Aquaculture Research in the Africa Region

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Foreword

Aquaculture is one of the most interesting and challenging scientific areas supported by the International Foundation for Science (IFS). Since its inception in 1972 funding for research to outstanding young scientists in this area has nearly reached two million U.S.dollars.

The workshop held in Kisumu, Kenya in October 1985, was the fifth organized by the Foundation for its aquaculture scientists. It was the first to be held in both French and English. The skillful interpretation by Mrs.T. C.Benamar and Mrs.T.Gaillard contributed a great deal to bringing the two linguistic groups closer together.

The IFS would like to thank the French Ministry of Research and Technology for its generous financial contribution to the workshop and the local Kenyan Organizing Committee for their support.

Sincere thanks are also in order to the IFS scientific advisers who attended and inspired the Kisumu meeting; Professors E.A.Huisman, The Netherlands; M.Kutty, Nigeria; H.J.Langholz, Germany; A.Lucas and J.Moreau, France.

The proceedings of this workshop are contained in this volume, which appears thanks to the hard work of Prof.Huisman, who not only edited the papers, but also arranged with PUDOC Press for publication. His colleagues from the Wageningen Agricultural University also deserve thanks, especially Mr.W.Heije, who redrew the graphs and Mrs.A.H.M.van Ingen-Bouwmans, who typed the manuscripts.

The greatest gratitude goes to the grantees themselves, for their contributions which appear in this volume and for their enthusiasm during the meeting.

Jaan Teär,
Director
International Foundation for Science

Opening Address by His Excellency the Minister for Tourism and Wildlife, J.A.Omanga.

Mr.Chairman, Madame Arosenius,

Distinguished Scientists,

Ladies and Gentlemen,

It is my great pleasure and privilege to welcome you all on behalf of the Kenya Government, on this occasion when the International Foundation for Science holds its symposium on Aquaculture here in Kenya. Mr.Chairman, I must first take this opportunity to express my heartfelt gratitude and thanks for the confidence and trust that the Foundation has in our country, indeed as manifested by your being here. It is a further manifestation and indication of your readiness and willingness to assist the developing countries, in particular those in Africa, in their effort to increase food production, particularly from aquatic sources.

Mr.Chairman, I am aware that your concern today is in relation to aquaculture, and how, I believe, aquaculture can be made to contribute significantly to the total food output, which will be needed more and more by the ever increasing populations. This is a welcome concern which we all share, and I shall wish you the best in your deliberations. Before I address you on aquaculture, however I am tempted, too, to use this opportunity to say something equally important in relation to the overall efforts by African countries to increase their fish production, both from the inland waters,, as well as from the oceanic waters around us. Kenya attaches great importance to the training of qualified personnel, without which our effort to increase food production would not be possible. It is my anticipation that foundations, such as yours, would assist the countries in Africa in the furtherance of their efforts to achieve a degree of self-sufficiency in manpower.

A symposium such as the one you are holding today offers an excellent opportunity for an exchange of views and information; the success of this symposium, I believe, depends to a large extent on the individual capability of the participants - the advantage of having qualified scientists is therefore rather obvious. To achieve a higher degree of self-sufficiency, Mr.Chairman, in this area, calls for cooperation amongst nations, organizations and above all willingness and readiness among the "haves" to share with the "have nots". Kenya is not blessed with facilities which can promote research and training. In spite of this Kenya is more than determined to contribute to the development of manpower by sharing its research facilities, by cooperating in all regional endeavours geared towards the promotion of scientific capability.

With trained manpower, I am sure that Africa could go a long way to alleviate food shortages, especially of protein shortages, for instance by a big increase in fish production.

Mr.Chairman, increased fish production, from whatever source, will depend to a large extent on management organized on a national scale, which as you know is a principal tool to permit sustained exploitation at an optimum level. As we are all aware, most current assessment concepts are not always applicable to the tropical stocks of both marine and freshwater origin, particularly in the developing countries. And yet it is these countries where major problems, especially as they affect artisanal fishermen, are most pronounced. Lack of adequate information based on sound scientific and statistical data, and relevant methods, has led to a situation which no longer can be acccepted, and the situation must be arrested. I call upon you African Scientists and friends to consider methods and approaches which will facilitate the gathering and interpretation of information so as to improve the management of our fish resources.

