in the female tilapias mouth during mouth brooding. Although the exact period depends upon temperature, hatched tilapia tend to sink downwards and show little swimming activity for about 5 days after hatching. During this period, dead eggs and egg cases tend to float out of the jar in the current. Another 2 days of initial swimming motions are usually required before the fish should be moved into the next stage of the incubation process.

CHAPTER 7

EARLY REARING

7.1 Introduction

Rearing the early stages of fish in a hatchery offers the opportunity to exclude predators and competitors, to manipulate environmental conditions and to provide sufficient feed easily. Survival is often more consistent for hatchery reared stock, and is typically in the region of 80% for experienced operators. Though newly hatched fry can be released directly into ponds, this is often associated with heavy losses and unpredictable survival, and so although facilities and other resources needed for hatchery management of fry rearing may be a little more expensive, the cost can be well justified.

This chapter considers the early rearing of African catfish, common carp and tilapia after hatching. The objective with controlled early rearing is to maximise growth and survival of the young stock within the financial and environmental means of the hatchery. The maximum growth rate for any fish is related to the growth potential passed from its parents, within the overall genetic potential of its species. This will be related to species selection and broodstock management (see earlier). Important external factors also limit maximum growth, particularly temperature and feeding, so these aspects are given special attention.

As mentioned in Chapter 3, the quantity and quality of available water is fundamental to successful production, especially during early rearing. Temperature is most important because it is difficult and expensive to manipulate, yet exerts a major effect on growth and survival. It is therefore especially useful for producers to be able to predict the effect of temperature on the growth and development of their stock. This can be done using the concept of effective degree days (see Box 7.1).

7.2 Determining early development

The early rearing phase of culture is the stage at which feeding is first introduced. The largest part of early rearing costs is often accounted for by feeding, and its effect upon survival, growth and health of stock is central.

First feeding is an important stage for hatchery reared stock, and requires skill and judgement to do well. Once feeding starts, there are many important factors in managing feeding to meet production targets including, the duration of feeding, individual meal size, the time between meals and interactions between these. The scope for growth, health and the nature of social interactions in the cultured stock are dependent on feeding conditions, and also on factors such as stocking density.

Box 7.1 Effective degree-days

As temperature has such a profound effect on development, the concept of *degree days* is widely used as a guide to the time required between different stages. This is simply the number of days times the temperature. Thus 15 days at 28°C = 420 degree days. Although the number of degree days needed to reach a particular development stage was originally thought to be independent of temperature, it has commonly been found to decrease as temperature rises. For species with a wide thermal range, such as these, it is therefore not so useful. However, an alternative can be used, which can apply over the range of temperatures in which catfish, carp and tilapia can be grown. This measure, *effective degree-days,* takes into account the threshold temperature below which development can not take place (approximately the lower lethal temperature of the species). The number of *effective degree-days* to a particular development stage does not vary greatly with temperature.

- Hence: time to a development stage = $D^0_{eff} / (t - t_0)$, where:
t = water temperature (°C) t_0 = threshold temperature (°C)
African catfish t_0 = 11.1; common carp t_0 = 14.5; tilapia (*O.niloticus*) t_0 = 12.7

- The values of D^0_{eff} = effective degree days, for these species are:
African catfish: hatching = 13, first feeding = 26.3, yolksac absorption = 35.7
Tilapia (*O.niloticus*): hatching = 54; first feed = 83; yolksac absorption = 208
Common carp: hatching = 30,

- Example: considering time until hatching in African catfish at 30°C
D^0_{eff} = 13, t_0 = 14.5 ; therefore time until hatching = 13 /(30 - 14.5)
= 0.84 days or 20 h (see Figure 6.2)

Source: Haylor and Mollah, 1994, Muir and Roberts, 1988, Kamler, 1992

It is important with each species to be able to recognise the different stages of development of fry, to ensure that appropriate management measures are taken, and that needs of stock are properly met. It is important that farm records and protocols are clear with regard to provision, stocking and production, and that purchasers are aware of the stage and quality of the stocks they buy. Working definitions of different life stages for aquaculture need to be practical and easily identified, Box 7.2 is provided as a guide.

Box 7.2 A guide to early development stages of African catfish

- *Embryo stage*: following fertilisation, early development takes place inside the spherical membrane of the egg. African catfish eggs are about 1.5 mm in diameter and usually green. The egg stage lasts between 18 and 57 hours depending on conditions. The embryo receives its food entirely from yolk for a further 48 to 96 hours after hatching.

- *Larval stage*: following the successful introduction of feeding, the developing catfish is referred to as a larva. During this period growth is very rapid and many developments take place. The larva develops a stomach and the digestive system begins to work. The body becomes darker and the fins become fully formed. Finally, the larva develops and begins to use special organs in its gill chamber that enable it to breathe air gulped from just above the surface of the water. The larva usually weighs 2.5 mg at first feeding and about 50 mg at the beginning of air breathing. The larval period lasts between 14 and 42 days depending on conditions.

- *Fry stage*: the fry is a small fish which resembles the form of the adult. It is easily distinguished by its periodic trips to the water surface when it releases 2 bubbles of air from its gill chamber and gulps in some more. It is possible at this stage to set out the fry into ponds for on-growing. The fry stage lasts from the beginning of air breathing up to 50 mm or 600-1,000 mg.

- *Fingerling stage*: small African catfish between 1 g and 5 g are referred to as fingerlings.

The effect of temperature on the development of the different life stages of African catfish is described as follows (Table 7.1), which is based on the concept of effective degree days and a further relationship to predict the time from yolksac to first air breathing. If conditions and resources permit, it is advisable to rear catfish in controlled conditions until they can breath

atmospheric oxygen. This ensures that fish are robust enough to withstand transportation, frees them from concerns about dissolved oxygen level when stocked into ponds and ensures that they are able to escape predation from many of the aquatic insects and larvae which are encountered in ponds. The next sections consider key issues in controlled hatchery production of African catfish up to the end of the larval period.

Table 7.1 Influence of temperature on early development of African catfish

Temperature ^{0} C	20	22	24	26	28	30	32	34	35
Time (hrs)* to:(phase)									
Hatching - (embryo)	56.5	41.5	33	27	23	20	18	16	15
First feeding - (larva)	115	84	66.5	55	47	41	36	32.5	31
Yolksac absorption	156	114	90	74.5	63.5	55	49	44	42
Time in days to:									
Air breathing ** (fry)	35	26	23	20	17	15	14	12.5	12

* to the nearest 30 minutes, ** days until air breathing = 5710 x (temperature) $^{-1.74}$
Source: Haylor and Mollah, 1994, Haylor and Oyegunwa, 1993

7.3 Fry management after hatching

Egg incubation and hatching have been described earlier, together with details of the basic facilities required. Following hatching, the embryos are more active and seek shelter, particularly moving away from light. The remains of the yolk which has nourished them in the egg is now in the form of a sac under the tiny needle-like body of the hatched embryo. Within a short period of time, this sac will be absorbed into the body of the fry, as it uses up remaining nutrients, after which it must feed externally.

Basic husbandry

Apart from periodically checking temperature, water quality and flow rate, and general operation of the culture system, the main activity at this time is keeping the fine screens over the outflow as clean as possible to prevent the jars or tanks from overflowing, and the stock spilling out. Meshes of around 500 µm (0.5 mm) meshes are required to prevent the embryos from escaping, but these can block up quite quickly. A small stiff brush is useful

at this stage (one per tank) for cleaning the screens. If an air blower is available an airline can be run to the outflow screens so that air bubbles continually scour the screen. This maintains a clear passage for the outflowing water and also discourages embryos from collecting around the outflow and becoming caught in the screen.

Water flows at this time are a compromise between providing sufficient dissolved oxygen to the developing fish, whilst not causing them to use up valuable energy, swimming against the current or be washed into the outflow. The most appropriate flow rate can be determined by practice and will vary with the design of the holding facility. Embryos are too delicate to be moved at this stage, but will grow and develop very rapidly in the troughs or jars in which they were hatched. A size difference between individuals may be noticeable as the fish grow and the stock should be monitored for any signs of cannibalism (see further). As far as possible, undeveloped, dead, damaged or unhealthy looking fry should be removed, e.g. using a simple suction tube or siphon.

First feeding

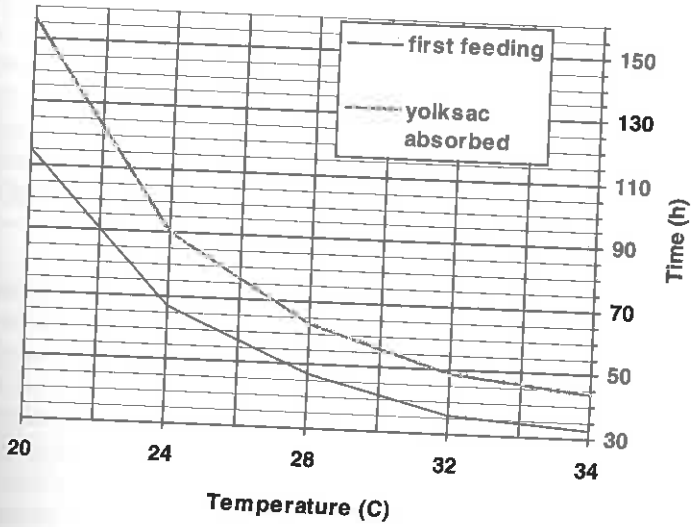
The timing of first feeding is very important. If feed is offered too early, the fish's digestive tract may be still poorly developed and as a result become damaged or blocked whilst uneaten feed will cause the water quality to deteriorate. On the other hand, if feed is offered too late the fish will begin hunting for food and may prey on other fry. Cannibal fish tend to grow very rapidly, will eat other fry and can very quickly cause a large reduction in the population. Any very large larvae developing at this time should be caught and removed to another tank.

If fish completely use up their yolk reserves before feed is available to them, they will loose the capacity to forage and die. This stage is sometimes described as the 'point of no return' (PNR). The onset of feeding should therefore fall after the beginning of foraging behaviour but before complete yolksac absorption. A guide to the timing of first feeding is given in Figure 7.1.

The window of opportunity, during which feeding can be established, begins earlier and becomes smaller as temperature increases. For example, at 20^{0}C the time between the onset of foraging behaviour and the point of no return is over 40 hours, beginning late on the fourth day after

fertilisation, whereas at 34^{0}C this period is less than 12 hours, beginning early on the second day after fertilisation.

Figure 7.1 Timing of first feeding of African catfish in relation to temperature



Adapted from Haylor and Mollah, 1994

To use this graph: select the temperature of the water. Follow the line up until it crosses:

1. the first feeding line - read off the number of hours after hatching,
2. the yolksac absorbed line - read off the number of hours after hatching.
3. first feeding should be timed between the two lines. See also Figure 7.3.

Example: at 28°C, first feeding ~46 hours after hatching; yolksac absorbed ~63 hours after hatching, first feed might be applied ~ 50-55 hours after hatching.

Larval feeding

Young fish grow very rapidly and their feed requirements are best met by feeding them regularly, until they show no further feeding response, i.e. fed to satiation. When feeding to satiation, the feed should be added in small quantities until the larvae no longer respond to further feed. This usually takes 30-35minutes. The larvae can consume up to 50% of their body weight in a single meal. During the first 6 days of feeding, food particles can actually be seen in the gut of the larvae, which is still quite transparent. If a binocular microscope is available this is a good way to check feed intake. After this time, the fish start to become more darkly pigmented on the underside, and the best evidence of digestion is the presence in the holding facility of tiny faecal (waste) particles. Excess feed and faeces can be siphoned from the tank following feeding, as cleaning prior to feeding tends to reduce appetite. Faecal and other wastes should be removed with minimal disturbance of the fish.

To maximise feed intake and growth of larval African catfish, attention must be paid to adjusting the amount of feed offered and the time between meals. Feeding to satiation involves fish eating until their stomach is full. The quantity that larval catfish can consume increases rapidly over the first few days of feeding, after which it becomes a constant of around 21% of their body weight. After the larval period, as the fish grow, their feed intake gradually decreases as they get larger. Because appetite is related to stomach emptiness the time between meals is important. Feed intake is maximised by frequent feeding (e.g. every hour) over 24 hours. However, this requires automatic feeding equipment or 24 hour staffing of the hatchery, either which may be difficult. If feeding is only possible over 12 hours daily, maximum intake tends to be reduced by about 20%. The effect of feeding schedule on the feed intake of African catfish larvae (fed the brine shrimp *Artemia* at 30^{0}C) has been calculated, and is shown in table 7.2.

When feeding 12 hours daily, the first ration of the day should be larger than subsequent rations. As an approximate guide the first feed would be around 40-50% of the total daily ration, with the later feeds divided equally. Table 7.3 provides further details.

Table 7.2 Estimated maximum food* intake (% bodyweight/day) for African catfish larvae at 30°C, relative to feeding schedule and fish size.

Feed interval (hours)	Feeds/ day	Larval weight mg						
		5	10	20	30	40	50	60
24h schedule								
1	24	36.6	43.9	47.6	48.8	49.4	49.8	50.0
2	12	34.7	41.6	45.1	46.2	46.8	47.1	47.4
4	6	30.6	37.6	40.8	41.8	42.3	42.6	42.9
6	4	28.5	34.2	37.1	38.0	38.5	38.8	39.0
12	2	21.8	26.1	28.3	29.0	29.4	29.6	29.7
12h* schedule								
1	13**	29.1	34.9	37.8	38.8	39.3	39.6	39.8
2	7	28.2	33.8	36.7	37.6	38.1	38.4	38.5
4	4	26.6	31.9	34.5	35.4	35.8	36.1	36.3
6	3	25.1	30.1	32.6	33.4	33.8	34.1	34.2
12	2	21.8	26.1	28.3	29.0	29.4	29.6	29.7

* food normally fed during daylight hours

** assuming fish are fed at the beginning and the end of the 12 hour period.

Table 7.3 Percentage of daily feed as first and subsequent rations.

Feeding Interval	First ration (% daily ration)	No of subseq-uent rations	Subseq't ration (% daily ration)
1	37	12	5.25
2	38	6	10.33
4	41	3	19.67
6	43	2	28.5
12	50	1	50

Feed types and formulations

The larval feeds used for primary nursing of African catfish are listed in Appendix I.1. African catfish larvae can be reared with either live or

prepared feeds from the beginning of feeding. Growth and survival over the first few days is improved if live feed is offered, but this is usually quite complicated to set up. Even if feeding is set up with live feeds, in the longer term, the space, time and cost involved usually favours replacement with prepared diets. Live feeds such as zooplankton, especially rotifers, are a good first feed, as are the eggs of a small brine shrimp *Artemia,* collected from salt pans and widely available in 1 kg tins as dehydrated resistant cysts which can be stored for long periods of time. These encysted brine shrimp eggs must be rehydrated and decysted and can be fed as eggs or hatched into free swimming nauplii[1]. Catfish do not require their first feeds to be moving and respond well to decysted but unhatched *Artemia,* which contain more nutrients than hatched *Artemia.* The preparation of these feeds is outlined in Appendices I.2 and I.3. If artificial diets are prepared for the larvae they must be formulated from a range of available ingredients to satisfy nutritional requirements. Diet formulation is the subject of Appendix I.4. The quantity of *Artemia* required for catfish rearing is estimated in Box 7.3.

Weaning

In practice, larval feeding can be carried out most successfully with a live feed (such as *Artemia* or rotifers) for the first four days of feeding, followed by four days of weaning onto a prepared feed, ground and sieved to the same particle size as the *Artemia* cysts or rotifers (150-250 µm, i.e. 0.15 -0.25 mm). For example, the weaning regime in Table 7.4 has been used with success.

[1] early young stage shrimp

Box 7.3 The quantity of decysted unhatched *Artemia* required for larval African catfish rearing

Day of Feeding	Weight of fish	Feed required (mg)	Number of *Artemia*
1	4.32	1.58	84
2	5.5	2.01	106
3	6.99	3.07	163
4	8.88	3.90	207
5	11.29	4.96	263

Total over 5 days per larva 823 *Artemia*

Assumptions: one dry *Artemia* cyst weighs 4.6×10^{-6} g (0.0043 mg); one hydrated, decysted *Artemia* weighs 0.0189 mg.

