Summary Report of the ICLARM Conference on The Biology and Culture of Tilapias, Bellagio, Italy, 2-5 September 1980

R.S.V. Pullin

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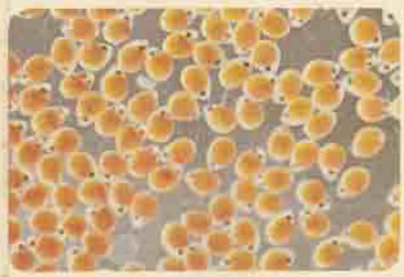

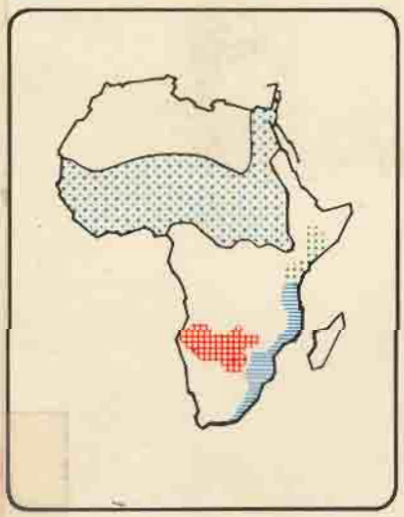

INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT

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Cover: Aspects of tilapia biology–eggs (courtesy of Philippine National Economic and Development Authority); feeding (pharyngeal teeth, S.H. Bowen; distribution (after E. Trewavas); pond harvest (*S. niloticus*, R.S.V. Pullin).

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Preface

TILAPIAS are a major protein source in many of the developing countries. Although endemic to Africa, their distribution has been widened by artificial introductions, mainly since the 1950s, to include much of the tropics and subtropics. Tilapias have many attributes that recommend them for culture. They show excellent growth rates on low protein diets, whether cropping natural aquatic production or receiving supplementary food. They tolerate wide ranges of environmental conditions, show little susceptibility to disease and are amenable to handling and captivity. They have a short generation time and breed in captivity. Most important of all, they enjoy wide acceptance as food fish because of their high palatability and history of use from inland fisheries. With all these advantages, tilapias could become prime domesticated species for fish culture.

This was recognized at the *ad hoc* FAO consultation on aquacultural research, Rome, 5-9 May 1980, in which tilapias emerged as the top priority group of cultured species. The report notes that the culture of tilapia species in ponds in tropical and sub-tropical countries, using agricultural by-products and manures as pond inputs and yielding two to three crops totalling 5,000 or more kg/ha/year, has been demonstrated to be feasible and economical and that for small-farm or low-cost-input culture, tilapia have greater potential in these geographical areas than any other food fish. In Africa alone, the potential yield of tilapia is estimated at 8 million tons and it is equally impressive for tropical and sub-tropical Latin America and Asia.

The culture of tilapias, however, is still beset with problems of rearing and general husbandry. These result from an inadequate research base on their biology, particularly behavior and physiology, and insufficient cooperation between fish biologists and culturists. The former have often pursued limited, essentially academic studies within their specialist fields and the latter have paid inadequate attention to published information. In particular, there has been a great deal of information gathered by field biologists which is relevant to the behavior, growth and reproduction of tilapias in culture systems.

This conference was convened by the International Center for Living Aquatic Resources Management (ICLARM) to bring biologists and culturists together to present reviews of existing information, to discuss current research areas and culture methods, to define future research requirements and to comment on any other measures which would help the future development of tilapia culture.

It was seen as a unique opportunity to address some of the unresolved problems for researchers and culturists alike, ranging from standardization of nomenclature

and techniques for the development of known genetic strains and hybrids to optimization of growth and feeding and control of reproduction.

ICLARM wishes to thank the Rockefeller Foundation not only for providing the superb facilities of the Bellagio Study and Conference Center but also for their generous sponsorship of the conference participants. The administrator and staff of the Bellagio Center also deserve special thanks for their hard work and help in ensuring the success of this conference. The full Conference Proceedings are dedicated to Dr. Ethelwynn Trewavas in recognition or her outstanding contributions to fisheries science and to mark the occasion of her 80th birthday.