Mr.Chairman, I am equally aware of the need to improve the fishing and general harvesting techniques. I know, thatwe in the developing countries will not be in a position to achieve the status of most developed countries all at once. But in trying we must address ourselves to all the problems. African scientists must endeavour to develop high technology, without which we shall not be in a position to fully utilize our aquatic resources. The situation is most critical when you take into consideration the two hundred mile exclusive economic zone, recently acquired by most coastal states in Africa.

Especially for the inland fishery industry, the problems of post-harvest losses are extremely serious. Mr.Chairman, these losses must be reduced to a minimum. I am aware that such losses are related to the distribution and marketing system, and it is my sincere hope that we shall not spare any effort to improve handling and processing of fish so as to increase general income not only for the fishermen but for the African countries in general as they strive to increase foreign exchange earnings from the meager resources at their disposal.

Most of the participants at this symposium are farmers of distinct importance; you are fish farmers with a particular assignment. As aquaculturists, you have gathered here to find ways and means to achieve a high output of fish from ponds, dams and rivers. Mr.Chairman, on a worldwide basis, aquaculture has made encouraging progress in the last fifty years, providing significantly large quantities of food fish, income and employment. However, and although half the countries practicing aquaculture are developing countries, African countries included, their share of this apparent significant development is, to say the least, very small. Your duty is to try to give an answer to my simple question: "Why?" Definitely, there must be some inhibiting factors which have continued to contain any meaningfull development of aquaculture in Africa. There is need therefore, Mr.Chairman, for a review of the problems and factors that appear to inhibit any breakthrough, so that Africa can also play a role in fish pond production. Secondly there is the definite need to develop techniques and methods which will lead to the increased development of aquaculture as an industry. The Foundation is in a good position to assist the countries in Africa in this endeavour, and it is my sincere hope and aspiration that your symposium will address itself to these and many other problems.

Mr. Chairman, Kenya is looking forward to the recommendations of this symposium. Let us hope that at the end of your deliberations Africa will see a hope, a hope that will be translated into tangible progress and meaningful development of aquaculture in Africa.

Mr.Chairman, I am sorry I had to make a very long speech. I am certain participants would wish to get on with what brought them here in the first instance. I hope nonetheless that my non-scientific speech will provoke thought and facilitate your deliberations.

Mr.Chairman, I now have the pleasure to declare the Symposium officially open.

Thank you.

THE IMPACT OF THE INTERNATIONAL FOUNDATION OF SCIENCE ON KENYA AND FUTURE COLLABORATION WITH THE KENYA NATIONAL ACADEMY OF SCIENCES

Address by

C.P.M.Khamala, Honorary Secretary, Kenya National Academy of Sciences, Department of Entomology, University of Nairobi, Kenya.

Hon.Andrew Omanga
Minister for Tourism and Wildlife

Miss Arosenius, IFS Representative

Ladies and Gentlemen,

Kenya trains its scientists at its three universities and at other universities and institutions in Africa and overseas. Currently, it is estimated that the annual output of first-degree young scientists and technologists from these sources is approximately 1.000. Many of them are of outstanding academic merit, and some gain employment in the universities and in scientific research institutions. On appointment, their greatest hope at this early stage of their careers is that they will be offered adequate research facilities in terms of funds and equipment to develop their academic talents in the fields of their interest.

Unfortunately, one of the most mounting concerns for these young scientists in developing countries, including Kenya, is the lack of funds to support their research activities. Although it is normal to find elaborate buildings and, sometimes, equipment in some of our universities and research institutions, usually donated through aid programmes by the developed countries, most governments of developing countries either regard research as a luxury, or their budgets cannot just afford to cover scientific research. Consequently no funds, or very little funds, are voted for research activities. This has led to a situation in which many well-educated scientists from developing countries leave their homelands to seek employment in developed countries, thereby creating what has come to be known as the brain drain. Others take to the easy option and waste their scientific skills and talents in local administrative positions, thus reducing the possibility of furthering the kind of science and technology that would accelerate national development.

There is a great need to reverse this trend and create in Africa an environment where scientists and science can fulfil their potentials. It is in this connection that we in the Third World must commend the work and initiatve of the International Foundation for Science and other bodies with similar noble objectives.