Larval growth is given by $W_t = 0.34\ e^{0.24t}$ for the larval period

Maximum intake of: 5 mg larvae = 36.6 % body weight
10 mg larvae = 43.9 % body weight

Therefore each 500 g tin of cysts: contains over 108 million cysts, which is sufficient to feed 130,000 larvae for the first 5 days of feeding

Figure 7.2 A guide to the change between larval weight gain and production per unit volume in relation to initial stocking density

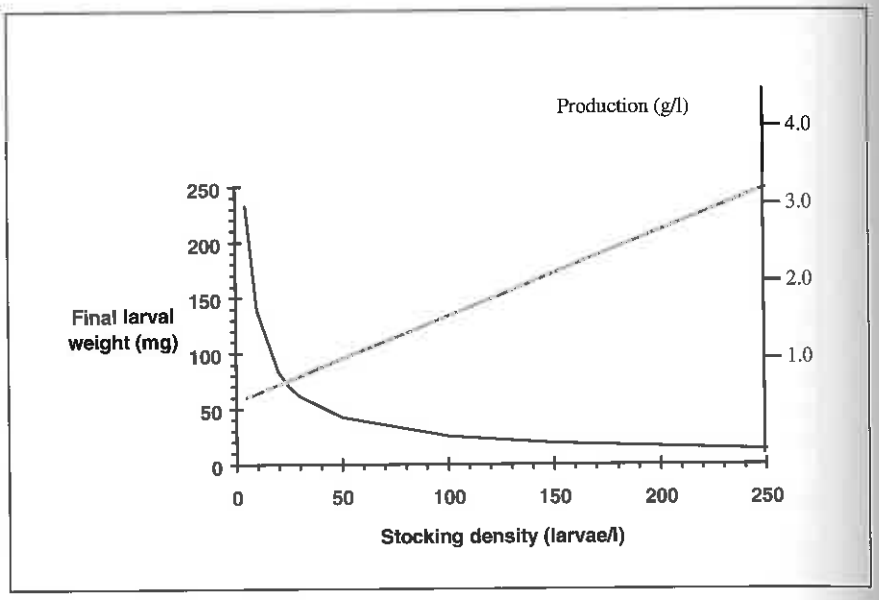


Figure 7.2 can be used for selecting stocking density, by selecting a target weight for the end of the larval period, and using the equivalent production per unit volume. Therefore if the target final weight is 100 mg, around 20 larvae/litre would be stocked, and for 40 mg final weight, 50 larvae/litre would be stocked. Alternatively, desired production per unit volume can be selected and the expected final larval weight read off from the graph. In either case, the total output can then be estimated by multiplying the stocking rate by the rearing volume available and taking account of expected mortality. Thus if the total rearing volume = 2 m^3 (2,000 litres), 40 larvae/litre are stocked, and survival = 30%, the expected production would be 2,000 x 40 x 30/100 = 24,000. As shown in Box 7.4, these figures may have to be adjusted if average oxygen levels are less than fully saturated, as the capacity of the system will be reduced by the lower oxygen levels.

Box 7.4 Adjusting production for oxygen levels - using ΔO

- Figure 7.2 is based on water which is fully saturated with oxygen. If oxygen levels are reduced, the stocking levels should also be reduced. This is not directly related to the oxygen saturation level – e.g. 50% of stocking at 50% saturation, but should be based on the difference between the actual oxygen level and the minimum acceptable level for the stock - sometimes called ΔO.

- Therefore, if the minimum acceptable level is 3.5 mg/l and the saturation level (100% saturated) is 8.5 mg/l, ΔO = 8.5-3.5 mg/l = 5.0 mg/l. If the water is only 80% saturated, the available oxygen level is 8.5 mg/l x 80/100 = 6.8 mg/l, and so ΔO = 6.8-3.5 mg/l = 3.3 mg/l.

- The weight of stock that can be supported is proportional to the ΔO value, and so if 500 g of fry can be produced when ΔO = 5.0 mg/l, the amount that can be produced when ΔO = 3.3 mg/l = 500 x 3.3/5.0 = 330 g.

As well as growth, the density at which the larvae are stocked will affect the water quality, the fish's behaviour, e.g. aggressive encounters and cannibalism, and the chance and spread of disease (see further). Densely stocked larvae require more flowing water to accommodate their oxygen requirements and to carry away wastes. Depending on the system design, this can generate currents against which the larvae are forced to swim (expending energy and reducing their scope for growth).

Optimal flow rates for larvae should supply sufficient dissolved oxygen and flush away wastes, but should not require the larvae to swim against the current generated. The current velocity which different flow rates generate depends on tank design. Circular tanks with a central drain have a tangential (rotating) flow pattern which if properly set up promotes even and well dispersed conditions with uniform water quality, and good distribution of the larvae and their feeds. Even with a limited water exchange the swirling water pattern can maintain good tank cleaning. The current velocity within tanks for a given type and orientation of inflow will depend particularly on factors such as the flow rate, the tank diameter to depth ratio, the position within the tank. For a given circular tank a theoretical maximum flow rate and biomass of larvae can be estimated for a given mean larval size. Box 7.5 provides some further details. At the end

of the larval period, once air breathing begins, the flow rate can be simply set to a level which does not require active swimming.

Box 7.5 Circular tank design and water flow

The following equations were generated from practical trials to relate the maximum tank flow rate (Qmax), and hence the typical velocities with the swimming speed of larvae of various sizes. This is done for shallow (diameter to depth ratio>10, e.g. >10 m wide for a 1 m tank) and deep (diameter to depth ratio<10) circular tanks.

Shallow tanks: Q max (*l*/min) = 3.25 $W^{0.28}$(mg) - 7.41
Deep tanks: Q max (*l*/min) = 0.48 $W^{0.28}$(mg) - 1.12

The table below gives the predicted maximum flow rates and biomasses for different types of circular tanks(14 m diameter), for different fish weights(@30°C.

Type of tank	Fish wt mg	0_2 cons mg/kg/h	Qmax l/min	Max biomass* kg
'Deep' (dia:depth<10)	20	1537	< 0	-
	30	1388	0.124	0.014
	50	1222	0.315	0.04
'Shallow' (dia:depth>10)	20	1537	0.109	0.011
	30	1388	1.01	0.114
	50	1222	2.31	0.29
Average (dia:depth=10)	20	1537	1.25	0.126
	30	1388	1.45	0.16
	50	1222	1.75	0.22

For rectangular tanks, the question of flow velocities is usually a little more simple, but this also depends on the features of the tank. In general, a longer, narrow and shallow tank (e.g. with a length:breadth:depth ratio of 6:<2:<1), such as a raceway or a trough has a more uniform flow pattern than a short, wide and deep tank, which is more likely to have uneven flow distribution, eddies, and low-flow areas, or 'dead spots'. Generally, where inlets and outlets are at each end of the tank, flows are highest along the centre and the surface of the water, and decrease towards the sides and the

base of the tank. As shown in Box 7.6, assuming reasonably uniform flow - which should usually be the aim, the average velocities can be estimated from the flow rate and the tank dimensions. The same method can be used to determine the maximum acceptable flow rate for fry of a given size within a specific tank.

Box 7.6 Velocities in rectangular tanks

- The average velocity (v) of water flowing evenly along a rectangular tank can be calculated from the flow rate, Q (e.g. litres/min) and the cross-section (CSA) of the tank (i.e. breadth x depth). Thus, v = Q/CSA. This can be compared with the swimming speed of the fry to ensure that velocities are acceptable.
- Therefore if the flow rate (Q) is 10 litres/min (0.01 m^3/min), the depth 0.2 m and the breadth 0.3 m, CSA = 0.2 x 0.3 = 0.06 m^2, and the velocity will be Q/CSA = 0.01/0.06 = 0.166 m/min, or 16.6 cm/minute.
- Though this is the average velocity, a less uniform flow may involve surface flows of 2-3 times this velocity, and side or base flows of 10-30% of these levels. It is important to take this into account - which can be done by looking at the way the water actually flows in the tank.

Finally, the size and position of tank outlet screens should be considered. If these are too small and the screen mesh is too fine, there can be continuing problems with clogging, and more importantly, high velocities near the screen may pull in and trap young larvae, particularly if they are in slightly poor condition. The velocity of water through screen can be calculated from the flow rate, Q and the actual open area in the screens, as shown in Box 7.7. If the velocities are too high it will be necessary either to reduce the flow rate, or to increase the open area for the screen - e.g. to use larger holes, or to increase the overall screen size.

At high density, the close proximity between individuals increases the incidence of cannibalism, although there is some evidence that high stocking density decreases territorial aggression. The potential for the transmission of disease is also increased by high stocking density (see Chapter 9).

Box 7.7 Screen velocities

- The velocity of water flowing through a screen can be estimated from v = Q/OSA, where Q = flow rate, e.g. litres/min, and OSA = the open surface area of the screen. OSA is less than CSA, the overall cross section area, i.e. screen height x width, and depends on the size of holes in the screen and their spacing. As the screen blocks – e.g. with wastes, debris, the OSA will reduce.
- OSA can be calculated either from suppliers technical data, or by using a %age of the CSA, e.g. 10-30% for a fine-mesh screen, or as much as 60-70% for an open, larger mesh screen.
- Thus, if Q = 50 l/min (0.05 m^3/min), and the screen is 40 cm(0.4 m) high x 60 cm (0.6 m) wide, and OSA = 30% of CSA, OSA = 0.4 x 0.6 x 30% = 0.072 m2, and the velocity through the screen = Q/OSA = 0.05/0.072 = 0.69 m/min.

7.4 Tilapia

The management of tilapia in spawning hapas is dealt with earlier, as is the initial stage in the incubation process, the incubation and hatching of eggs. This section considers the second stage, the early rearing of tilapia.

Unlike African catfish or common carp, mouth brooding tilapias (e.g. *Oreochromis niloticus*) do not pass through a larval stage and already possess well developed fins and a large mouth at first feeding. Their development is effected by temperature, as described in Table 7.4 and Figure 7.3. The table was generated using the concept of effective degree days described earlier using data from a range of sources.

Table 7.4 The influence of temperature on the early development of *O. niloticus*

Temperature ^{0} C	**20**	**24**	**28**	**30**	**34.5**
Time (h) to:					
Hatching	178	115	85	75	60
First feeding		176	130	115	
Yolksac absorption		442	326	289	

Seed management after hatching

The following protocols are now well developed as the basis for commercial scale tilapia seed production. The size of the facilities can be adjusted for local conditions, but the general principles - stocking density, water flows, operation times, etc should be observed.

Five to six days after hatching at 28^{0}C, the fry become more buoyant and more motile, associated with the inflation of the fish's swim bladder[1]. This so called swim up phase, which will vary with temperature, is the point at which fry are transferred to shallow 0.08 m^2 rectangular trays (e.g. 0.4 long x 0.2 m wide), at a density of 15,000 per tray for a further 4 days rearing. Filtered water enters down the long side of the tray, creating a gentle circular motion which causes the fry to constantly roll over one another in the centre, mimicking the churning action in the mother's buccal cavity during natural incubation. Systems which do not move or turn the fry may result in lower survival. Water leaves via screened holes in the side of the tray after a short period of time.

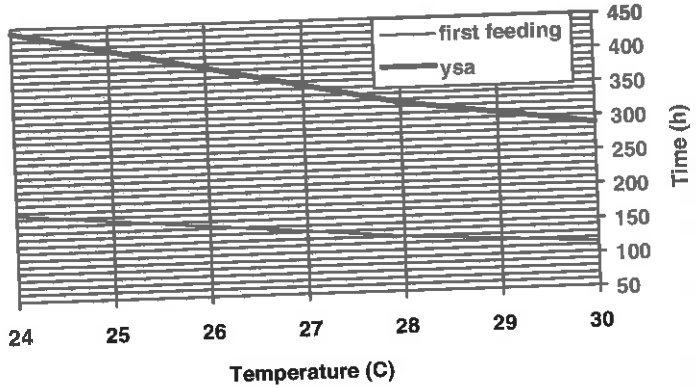
First feeding

For first feeding the fry can be transferred to 5.4 m^2 (3.6 x 1.8 m) hapas in tanks or earthen ponds. Each hapa can accommodate 30,000 larvae, equivalent to about 12 larvae/l of rearing container. As with other fish the

[1] For most fry, the swim bladder, a gas filled organ which acts as a buoyancy regulator, develops in the early stages. The young fish may need to gulp air at the surface to fill the bladder. If this is restricted, due e.g. to physical damage, poor nutrition, or poor tank surface conditions, the fish may not develop properly and may not survive.

timing of first feeding is important and should fall between the onset of foraging ability and the so called point of no return when fish are no longer capable of taking feed. A guide to the timing of first feeding is given in Figure 7.3.

Figure 7.3 Timing of first feeding of mouth-brooding tilapias (*O. niloticus)* in relation to temperature



[First feeding should be timed to fit between the two lines]

The window of opportunity during which feeding can be established is much broader than for the carp and catfish, but as before begins earlier and becomes smaller as temperature increases. For example at 24^{0}C the time between the onset of foraging behaviour and the point of no return is 266 hours, beginning around 7 days after hatching, where as at 30^{0}C this period is 174 hours, beginning late on day 4 after hatching.

Fry feeding

Unlike African catfish or common carp, tilapia do not require a live first feed. A good quality prepared feed which stimulates a good appetite, ground and sieved to the right particle size (starting at 250 µm), should be provided frequently, usually 5 times daily, to fry stocked at 12 fry/l in hapas in tanks or ponds. It is important that fry feeds are made and stored correctly, to ensure that they do not spoil. Damage created due to bad

feeding at this stage may be impossible to correct later. Any food which appears discoloured, smells stale or rancid, or has been attacked by worms or weevils should be discarded. If it is intended to control the problem of precocious, prolific breeding during the on-growing phase of tilapia culture, it is necessary to stock fish of one sex, normally the faster growing male. This is usually achieved through sex reversal (Box 7.8).

Box 7.8 Sex reversed tilapia seed

- One of the most cost effective and most simply managed techniques for sex reversal of tilapia seed is to administer feed containing 17 alpha methyl testosterone (MT) for 21 days from first feeding.

- If used properly, this standard technique can reliably produce over 99 % functional males and will effectively control breeding in ponds as the fish mature. MT treated fish also have a faster individual growth rate. In SE Asia, where the technique is now being used commercially, MT treated seed retails at approximately 5 times the price of untreated seed. Producers favour the MT fish because unwanted breeding in ponds is much reduced, the variation in final yield is reduced, and more fish are produced of a larger size, with better prices.

The preparation of a methyl-testosterone (MT) treated first feed for tilapia is described in Appendix I.5. MT usually has to be imported from specialist suppliers, but can be stored until use. An alternative to using MT (which can be problematic if it involves ordering from overseas and acquiring foreign exchange) is to use local ingredients such as ram testis as a protein source, as well as a source of male hormone for sex reversal. Although not at the commercial stage, the technique has been investigated under field conditions in Nigeria and also in controlled conditions in Scotland and appears to share the sex reversing characteristics of the MT diet as well as promoting good growth. The preparation of the ram testis diet is described in Appendix I.6.

7.5 Common carp

The spawning, egg incubation and hatching of common carp has been described in previous sections. As with African catfish, the different

developmental stages need to be defined and easily identified. Box 7.9 is provided as a guide for common carp.

Box 7.9 A guide to early development stages of common carp

Embryo stage: following fertilisation, early development takes place inside the spherical membrane of the egg. Carp eggs are about 0.6-1.2 mm in diameter. The egg stage lasts between 48 and 312 hours depending on conditions. The embryo receives its food entirely from yolk for up to 144 hours after hatching.

Larval stage: although the classical definition of the larval period commences with the transition to external feeding, the description commonly covers the last two embryonic stages (1&2) and the first larval stage (3). Initially, hatchlings attach themselves to the container wall (1); after 1-2 days they begin free swimming (2) and after several more days, gulp air from the water surface, fill their swim bladder and assume a horizontal swimming position. This stage (3) coincides with the development of a functional digestive system when the fish become true larvae and begin first feeding. Fin differentiation is complete at about 12 mm and live weight of 15 mg.

Fry stage: the term fry usually describes a carp weighing at least 100 mg where coloration is complete and scale formation well advanced. Fry can be up to 2-3 g.

Seed management after hatching

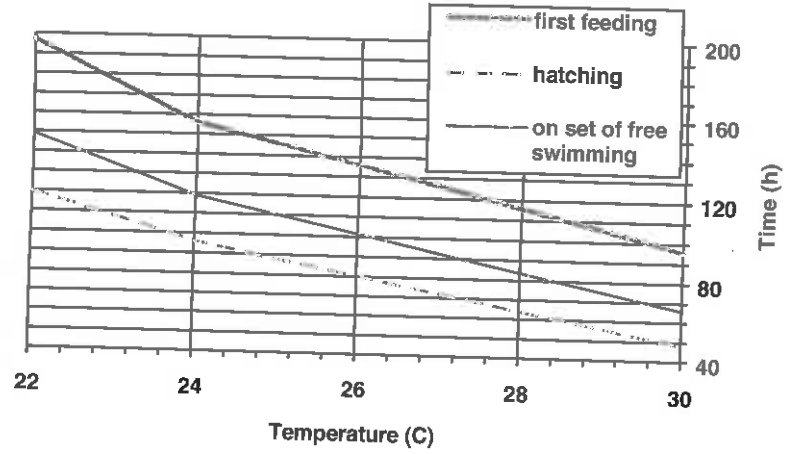
After hatching, carp attach themselves vertically to the wall of their container for several days. As with other developmental stages the exact duration depends on temperature. Carp are considerably affected by viscosity[2] effects of the water during the first days after hatching, which increases the energetic cost of swimming. The early swimming activity appears uncoordinated with fish orientated at an angle to the horizontal. Apart from periodically checking of temperature, water flows and general operation of the culture system, the main activity at this time is keeping the fine screens over the outflow as clean as possible to prevent overflows.