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Contents*

*The full proceedings of the Conference have been published separately by, and are available from, ICLARM. Citation for the proceedings is: Pullin, R.S.V. and R.H. Lowe-McConnell, Editors. 1981. The biology and culture of tilapias. ICLARM Conference Proceedings 7. International Center for Living Aquatic Resources Management, Manila, Philippines

Introduction

This conference brought together 19 tilapia biologists and experimental culturists from 10 countries. It was built around 15 major review papers tabled by the participants. These were grouped under three main session headings as follows:

Biology	taxonomy and speciation, ecology and distribution, tilapias in fish communities, and life histories.
Physiology	environmental, reproductive, feeding, digestion, metabolism and growth.
Culture	ponds, cages, diseases, hybridization, genetic markers, control of reproduction and mass fry production systems.

It was a technical conference and did not consider the commercial aspects and economics of tilapia culture apart from some brief remarks on cage and pond culture systems. A conference on the development and management aspects of tilapia culture is being planned for 1983.*

This summary report is organized under the three major session headings and has been distilled from the abstracts of the papers presented, the overviews of session chairmen and the discussion sessions (which formed a large part of the conference). The conference also produced a consensus statement and recommendations for future research, the main points of which are reproduced here.

Session 1: Biology

The session was concerned mainly with field studies and provided a good background for the subsequent sessions which were largely on laboratory studies and culture. The scale of the theatre for field studies is vast, e.g., Lake Victoria, over 6.5 million ha; the Kafue floodplain, around 121,000 ha. Sampling such huge areas presents special problems and catch statistics are far less reliable than, for example, emptying a culture pond. The need for accurate data on the distribution, growth and production of tilapia in natural waters was recognized by all.

Dr. Trewavas grouped the tilapias into two genera, *Tilapia* and *Sarotherodon*, characterized by their reproductive and feeding habits and morphology (but see below: Consensus Statement, Standardization). There is some overlap in feeding habits, some species of both genera feeding on detritus and periphyton, but for reproductive habits, substrate-spawning and mouthbrooding characterize the two genera.

Drs. Philippart and Ruwet presented a comprehensive review of the ecology and distribution of tilapias. This included distribution maps and records of introductions and transfers of all the major species on a world-

*Details from O.H. Oren, Israel Oceanographic and Limnological Research, Tel Shikmona, Haifa, Israel.

wide basis. Their paper is a most useful source of reference for both field biologists studying wild populations, and culturists wishing to document the source of cultured strains and to collect new material for culture trials.

Dr. Lowe-McConnell reviewed the information available on the ecology and behavior of tilapias in natural fish communities, on species interactions and on factors controlling tilapia numbers, particularly the conditions under which tilapia switch from growth to reproduction. Maturation and maximum sizes tend to be smaller (i.e., the fish 'dwarf') in small bodies of water than in larger ones, and populations of fish with low weight for length switch to reproduction at a smaller size than those in which the fish are in better condition. Males tend to grow larger than females in 'dwarf' populations, even in species in which the two sexes grow to comparable sizes in large lakes.

Comparison of tilapia growth rates from different lakes and rivers shows that within a water body, the various species grow at different rates, the faster-growing species reaching a larger size. But a given species will grow at different rates in different water bodies, suggesting that environmental differences are more potent than genetic ones in determining maturation and maximum sizes.

Studies of biomass, production, yield and turnover rates from the Kafue floodplain and Lake Kariba show that only a small part of the total production is cropped as yield in natural waters. The great plasticity of tilapia growth in natural waters suggests that concentrating research on environmental and behavioral factors affecting growth and the switch to reproduction is likely to be very fruitful for the improvement of tilapia culture.

Drs. Noakes and Balon presented an evolutionary perspective on the life histories of tilapias. They suggested that life styles of tilapias fall into two clearly defined categories, altricial and precocial and that a significant evolutionary mechanism exists for changes between these. The major evolutionary trend has been from a more altricial style, the nest-spawning guarders (equivalent to substrate spawners), to the more precocial style, the mouthbrooding external bearing species (equivalent to mouthbrooders). The major distinction between these is largely a consequence of heterochronous shifts in ontogeny, particularly the lack of a larval period in the ontogeny of the bearers.