It was in 1972 that I first met the IFS representative who had come to the Faculty of Science at the University of Nairobi to explain the aims and objectives of his newly established organization. Here was an organization which had just been established by national academies and/or research councils in 12 developed countries following the concern that had repeatedly been expressed in international scientific circles regarding the need to assist promising young scientists of the Third World to build up their scientific capabilities and become established members of the international scientific community. The nature of assistance was to be financial support to purchase equipment, expendable supplies, fieldwork, etc. The IFS would also support and advise its grantees on how to achieve their research goals and develop their scientific skills through contacts with other experienced researchers through workshops like the one being launched to-day.

This news was well-received by all of us who were present on this occasion. Since, at the time, some of us were young promising scientists ourselves, we immediately seized this opportunity and applied for IFS grants. This group included Professor S.Gombe, Professor S.K.Imbamba, Professor G. Maloiy and myself.

My IFS research grant number was 28 (802 grants were given out by the close of 1984). The total number of Kenyans who have so far benefited from IFS research funds is about 20, with a few still in the pipeline. This is a small number compared to some countries in Southeast Asia and Latin Ameria. The reason for this may be our young scientists lack of information and the limited choice of areas IFS has identified to support. For example, fermentation is not a favourite in our country.

Although, in my time, the level of funding was small (maximum of 5.000 US dollars per annum), it was still worthwhile. Speaking for myself, this grant enabled me to advance, in a small way, my academic career and expand the scope of my research activities. During my grant period - my grant was renewed twice - I was abled to research and publish four papers in international journals and train two Master of Science graduates on the grant, one of whom later joined a new generation of IFS grantees. The results of our research on "Pest management of grain legumes" have been incorporated in the national grain legume improvement programme, thus becoming beneficial to agricultural production in Kenya by helping the production of grain legumes, an important source of cheap, high quality proteins for the majority of our people. I strongly believe that other Kenyan IFS grantees have benefitted and will continue to benefit.

I would now like to say a few things about the role of the Kenyan National Academy of Sciences, as the national member organization to IFS. Kenyans know that the present Academy has passed through a number of stages since the days of the East African Academy founded in 1963. However, the relation between the Academy and IFS since its inception in 1972 has remained unchanged. The Academy has a three-fold role. First, the KNAS contributes, in a small way, to the IFS fund through an annual membership fee. Second, the KNAS acts as a referee for the research proposals submitted by Kenyan applicants to IFS for funding. Third, the KNAS has always been invited to attend and participate in the IFS General Assembly which is the supreme policy-making organ. Since its inception three General Assemblies have been held, one in Stockholm, one in Chiang Mai, Thailand, and one in Rabat, Morocco. We missed the Morocco meeting last year because of our local travel clearance logistics.

For the future, the KNAS would like to see its relationship with IFS expanded. Specifically, we would like to enter into a collaborative understanding with IFS whereby the KNAS would spearhead the IFS programme by identifying and promoting promising young Kenyan scientists and processing their applications for research grants. In this connection the KNAS wishes to propose to the IFS that it could also serve in the supervision and encouragement of IFS grantees within the Eastern and Southern African subregion by staging regional workshops and seminars. We could also promote contacts of individual IFS grantees in Africa among themselves through national academies and/or research councils with which we have already established collaborative activities. In this regard, African national academies could provide follow-up contacts with the IFS ex-grantees and use them to form a nucleus of high-level manpower to give advice on national and international research activities. Another area where the KNAS could be of assistance in furthering IFS objectives would be in the dissemination of the research findings produced by IFS grantees. The KNAS has a well established scientific journal of international repute called the Kenya Journal of Science and Technology. IFS grantees are invited to publish their findings in this journal.

At this juncture, it is perhaps appropriate to mention that this week the Chairman of the Academy, Professor Thomas R.Odhiambo, is on a visit to Stockholm and has planned to meet the IFS authorities to discuss some of the collaborative areas I have just elaborated.

We in the KNAS strongly believe that it is only through such involvement in the IFS work that its objectives can be effectively promoted and strengthened in Africa. This cannot be achieved by merely acting as referees to the IFS applicants research proposals.