[2] Resistance to flow (e.g. stickiness) of water. As water warms up its viscosity decreases, and it flows more easily.

First feeding

Figure 7.4 can be used in a similar way to these used for catfish and tilapia, but it does not include the timing of the yolksac absorption or PNR for carp larvae, as there is insufficient data. Instead, the graph shows hatching time, the time at which the larvae became free swimming, and the time at which larvae are usually fully feeding.

Figure 7.4 The timing of the onset of hatching, free swimming and first feeding in relation to temperature



Source: FAO, 1985; Koputakha Fish Hatchery (pers. Comm.); Mohsin Masters Hatchery (Pers. Comm.)

As the development of the digestive system ties in with the so called 'swim up' phase, when the fish gulp air and fill their swim bladder, the associated change in swimming behaviour (to a horizontal co-ordinated movement) is a useful indicator of the best time to begin feeding.

Larval feeding

Although technology is improving with artificial feeds, live first feeds are still needed for carp. Technically, *Artemia* have many advantages because live feed can be produced on demand from dormant cysts. In practice

decysted, unhatched *Artemia* are an excellent feed for up to two weeks from first feeding and are preferred to hatched *Artemia*. In addition, cyst requirements can be reduced, and cheaper strains with poorer hatchability can be used, provided they have sufficient nutritional quality. The preparation of these feeds is outlined in appendices I.2 and I.3. If artificial diets are prepared, they must be formulated from a range of available ingredients to satisfy nutritional requirements. Diet formulation is the subject of Appendix I.4.

At temperatures close to the middle of their optimal range carp larvae require 200-250% of their body weight of *Artemia* nauplii each day, over the first 5 days of feeding in order to achieve maximum growth, reducing to 100-120% over the subsequent five days. Five days feeding with nauplii is the minimum amount of time required before adaptation to an artificial diet is possible without impaired growth or weight loss. By using decapsulated cysts as a direct food source for carp larvae, instead of nauplii, the quantity of cysts needed can be reduced by about 25-35%. From Box 7.10 it can be seen that one 500 g tin of *Artemia* cysts is sufficient to feed 50,000 larvae for the first five days of feeding, after which they can be weaned onto a prepared feed. Weaning should not begin until the fish reach about 10 mg. To ensure a smooth transition onto a prepared feed weaning can be conducted as for African catfish, see Table 7.4. Frequent feeding is recommended, the larvae should be fed at least 5-6 times daily with cysts or nauplii. *Artemia* nauplii will survive 3-4 hours in fresh water.

Stocking density

Little has been published regarding controlled production of common carp after the swim up stage. Table 7.5 is drawn from information supplied by several hatcheries producing common carp in the tropics and may serve as a guide.

Box 7.10 The quantity of decysted unhatched *Artemia* required for larval carp rearing

Day of feeding	Weight attained (mg)	Feed required (mg)	number of cysts
1	1.65	2.31122	
2	2.12	3.81202	
3	4.48	6.27332	
4	7.39	10.35548	
5	12.18	17.9947	
	2151 cysts/larva		

Assumptions: one *Artemia* cyst weighs 4.6 x 10^{-6}g:one hydrated, decysted *Artemia* weighs 0.0189 g
Feed intake for maximum growth: 200-250% for first five days
Therefore each 500 g tin of cysts contains over 108 million cysts and is sufficient to feed 50,000 larvae for the first 5 days of feeding

Table 7.5 A guide to stocking for controlled production of common carp in hatcheries.

Stage	Stocking density	Notes
Egg incubation	14,000-20,000 eggs per l	7 200 l rearing jars, 8-20 l pm
Yolksac absorption	2,500 hatchlings per l	500,000 per 200 l jar, 20+ l pm
First feeding	500-1 , 000 per l	100-10,000 l troughs, 0.1-0.2 m deep, water flow sufficient to maintain 4.5 mg/l oxygen at outflow.

According to the table, 5 x 7 l egg incubators. will be sufficient to supply 500,000 hatchlings in a 200 l rearing jar. In some cases it may be possible to arrange the rearing containers so that swim up larvae can overflow into rearing troughs.

CHAPTER 8

HANDLING COMMON PROBLEMS

8.1 Introduction

The most common problems which arise during the operation of a hatchery are concerned with four main areas;

- general operation and management;
- water quality;
- behavioural problems (e.g. cannibalism and territoriality);
- disease.

These are all clearly linked with each other, with poor operation and management leading to poor water quality, stress, increased likelihood of behavioural problems and hence, through all of these, greater susceptibility to disease. As far as possible, these problem areas should be thought through before setting up in production, though some problems may always arise unexpectedly, and need to be tackled promptly and thoroughly.

8.2 General operation and management

Careful attention to good husbandry practice is essential to offset common problems and avoid disease. However, certain design features can greatly reduce the incidence of problems and the guidance of the earlier part of the text should be followed. For example, if it is available, and within technical and financial means, the use of borehole water can avoid many of the problems with pollution and disease which can occur with surface supplies. Sand and gravel filtration of hatchery water supplies can greatly reduce the likelihood of many diseases, particularly parasitic infections, as well as providing water of consistent quality, especially in keeping down suspended solids levels. Simple but well built facilities, with sufficient access and working space can make routine operations safe and effective. Routine practices of monitoring the system and the fish, keeping tanks and other facilities clean, and removing dead fish promptly, can be of substantial benefit to good performance.

The introduction into the hatchery of other diseases, notably viruses, should be carefully avoided. There is very little treatment available for virus diseases and their occurrence can be very serious. These and other diseases can enter a farm along with eggs or live fish from wild or other farmed sources. Local wild fish and birds (and their droppings) can carry disease and should be discouraged from entering the holding facilities. Finally, visitors can also be a source of disease and should be discouraged from contacting the water, eggs or fish in the hatchery.

Many routine husbandry operations or management practices involve handling or can induce stress in some way. For example, large numbers of larvae and fry can die if they are handled excessively, roughly, or at the wrong time (such as directly after feeding) or if they are disturbed through other operations. Potential sources of problems include:

- netting, for sampling, grading, catching for sale
- siphoning, e.g. to clean tanks
- grading, to redistribute stocks, and/or selecting for sale
- bathing, e.g. with disease treatment chemicals
- transport, between different parts of the hatchery, or to customers

Obviously most of these operations will have to be carried out at some stage. The important thing is to do these carefully, and with continuing thought for the possible effects on the fish. Other routine areas of management which may lead to stressful conditions can include,

- over-feeding, in general, or in particular conditions, such as during or after handling, or in poor water conditions
- frequent disturbance, through noise, light changes, splashing, violent movement etc
- poor conditions, overcrowding, poor water quality etc
- over stocking, etc, throughout the system, or during handling, or grading etc

Bad handling, poor husbandry and poor tank conditions can therefore lead to longer term stressing of fish, which may make them more susceptible to damage and disease. Management actions should then be carefully considered and carried out. Thus, while holding tanks should be cleaned regularly, an area of the tank should be maintained as a refuge while

cleaning (this area can be cleaned last, after allowing the fish to move to a cleaned area). Cleaning routinely allows the fish the opportunity to become accustomed to the experience. All operations should be carried out with gentle movements, quietly and quickly. Fry appear to be much more robust than larvae and respond well to small amounts of handling, e.g. hand netting, siphoning, sorting, etc. So where possible (e.g. where the larval phase is short) these activities should be postponed until the fry stage.

8.3 Problems in water quality and the fish environment

All three species groups featured in this book tolerate a broad range of environmental fluctuations, as in fact is found in their natural habitat (see earlier). However, if conditions change significantly from the normal ranges, their growth rate and survival will be reduced. While any fluctuations outside normal ranges are undesirable, sudden changes in conditions are more difficult for confined fish to deal with than gradual changes. Some common water quality problems are considered below.

Oxygen and water flows

Oxygen is often the first limiting factor in intensive fish culture. Fish which take up oxygen from the water such as carp or tilapia, (or catfish larvae before they metamorphose into fry and can breathe oxygen from the air) depend entirely on the oxygen dissolved in the water in their culture tank. As the fish use up dissolved oxygen, this must be replaced by incoming oxygenated water as the movement of oxygen through the surface from the air is very limited. As described earlier, fully oxygenated water is said to be 100% saturated; this concentration varies with water temperature. The weight of oxygen and hence supply of water required by the fish depends upon the temperature (which affects the metabolic rate of the fish) and the fish weight (see appendices for details).

Fish gulping at the surface or fish collecting around water inlets are common signs of limited oxygen, which may be due to low water flows. lower than normal incoming levels, excessive feeding, or low atmospheric (barometric) pressure, which can reduce saturation levels. Rapid action is required to restore suitable conditions. Short-term responses would include increasing water supplies (as long as this does not limit supply elsewhere in the hatchery where it may also be needed) and aerating or oxygenating the water. Aeration can be done with a compressed air supply, splashing or

agitating the water. A small air blower operated from a battery or mains electricity can be used. A small water pump can also be used, taking water out of the tank and returning it with as much splashing as possible. Where no other means exists, splashing by hand for a sustained period can increase the dissolved oxygen level.

Bottled oxygen can also be used to supply a simple diffuser (air-stone), but should be used sparingly, as it is expensive, and can be easily wasted. As the oxygen dissolves easily, most of the bubbles from the diffuser should disappear before they reach the surface. If an oxygen bottle is available, it is useful to store it on a stable but mobile trolley so that it can be easily moved from place to place as needed. It is good practice to store a 32 mm spanner on the same mounting to adjust the regulator and to keep to hand a clean, disinfected and washed diffuser. The same assembly can be used for preparing fish for transport (see Chapter 9).

If there are no other means to restore suitable conditions during the problem period, it may be necessary to adjust water, air or oxygen supplies so that the most valuable stocks are protected (depending also on how the different stocks are responding). This decision depends on local circumstances, but generally, broodstock are the most valuable and important, and fry which are just ready for sale are also worth protecting. However, it is not usually a good idea to move the fish, unless absolutely necessary, as the additional handling and stress will increase their oxygen demand and will also make them less likely to withstand the poor conditions.

As soon as the oxygen levels are restored to the water, fish will begin to behave more normally. It is then possible to rectify the problem which has given rise to low oxygen levels. Longer term responses include reduced feeding levels, possibly thinning out and reducing the stock levels, improving the water supply and/or improving the aeration of the water, e.g. by splashing it well as it enters the hatchery. Small aerators can be installed for more regular use, but this can be expensive and may place too great reliance on equipment and power supplies.

The onset of air breathing in catfish can sometimes be associated with a short period of reduced growth rate and a temporary increase in death rate. At this time (about 14 days after first feeding at 30^0C), the catfish, which

tend to seek dark sheltered places, struggle against the increase in buoyancy associated with initial air gulping. The usual activity patterns of the fish, including feeding, can be interrupted and excess feed should not be allowed to build up. The unusual behaviour passes within 24-48 hours.

Temperature

Good growth rates of larvae and fry can be achieved within their optimal ranges (described earlier). At temperatures outside this range, growth is slower and the size variation in the population can be greater, sometimes leading to other problems, such as cannibalism (see further). Temperature also affects the rate of build up of bacteria and fungus in holding tanks, the concentration of oxygen in the water, the uptake of oxygen by the fish, the toxicity of ammonia and the food conversion ratio. While low temperatures may not be too problematic (provided they are within the limits of tolerance) high temperatures may cause more concern. In both low and high temperatures, feed consumption will fall, so it is important to reduce feed rates, to avoid fouling up the holding tanks. Overfeeding at high temperatures is particularly dangerous, as this is often associated with low oxygen levels. This can be a particular problem if fish are fed heavily in the cooler, early part of the day, and water then heats up significantly later.

The rate of change of temperature is also important, and stock are less stressed if change occurs gradually than if these are sudden changes. During periods of raised temperature, particular attention should be paid to oxygen levels, with aeration or oxygenation available for emergencies (i.e. clean and disinfected diffusers available for connection to an air blower, or to an oxygen bottle and regulator). Cleaning frequency may be increased, especially if feathery filaments e.g. of *Myxobacteria* or *Saprolegnia,* (see later) appear in the water and build up around debris. However, stressful activities should be minimised.

Ammonia and pH

A common product of the breakdown of biological materials, particularly protein, is ammonia. Ammonia is the principal excretory product of nitrogen metabolism[1] in fish and will also be released by the bacterial breakdown of excess food, faeces, etc. As earlier noted, ammonia can be very toxic to fish, and this toxicity is affected by the pH. In high pH

[1] i.e. the use of proteins in feed to make the proteins in the fish.

conditions, toxicity is markedly increased. If the pH drops too much – e.g. from sudden rainfall - though ammonia is less toxic, the fish may be affected by dissolved metals. If ammonia concentration reaches a high level, the stocking density of fish can be reduced, flow rates or aeration/oxygenation initiated and greater attention paid to cleaning, level of feeding, etc. The alkalinity of the water should be maintained above 20 mg/l to prevent rapid fluctuations in pH, though most natural surface and ground waters are above this level. If there is a problem with alkalinity (this can usually be checked by an local extensionist or agriculture adviser) the water supply can be 'buffered' by running the water through a filter bed filled with limestone chips – e.g. ½" to ¾" pieces. If possible the bed should be large enough to allow at least 5 minutes contact. Therefore if the flow rate is 50 litres/minute, a bed of 50 x 5 = 250 litres would be needed.

Light levels

Newly hatched larvae are attracted to dark places and always seek shelter. As the fish get older they continue to prefer darkness or near-darkness. Growth rates, though not survival rates, have been shown to decrease in conditions of full lighting. In very well lit (e.g. open, sunny) conditions, light excluding or reducing lids, or an overhead cover should be used. Agricultural "shade" netting can be used if this is available, or palm frond or hessian sacking can also help cut down direct sunlight. Direct sunlight should not be allowed to fall on rearing tanks as the fish will move into the shaded areas, thereby decreasing the effective tank volume available to the fish. As far as possible, hatchery buildings should be located and designed to ensure that this can not happen.

8.4 Behavioural problems

Larvae are difficult to count, and the rate of mortality and its causes can be difficult to determine. However, it has been shown that losses of healthy larvae and fry held in tanks supplied with good quality water are often due to two main causes, both of which are behavioural: cannibalism and territoriality. If uncontrolled, losses from these two sources can severely affect a population. Losses of young fish from such sources is a common problem with a wide range of species including catfish, carp and tilapia, although little documented.

Cannibalism

Hungry fish begin to forage for food. This usually takes the form of active swimming, nose down at an angle to the bottom, in so-called "helicopter mode". It is at this time that cannibalism occurs. In all three species the management of losses due to cannibalism can be controlled by providing adequate food and regulating stocking density. The provision of sufficient feed, at the appropriate interval and of the right size and type is important (see Chapter 7). Appropriate stocking density must also be evaluated; usually this is a compromise, high enough to be productive, and hence cover the investment in rearing facilities, but not so high as to promote an unacceptable loss from cannibalism. The management of cannibalism in hatchery systems has been more closely studied in catfish than the other two species and provides a useful general framework for control. In catfish two forms of cannibalism (Types 1 and 2), can be described (see Box 8.1).

Territoriality

Both larvae and fry exhibit territoriality (the defence of a piece of territory), often after the establishment of a hierarchy of dominance within a population. The territorial behaviour, unlike cannibalistic behaviour, is initiated by an intruder making contact with the ultimate aggressor (defending a territory). Usually this takes the form of head to head contact between two fish within the territory of one (see Box 8.2). The result of territorial encounters depends on the fish, but can include high stress, and losses from disease, wounding or actual mortality.

Box 8.1 Cannibalism in African catfish

Type 1 cannibalism: a foraging fish identifies the tail of another as food. The fish lunges at its prey and holds it firmly in its mouth. The body is consumed and the head bitten off and discarded. The attacking fish may also die in the course of this There are four signs to be aware of, and three potential remedies. Type 1 cannibalism can begin a few days after starting exogenous feeding, e.g. at about 8 mm, and ceases to be significant after the fish have reached 80 mm.

Signs of type 1 cannibalism

- Fish which swim unusually and appear to have two heads
- "Helicopter mode" fish lunging at siblings
- The presence of discarded heads on the tank bottom or on outflow screen
- A dead fish with another in its mouth

Potential remedies

- Increase feed offered by adding more feed, extending the feeding period, or increasing the frequency of feeding
- Remove any fish which are much larger than the rest of the population (these fish are often cannibals, or because of their size can more easily prey on smaller siblings and therefore more likely to begin cannibalism)
- If the fish are robust enough and the stocking density is very high it may help to reduce the number of fish per tank, as this will decrease the chances of foraging fish encountering potential prey (see Territoriality).