Session 2: Physiology

Dr. Moriarty in his overview drew attention to the lacustrine habitat of many tilapias which made them well-adapted to culture in enclosed waters. The microphagous habit of many tilapias, especially their ability to utilize blue-green algae, is a major factor in their high yields from shallow lakes.

Dr. Chervinski described the environmental tolerance limits of tilapias with respect to temperature, salinity, dissolved oxygen, pH and un-ionized ammonia. From the culture point of view, low temperature tolerance limits are the most important. Tilapias in general do not grow at water temperatures below 16°C and are not able to survive water temperatures below 10°C for more than a few days. Low temperature tolerance is affected by prior acclimation temperatures. Tilapias are tolerant to high water temperatures, e.g., 41°C for *S. aureus*. Although many tilapias are euryhaline and are able to survive, grow and even reproduce in sea water up to 40‰ salinity, there are few growth data available under these conditions.

Drs. Jalabert and Zohar gave a detailed account of the reproductive physiology of tilapias. Gametogenesis is characterized by a low production of gametes, related to the high efficiency of parental care. In substrate-spawners *(Tilapia)* the number of small sticky

eggs is approximately related to the cube of body length, whereas in mouthbrooders *(Sarotherodon)*, the eggs are bigger, not sticky, and their number is related to the square of body length.

Despite some attempts, specific tilapia gonadotropins have not yet been satisfactorily purified. Also the role of specific prolactins in osmoregulation and parental care behavior must be confirmed; their possible inhibitory action on gametogenesis needs investigation. The precise nature of steroids which mediate the pituitary action during different phases of the reproductive cycle also needs more research.

Both groups seem to exhibit a capacity for early sexual maturation, the reason for which is not clear. There is also unlimited successive breeding through whole populations in equatorial areas and an increased tendency for seasonal breeding with increasing latitude, with maximum activity during maximum temperature and light intensity.

Dr. Bowen discussed the herbivorous and detritivorous habits of tilapias. In addition to microorganisms, detritus is digested and is a major nutritional resource for many tilapias. Whole diet assimilation efficiencies are lower for tilapias than for carnivorous fishes and food quality appears to limit the growth of tilapias in some natural populations. The limited data available indicate that within a given water body, tilapias select precisely the food that will maximize growth. The combined abilities for cell wall lysis and selective feeding suggest that tilapias hold considerable promise for low technology, protein efficient aquaculture.

In studying feeding, digestion and growth, temperature is an important factor to consider. Dr. Caulton showed how *Tilapia rendalli* utilizes temperature variations in its lake environment to maximize growth. By constructing careful energy budgets, he demonstrated that faster growth rates were achieved when fish moved into warm inshore areas during the day (where feeding and digestion rates were faster) and then retreated to cool deeper areas at night, where energy demands were less, than if the fish remained at a constant temperature. Access to deep waters can therefore improve yields but yields will also be high in shallow waters where diel temperature changes are more pronounced. Aquaculturists should take note of such physiological optima and with careful design of ponds and water management could create a diel temperature variation resulting in enhanced growth potential and decreased food conversion factors.

Session 3: Culture

The culture of tilapias in ponds was reviewed by Drs. Hepher and Pruginin. They concentrated on the management methods used to overcome unwanted recruitment and consequent overcrowding/stunting, e.g., mixed sex culture (harvesting before sexual maturity) and monosex male culture. They also discussed the fertilization of ponds with organic manures and inorganic fertilizers. Tilapias are particularly responsive to organic manuring and are ideal candidates for integrated culture systems using livestock wastes.

Dr. Guerrero provided a broader view of recruitment control in tilapia culture including monosex culture, the use of predators, suppression of reproduction in cages, stock manipulation (grading and selective harvesting), irradiation, chemical sterilants, and environmental manipulation (salinity, light and temperature).