With these few words, on behalf of the Kenyan scientific community, and in particular, the KNAS and all Kenyan IFS grantees I wish to express my heartfelt gratitude to the IFS authorities for selecting Kenya to host this prestigeous Workshop on Aquaculture in Africa. I take this opportunity to join the Guest of Honour in extending a warm welcome to all the foreign participants to Kenya and in particular to Kisumu.

Thank you.

Discours d'ouverture de la réunion FIS sur l'aquaculture en Afrique, par Madame Chr.Arosenius, Secrétaire Scientifique de la FIS.

Monsieur le Ministre du Tourisme et de la Nature,

Monsieur le Directeur de l'Institut des Recherches Marines et des Pèches,

Mesdames, Mesdemoiselles, Messieurs,

En ma qualité de représentante du secrétariat de la Fondation Internationale pour la Science, j'ai le plaisir de vous souhaiter à tous la bienvenue à cette REUNION FIS SUR L'AQUACULTURE EN AFRIQUE, et de vous transmettre le bonjour et les voeux de mes collègues à Stockholm.

L'aquaculture est pratiquée depuis des temps immémoriaux dans certaines parties du monde: en Chine, par exemple, on élève des carpes depuis plusieurs milliers d'années. Par contre, bien que ce mode d'élevage existât il y a environ 3.000 ans en Egypte, ces techniques n'ont plus été pratiquées, et par conséquent ont été oubliées dans cette partie du monde. L'aquaculture a maintenant fait de nouveau son apparition en Afrique et représente un complément nécessaire aux productions Agricoles et de la Pêche. L'aquaculture produit également un apport de protéines de qualité, crée un besoin de main-d'oeuvre aux niveaux familial et industriel et procure des devises étrangères.

Mises à part les régions complètement désertiques, les ressources potentielles de l'aquaculture sont prometteuses dans ce grand continent de l'Afrique. Il existe de nombreux emplacements potentiels le long de rivières telles que le Nil, le Zaïre et le Niger, ainsi que dans les lacs et le long des côtes. Il existe également en Afrique de nombreuses espèces locales de poissons faciles à élever, par exemple le tilapia et le poissan-chat pour n'en citer que deux. Il se peut qu'il existe aussi d'autres espèces appropriées qui n'ont pas encore été découvertes.

A présent, seulement 0, 1% de la production totale mondiale d'organismes aquatiques cultivés provient du continent africain. Un des problèmes qui se posent pour renverser cette tendance et améliorer l'aquaculture en Afrique est le manque de personnel qualifié. La modeste contribution que la FIS apporte en accordant des bourses de recherches pour remédier à cette situation sera peut-être, je l'espère, bénéfique aux populations africaines.

Pour ceux qui ne sont pas très au courant des activités de la FIS, je dirai simplement que notre Fondation est une organisation non-gouvernementale qui a été fondée en 1972, et dont les membres sont composés d'Académies Scientifiques et Conseils de Recherche. Un tiersde ces membres sont situés dans des pays indistrialisés tandis que les deux tiers restants proviennent de pays en développement. Onze pays contribuent à notre budget qui s'est élevé l'année dernière à deux millions de dollars des Etats-Unis.

La Fondation Internationale pour la Science accorde des bourses de recherche dans les sept domaines suivants: l'aquaculture, les productions animales, les productions végétales, l'afforestation et les mycorhizes, la fermentation et la microbiologie appliquée, les productions naturelles et la technologie en milieu rural. Nos boursiers sont de jeunes chercheurs au début de leur carrière scientifique, nés et travaillant dans des pays en développement. La FIS compte aujourd'hui presque 900 boursiers répartis dans 83 pays différents.

En plus des bourses qu'elle accorde, la FIS est en mesure, s'ils le désirent, d'aider ses boursiers à acheter le matériel, la littérature scientifique et les fournitures dont ils ont besoin pour mener à bien leurs recherches. Nous essayons aussi de les aider à se créer des contacts dans la communauté scientifique. Ce but est parfois atteint en leur fournissant les moyens matériels de participer à des réunions régionales et internationales pour y présenter leurs projets, ou en organisant nos propres réunions pour nos boursiers. La FIS organise environ trois réunions par an et essaie de les dsitribuer équitablement entre les différents domaines scientifiques de son programme de recherche.