Type 2 cannibalism: is characterised by prey being swallowed head first and whole. It begins when the size variation is such that the head of the smallest fish is smaller than the mouth size of the largest. As size variation tends to increase with age, type 2 cannibalism is more common in fry and older fish than in larvae. It is less common than type 1 cannibalism and is encouraged by anything increasing size variation, e.g. uncontrolled type 1 cannibalism.

Signs of type 2 cannibalism

- Aggressive behaviour particularly in bigger fish resulting in consumption of smaller fish
- A sudden and rapid reduction in the size of the population of a tank which has a visible size variation between the fish but no other obvious signs of fish loss, e.g. dead fish, missing screens, open lids, etc.

Potential remedies

- Increase the feeding rate, feeding period and/or feeding frequency
- Sort the population by size using sorting grids or appropriately sized mesh bags and stocking similar size fish together
- If the stocking density is very high it may help to reduce the number of fish

Box 8.2 Territoriality in hatchery reared fish

Signs of territoriality

Three common signs of this form of behaviour are as follows:

- head to head contact resulting in a brief but violent encounter (e.g. for catfish, barbel-biting), followed by a short chase in the general direction of the intruder
- a fish swimming (into the territory of another) followed by a brief chase and some body biting
- the presence of one or two fish dead on the tank bottom, often with obvious wounding (*n.b.* tilapia will pick a carcass clean in a short time; however dead African catfish are not cannibalised but remain distinguishable from discarded heads resulting from Type 1 cannibalism)

Remedies

- if the fish are robust enough and the stocking density quite low, e.g. <50 fry/litre it may help to increase the number of fish per tank. For example, it has been shown that increasing catfish fry stocking density from 50 to 150 fry/litre can significantly reduce territoriality without significantly increasing cannibalism
- providing shelter (e.g. rolls of 4 mm plastic mesh) combined with keeping fry at high density (e.g. above 100 fry/litre) may also benefit. Shelter suppresses cannibalism which is an important cause of mortality at high stocking density. However, at lower density, e.g. <100fry/litre, shelter promotes territorial behaviour (already an important source of death at low stocking density)
- well fed fish tend to be less aggressive. Therefore, as with cannibalism, it may help to improve the feeding rate, feeding period and/or feeding frequency.

8.5 Disease - basic issues

The fish species considered in this book are known to survive adverse environmental conditions well, and so far only minor health problems have been encountered under controlled hatchery conditions. The small amount of information available about disease should not, however, be taken to suggest that there are no problems. Diseases of warm water species of fish have not yet been extensively studied, but are known to have very serious effects if not well managed. Disease can be carried by a number of agents, including fungi, virus, bacteria and parasites. Many of

these are present in the environment, but may only affect stock if they are already weakened or stressed. Some agents may be directly responsible for disease, others are secondary in effect attacking after a fish has been affected by something else. It is important to understand whether problems are created by single agents, or a number of agents, and other factors. Minimising disease in the hatchery is essential and may be summarised as follows:

a) Disease prevention: try to avoid disease problems

- Choice of appropriate culture system
- Maintenance of hygiene practices
- Disturbance or reduction of a link in transmission cycles of infectious diseases
- Taking account of times when a high risk of disease is present.

b) Disease management: if disease does occur, try to reduce its impacts

- Early and accurate disease recognition
- Rapid and appropriate disease treatment.

These are discussed further in the following sections.

8.6 Disease prevention

Choice of appropriate culture system

This has been reviewed in the earlier parts of the manual, which has noted the fundamental points of good layout, sufficient space, volume and water, and good husbandry procedures. It is clear that a good system, with good water quality and a layout which permits easy handling, regular cleaning and routine inspection of stocks will offer particular advantages.

Maintenance of hygiene practices

A basic issue is that hatchery areas should be kept clean - tanks and pipes scrubbed, wastes and slime growths removed from surfaces, tools and nets which are in contact with hatchery water kept clean. Staff should also observe basic hygiene practices, and should seek to avoid cross-contamination from various sources. As a basic principle it is better to assume things are dirty until it is known that they have been cleaned or disinfected. It is also best to have a clearly marked location for cleaned

equipment, such as nets, buckets or brushes.

Regular, systematic disinfection of all hatchery equipment can be achieved quite inexpensively using sodium hypochlorite (NaOCl). Tanks, raceways and containers can be filled completely with the disinfection solution, the overflow blocked and the inflow shut off, so that the tops of the tanks and raceways remain wetted by the disinfection solution for 20 minutes. All equipment used around fish that is not harmed by chlorine can be cleaned and soaked in the solution. A 1-2% solution (i.e. 1-2 parts per 100 parts of water, or 10-20 ml per litre - see Box 8.3) is effective against bacteria, virus, protozoans and fungi. Hypochlorite is corrosive to metal and very toxic to fish, and so thorough washing is necessary after disinfection (toxicity may also be inactivated by adding 2 parts of sodium sulphite per 1 part of chlorine).

Box 8.3 Calculating concentrations

For solid materials, a concentration of 1 in 1,000 (1:1,000) equals 1 g of material in 1,000 ml, or 1 litre of diluting liquid (e.g. water or solvent). Thus 1 in 1,000 = 1 g/litre or 1,000 mg/litre, 1 in 500 = 1 g in 500 ml or 2 g/litre, etc.

For liquids 1:1,000 equals 1 ml in 1 litre, and if density = 1 g/l = 1 mg/litre.

Another option is to use % solution, a 10% solution = 10 g per 100 g or 10 ml per 100 ml, etc. Assuming a density of 1 g/ml for the liquid, 10% solution = 100 mg/litre.

A footbath can also be used at the point of entry to the hatchery. NaOCl baths should be replaced every two days. Storage of equipment in a hypochlorite bath is not advised and prolonged contact with nets should be avoided. Organic material in or on tanks or equipment will greatly reduce the effectiveness of this disinfectant.

Commercial bleaches and disinfectants may also be available. Many of the cheaper materials are simply various formulations including NaOCl, and would be used directly, or diluted according to manufacturers instructions. Other disinfectants which may be available are the various formulations of quaternary ammonia and iodine compounds, with trade-names such as such as FAM and Vanodine. However, these compounds are usually more

expensive. If these are used, follow the manufacturers' instructions. In some cases, if no other disinfectant is available, a simple salt solution may be used - this is usually made much stronger than a bleach solution – e.g. 10% or more. Finally, boiling water or steam can be used to sterilise various articles, though boiling temperatures are not sufficient to ensure complete sterilisation.

It is important to set up appropriate ways to dispose of disinfectants and other materials. These will depend on the site and the situation, but the usual approaches are to dilute and/or neutralise the chemicals involved and to bury or compost organic materials. If possible, the manufacturer's instructions for disposal of chemicals should be followed. Table 8.1 summarises good practice. If there are large, fast flowing rivers nearby, it is quite simple to dispose of the small quantities of material involved. Otherwise it is a good idea to make a 'soak-away' area - a simple filter bed, filled with rocks or chips to allow the liquid materials to slowly drain and dilute. This should be at least 10 times the daily volume of washed out chemicals, allowing for dilution. Therefore, if 10 litres of disinfectant is to be disposed in a day, and is firstly diluted to 200 litres, the filter bed should be 200 x 10 = 2,000 litres, or 2m3. This can be constructed simply by digging out a suitable hole - usually no more than 1 m deep, and filling it with rocks or broken brick or concrete, typically ½" to 4" pieces.

If a soak-away is difficult to construct, and there are no large receiving waters, it may be necessary to disperse liquids over the ground. Try to do this over as large an area as possible - at least 1 m^2 per litre of diluted waste, and do this in areas where there is no risk of contaminating nearby fields or drinking water.

Disturbance of transmission cycles

The control of some infectious diseases in fish (mainly metazoan parasites, see later) can be achieved by the destruction or limiting one or more stages in the infective agent's life cycle. Many parasites require a resting stage, or one or more animal hosts to complete the life cycle. Each stage of development and each host offers an opportunity to disrupt the transmission of a parasite. Appropriate precautions include removal or discouragement of molluscs such as snails or crustaceans (e.g. copepods) or piscivorous birds, preventing contact with soil or simply reducing the stocking density.

High risk times

The outbreak of a disease is caused not only by the presence of fish hosts and the disease agent together, but is the result of an interaction between these and the environment. Hence, there are times when a higher risk of disease exists, and this should be taken into account. This includes periods during which stressful operations have to be carried out, such as tank cleaning, crowding, netting, handling and sorting, each of which also carries the risk of physical damage (and secondary infection). Sudden changes in conditions such as rapid rise or fall in temperature without acclimation or a sudden increase in suspended solids can also be stressful and damaging. These may occur with seasonal rains, when many parasites are adapted for reproduction and dispersal. Other high risk times include transportation, which may follow netting and involve crowding, deterioration in water quality and changes in conditions, and nutrient loading of a system, which may be detrimental both to fish health and the chemical treatment of a disease.

Table 8.1 Disposal of disinfectants and other wastes

Material	Methods of disposal
Hypochlorite solution	Dilute to at least 0.5%, soakaway/disperse
FAM, Vanodine	Dilute to at least 0.5%, soakaway/disperse
Salt solutions	Dilute to at least 1 ppt (1 g/litre), soakaway/disperse
Tank cleanings	Disperse into large streams or if only organic wastes, dig into soils or put into compost heap
Acids, alkalis	Dilute or neutralise, soakaway/disperse
Dead fish	Dig into soils, or put into compost heap; if highly infectious disease problem involved, dig into a disposal pit, with agricultural lime

8.7 Disease management

If a disease outbreak has not been prevented, then its careful management can reduce fish losses. Early and accurate disease diagnosis is important, in order to allow rapid and appropriate treatment. Common signs of health problems include fish swimming near to the surface, loss of appetite, unusually sluggish behaviour, flashing or darting movements, unusual coloration, bulging or opaque eyes, lesions or bleeding, and shortening or loss of barbels. Often the first signs of a problem are unexplained fish deaths.

Living or moribund fish should be examined in order to identify the cause of the problem as soon as signs are noticed (fish that have died are not suitable). Where possible this should be carried out by a fish pathologist or a diagnostic laboratory. Infectious disease agents may be broadly divided into bacteria, viruses and fungi, as well as protozoan and metazoan parasites. A reddish coloured gastrointestinal tract and gut cavity, enlarged spleen and excessive fluid in the gut are general signs of bacterial disease. If bacterial or unknown disease agents are suspected, several live infected fish should be taken to a qualified laboratory for the bacteria to be microscopically identified and professional advice given.

Box 8.4 provides an outline for a routine examination for fish parasites, which are amongst the most common problems for warm water fish hatcheries.

Box 8.4 Routine examination of fish for parasites

1) Whenever possible examine fresh material. Fish should be obtained live, and killed immediately prior to examination. There are several good reasons for this:
   - parasites are more easily recognised and identified
   - parasites especially ectoparasites may leave the host after death
   - collection of blood parasites is nearly impossible after death
   - decomposition starts immediately after death and parasites may be destroyed by the host's enzymes
2) Handle fish as little as possible, to avoid disturbing external parasites.
3) Kill fish by cutting through cranium or through the spinal cord immediately behind the head - don't use anaesthetic, as this may affect parasites.
4) Fish should be kept wet at all times during examination.
5) If the fish is already dead, refrigerate but keep moist. Do not freeze as most small parasites become unrecognisable and only large helminths and crustacea can be recovered. If examination is to be delayed, place the fish, or sample pieces in 10% formal saline (see later) slitting open the body cavity to allow fixative to penetrate internal organs.
6) It is essential to examine skin and gills for ectoparasitic protozoa e.g. flagellates immediately after death as these may die or leave the fish very quickly.

With reasonable skills and equipment, hatchery staff can do much of this

work themselves. Otherwise, materials will have to be collected so that an extensionist or other skilled person can be consulted. The equipment and materials required for examination of fish for parasites and other agents is listed in Box 8.5

For those who have a sufficient knowledge of fish anatomy and basic microscope procedures, Box 8.6 describes the basic procedures and the examination of external conditions on skin and gills, while Box 8.7 describe examination of internal organs. Further information and illustrated descriptions of the techniques used in hatchery diagnosis of fish diseases can be found in Roberts and Shepherd (1997). Although designed for salmonid hatcheries all of the techniques and most of the pathogens and treatments given are closely similar to those applying in the tropical fish hatchery.

Box 8.5 Equipment and materials required for examination of fish for parasites

The instruments required for fish are typical of those used in any dissection. It is useful to have, in addition, a bottle of physiological saline to keep tissues moist, otherwise evaporation can cause the destruction of fragile parasites such as protozoa.

Ideally, a good compound microscope, should be available preferably with an internal light source. Many small protozoan parasites are easier to identify under phase contrast and a microscope with this system should be used if available.

A binocular or dissecting microscope is also necessary as many small worms, cysts, etc are not quite visible to the naked eye. If a binocular microscope is not available a powerful hand lens may be used, though this is not nearly as satisfactory.

Glass slides and coverslips should be spotlessly clean, otherwise details of small parasites will be obscured and identification may be impossible.

Other items of equipment include, a dissecting board, petri dishes, Pasteur pipettes, paper towels, paper tissues, spare scalpel blades.

Ensure all items are prepared before killing the fish as some parasites die very quickly following the death of the fish.

Fixatives where required, can be stored for reasonable periods. Formol saline is made by diluting formalin in the rates 1 part 40% formaldehyde to 9 of clean water. Ideally this should be buffered, if this is not available, alcohol (40% or more) can be used.

Box 8.6 Basic procedures - external examination

Kill fish quickly by cutting through the spinal cord with a sharp scalpel in the region immediately behind the gills. Blood can be collected at this stage from the heart or major vessels using a Pasteur pipette. Place a few drops on a slide and allow to clot. A smear can also be made, fixed in methanol for 10 minutes and stained later.

Examination of skin

- Take scrapings for high power microscope examination (several, if fish is large). Scrape with a sharp scalpel from head to tail and place mucus and epithelial (outer skin) cells on a slide in a drop of water. Avoid scraping off scales as these reduce the visibility of small protozoa. Thin preparations are essential. Spread scrapings thinly, cover with a coverslip and examine under high power. Scrapings should be made along the back of the fish, including head, fins, the area around the anus and from any wounds or sores (lesions) or discoloured areas.
- Examine the entire fish under low power using a binocular microscope. Be sure to examine under fins as well as other areas. Large metazoan parasites such as *Argulus* can be seen in this way.

Examination of gills

- Remove the operculum (gill flap) and examine inside.
- Remove a whole gill and place on a slide or in a petri dish (add water if necessary) and examine under low power with a binocular microscope. Separate the primary lamellae (gill fins) with needles to observe large monogenea and crustacea. Examine any lesions in detail.
- Cut off lamellae to remove the gill arch. Place lamellae on a slide and spread thinly - chop if necessary and cover with coverslip. Examine under high power.

Box 8.7 Examining internal organs

- Make incision along the belly towards the head. Remove the abdominal wall to expose the visceral (internal organs). Examine the visceral surfaces, abdominal cavity and pericardial cavity (i.e. around the heart) carefully under low power using a binocular microscope. Examine any abnormalities or cysts, spots etc in detail under high power.
- Remove the alimentary canal and associated organs by cutting across the oesophagus and around the anus. Divide the alimentary canal into stomach, pyloric caecae, fore-, mid- and hind-intestine, and rectum: note that carp do not have a stomach as such. Examine their surface and scrape contents onto a slide. Examine contents under high power microscope. Compress sections of alimentary canal between slides and examine under high power.
- Dissect and make squash preparations from heart, liver, gall bladder, spleen, kidney, gonads, urinary bladder and swim bladder. Make slide preparation.
- Dissect out eyes and open the nares (nasal passages). Examine under low power and high power for helminths. Squash lens and examine for eye flukes. Dissect out the separate tissues of the eyes carefully to determine the location, as the site is helpful for identifying the parasites.
- Remove skin, and slice the muscle to examine for helminth larvae and protozoan cysts.
- Open the cranial cavity, examine and make smears of the brain tissue.

The most easily identifiable infective agents are parasites, and common examples are considered below.

Protozoan parasites

a. *Costia*

One of the most common ectoparasitic problems in hatcheries is caused by the flagellated protozoan *Costia*. In low numbers these live mutually with young fish deriving part of their sustenance from cell debris from the host. They inhabit skin and gill chambers and can multiply very rapidly. They attack living cells, and thrive when fish are crowded and environmental conditions are bad, e.g. low dissolved oxygen, high ammonia, low pH, etc, and at temperatures between 10-25°C. 30°C is very close to the upper lethal limit of their temperature tolerance.