Dr. Coche presented a world review of tilapia cage culture including site selection criteria, construction and design of cages, management of stocks and a wealth of production data. Adult tilapias may be raised in cages by extensive, semi-intensive or intensive methods. Extensive systems based on natural feeding are used in eutrophic lakes and

fertilized water bodies. Semi-intensive systems (where low-cost and low-protein diets are fed) have been successfully developed on an experimental scale either combining phytophagous tilapia and a vegetable diet or utilizing agricultural by-products in the presence of algal blooms. With intensive methods, feeding aspects become more important from the economic viewpoint.

Dr. Henderson observed that one of the major difficulties in comparing different culture systems is the lack of an appropriate yardstick for performance. One of the more obvious examples is the expression of the productivity of a system as the biomass per unit of time *per unit area.* For cage and pen systems, however, one hardly bothers to calculate such figures. From the point of view of the culturist, input-output information is of more interest. Unfortunately, the commonly quoted feed conversion ratio is not a very satisfactory biological index unless the water content of the feed is taken into consideration. Growth rate and production are of direct interest to both the scientists and the culturists, but are difficult to compare for different lengths of growing season. Dr. Coche gave special attention to these problems, providing several different measures of performance to compare cage culture systems. Recognizing that it may not be very useful to compare the efficiency of the use of space, say, between pond and pen culture, it does nevertheless seem worthwhile to define standard performance criteria for culture systems. These criteria should obviously extend to economic as well as biological factors.

Dr. Henderson also noted that only pond and cage culture systems were reviewed at the conference and he referred to two other systems. One is the very intensive culture of tilapias in tanks and in raceways, systems which are particularly appropriate in utilization of waste thermal waters. The other is extensive culture in small reservoirs, natural lakes and ponds. The highly intensive culture systems pose special problems of providing complete diets as well as removal of wastes from the system. Management of extensive systems, on the other hand, should be of interest in relation to the extent to which cage or pen culture can or should be combined with harvest of the more free-living stocks. This is an important question in, for example, the improvement of the fisheries of the 10,000 or so small reservoirs of Sri Lanka. In small reservoirs, there are some interesting possibilities for the control of reproduction of tilapias through water level control: for example, by exposing nests at critical periods.

The review of tilapia diseases by Prof. Roberts and Dr. Sommerville confirmed that they are more resistant to diseases than many other species. Nevertheless, a wide range of disease problems can occur. The increased movement of both tilapia broodstock and seedstock across national boundaries brings attendant risks of transfer of parasites and disease, and of contamination of stocks with genes of related species. In most countries, there is as yet very little control on either the species, or more importantly, the health of the fish transported. Roberts and Sommerville noted that the diseases of tilapias have not been as well studied as those of other cultured species, because their culture has only recently been developed to an intensive level where disease problems are more evident and because diagnostic facilities are, in general, poorly developed in areas where tilapia culture is most common.

Without doubt, the major problem in tilapia culture is the reliable and economic production of suitable seed. Tilapias are too prolific in some culture operations and yet have too low a fecundity for easy mass rearing. Mr. Mires gave comparative data on the spawning capacity and spawning frequency of female tilapias in intraspecific and interspecific crosses.

Hybridization of tilapias continues to be of great importance in culture. Dr. Lovshin

showed that tilapia hybrids have impressive growout potential using a wide variety of commercial and agricultural by-products as diets. The opportunity of stocking all-male tilapias without prior manual sex separation has tantalized fish culturists for many years. However, all-male tilapia hybrid culture has yet to be accomplished on a large commercial scale.

When the technology for producing all-male tilapia hybrids on a commercial scale becomes available, production is most likely to come from government and private hatcheries with sufficient money to build properly designed facilities and to hire trained biologists. Dr. Avtalion's account of electrophoretic genetic markers showed how basic science can assist the culture industry. He reviewed enzyme and other protein markers in *Sarotherodon* and *Tilapia*, with special emphasis on their use for the identification of species and hybrids.

Consensus Statement

The conference participants agreed on the following statement:

1. *The value of fundamental research*

Fundamental research on the taxonomy, genetics, physiology and ecology of tilapias has produced a large amount of information of direct benefit to the culture industry and merits increased and sustained financial support.