La réunion FIS sur l'aquaculture en Afrique que nous inaugurons aujourd'hui est la cinquième ayant pour thème l'aquaculture: la première eut lieu en Malaisie en 1978, la deuxième à Abidjan en 1979, la troisième en Thailande en 1980 et la quatrième en Colombie en 1981.
La FIS finance à présent 140 projets sur l'aquaculture dans des pays en développement. Vingt-neuf (29) de ces projets sont en Afrique et 17 boursiers FIS africains sont des nôtres aujourd-hui.

En organisant une réunion de ce genre, la FIS poursuit plusieurs objectifs. Un des buts principaux est de promouvoir des contacts personnels entre nos boursiers, surtout ceux qui conduisent des recherches sur un sujet commun dans une même région. Mais nous essayons aussi leur donner la possibilité de se créer des relations avec des chercheurs travaillant dans d'autres parties du monde, comme par exemple les conseillers scientifiques de la FIS. Nous avons cinq conseillers à cette réunion et l'un d'entre eux a été boursier de la FIS au début de sa carrière scientifique. J'espère que, dans le courant de cette semaine, vous n'hésiterez pas à les aborder et à discuter avec eux. Ils sont ici, également en tant que représentants de la FIS, pour vous aider et vous conseiller.

Je ne voudrais pas terminer ce discours d'inauguration sans remercier ceux qui, par leur aide et leur dévouement, l'ont rendue possible. Tout d'abord je citerai le Ministère francais de la Recherche et de la Technologie pour sa contribution financière. Je voudrais ensuite remercier tout particulièrement Monsieur Ochieng, notre organisateur local, qui s'est pratiquement occupé de tous les arrangements ici à Kisumu et sans qui cette réunion n'aurait pu se faire, ainsi que son Directeur, Monsieur Allela, qui a bien voulu mettre Monsieur Ochieng à notre disposition, et nous aider en nous permettant d'utiliser les véhicules de son laboratoire. Je voudrais aussi citer le Professeur Khamala, représentant notre organisation membre au Kénya, ainsi que Monsieur Arunga, Sous-Directeur des Pêches, pour leur soutier. Enfin, je voudrais remercier tout particulièrement son Excellence, le Ministre du Tourisme et de la Nature, d'avoir accepté d'inaugurer offieciellement nos débats.

J'espère que cette réunion sera le point de départ de collaborations actives et de contacts personnels entre tous les participants. Je vous souhaite à tous une bonne semaine.

CURRENT STATUS AND ROLE OF AQUACULTURE WITH SPECIAL REFERENCE TO THE AFRICA REGION

E.A.Huisman

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Summary

The current status of aquaculture is quantitatively assessed per commodity and per region. Both aquaculture husbandry and farming systems currently in use for aquaculture production have been summarily categorized. The role of fish in general and of farmed fish in particular has been assessed against the background of meat consumption and per capita income. This analysis stressed the commercial character of fish farming. In view of this, aquaculture development in Africa has been discussed taking into account status, objectives, target groups and the role of recipient governments and donor agencies in past and present development projects. In view of the fact that aquaculture development in Africa must still be regarded as a novel introduction, alternative approaches to aquaculture development should include long-term financial and marketing assistance and reconsideration of the target group of subsistence farmers in order to focus on the commercialisation of aquaculture rather than family nutrition as the overall objective.

Résumé

La situation actuelle de l'aquaculture est évaluée quantitativement par produit et par région. Les systèmes de production et d'élevage aquacoles actuels sont divisés en plusieurs grandes catégories et le rôle du poisson en général et du poisson d'élevage en particulier est évalué par rapport à la consommation de viande et au revenu par habitant. Cette analyse met l'accent sur le caractère commercial de l'élevage de poissons. L'évolution de l'aquaculture en Afrique a donc été examinée compte tenu de la situation existante, des objectifs, des groupes-cible et du rôle joué par les gouvernements bénéficiaires et les organismes donateurs dans les projets de développement actuels et passés. Etant donné le caractère de nouveauté des activités aquacoles en Afrique, il conviendrait de favoriser leur développement par une aide financière et à la commercialisation, à long terme, et par un nouvel examen du groupe-cible des paysans de subsistance. Ainsi, l'accent serait mis sur la commercialisation de l'aquaculture qui deviendrait ainsi l'objectif global, plutôt que sur la consommation familiale.