Table 8.2 Bath treatments for the control of *Costia*

Compound	Dosage and Time	Method of use	Remarks
Acetic acid	1:20 to 1:50 (2 - 5%) for 1 min or less	Dip	May be used daily as needed
Copper sulphate	1:250,000 to 1:1,000,000 (1 - 4 mg/l) for 1 hour 1:500 to 1:2,000 (500 - 2,000 mg/l) for 1 min	Bath or dynamic Dip	Alkalinity of water determines safe concentration to use (seek advice)
Formalin	1:4,000 (250 mg/l) for 1 hour 1:2,500 (400 mg/l) for 10 to 15 min	Bath Dip	Some fish may be sensitive; test a small number of normal fish before use
Furacin	1:250,000 to 1:500,000 (2 - 4 mg/l) for 1 hour	Bath	May not be effective in cold (<12°C) water
Malachite green	1:15,000 (66.7 mg/l) for 10 - 30 seconds 1:200,000 (5 mg/l) for 1hr 1:10,000,000 (0.1 mg/l)	Dip Bath or flowing Continuous	May be used daily May be used daily In ponds
Potassium permanganate	Up to 1:250,000 (up to 4 mg/l) for 1 hour	Dip, bath or flowing	Concentration used depends on organic matter suspended in the water
Quinine hydrochloride	1:50,000 (20 mg/l) indefinitely	Bath	Allow to remain in water; detrimental to aquatic plants
Sodium chloride	1:30 to 1:50 (3-5%), for 1 – 2 min 1:100 (1%) for 20 - 30 min	Dip Dip, bath or flowing	Can be used daily Can be used daily
Temperature	–	–	Raise temperature above 30°C

Costia are quite small; they are about the same size as epithelial cells but move erratically. When moist, freshly prepared skin scrape is examined under the microscope, more than five *Costia* per low power field (x 100) is cause for concern. Extremely high mortalities can occur amongst larvae and fry within a few days if no treatment is carried out, especially if the fish are weakened by poor management. Control depends upon the severity of the problem. (Box 8.2). Light infestation may be controlled by

increasing water flows, reducing stocking density, ensuring the temperature is near or above 30°C and the pH is just above neutral. Severe cases require dip bath or flushing treatments. Refer to Box 8.1 earlier for guidance on concentrations of treatments. A common source of problems is the presence of adult or older fish in the hatchery water supply. High organic loading of culture systems can result in a large build up of *Costia* in association with other organisms, which can be harmful.

b. White spot

This is one of the most prevalent diseases of fish. It is identified by the naked eye by the presence of small (1 mm) white spots in the skin and gills. The life cycle of the parasite (*Ichthyophthirius*) includes a stage encysted on vegetation, a free swimming infective stage and a stage encysted on the fish (the white spots). One mature "egg" can release 250 – 1,000 infective stages! Life cycles within the stain tissue of the fish are almost impossible to remove chemically without harming the fish. Reducing density, removing any plants and particularly increasing water flow for three days are appropriate restrictive measures. Stages of the fish may be controlled by bath treatments (see Table 8.3).

Table 8.3 Bath treatments for the control of white spot

Compound	Dosage and Time	Method of use
Formalin	1:5,000 (200 mg/l) 1:50,000 (20 mg/l)	1 hour bath Continuous for 5 days
Malachite green	1:666,000 (1.5 mg/l)	6 to 24 hour bath
Malachite green plus formalin	1:5,000,000 MG + 1:40,000 formalin (0.2 MG to 25 formalin mg/l)	3 to 5 hour bath on alternate days
Methylene blue	1:1,000,000 (1 mg/l) to 1:333,000 (3 mg/l)	Constant bath for 3 days
Potassium permanganate	1:250,000 (4 mg/l)	30 minutes to 1 hour bath
Quinine hydrochloride	1:50,000 (20 mg/l)	Add to water and leave until decomposed
Sodium chloride	3% (30,000 mg/l)	1 hour bath daily for 7 consecutive days
Temperature	32°C	5 days in aquaria

The treatments detailed above may also be used against the ciliate

ectoparasites *Trichodina* and *Chilodinella* which have been reported to affect the skin of *Clarias*.

Metazoan parasites

Metazoans are larger and should not present a problem in hatcheries especially if the water is filtered. Small flatworms such as *Dactylogyrus* and *Gyrodactylus* are known to infect fish in ponds. Under the microscope they resemble leeches but are about 0.5-1.0 mm long. Infected fish show responses to external irritation. *Dactylogyrus* typically affects the gill, while *Gyrodactylus* has been reported to affect the lower lip of African catfish as well as the skin, gills and elsewhere on other fish. They are not removed by formalin and require the fish to be dipped or bathed in organophosphorous compounds. These compounds may have serious environmental effects in cold water aquaculture situations because they are stable at low temperatures. However, at temperatures above 27°C they breakdown very rapidly. ***They are, however, toxic to humans and must be used with rubber gloves and protective clothing***. A 1% dip for 2-3 minutes is recommended to treat both kinds of flatworm, and a second treatment can be carried out after 5-7 days if necessary.

Two copepod crustaceans - the louse *Argulus* and the 'anchorworm' *Lernea* - as well as another crustacean, *Dolops*, can infest the body, fins and gills of fish. The treatment for all is the same as for the flatworms mentioned above, though more treatments may be required. In ponds 2.5-5.0 mg/*l* baths may be applied.

The small intestine, large intestine, body cavity, urinary bladder, brain cavity and gall bladder of fish may sometimes be infested by other worms (trematodes and cestodes). These, however, occur mainly in larger fish in ponds. They rarely kill fish, and treatment is often impractical. Their numbers may be reduced by discouraging birds and removing molluscs from ponds, and regular drying and liming of ponds. The viscera of fish should be removed before consumption and not fed to other fish.

Waterborne fungus and bacteria

The common aquatic myxobacteria and the fungus *Saprolegnia* should be mentioned. The latter appears as cotton-like threads on dead eggs, egg cases or fish as well as secondarily invading damaged or wounded fish tissues. The former, particularly in static or slow flow-through systems,

appears as a mass of gelatinous fibres in the water.

The fungicide malachite green can be used to treat *Saprolegnia*. Use as a 1-2 mg/*l* bath for one hour (e.g. for eggs), or a 67 mg/*l* dip for 1 minute or as a 1% local swab (for brood fish). Myxobacteria which affect the gills are treated for 1 hour with Chloramine T in a bath at 1 mg/*l* (or 4 mg/*l* in hard water).

All the treatments mentioned should always be applied to clean, aerated water in clean tanks. Only a small number of fish should be treated initially. Fish should be monitored throughout and returned to fresh water if distressed.

Because hatchery rearing of fish in Africa is at an early stage of development most of the treatment protocols mentioned are based on toxicity of treatment chemicals to the organisms involved. Care should always be taken, as the toxicity of the treatment chemicals to young fish is largely unknown.

Diseases of unknown causes

Two serious diseases of unknown cause but probably nutritionally related affect young African catfish. The so-called "ruptured intestine syndrome" develops in fish mostly between 3 and 5 g at high feeding levels and can cause 70% mortalities. Fry or fingerlings stay in a vertical position at the water surface or swim actively with a swollen belly. The intestines become necrotic and intestinal bacteria invade the abdominal wall, producing fluid and gas. The belly often breaks open. During an outbreak, the supply of food should be replaced by fresh food high in minerals and vitamins for a few days. Ailing fish should be removed.

"Broken head disease" affects fish greater than 10 cm and involves the destruction of the air breathing organs. It is therefore not common in hatcheries. It is believed to be associated with lack of vitamin C in the diet in fish at high density. Where water is very muddy very little phytoplankton is available. Normally catfish acquire vitamin C from their prey or from the phytoplankton contained within the intestine of prey. On pelleted or waste feed in muddy ponds little vitamin C is available to them.

Table 8.4 Further compounds for the treatment of fish diseases

Compound	Method	Concentration of active ingredient/time	Use	Comments
Copper sulphate ($CuSO_4$)	Bath Flush Dip	0.2 ppm 'permanent' 0.5 ppm (soft water) up to 2 ppm (hard water) for 30 min 500 ppm 1-2 min	External protozoal, bacterial, fungal infections Crustacea, leeches Algicide, molluscicide	Very toxic to fish, especially in soft water. Toxic to invertebrates in aquaria and bacterial filters. Add acetic acid to same concentration when using in hard water
Potassium permanganate ($KMnO_4$)	Bath	2 ppm 'permanent' (3-4 ppm if high organic loading) 5 ppm for 1 hour or 500 ppm for 5 mins	External protozoa and bacteria	If organic loading is high, may require repeat in 24 hours. Toxic at high pH. Do not mix with formalin.
Chloramine T	Bath Flush or flow	2.5 ppm (soft, pH 8); up to 20 ppm (hard, pH 8) for 1 hour	External bacterial infections (BGD), external protozoans and monogeneans	Do not mix with formalin. Avoid contact with metal. Toxic in soft/low pH water.
Common salt (NaCl)	Baths Baths Short dip	1,000 - 2,000 ppm (0.1 - 0.2%) 'permanent' 3,000 ppm (0.3%) 30 min 1% for 3 days 20,000 ppm (2%) 20-30 mins 30,000 ppm (3%)	Saprolegnia some external protozoa Leeches, Crustacea Argulus External protozoan, e.g. costia Saprolegnia	

CHAPTER 9

TRANSPORT AND DELIVERY

9.1 Introduction

Once the fish have been safely first fed and are well settled in their initial holding and rearing conditions, they will be ready for the next stage in production. In most cases this will simply involve the sale and dispatch of the fry to customers - either farmers producing the fish to market size, or specialist fingerling producers who may part-grow the fry to an intermediate size before selling them on to market producers.

It is important to make sure that stock is healthy and in good condition, as this will establish the reputation of the hatchery and make sure that customers will demand its fish, as they know they can obtain good results from using them. It is also important from the point of view of reducing the risks of spreading disease. Although poor quality, unhealthy fish might be sold, they could contaminate stocks elsewhere, may threaten the customers operations, and could contribute to the overall loss of potential for fish farming. The hatchery operator therefore has a duty - for obvious commercial reasons, as well as in safeguarding fish farming in general - to try to produce good quality and healthy stock.

The use of good transport and delivery methods is obviously very important. In some cases, the hatchery producer can sell the fry directly, and the buyer will take responsibility for collecting and transporting the fry. In other areas, independent dealers will uplift and transport the fry to areas where there is a demand. Often, however, the hatchery producer may have to arrange to transport the fry to the farms of the buyers. In all of these circumstances it is important to ensure that stock are transported safely and efficiently. There is obviously little advantage in producing clean, healthy, good quality fry, only to have them badly damaged by poor transport and handling. Even if the hatchery producer does not carry out too much of the fry transport, it is in their interests to ensure that others carrying out the transport - whether farmers, dealers, or contract transport agents - do so using reliable and effective methods.

Fish transportation and distribution is therefore an important activity. It is

a stressful period for fish (see previous section) and requires skill and organisation to minimise journey time, and prevent conditions in transport containers from deteriorating to unacceptable levels. As mentioned at the beginning of this book, the hatchery producer needs to think about the distances between their hatchery and the customers, and ensure that fry can be safely and efficiently delivered to them. This section provides guidelines to allow producers to plan and arrange transport.

9.2 Before transportation

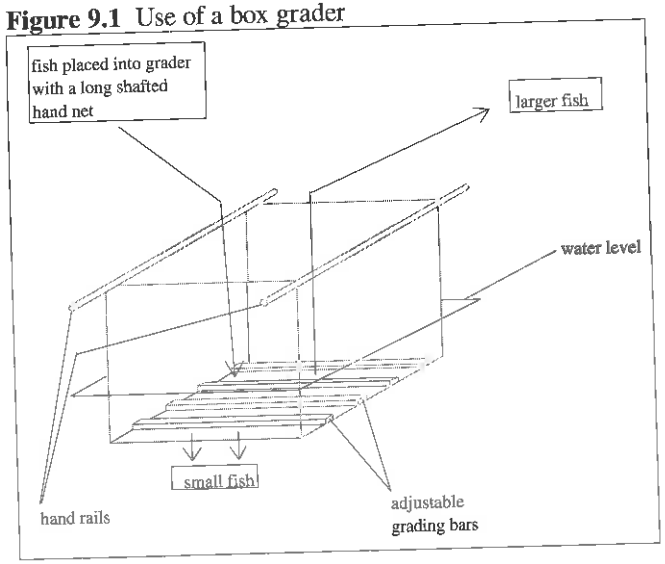
Prior to transportation fish are commonly sorted, weighed and placed in a temporary holding facility where they may be easily accessed and loaded into containers for transport. Fish are often transported to the point of sale, where they may be sold by length or weight. In either case fish consignments should contain fish of similar size in order to provide better for their needs during transit, as well as to deter cannibalism and competition in transit and after stocking.

Small numbers of fish can be graded by eye or with a box grader (Figure 9.1). This should be done quickly but carefully with good conditions provided for the graded fish to recover before transportation.

If fish are to be sold by weight, small quantities can be weighed in a container of water on a standing scale, in a bucket with a spring balance or with a beam balance. Standing scales tend to be most accurate but also most expensive, a beam balance is the next best option (and also portable), whilst a spring balance can be very unreliable. Fish are usually added to a pre-weighed quantity of water to reduce stress and potential for damage.

Netting , grading, etc. is best done early in the morning or after the heat of the day has passed. Before fish are transported it is good practice to hold them in good conditions (borehole water can be used if this is available) in a tank or hapa without feeding. This allows fish to get rid of faeces which would contaminate water in the transit container. Also, the absence of food reduces oxygen demand and ammonia production by the fish again helping to keep transport water in better condition. Four hours may be sufficient for fry, several days may be necessary for older fish. Holding also provides an opportunity to check for signs of disease or handling damage which as well as damaging customer relations could unnecessarily spread disease.

Figure 9.1 Use of a box grader



9.3 Transportation

Fry and small fingerlings can be transported over short distances in 20 - 25 l plastic bags, (typically 0.3-0.5 mm thick, 55-60 cm in diameter and 80 -90 cm deep), filled one third with water and then blown up with oxygen from a compressed oxygen cylinder and tied tightly at the top. Placing the bag inside another one affords extra safety from accidental damage. Compressed oxygen is available in various sizes of cylinder, e.g. 3, 5, 7, 10, 40 and 50 litres. The capacity of a cylinder is measured in terms of pressure which when full is usually between 140-200 bar[1]. Volume is related to temperature and pressure so that a 50 l cylinder at 200 bar will be approximately equivalent to 50 x 200 = 10,000 litres of oxygen at atmospheric pressure (i.e. when released). This would be sufficient for 300-400 bags if carefully used.

An oxygen cylinder must always be used with a regulator, properly fitted and firmly connected to a piece of high pressure pipe. A 32 mm spanner should be available to service the regulator, which will rapidly freeze if it

[1] 1 bar is approximately equivalent to normal atmospheric pressure.

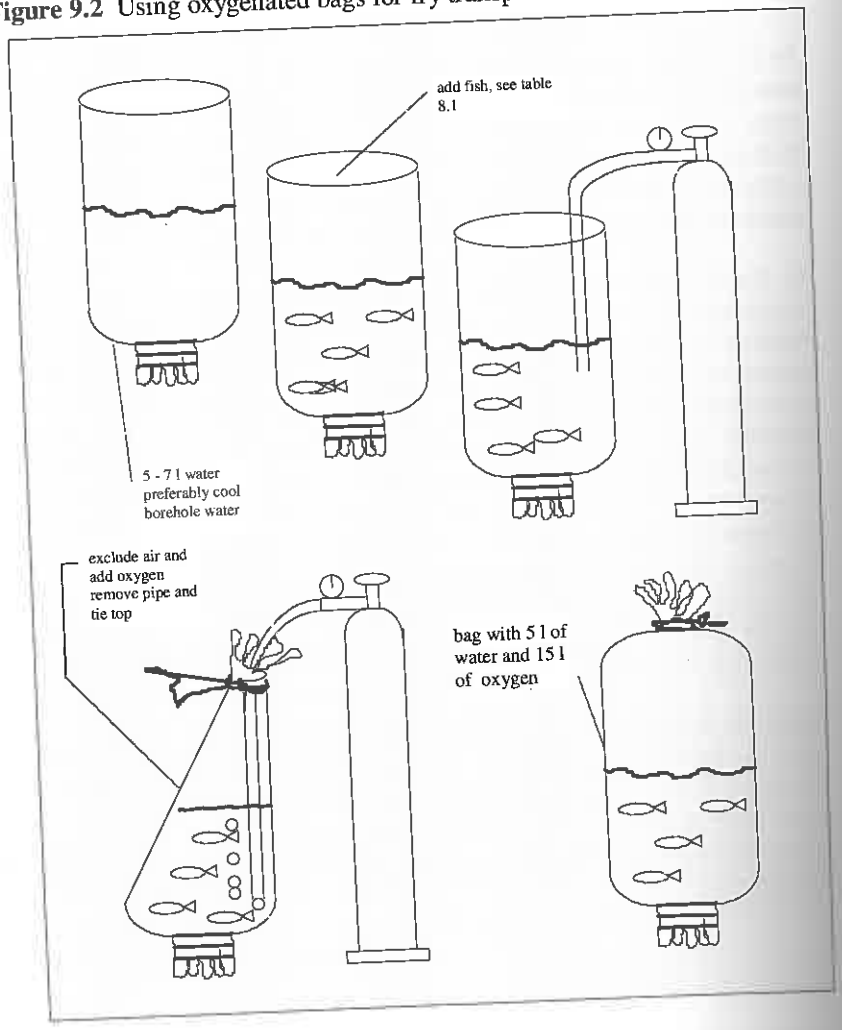
leaks oxygen! The cylinder capacity, the functioning of the shut-off valve, the test pressure and the weight when empty, should be tested by a supplier at least every five years, as pressurised cylinders can be very dangerous if faulty.