2. *Standardization*

The scientific nomenclature used for the tilapias remains a matter of controversy among taxonomic experts, but for the published proceedings it was agreed to accept the division of the tilapias into the genera *Sarotherodon* (mouthbrooders) and *Tilapia* (substrate-spawners). However, the subgenus *Oreochromis* has since been raised to generic status (Trewavas, in press).* The maternal mouthbrooding tilapias so far used in fish culture should now be referred to as *Oreochromis* (e.g., *Oreochromis mossambicus, O. niloticus, O. aureus*). The generic name *Sarotherodon* is now restricted to a West African group (which includes *S. melanotheron*) and to *S. galilaeus*.

To avoid confusion, all descriptions of hybrid crosses should be given with the female parent first.

The various laboratories establishing collections of so-called pure strains of tilapias should collaborate to standardize the nomenclature for these. The geographical origin and history of transplantation of strains should be documented as a first step and information on electrophoretic and other genetic markers exchanged on a regular basis. The present situation is very confused and should not be allowed to worsen.

All scientific researchers should use fish of known origin and history and the fullest possible information on these should be given in the methodology of all published works. Ideally, all fundamental research should use pure strains of fish, but this must be seen as a long-term objective, particularly in the developing countries.

3. *Conservation of genetic material*

Collections of pure strains of tilapias should be established both to improve the genotypes of cultured stocks and to supply standard material for research. It should be recognized that some strains and hybrids developed by commercial operators could be

*E. Trewavas. A review of the tilapiine fishes of the genera *Sarotherodon, Oreochromis* and *Danakilia*. Br. Mus. (Nat. Hist.) London. (In press)

the subject of industrial patents. Collections should be replicated at several sites and should maintain sufficient numbers of broodstock to avoid inbreeding depression, except where inbred lines are developed intentionally.

Information should be collected on the sites at which pure wild stocks of tilapias can still be found. Aquatic reserves should be established at critical locations to conserve these stocks and any rare species and especially to protect them from any contamination by fish introductions.

4. *Fish introductions and transfers*

The continuing widespread introductions and transfers of tilapias are a cause for concern, and there is a clear need for the involvement of competent technical bodies to advise on and control these in the future. The possible adverse effects of introductions are ecological damage, contamination or elimination of endemic wild stocks and transfer of pathogens.

Introductions and transfers of tilapias will, however, be essential for the future development of the culture industry, especially as new strains and hybrids are developed. The risks of pathogen transfer can be minimized by moving only early life history stages (which are less prone to carry pathogens than broodstock) from reputable suppliers and by enforcing medication, inspection and the destruction of packing materials on arrival.

5. *Health aspects*

The use and abuse of antibiotics in fish culture requires urgent control and legislation. Control measures to contain the spread of fish diseases should also be considered by appropriate authorities, including the right of officials to inspect fish and farms for the presence of diseases, to restrict fish sales and movements as and when necessary, and to require farmers by law to notify the appropriate authorities of outbreaks of designated serious diseases.

6. *Information resources*

Recent bibliographies and reviews and others in press have collated much of the large volume of literature on the biology and culture of tilapias but have missed a considerable amount of so-called "grey" literature, particularly reports and documents with a limited circulation from Africa, Asia and Latin America and material published in local languages. There will be a continuing need for information collection and dissemination (for example, as special bibliographies) as the literature on tilapias continues to grow. To facilitate this and to lessen the volume of grey literature, published material should, wherever possible, be in a form for direct input into abstracting services and computerized data bases.

Research Requirements

Research priorities on tilapia biology and culture, identified by the conference, fall into six broad categories. A summary of topics worthy of sustained research follows. Table 1 summarizes near-term and sustained research needs.

1. *Genetics*

Applied research on the applied genetics of tilapias can have rapid payoffs for the culture industry and merits sustained support as the industry expands. It should be recognized,

however, that all work on genetic improvement is high risk (high investment) research.

Although some of the tilapias currently available have good culture characteristics, there is much room for improvement by selection of strains for fast growth, higher fecundity and later maturation. The screening of new species and hybrids for culture in freshwater could be beneficial and is required urgently for brackish and seawater culture where there are few culturable finfish species available of which the life cycles have been closed in captivity.