Introduction

Notwithstanding the fact that aquaculture is thought to date back as far as animal husbandry, it only started developing into a viable industry in recent times.

In 1966 the U.S.President's Science Advisory Commission assessed the global aquaculture production to be around one million tonnes. Now, some 20 years later, total production, excluding seaweed, amounts to close to 10 times as much.

Although reliable statistics are scarce, and data are sometimes contradictory, present-day production based on FAO and other data, is set out in Table 1.

Table 1. World fish culture production by region and by commodity group (Estimate for 1985).

Region	Finfish	Molluscs	Crustaceans	Total
	(Metric tons and percentages (%))			
Asia & Oceania	2,912,150 (72.7)	4,466,150 (84.4)	133,550 (79.1)	7,511,850 (79.3)
Latin-America	21,500 (0.5)	38,500 (0.7)	17,900 (10.6)	77,900 (0.8)
Africa	11,550 (0.3)	250 (-)	- (-)	11,800 (0.1)
North America	154,950 (3.9)	144,800 (0.7)	17.450 (10.3)	317,200 (3.3)
Europe	908,150 (22.6)	643,900 (12.2)	100 (-)	1,552,150 (16.5)
Total	4,008,300 (42.3)	5,293,600 (55.9)	169,000 (1.8)	9,470,900 (100)

This output is the result of various husbandry and farming systems used around the world. These systems are dealth with below, prior to the section on the role of aquaculture.

Aquaculture husbandry systems

Basically there are only two types of aquaculture husbandry systems, viz.

- systems with stagnant waters, and
- systems with water exchange.

This latter system also has two variations: flow-through and recirculation.

From a biological point of view, a stagnant aquaculture system can be regarded as a natural ecosystem, since a stagnant pond serves the basic ecological processes, i.e. production, consumption and decomposition, at all trophic levels. The productivity of a pond depends on its capacity to trap solar energy which, together with the available nutrients, maintains the ecological cycle of "eating and being eaten". The fish farmer's objective is to direct the energy and material flow in this cycle most efficiently towards the end product, be it finfish, molluscs or crustaceans.

Since production in stagnant aquaculture systems is primarily dependent on solar energy influex, production is surface-related.

Increased productivity in stagnant pond culture can be achieved by increasing the nutrient availability through fertilisation/manuring and/or supplemental feeding. In this way only two ecological functions e.g. production and consumption, are artificially reinforced. These intensification measures stimulate the "wealth" of the pond, but increased "wealth" often coincides with decreased "well-being". This is also the case here, since the increased levels of production and consumption cause the other ecological function to go awry e.g. decomposition, and subsequent deterioration of the culture environment.

Remedies to this malfunctioning can be geared to cure symptoms, for instance aeration to improve decomposition, or can be more structural, e.g. water exchange.

It is here that the scenario using aquaculture husbandry systems with water exchange by flow-through or recirculation can be staged.

Flow-through systems can no longer be regarded as ecosystems since they serve only one basic ecological function e.g. consumption. The other two functions take place outside the culture system; for instance the production function is carried out in the Humboldt Current, e.g. Peruvian fish meal as fish feed ingredient, and the decomposition function is "discharged" with the water to the surrounding environment.

Fish culture in recirculation systems constitutes an improvement since it serves two ecological functions: consumption and decomposition. The latter function involves bio-technological means such as sedimentation, filtration, bio-degradation, aeration, sterilisation of water, which are common in waste-water treatment processes.

In contrast to the surface-related production of stagnant ponds, production in systems with water exchange depends on the flow rate. More precisely, production in these systems depends on oxygen consumption in the system and the oxygen influx (by waterflow and/or aeration) into the system.

Aquaculture farming systems

In attempting to categorize the great variety of farming systems currently in use the following three approaches can be adopted:

Captural versus cultural

The difference between these two systems is essentially the stocking method. In captural systems fish (eggs, larvae or even adults) enter the pond concomitantly with the water during pond (re)filling; quantitative regulation of stocking is almost non-existent.

This system is mainly used in rice fields and tidal ponds, which cover millions of hectares, especially in Southeast Asia. The adverse effects of rice culture intensification have decreased the popularity of this farming system, although quite some countries in Asia still stress this activity (Kassim et al., 1979).