To use oxygen from a cylinder, the bag should be filled with the correct amount of water and fish, squeezed down to get rid of any air, and the oxygen pipe universed into the water, allowing the oxygen to bubble through the water (this also increases the available oxygen in the water), carrying out at the top of the water surface to fill up the bag. The bag should be tied very tightly to avoid leaking out (see Figure 9.2).

In many cases hatchery producers or distribution agents may find it convenient to keep oxygen cylinders. In other cases, oxygen might be obtained e.g. from garages or workshops using oxygen - mix welding equipment, which is quite common. Where compressed oxygen is unavailable, an alternative is to use hydrogen peroxide where this is available e.g. from a local chemist. The oxygen contained within this chemical can be released by contact with a suitable catalyst. The liver and viscera of fish can be used, and 10 g of liver mixed with 500 ml of hydrogen peroxide can release enough oxygen to fill a plastic bag for fish transport. Peroxide solutions come in different concentrations 100 ml of a 6% solution can generate sufficient oxygen to transport 100 x 2 g fish (3 cm) for up to 15 h (200 ml of 3% solution or 50 ml of 12% would be required as an equivalent).

Hydrogen peroxide is poisonous if in direct contact with fish so the oxygen must be generated in one bag with liver and peroxide and squeezed through a hose pipe connecting to the bag containing the water and fish. Care must be taken not to let any of the foaming fluid in the oxygen generating bag enter the bag with fish, or to allow any of the oxygen to escape.

Figure 9.2 Using oxygenated bags for fry transport



Transport of fish of all sizes can be carried out in tanks (see Figure 9.3), which can be fitted onto the back of a pickup or truck, or an agricultural trailer. In these cases, bottled compressed oxygen, supplied to diffusers held at the bottom of the tank, can be used to maintain oxygen levels while the fish are being transported. However this should be regulated carefully, to avoid wasting oxygen. An alternative, especially if motorised transport is used, is a portable air blower which can run off the vehicle battery.

Tanks should have a drain valve for the transport water and larger ones can have a special valve or penstock gate fitted at the base to drain out the fish directly. Nets are sometimes hung inside the transport tanks to prevent the fish from bumping against the sides of the tank, and to facilitate removal of fish. Ideally, tanks should have sealable lids, so they can be filled completely with water to minimise surging during transit. Large tanks may be fitted with baffles for the same reason. Transport containers can be made from metal, wood, various plastics and fibreglass. They should be robust and light. It is important that they are clean and that the materials they are made from are non-toxic.

Figure 9.3 Transport tanks for fry

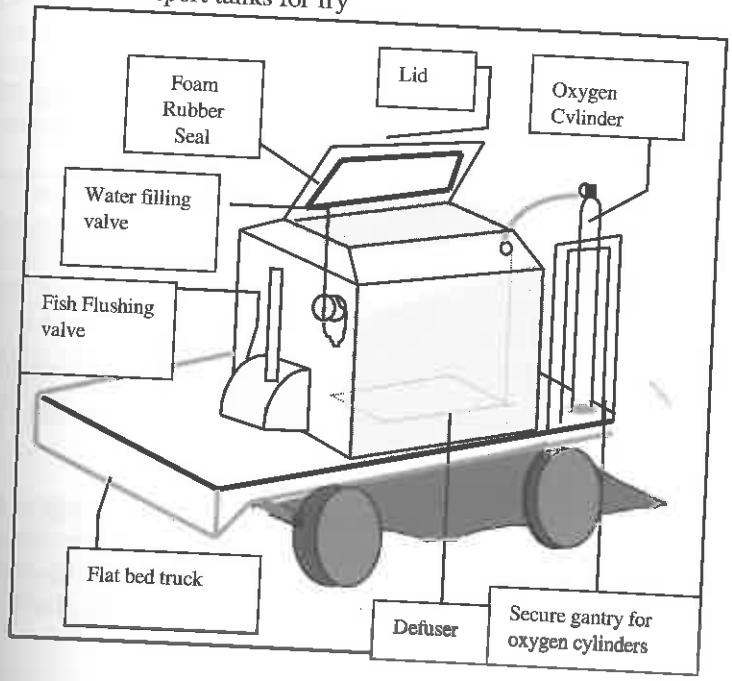


Table 9.1 Some facts and figures for the transportation of live fish

Species	Size	Quantity	Method	Duration
Carp	early fry	100,000	bags with 20 l water and 20 l of oxygen	Several hours
Carp	2.5 cm	2,000	bag with 5-7 l water and 15-20 l oxygen	5 hours
Carp	7.5 cm	200	bag with 5-7 l water and 15-20 l oxygen	5 hour
Carp	250 g	200 kg	1,000 l tank with oxygen diffuser	5 hours
Carp	0.9 kg	250 kg	1,000 l tank with oxygen diffuser	5 hours
Tilapia	1 g	50 per l	bags with 5 l water 15 l oxygen	48 hours still supersaturated
Tilapia	10 - 12 cm	5.5 - 6.5 kg	167 l metal can, no aeration	not specified
Tilapia	fry	70 g	in plastic bag with oxygen generated from 40 ml of 6% hydrogen peroxide	18 hours
Various	just feeding	5,000-8,000	bag with 5-7 l water and 15-20 l oxygen	not specified (typically 2-8 hours)
Various	just feeding	100,000 per 100 l	tank supplied with oxygen	"
Various	3-4 week fry/fingerlng	500 – 2,000	bag with 5-7 l water and 15-20 l oxygen	"
Various	3-4 week fry/fingerlng	10,000 per 100 l	tank supplied with oxygen	"

These guidelines are taken from a variety of sources developed in Africa or for other tropical regions.

The fish should be kept as cool as possible during transport within their normal range. Although it may be a bit more costly, insulation should be considered if transport is to take place during the day. A wet rug or grass mat over bags or tanks, from which water will evaporate during the

journey, will also provide some cooling. Packs of ice can also be used to lower water temperature if placed on top of bags of fish with water and oxygen. However, the same ice packs placed inside the bags will cause too rapid a temperature reduction. Alternatively, temperatures can be kept down by loading fish at dusk, transporting overnight and discharging in the early morning.

The density at which fish can be transported (see Table 9.1) depends on several interlinked factors. Where fish are crowded during transport they require constant supplies of oxygen. Tanks filled with cool clean water (no more than a few degrees below the water temperature in which the fish are kept prior to transit) should be saturated with oxygen (so that bubbles can be seen slowly rising from the diffuser). Water temperature affects the quantity of oxygen that will dissolve and thus the amount available to the fish. Small quantities of water e.g. in plastic bags, can rapidly heat up if left in the sun, producing stressful conditions of high temperature and low dissolved oxygen. Increasing temperature also increases the rate of metabolism of the fish, also increasing demand on their oxygen uptake and their waste production. On long journeys, water may need to be changed, due to a built up of wastes, especially ammonia. The new water may well be of different temperature and quality (water quality should be as good as possible). If this has to be done, the water should be added to replace about one third of the volume of the container each 15 minutes, until a satisfactory quality is reached.

In Asia successful transport systems have developed without the aid of oxygen, using simple tin pots, bamboo or cane baskets, or cleaned oil drums filled with water covered with a muslin cloth which lies on the water surface. Smaller containers can be transported long distances on foot, suspended from shoulder-poles, or by bicycle or public transport. The water is continually splashed to supply oxygen by patting the cloth with the palm of a hand. Splashing must be continuous for the duration of the trip. Water can be changed as above.

9.4 After arrival

Once the fish have reached their destination, they need to be carefully introduced into their new environment. Once again account must be taken of any differences in water quality, especially temperature. If the water in

the site is more than 3^0C higher than that in the transport container, the difference must be overcome by slowly mixing the water. With changing water during transport, gradually replace the transport water with local water. As before one third of the water in the transport container should be replaced every 15 minutes until little temperature difference remains. Transport bags can also be placed unopened in the receiving water for a short time (up to 30 minutes) until temperatures inside and outside the bag equalise. The bags can then be opened and the fish allowed to swim out. In some cases it may also be useful to paddle a little of the outside water into the bag to encourage the two waters to mix.

If there is a difference in salinity between the transport water and the receiving site this may take longer to overcome. Fish delivered to marine or brackish water areas from freshwater hatcheries should be put in fresh water on arrival, and the salinity altered gradually - perhaps 5 parts per thousand every 2 days[2]. Small fish may be less tolerant of salinity changes and this should be taken into account.

9.5 Other points to consider

It is advisable, though not always possible, that fish delivered to another site should be kept separately from other stock and observed for signs of disease. Equally, upon return from a delivery any equipment should be disinfected as a routine hygiene procedure and also to guard against the transfer of disease to the hatchery (see Chapter 8).

In many cases the cost of transport is normally borne by the seller (and is thus reflected in the greater cost of the fish). Regardless of the arrangement, responsibility for the fish during transit should be agreed in advance. Routes should be well known as delays should be avoided. Unaccompanied fish should be well advertised, i.e. that they are perishable and living, and arrangements should be clear and detailed prior to shipment. Account should be taken of likely delays, festivals, public holidays, industrial disputes, etc. Sending fish in this way entails very high risk and should not be undertaken with valuable stock.

[2] full strength seawater ~ 35-40 parts per thousand (ppt), so it would take about 2 weeks to accelerate stock to full salinity.

Carp, catfish and tilapia all possess spines on their fins which can cause damage during transport. Where available Acriflavine powder, a fish antiseptic can be added to the water to protect against infection. One level teaspoon of powder is dissolved in one litre of distilled water by shaking. Two drops of this solution can then be added for each 4-5 l (gallon) of water in transport bags, after which the water should appear pale green.

The counting and grading of the fish can sometimes be a problem between seller and buyer. Ideally, the buyer should be able to see the fish, agree on the batch to be sold, and should participate in the counting and weighing before transport. If this is not possible, the buyer should be able to count the fish being received. It is quite common to allow an extra number (e.g. 5-10%) to allow for miscounts, incidental losses, etc. The conditions of selling the fish should include provision for payment and for losses subsequent to transport. Usually a certain part of the total price is paid at the time of delivery with the remainder on receipt of the fish or within an agreed period of time. Commonly, transport losses using the seller's transport, and fish dying within the first few days may be the responsibility of the seller, as it is reasonable to suppose that losses may have been caused by earlier conditions and/or transport handling. Thereafter however, they become the full responsibility of the buyer. As will be discussed later, good customer relationships are important, and it will be useful for each party to develop a positive and trusting link. This will also help if the hatchery wishes to expand and develop new stocks or species, as other customers will hear of the good reputation of the hatchery.

CHAPTER 10

ORGANISING, PLANNING AND MARKETING

10.1 Introduction

The previous sections have discussed most of the important factors involved in operating, designing and managing a hatchery. The early parts of the book introduced the basic questions of defining whether a hatchery might be a useful and viable venture. The next sections have shown the practical aspects of operating and managing a hatchery. This final section returns to the issue of deciding how to go ahead with a hatchery business, and takes up the practical issues of developing a hatchery business once the fundamentals have been understood and a realistic technical perspective has been gained. Assuming that the production of fish seed appears to be viable and attractive, the next stage is to plan its development, management and organisation. The main tasks involved in managing the start up of a hatchery involve:

- Establishing a work planning structure (WPS).
- Scheduling suppliers and contractors, inspecting goods and construction.
- Recruiting, assigning tasks and supervising labour.
- Developing the business.

These are discussed in turn:

10.2 Establishing a work planning structure

As with any development, work planning begins at the early stages of the venture. Planning prior to start up is generally broad and tentative. It then becomes necessary to prepare detailed and updated plans of work, anticipating and estimating requirements and setting up a control and accounting system that will record and monitor the various items of resource use and expenditure.

Organising the plan of work begins with the intended outputs and involves breaking down the process of seed production into manageable units and

identifying all the necessary component activities. A work breakdown structure is illustrated below, showing three levels, with progressively more detail. Although this is particularly relevant for a medium to large scale hatchery, the principles and the functions involved, are also needed, if on a simpler and more modest level, for a small scale artisanal unit.

Figure 10.1 Illustration of a work breakdown structure for a hatchery

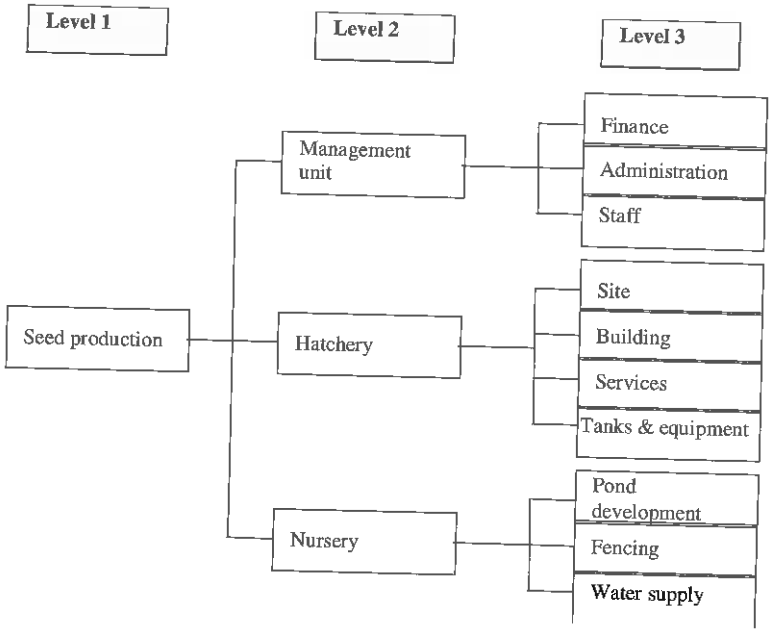
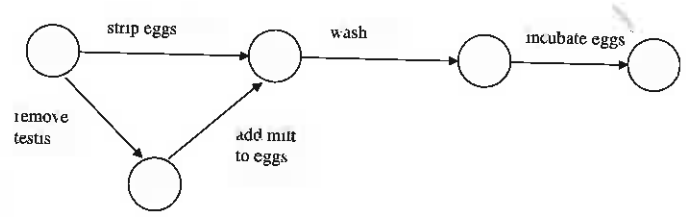


Figure 10.2 A simple network: Spawning catfish



Systems such as these can be developed in more detail to form "critical path" networks, which allow various processes (e.g. construction, water supply development, spawning cycles) to be planned with some precision, and various resources (materials, labour, management) to be applied as appropriate. Box 10.1 shows a simple example. For most projects, however, a simple written schedule - e.g. summarising the essential tasks and associated responsibilities, or a bar-chart, can be drawn up. These can identify the approximate timings of key features, without too much complexity, and will allow some degree of management control.

Box 10.1 Project scheduling example – installing fish tanks

Activity	Normal duration	Description
A	1	remove top soil
B	2	prepare levels for tanks and drainage
C	0.5	take delivery of pipes
D	0.5	take delivery of tanks
E	3	plumb in drainage
F	3	install tanks
G	3	plumb in water supply
H	1	make good all surfaces

Network:

Event	Earliest time (days)	Latest time (days)
Start	0	0
Soil removed	3	3
Pipes delivered	3.5	5
Tanks delivered	3.5	5
Levels prepared	5	5
Drainage plumbed in	8	8
Tanks installed	11	11
Water supply plumbed in	14	14
Surfaces made good	15	15
Project duration	15	15

10.3 Recruiting, training, assigning tasks and supervising labour.

In many cases, hatcheries are new projects and there may not be an immediate pool of skilled staff. Even if such staff are available, it is important to select them carefully, and make sure they learn how to carry

out the hatchery activities effectively and reliably.

Recruitment

The recruitment process will vary depending on the job specification and local custom and practice. Where it is relevant, it may be necessary to be aware of government legislation regarding contractual obligations of employers and employees, health and safety.

The first stage to recruiting is to compile an accurate job description so that candidates attributes can be matched to the specifications of the job. (Note: it is useful to do this even if you already have someone in employment, as it helps you realise how well that person will meet your needs, and where training (see below) may be useful. The second stage is to advertise the job description through word of mouth or via the local media in order to attract potential candidates. The third stage is to interview. Depending on the job, this may range from a brief conversation with a likely potential employee to a formal process involving a panel of informed people asking structured questions to a series of candidates.

A job description results from a logical process of task definition and allocation. After recruitment it can represent a framework for performance evaluation and monitoring as well as a basis for the definition of training needs. As literacy may not be a requirement for some hatchery jobs, special attention should be paid to communication when dealing with recruitment, training and supervision. Patient, well structured verbal communication with prepared material in the form of pictures may be useful.