Future studies on hybridization should therefore include the development of hybrids which perform well in saline waters. Hybridization work should also include studies on hybrid vigor, and should not be restricted to the search for crosses resulting in all-male progeny. For the developing countries, however, the improvement of cultured strains should have priority over hybridization studies as the continuous development of hybrids requires elaborate facilities for the isolation and the characterization of parents.

The elucidation of sex determination mechanisms in tilapias is a pressing need in order to explain the sex ratios of progeny from the various hybrid combinations either in current use or for future development. The greatest benefit to the culture industry from this would be the reliable production of 100% all-male progeny.

2. *Reproduction*

The design of systems for mass fry and fingerling production is the most important single requirement for the culture industry. The private sector is expected to develop such systems rapidly if given the necessary biological data and basic guidelines from researchers. This requires technological as well as practical extension work by leading aquaculture research centers.

The other important research areas related to reproduction can be summarized as behavioral studies. For example, broodstock performance is likely to be controlled by behavioral factors. Compatibility in hybrid crosses is one area in which near-term research and application of the existing published information on the reproductive behavior of tilapias would be useful.

Variability in reproductive performance has many causes, including possibly a genetic basis. Attempts should be made to explain the large differences in time to first maturation, fecundity, spawning frequency, etc., observed by different workers within a single species under different conditions. This work overlaps the narrower aim of suppressing gametogenesis by environmental, behavioral or physiological manipulation.

The importance of communication via dissolved organic compounds (pheromones) should also be investigated. If chemical communication is significant in the reproductive behavior of the tilapias, then the culturists could conceivably develop techniques either to encourage or suppress spawning by chemical means. Cryopreservation of gametes is a useful technique for storing genetic material cheaply. Experience with other fish indicates that only spermatozoa are amenable to cryopreservation. Techniques for tilapia semen should be developed.

Control of tilapia recruitment, especially in pond culture, remains a difficult problem. Recruitment control by predators offers a viable solution for culture in both developed and developing countries. Research is needed to identify suitable predator species and to study predator-prey relationships.

3. *Feeding, growth and maturation*

The feeding of tilapias, particularly detritivory, merits much greater study. The methodology for determining microbial proteins, detrital composition, etc., needs further improvement.

The dietary requirements of the important culture species and hybrids must be defined so

Table 1. Summary of research priorities on the biology and culture of tilapias. A broken line between the columns indicates scope for both near-term and sustained work on the adjacent topic(s).

Near-term research priorities for both public-funded institutions and the private sector.	Priority research areas for sustained work, which would benefit from institutional collaboration.
1. Genetics	
Screening of new species and hybrids for freshwater and saltwater culture	
Selection for fast growth, higher fecundity and later maturation	
Elucidation of sex determination mechanisms	
2. Reproduction	
Design of mass fry and fingerling production systems	Variability in reproductive performance
Behavioral studies relevant to broodstock performance	Suppression of gametogenesis by environmental, behavioral or physiological manipulation
Chemical communication in reproductive behavior	
Cryopreservation of gametes	
Recruitment control by predators	
3. Growth and Nutrition	
Nutritional requirements of young, growing and mature fish	Feeding niche dynamics in polyculture
Incorporation of local materials in formulation of supplementary feeds	Metabolic pathways in relation to growth and gametogenesis
Feeding behavior in culture systems	
Digestive physiology in relation to feeding practices in culture	
4. Facilities and Equipment	
Development of integrated farming systems	
Pond and cage design	
5. Environment	
Pen, cage and pond effluent studies	
6. Fish Health	
Diseases and pathology	
Acclimation and stress reactions in culture systems	

that supplemental feeds can be formulated on a sound technological basis. Because supplemental feeds are a major cost item in intensive or semi-intensive culture, studies on the physiology of digestion and assimilation in relation to feeding rate and frequency are important. The use of locally available dietary components can reduce feeding costs, but must be nutritionally adequate.