In contrast, in cultural systems stock is controlled on the basis of species, size/age class or sex.

Subsistence versus commercial

In the industrialized countries aquaculture is (almost) exclusively commercial. In the developing countries aquaculture is intended for both subsistence and commercial purposes except in Africa, where commercial aquaculture is still poorly developed (CIFA, 1983). Subsistence farming usually carried out in small stagnant ponds, requires low inputs, and serves the objective of family nutrition. Commercial farming, in both stagnant ponds and in flow-through/recirculation systems, focusses on local and foreign markets as sales outlets for both food and/or cash crops.

Level of integration

Categorization also can be based on degree of integration, e.g. the following three farming systems:

Monocultures, which utilize the production potential of the system by a single species or even by a single sex, for instance mono-sex culture of tilapiine species. Both stagnant ponds and flow-through/recirculation systems are used.

Polycultures consist of (balanced) mixtures of fish species in the same production unit, which thansk to their species-specific food preferences and/or habitat niches do not compete with each other for food and/or space. In fact some species combinations have a synergistic effect on each others production level (Reich, 1975). Polyculture is mainly pratised in stagnant ponds but also in systems with limited water exchange like tidal ponds. Integrated farming systems consist of a fish culture component integrated in an agriculture and/or animal husbandry component, e.g. rice-cum-fish and duck-cum-fish culture. In these systems fish culture is applied for valorization of the waste products of the other components (Pullin & Shehadeh, 1980). Integrated fish farming is almost exclusively practised in ponds with little or no water exchange.

Current role of aquaculture

In order to assess the current role of aquaculture, data on fish consumption, meat consumption, income, fish culture production and fish catch in countries which reported to have aquaculture production, have been collected and processed on a per capita basis (FAO, 1984; Huisman & Machiels, 1986).

Based on this and data from Table 1, the coverage-percentage, i.e. the aquaculture production expressed as a percentage of total fish (product) consumption, is given on a per region basis in Tabel 2.

Table 2. Fish consumption, fish culture production and the coverage-percentage.

Region	Fish consumption ($kg.caput^{-1}.yr^{-1}$) A	Fish production ($g.caput^{-1}.yr^{-1}$) B	%-Coverage ($\frac{B}{A}$ x 100%)
Asia & Oceania	15.8	2,248	14.2
Latin-America	9.8	208	2.1
Africa	10.5	34	0.3
North America	16.6	749	4.5
Europe	18.0	1,566	8.7

Recently the concept of "Aquaculture Developed Countries (ADC's)", based on the level of per capita finfish production, and of "relative ADC's", based on the aquaculture coverage percentage, have been formulated.

The top 15 countries, using both concepts and ranking order are given in Table 3 (FAO, 1984; Huisman & Machiels, 1986).

Based on these data and the previously mentioned analysis on per capita basis the following conclusions can be drawn.

- Most of the ADC's have a per capita fish catch which exceeds - sometimes even by far -the per capita fish consumption.
- On a worldwide basis the fish to meat consumption ratio is high in low-income countries and low in high-income countries (except Japan) as illustrated in Figure 1.