Training

Training can be split into two broad areas, induction training and technical skills training. Induction is a process designed to integrate new employees into the business. New employees should be introduced to relevant background information, plans, products, facilities and practices. The details of the employees' responsibilities should be clearly defined as well as pay structure, safety issues, codes of conduct and opportunities for advancement. As noted earlier, in such a relatively new industry it may be difficult to acquire staff who already have the necessary skills. Therefore in addition to induction training some kind of early job skills training will be important. Appropriate technical training may be available from the local

extension or section of the relevant department responsible for fish farming or from local aquaculture projects if they exist. Alternatively, you may have to acquire this yourself, or together with other farmers or hatchery operations.

Assigning tasks and supervising labour

Trained and experienced staff are an important resource. The work environment should aim to satisfy their basic and motivational needs so they are encouraged to remain in the job and to do their best. Box 10.2 considers ways to satisfy the needs of employees.

Box 10.2 Meeting staff needs

Basic needs		*Motivational needs*	
Earnings and benefits:	Fair package for local conditions - levels of pay, incentives, food accommodation, use of transport	Satisfying jobs:	Allocate jobs that allow individuals to use their abilities
Working hours:	Balance the demands of fish seed production with the domestic need of employees	Proper resources:	Provide equipment and materials in good condition
Job security:	Provide what reassurance you can about future employment	Feedback results:	Where the results of work are not obvious provide where possible achievable goals
Working conditions:	Aim to remove danger and discomfort from the workplace	Where achievement needs are strong:	Where practicable provide responsibility for planning and carrying out tasks
Order and stability:	Provide a clear picture of duties and role	If affiliation (friendship) needs strong	Involve in team work, allocate jobs which require support for others (e.g. induction)
Fair treatment:	Allocate tasks and handle problems without favour or prejudice	Where power motivation is strong:	If capable consider supervisory tasks and involvement with the broader issues of production.

While it may not always be feasible to provide all of these, it is important to try to aim towards satisfying these and similar requirements as far as

possible. Communication is particularly important, and staff will accept less than ideal conditions if they understand the reasons, and may be encouraged to help improve matters, to benefit the hatchery and in turn, their own satisfaction.

10.4 Monitoring and record keeping

These are very important functions in a hatchery, and should be carried out even at the simplest level. Even the smallest hatchery should have a record book, which ideally should be filled in daily. Larger and more commercialised hatcheries should keep separate records for particular purposes. Six important reasons for keeping good records are as follows:

- *Fish health*: monitoring water quality, behavioural changes and recording disease events, and treatment results will provide valuable data for the diagnosis of disease, guidelines for treatment and the identification of high risk times.
- *Planning*: accurate production and resource requirement records are essential for planning and scheduling, e.g. stock biomass over time in relation to conditions, and related resource requirements such as labour, feed, seed stock, water, aeration, equipment, etc.
- *Development*: performance comparisons from collected data e.g. successive batches of spawning and hatching groups will allow methods to be continually improved and updated, allowing adaptation to local conditions and requirements.
- *Service*: production and customer information will allow production to be better planned, aid in scheduling, allow continuity of service and help with after sales backup, thus promoting a good customer service.
- *Experimentation*: this takes place at a simple level - e.g. trying out modified techniques, or on a more organised basis - carrying out research as on possible new approaches. Unless it is specially funded, acquired research may not be too compatible with commercial production. However, results from simple modifications can be very valuable, and should be recorded, so the many advantages can be measured. Finally, at a larger scale hatchery records can aid overall development of the industry when collated from a region, usually by another organisation.
- *Management*: includes of all of these areas and as a manager may not be specifically involved in any particular area, records play a vital role in the provision of information about the hatchery. The executive

decisions required of a manager depend on accurate, up to date information passed on in some recorded form.

Where feasible, it is useful to monitor and record the following data, recorded daily and immediately in the event of any problems.

Stock biomass data
The following information can be recorded. Ideally, this should be done for each tank or pond unit, and if possible a system should be set up to identify each batch, from their parental origin to their transport to the customer.

- initial stocking density
- stock origin
- stocking date
- individual and total weight estimate
- grading and harvesting
- other remarks

Egg densities can be estimated for catfish by taking a small representative sample of the rearing mesh to which eggs are adhered and counting the eggs in that area, e.g. a 10 cm x 10 cm square, then multiplying up by the area of mesh covered by the eggs; carp and tilapia eggs can be weighed and a sample weighed and counted - and similarly used as a conversion factor.

Larval growth rate can change significantly on a daily basis and hence should be sample weighed daily if records are required. Fry weight increases significantly every 5 days at high density and hence should be sample weighed every 5 days. Remember unnecessary weighing can cause stress and mortality.

Feed requirements
Individual and total feed requirements should be estimated for each culture vessel at the same frequency and time as weight estimates are taken. This allows food conversion indices; conversion indices to be calculated; these can be monitored to assess performance, and can also be used to plan feed supplies.

Water and environmental quality
temperature (water and air)
weather/rainfall
dissolved oxygen
ammonia
pH
flow rate
remarks

Costs and benefits
All costs incurred, and sales made should be recorded. This can be done using simple book keeping techniques - e.g. with a "single entry" cashbook, with copies of purchase and sales receipts. For larger hatcheries, more specialised records may be required, which may be developed to analyse the profitability of particular batches, production areas, or the efficiency of particular work teams.

Overall, a balance must be made between the time required to collect information and use it for analysing performance and planning ahead, and the practicalities of focusing on the most useful information. In practice, this can be determine as the project proceeds. It may also be important to record other matters such as equipment purchase and repair details, maintenance schedules, etc.

10.5 Marketing

The importance of effective marketing has been noted earlier. Three important functions which are particularly relevant are:

- identifying customer needs - through basic market research.
- developing fish production systems that offer attributes most capable of satisfying those needs.
- use of price , promotion and distribution to generate the required levels of sales.

Identifying and satisfying customer needs
As mentioned earlier it is important to be aware of the structure and the needs of the market you aim to supply, and collect what information is readily available from potential customers, extension agents, other fish

seed producers and their customers, and from secondary data, i.e. already collected for some other purpose, government statistics, trade reports, magazines and databases (Infofish, Globefish, etc.). This will be the lowest cost source of information available. Conducting market research specific to your needs, will be useful if the information significantly reduces the risk of making a bad decision at an acceptable cost. Customers for fish seed are, on-growing units, other fish farms, government or private culture-based fisheries or other stocking programmes, collective marketing organisations, other seed suppliers, fry traders, research institutes, schools, etc. There could be a wide spread of potential products, ranging in quality, quantity, age/life stage, gender, genetic identity, etc. Clearly the bigger and more complex the project, the more their qualities will be important.

It is also important to understand the structure of the market - competitors, opportunities for collective marketing, the distribution channel and the numbers and position of intermediaries. Over the longer term it is also important to be aware of the broader business environment. This includes elements such as, national development goals and objectives in fish production, technology trends, economic trends, legislation (see again checklist 1). Once an understanding of the market is gained and an appreciation of the potential products, the next important decision is to determine which market space the hatchery can best supply, e.g. first feeder, sex-reversed tilapia fry, air-breathing catfish, etc. The hatchery need not limit its self to one product. The market should be considered together with operational issues, e.g. as fish grow they need to be stocked less densely. This can involve investment in more rearing space and facilities, or restricting production to younger life stages, or selling part of the developing stock, etc. Some hatcheries choose to supply one market area, e.g. selling at the onset of first feeding, which can be cheap in terms of infrastructure and operating costs, especially if spawning is conducted to order! Others, may aim for competitive advantage in some bio-technical sphere and might develop more sophisticated and higher priced products such as sex reversed or triploid fish, or fish selected for better growth characteristics, dress out weight, late or early maturity, coloration, etc.

Price, promotion and distribution

When setting the price at which a product is to be sold it is common to use the 'cost plus pricing' formula, where price = cost of production + required profit.

However, in the end it is the market demand which will control prices rather than the expectations of the supplier, where the prevailing market price represents the between. Often balance of supply and demand price, is related to quantity of production as bigger hatcheries can produce fry more cheaply, and this needs to be taken into account when deciding on the size of the hatchery. Price can sometimes also be used to influence demand for fish seed, as a lower price level will often boost demand. For smaller producer with limited marketing resources price can be set and changed in relation to that of a dominant seed producer.

Where a number of small producers act independently they will have little individual resistance to attempts by on-growing farmers or traders to depress prices, especially if their mobility and thus choice of outlet is also limited. For this and other reasons collective marketing can be effective. Collective marketing organisations can develop into a major supply source locally (and nationally). They can achieve price stability which is of particular benefit to members. Collectively, they can buy or hire useful but occasionally used equipment (e.g. for transport, see Figure 9.2), bulk buy inputs, share professional services (e.g. veterinary specialists, consultants, etc.), better represent their common interests and attract more easily, support and collaborative attention.

Promotion of hatchery products takes two forms,

- advertising the products, prices, quantities, location of the hatchery and transportation options, this can be done through local media, word of mouth or through "gendays", local meetings, trade shows etc.
- advertising and informing about the nature of products (especially the more sophisticated ones).

For more developed hatcheries with more specialised products this may also involve formal or informal training in after delivery seed care (costed or as an after sales service) or a more detailed explanation of the nature and benefits of particular products. This can add value to the hatchery products provided and also prevent loss of fish which might otherwise be blamed on suppliers.

In some cases it may even be possible to help the less skilled on-growing

farms in organising their techniques, and so improve their profitability, and create in the longer term, the opportunities for further sales. Good customer relationships are obviously very important.

Distribution in aquaculture is often conducted by 'middlemen'. In many instances such traders offer a vital link between remote fry producers and their potential customers. Their contacts with both hatcheries and on-growers put them in a position of power by virtue of information. They are often accused of demanding excessive profits and their mark-ups are said to reduce customer demand. Where intermediaries are used for distribution by a hatchery it is important to retain power within the relationship so that hatchery producers are able to demand a reasonable return. Although traders may often offer credit to help develop production facilities, there may be considerable restrictions on selling practices or prices, and so such arrangements have to be carefully weighed up.

10.6 Longer term development

It is hoped that the material in this text has helped potential hatchery producers to understand the possibilities and opportunities, and to make good decisions about setting up and running hatcheries. As noted at the beginning, successful hatcheries will be crucial to the development of aquaculture in Africa, and in bringing in the many benefits that aquaculture can deliver. It is hoped that those who do take up hatchery production will be successful and will form the core of thriving businesses, with potential to expand, and provide benefits to producers and local communities alike. Once this base is established, there will be opportunities to develop more specialised and productive systems, and to make aquaculture in Africa a fully positive and rewarding sector.

Appendix I.1. Larval Feeds use for primary nursing of African catfish

Feed Live Feeds	Mortality	Growth	Notes	References
Zooplankton			First trials in trays and troughs with aeration	Jocque, 1975; Pham, 1975
Phytoplankton and zooplankton (predominantly *Daphnia pulex*)	2.8% first 10 days		Suitable first feed (10 days). or second period (after 10 days) following a zoo plankton or a yeast diet.	Hecht, 1981
Combination of Live and Dry Feed				
Zooplankton (10 days) -- shrimp meal (92%) plus vitamin mix (8%) plus tetramycin (0.5%), (11 days)	15% from 7 days to 28 days old	57 mg -- ca. 200 mg in 21 days	in ponds	Carreon *et al.*, 1976
Zooplankton plus trout starter feed	30-50%	2.3mg -- 844-1018 mg	28 days	Hogendoorn, 1980b
Artemia nauplii plus trout starter feed	4-33%	2.3mg -- 455-1027 mg	28 days	Hogendoorn, 1980b
Artemia nauplii (28 days) – Trouvit "O" trout starter		0.5g -- 10g	3-4 weks	Hogendoorn, 1981
Plankton plus Torula yeast *(Candida utilis)*(1:1)		2.3mg -- 13mg	10 days	Hecht, 1982
Artemia (5 days) – *Artemia*/Salmon fry feed (7 days) – salmon fry feed (24 days)	6%	First feeding larvae – 1.71g	36 days	Meske, 1984
Artemia (10 days) – *Artemia*/Salmon fry feed (7 days) – salmon fry feed (19 days)	5%	First feeding larvae -- 2.52g	36 days	Meske, 1984
Artemia (15 days) – *Artemia*/Salmon fry feed (7 days) – salmon fry feed (19 days)	17%	First feeding larvae – 3.85 g	36 days	Meske, 1984
Artemia/artificial dry diet** of Uys and Hecht (1985) (1:1) (10 days) -- artificial dry diet of Hecht and Appelbaum (1987)*** (40 days)	20.2%	First feeding 5.3g	50 days	Hecht and Appelbaum, 1987

Feed	Mortality	Growth	Note	References
Dry Feeds				
Dry trout starter	90%	-	Unsuccessful	Hogendoorn, 1980b
Dried inactive yeast	100%	-	Unsuccessful	Hogendoorn, 1980b
Ground *Clarias* fingerlings	100%	-	Unsuccessful	Hogendoorn, 1980b
Frozen zooplankton	100%	-	Unsuccessful	Hogendoorn, 1980b
Frozen *Artemia* plus trout starter	26%	2.3 mg – 330mg	28 days	Hogendoorn, 1980b
Soya		slow growth		Hecht, 1981
Tetramin (aquarium feed)		slow growth		Hecht, 1981
Ground trout pellets		slow growth		Hecht, 1981
Egg yolk		slow growth	very slow alimentary canal depletion rate	Hecht, 1981
Salmon fry diet)	93-96%		Unsuccessful	Meske, 1984
Eel fry diet)				
Torula yeast (*Candida utilis*)	1.6%		10 days	Hecht, 1981
Ground trout pellets plus Torula yeast (1:1)		2.03mg – 5.5 mg slow	10 days	Hecht, 1982
Fish meal plus Torula yeast (1:1)		2.03mg -- 12.5 mg	10 days	Hecht, 1982
Blood and carcasemeal plus torula yeast (1:1)		2.08 mg -- 6 mg (slow)	10 days	Hecht, 1982
Ewos C10 'Larvastart'* plus torula yeast (1:1)		2.03 mg -- 4 mg (slow)	10 days	Hecht, 1982
Decapsulated *Artemia* cysts	4-78%	First feeding -- 50 mg	7.4-78.7 day (depending on feeding level)	Verreth and Den Bieman, 1987
-	4%	First feeding – 100 mg	14 days	Verreth *et al.*, 1987
Dry larval feed enriched with acetone extract of *Artemia*	80%	slow growth	Hepatic ultrastructure revealed nutritional deficiency	Verreth *et al.*, 1987
Microencapsulated egg diet	7-36%	slow and variable growth		Verreth *et al.*, 1987
Microencapsulated egg diet with addition of casein and vitamin/Mineral mix	8%	First feeding – 15.8 mg	14 days	Verreth *et al.*, 1987
Artificial dry diet of Appelbaum and Van Damme (1988)**;***	22%	First feeding -- 141 mg	15 days	Appelbaum and Van Damme, 1988
Artificial dry diet of Uys and Hecht (1985)**	5%	2.89mg -- 6.39-7.91 mg	10 days	Uys and Hecht, 1985

Footnotes (Continued overleaf)

* A formulated dry feed alternative to *artemia* nauplii for carp.

** Artificial Diet (Uys and Hecht 1985)

Dried Torula Yeast (*Candida utilis*)	69.8%
Brown fishmeal	23.3%
Vitamins	0.9%
Methionine supplement	6.0%
Furanace	4 ppm
Endox	250 ppm
plus fish oil (cod) and soya bean oil (1:1)	6.0% of total dry wt of feed

*** Artificial Diet (Hecht and Appelbaum, 1987)

Israel *Tilapia* pellet meal	55.5%
Yeast (*Candida* sp)	27.6%
Peruvian fish meal	13.9%
Spirulina platensis	2.95%
Vitamin C	0.05%
Soya bean oil	6.0% of total dry wt of feed (added prior to feeding)

**** Artificial Diet (Appelbaum and Van Damme, 1988)

Norwegian Fishmeal (70% Protein)	15.5%
Yeast (*Candida* sp)	63.5%
Cod liver oil and soybean oil (1:1)	11.5%
Bloodmeal (cattle)	2.5%
Vitamin premix	3.5%
Mineral premix	3.5%

Appendix I.2 Live feed culture (Artisanal)

To culture live feed a 10 x 10 x 0.25 m pond can be dug. Water at 0.6 L/min should be supplied constantly to the pond, with 17 L/min available (in order to fill the pond in 24 hours). Water should enter the pond through a filter box or basket. Before filling, the pond bottom should be cleared of vegetation and sprinkled with about 15 kg Calcium Oxide (quicklime). One kilogram (dry matter) of poultry waste and dry straw (where available) is also added to the filled pond. This will encourage the development of bacteria which in turn will encourage zooplankton growth. After a few days the most abundant zooplankton will probably be rotifers, followed over time by cladocerans, then larger cladocerans and copepods. If by this stage the catfish larvae are still small, the larger zooplankton can be selectively eliminated since rotifers are probably the best food. This will reduce the food competition by the cladocerans in favour of the rotifers and should eliminate predatory copepods. Adult cladocerans and copepods are eliminated by chemical treatment with an organophosphate (though their eggs are not!). At 30°C most organophosphates have a half life of 24 hours. Various trade name pesticides are available, such as Flibol, Dipterex or Masoten, which belong to a group called trichlorfon. These break down to dichlorvos (at high temperatures in high pH conditions, the breakdown is rapid). Dichlorvos is a compound 100 times more toxic and is also available under the trade names Nuvan or Aquagard. 0.5 - 1 g/m^3 (or 0.5 - 1 ppm) is an appropriate dose, dissolved in 10 L of water and distributed evenly over the pond surface. Note that organophosphates are toxic and can be absorbed through the skin - gloves and protective clothing should be worn.