More attention should be paid to *published information* on the feeding behavior and digestive physiology of wild fish and more research performed on these topics using fish in culture systems both with and without supplemental feeding. The study of feeding niches in polyculture systems is also important as there is evidence that some tilapias can cross from niche to niche, which could reduce the number of species for a specific system and also maximize production.

4. *Facilities and equipment*

The design of integrated agriculture-aquaculture farming systems is a high priority area for further research. While such developments must consider the public health aspects of producing human food from agricultural wastes, it is important that any apparent health hazards are assessed against those that exist anyway in normal agricultural and aquacultural practice. For example, by using animal manures to fertilize ponds, are more health hazards created than those already present in intensive animal production systems or in culture pond water?

5. *Environment*

Methodologies and standards are needed to assess environmental impact of effluents from aquaculture sytems. This applies to pens and cages in enclosed or semi-enclosed bodies of water and to ponds, whether as periodic run-off or when draining to harvest (particularly in fertilized systems).

6. *Fish health*

Sustained research on the parasites and diseases of tilapias and their pathology is essential as the culture industry continues to expand.

Acclimatization and stress reactions of fish in culture systems are poorly understood and have wide implications for growth, survival, reproductive performance and susceptibility to pathogens. Studies in both these areas are urgently needed.

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TITLES IN THIS SERIES

- **Small boat design. Edited by J.M. Reinhart. 1979. ICLARM Conference Proceedings 1, 89 p.**

  Contains the 16 papers by boat and engine specialists presented at the joint ICLARM-South Pacific Commission workshop in Noumea, October 1975. Deals with the boat and engine design needs of South Pacific fishermen. US$4 surface; $12 airmail.

- **Law of the sea: Problems of conflict and management of fisheries in Southeast Asia. Edited by F.T. Christy, Jr. 1980. ICLARM Conference Proceedings 2, 88 p.**

  Proceedings of a workshop held jointly by ICLARM and the Institute of Southeast Asian Studies in Manila, November 1978. Contains 12 papers and a summary of the workshop discussions. Focuses on two fundamentally important issues—allocation and implementation. Published jointly with the Institute of Southeast Asian Studies, Singapore. US$4 surface; $12 airmail.

- **Summary report of the ICLARM-ISEAS workshop on the law of the sea. By F.T. Christy, Jr. 1980. ICLARM Conference Proceedings 3, 20 p.**

  A supplement to Conference Proceedings 2. Contains the summary only of the ICLARM-ISEAS Workshop on the Law of the Sea. Free.

- **Integrated agriculture-aquaculture farming systems. By R.S.V. Pullin and Z.H. Shehadeh (Editors). 1980. ICLARM Conference Proceedings 4, 258 p.**

  Contains the 24 papers presented at the conference on integrated agriculture-aquaculture farming systems, held in Manila, 6-9 August 1979. A joint publication with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture, College, Los Baños, Laguna, Philippines. The book provides an overview of integrated agriculture-aquaculture farming systems as currently practiced in many Southeast Asian countries; reviews available experience and technology; discusses the social and economic aspects of these systems, and identifies research and development requirements. US$10 surface; $25 airmail.

- **Fish behavior and its use in the capture and culture of fishes. J.E. Bardach, J.J. Magnuson, R.C. May and J.M. Reinhart (Editors). 1980. ICLARM Conference Proceedings 5, 512 p.**

  Proceedings of the Conference on the physiological and behavioral manipulation of food fish as production and management tools, Bellagio, Italy, 3-8 November 1977. The book includes the 18 presented papers by leaders in this field; their discussions of the presentations; and an introductory perspectives chapter. Excellent subject and species indexes are also included. The papers are grouped into three categories: Sensory Capabilities and Fish Behavior; Reproduction and Recruitment; Behavior and Distribution. US$15 surface; $25 airmail.

- **Summary report of the ICLARM conference on the biology and culture of tilapias. By R.S.V. Pullin. 1981. ICLARM Conference Proceedings 6, 13 p.**

  A summary of the 15 major review papers and the discussions of the three major sessions—Biology, Physiology and Culture—of this conference, which brought together 19 eminent tilapia biologists and experimental culturists from 10 countries. Free.