Over the next five days rotifer abundance should increase, but there should be no copepods or cladocerans. Plankton can be harvested from the pond with a plankton net (120 - 180 micron mesh) and fed to the catfish larvae. Manure should be added as required. Under optimal conditions a rotifer population doubles every 4 days, i.e. 25% may be harvested daily.

Appendix I.3 The preparation of decysted *Artemia*

Artemia salina is a shrimp which lives in salty conditions and can survive very high salt concentrations as a resting egg or cyst. The eggs make an excellent feed, and in this state the eggs can be transported dry and subsequently fed or even hatched when given the right conditions. Upon hatching into nauplii the artemia lose some of their nutritional value, so are best fed to catfish larvae as eggs. The eggs should be hydrated and the cyst coat removed before feeding, to prevent the latter from blocking or scouring the digestive tract of the larvae.

A. Hydrating

Add about 50 g of cysts to 1.5 L of water and vigorously aerate for 1 hour at 25°C to hydrate them. An airstone connected to an air pump or air line placed in a conical vessel and secured with a cotton wool bung is appropriate.

B. Decysting

Wash hydrated eggs in a 150 mm mesh. Place cysts in mesh in a 500 ml funnel (the outflow blocked with a bung) and add a solution of bleach (see Appendix II) and water 1:1 to cover the cysts to dissolve the capsule. Leave for 5 minutes or until the cysts turn orange (decysted eggs can easily be identified microscopically). Remove and rinse thoroughly. Stir for five minutes in 1 g/L sodium thiosulphate and allow to settle (debris will float while cysts will settle). Pour off the debris. Place in a concentrated brine (see Annex 2) solution for five minutes; cysts will float and debris will sink. 100,000 catfish larvae will consume about 4 L of *Artemia* or 1 kg of dry cysts up to the end of weaning.

Appendix I.4 Diet formulation

The cultivation and collection of live food organisms from ponds can be unreliable and cumbersome and the purchase and preparation of *Artemia* can be both expensive and time consuming. The preparation of a dry diet which can be fed to larvae and fry is therefore an attractive proposition.

A requirement for protein (40-42%), lipid (10-12%) and the protein to energy ratio of 26-29 mg protein per kg of digestible energy has been identified by Uys (1989) for African catfish (*Clarias gariepinus*) juveniles and adults. The nutritional requirements for larval catfish have not been identified, however, one feed developed in southern Africa for larvae is made as follows:

Torula yeast (*Candida utilis*)	50%
Fish meal	43%
Vitamin premix	1%
Cod liver oil	3%
Sunflower oil	3%

The procedure involves mixing the yeast and fish meal into a dough, rolling into thin cakes and drying in an oven at 45°C, then grinding and sieving into particles in the size range 125 - 200 mm and 200 - 350 mm respectively, and storing below 5°C. Oil is added on a daily basis before use, and feed unused after 24 hours is discarded.

Torula yeast is high in protein and low in fat, methionine and cystine (necessary amino acids). It is also not readily and cheaply available. However, locally available products perhaps presently underutilized are potentially suitable feed ingredients, e.g. crop residues.

When formulating a complete diet for larval or fry the gross dietary requirements that are known must be taken into account.

E.g. Known African catfish dietary requirements

crude protein	40 - 42%
crude lipid	10 - 12%
digestible energy	14 - 16 kJ/g

The optimum protein to energy ratio is 26 to 29 mg protein/kg of digestible energy.

Quantitative requirements for African catfish in terms of amino acids and vitamins are as yet unknown. The requirements for channel catfish, which may be taken as a guide, are given in the following tables.

Amino acid requirements for channel catfish

Amino acid	Requirement (% digestible protein)
Arginine	4.3
Histidine	1.5
Isoleucine	2.6
Leucine	3.5
Lysine	5.0
Methionine	2.3
Phenylalanine	5.0
Threonine	2.0
Tryptophan	0.5
Valine	3.0

Vitamin requirements for channel catfish

Vitamin	Recommended mg/kg
Thiamin	11.0
Riboflavin	13.2
Pyridoxine	11.0
pantothenic acid	35.2
nicotinic acid	88.0
folic acid	2.2
vitamin B12	0.09
choline chloride	550.0
ascorbic acid	375.6
vitamin A	4400 (IU)
vitamin D	2200 (IU)
vitamin E[3]	55
vitamin K	11

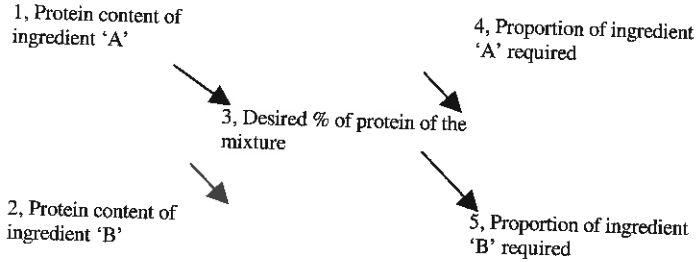
Armed with the nutritional requirements of the species, the approximate composition of a range of locally available ingredients and a knowledge of constraints and anti-nutritional factors, a diet can be formulated. Because this involves fixing of a large number of variables between maximum and minimum levels, as well as in relation to one another, it lends itself to linear programming or quadratic programming techniques. If a micro computer is available, a range of least cost diet formulation packages and spreadsheets can be used. However, with much patience and organisation, and with the use of trial and error, one can formulate a diet worthy of feeding trials without the aid of a microchip. This involves balancing the amino acid profile of the diet, the levels of crude protein, crude lipid, crude fibre, non-fibrous energy, ash and maybe total energy. Where possible, regard should be taken of palatability, digestibility, cost, pelletability and toxins.

A useful approach is as follows:

1) Ignore initially some of the less important variables.
2) Use initially few ingredients.
3) Formulate the diet based on balancing the protein level (using Pearson's Square method).
4) Critically analyze the diet.
5) Adjust the diet by adding more ingredients with high levels of any deficient components and reducing the original components correspondingly. At this point considered inclusions and exclusions may be made.
6) If the diet appears balanced, begin feeding trials. If not, repeat steps 5 and 6.

Pearson's Square method

A cross is constructed thus:



Subtracting 3 from 1 gives value 5
Subtracting 3 from 2 gives value 4
regardless of the + or - sign

Instead of ingredient 'A' or 'B' a predetermined proportion of two ingredients may be substituted and the final proportion of the two calculated in relation to the requirements

Nutritional and anti-nutritional characteristics of some common feed components

Component	Benefits	Drawbacks	Comments
Maize meal	- 60-70% starch, of which 60-70% is digestible - starch acts as a binder in pelleting	- low in protein - 20-30 mg/kg of pigment, which may lead to pigmentation of the flesh	- heating increases digestibility
Maize gluten meal	- higher in protein than maize (40-60%) - good source of methionine*	- 200-350 mg/kg pigment	
Rice	- 12% protein, 12% fibre and 12% fat	- at high inclusion levels may reduce FCR and decrease palatability	
Peanut	- contains most essential amino acids - about 52% crude protein	- deficient in lysine*, methionine, cystine* and threonine*	- if oil is mechanically extracted will contain about 6% crude lipid
Blood meal	- very digestible and rich in animal protein - rich in lysine	- deficient in methionine - high leucine* levels may inhibit isoleucine* uptake	- unpalatable at high inclusion levels
Cottonseed meal	- in certain areas might be an important protein source	- low in available lysine - contains free gossypol*, which is toxic	- method of processing affects level of free gossypol

Problems to consider with practical feed formulation

Component	Problems	Comments
Oilseeds (eg. soyabean)	- contain trypsin* inhibitors	
Legumes (eg. peas and beans)	- contain phytohaemoglytinins that denature haemoglobin* and cause clotting of red blood cells	- may be overcome to some extent by heat treatment
Brassicas (eg. rapeseed)	- contain goitrogens* that affect the thyroid and its hormone production; also cyanogens*	
Sorghum, cassava, linseed and some legumes	- contain cyanogens with toxic effects	
Eggs	- contain avidin, which binds the vitamin biotin	
Trash fish	- contain thiaminase, which destroys the vitamin thiamine	
Potatoes	- contain solanine, and alkaloid*	
Peanuts	- may contain aflatoxins* from the fungus *Aspergillus flavus* if feed contains more than 10% moisture	- to reduce the risk of aflatoxins, store feeds at low humidity wherever possible

APPENDIX 1

Diet formulation for African catfish - South Africa

Ingredients %	Diet formulations from South Africa						
	1	2	3	4	5	6	7
maize		30.0	10.5		18.0		
wheat				14.0	18.0		
Cotton seed cake			25.0				
Soya oil cake	10.0		10.0	10.0		30.0	36.8
Fishmeal	24.7	10.0	20.0	10.0	43.5	28.2	21.2
poultry by-product	10.0	10.0	9.0	10.0			
Carcass meal	10.5	39.5		22.7	10.0	25.0	30.0
Lucerne meal	30.0						
Tomato waste			8.0	20.0			
Fish acid oil	6.8	2.5	7.5	3.3	2.5	0.7	
Molasses powder	8.0	8.0	10.0	10.0	8.0	10.0	10.0

Diet formulation for African catfish - Central and West Africa

Ingredients %	Diet formulations from Central Africa						Diet formulation from West Africa
	1	2	3*	4*	5*	6*	
Maize	5.55	6.05					33.0
Wheat							
Cotton seed cake	25.0	25.0	25.0	25.0	25.0	25.0	
Soya oil cake							
Fishmeal							
Poultry by-product							
Carcass meal							
Lucerne meal							
Tomato waste							
Fish acid oil							
Molasses powder							
Wet brewery waste (25% DM)			78.0	60.0	61.0	44.0	
Wet brewery waste (15% DM)				30.0		30.0	
dry brewery waste	15.0	10.0					
Rice bran	15.0	15.0	15.0	15.0	15.0	15.0	13.0
Groundnut cake	25.0	25.0	25.0	25.0	25.0	25.0	44.0
Sesame seed cake	10.0 1	10.0	10.0	10.0	10.0	10.0	
Blood meal		5.0			5.0	5.0	5.0
Vitamin/mineral mix	0.25	0.25	0.25	0.25	0.25	0.25	2.0
Bone meal	2.0	2.0	2.0	2.0	2.0	2.0	
Salt	0.5	0.5	0.5	0.5	0.5	0.5	
Palm oil	1.0	1.0					
L-lysine	0.5	0.2	0.5	0.3	0.2		
DL-methionine	0.2		0.2	0.2			
Gentian violet			5.0	5.0	5.0	5.0	
Water							3.0

* moist diet ingredients do not add up to 100%

Appendix I.5

MT Diets

A commercial starter diet, or home made feed is sprayed with 17-methyltestosterone dissolved in 95% alcohol at a rate of 40 mg hormone kg diet. The alcohol is allowed to evaporate at room temperature before use. 17-methyltestosterone is available commercially by mail order from chemical companies, though in some countries its use may be controlled or restricted to veterinary prescription.

Appendix I.6

Ram Testis diets

Despite advances in production of all-male or predominantly male populations of tilapia by hormone sex-reversal (Guerrero and Guerrero, 1988) or hybridization (McAndrew and Majumdar 1989) little widespread use of these techniques is evident in African tilapia aquaculture. This is particularly so in remote rural area where animal protein is often limited in human nutrition and thus effective fish culture is potentially most valuable. There is therefore, a requirement for technology appropriate to these areas that might improve the quality and quantity of tilapia produced. Such technology must be simple and draw on locally available resources that are inexpensive and where possible presently under-utilized.

Browsing and grazing animals are commonly kept in rural Africa. Following their slaughter most if the animal is utilized for human consumption. The testes though sometimes eaten are less favoured. They are therefore readily available and represent an inexpensive source of animal protein for inclusion in fry feeds. In addition, testosterone levels present in such feeds following processing, may affect the expression of phenotypic sex in the fish in favour of maleness. Rams are traditionally slaughtered on festive occasions in many African countries; Therefore ram testes are particularly abundant following Christmas or Sahlah (Ramadan).

In suitable areas rice is commonly grown in small quantities by individual farmers and many towns have a mill where farmers process their small quantities of grains. Rice bran is therefore often cheaply available all year round from local mills. This diet is based on ram testis and rice bran (supplemented by a cheap and locally available vitamin and mineral mix produced for chickens) with 250 mm feed particles.

A diet, formulated using the Peterson Square method, (see Appendix I.4) is made from ram testes, rice bran, vitamins and minerals, to be of the same proximate composition as other fry diets (see table below). Frozen testes are processed into a slurry and dried at 40°C overnight in a drying cabinet. The dried testes material is then mixed with the other ingredients, pelleted (using a Hobart pelletiser) dried again until they contained 6% moisture, then crushed

seived and stored. Although phosphorus has been shown to be required by juvenile *O. niloticus* at a level of about 0.46% of the diet (Haylor, Beveridge and Jauncey, 1988), it is considered that its availability to the fry may be reduced by the high rice bran inclusion in the 'ram testis' diet. Calcium phosphate is therefore added to the diet at a level of 1%. Treatment diets are fed for 40 days (after Macintosh, Varghese and Rao, 1985).

Table I: Proximate Composition of Ram Testis

Moisture %	85.19
Crude Protein %	78.62
Crude Lipid %	14.68
Crude Fibre %	0.15
Ash %	5.24

Table II: Composition of the Ram Testis diet

Moisture	6.0%
Ram Testis	63.7%
Rice Bran	27.3%
Vitamin and Mineral mix (for chicken farmers)	2.0%
$CaPO_4$	1.0%

Table III Proximate Composition of Diets*

	Ram Testis Diet
% Moisture	9.0
% Crude Protein	53.7
% Crude Lipid	10.7
% Ash	11.0
% Non Fibrous Energy	15.6
	100

* Proximate analysis were carried out according to methods detailed in ADCP (1980).

The use of ram testis in fry diets warrants broader study particularly with regard the levels of testosterone present in the testis (e.g. variation with age and season) as well as the effect of processing on the resultant dietary levels.

Appendix II.1

Conversion of weights and measures

Unit	Gallon	Pound	Fluid ounce	Cubic foot	Litre	Gram	Kilogram
1 gal				0.1337	3.785		3.785
1 lb						453.59	
1 litre	0.264		33.815				1.0
1 kilogram		2.205					

Relationship between proportion, parts per million, and percent

Proportion	Parts per million	Percent (%)
1:100	10,000	1.0
1:4,000	250	0.025
1:25,000	40	0.004
1:1,000,000	1	0.0001

Miscellaneous conversion factors

1 metre = 100 centimetres = 3.281 feet = 39.37 inches
1 centimetre = 10 millimetres = 0.394 inches
1 inch = 2.54 centimetres = 25.4 millimetres
1 cubic foot per second = 448.8 gallons per minute = 1,698.7 litres per minute
1 cubic foot per minute = 7.4805 gallons per minute = 28.314 litres per minute
1 part per million = 1 milligram per litre = 1 microgram per millilitre
Degrees Centigrade = 0.556 x (°F - 32)
Degrees Fahrenheit = (°C x 1.8) + 32

APPENDIX 2

Discount Rates (see Chapter 2)

Period	12 %	14 %	16 %	18 %	20 %	22 %	24 %	25 %	26 %	28 %	30 %	40 %
1	.893	.877	.862	.847	.833	.820	.806	.800	.794	.781	.769	.714
2	.797	.769	.743	.718	.694	.672	.650	.640	.650	.610	.592	.510
3	.712	.675	.641	.609	.579	.551	.524	.512	.500	.477	.455	.364
4	.636	.592	.552	.516	.482	.451	.423	.410	.397	.373	.350	.260
5	.567	.519	.476	.437	.402	.370	.341	.328	.315	.291	.269	.186
6	.507	.456	.410	.370	.335	.303	.275	.262	.250	.227	.207	.133
7	.452	.400	.354	.314	.279	.249	.222	.210	.193	.178	.159	.095
8	.404	.351	.305	.266	.233	.204	.179	.168	.157	.139	.123	.068
9	.361	.308	.263	.225	.194	.167	.144	.134	.125	.108	.094	.048
10	.322	.270	.227	.191	.162	.137	.116	.107	.099	.085	.073	0.35

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INDEX