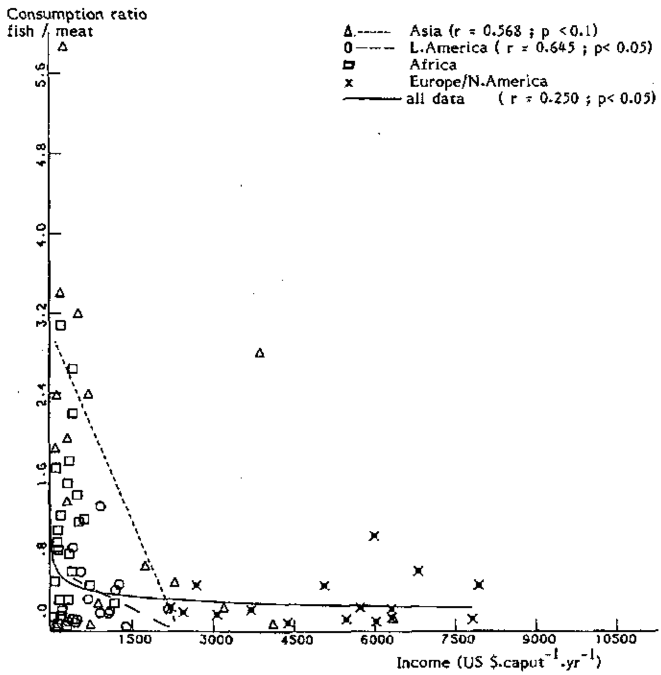

Fig. 1. Fish/meat consumption ratio vs.income

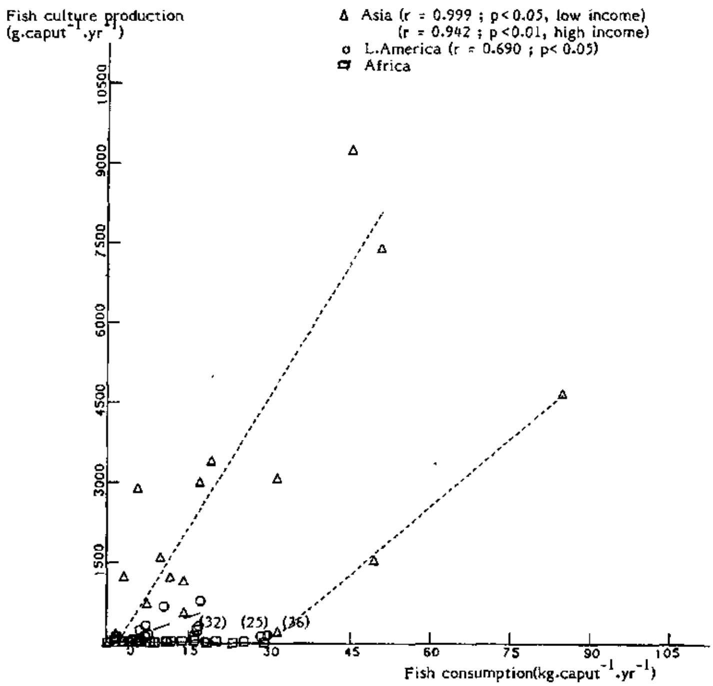

Fig. 2. Fish culture production vs.fish consumption
(x) see text and Appendix I.

Table 3. "ADC's" and"relative ADC's", the top 15 in ranking order.

"ADC's"		"relative ADC's" *	
Country	Finfish production ($g.caput^{-1}, yr^{-1}$)	Country	%-Coverage
Taiwan	7,181	Netherlands	74.9
Denmark	3,338	Hungary	68.8
Philippines	3,081	China	50.8
Israel	3,019	Bulgaria	46.8
Bulgaria	2,575	Yugoslavia	42.3
Hungary	2,472	India	40.0
Japan	2,136	Romania	30.6
Norway	1,953	Malaysia	20.6
Romania	1,861	Thailand	17.8
Hong Kong	1,524	Israel	17.7
Yugoslavia	1,303	Spain	16.5
USSR	1,280	New Zealand	16.3
India	1,213	France	15.3
Sri Lanka	1,158	Rep.Korea	14.7
Indonesia	1,071	Czechoslovakia	11.5
Total population:	1,378,965,000	Total population:	1,958,012,00

* Taiwan is excluded by lack of data.

. Despite the above, fish consumption in general is a function of income.
. Both in Asia and Latin America fish farming is correlated with fish consumption (Figure 2).

It, therefore, can be stated that capture fisheries paves the way for aquaculture development by making the commodity acceptable to the whole society and by establishing markets and market infrastructures.

An aquaculture expansion concept, therefore is thought to be based on fish availability (from capture fisheries) and buying power, as is demonstrated in Figure 3. This concept incorperates a quasi "circulus viciosus" in the sense that the resulting per capita increase of aquaculture production in turn expands the input factor, fish availability. This fly-wheel action will ultimately lead to an autonomous growth of the aquaculture industry. FAO (1984) argues that this autonomous growth will be obtained when a threshold production which, for finfish, is 50-100 g per capita per annum, is exceeded. The importance of this for aquaculture development planners is obvious. But this concept also stresses the fact that ultimately aquaculture can only justify it's"right to exist" if it is economically viable.

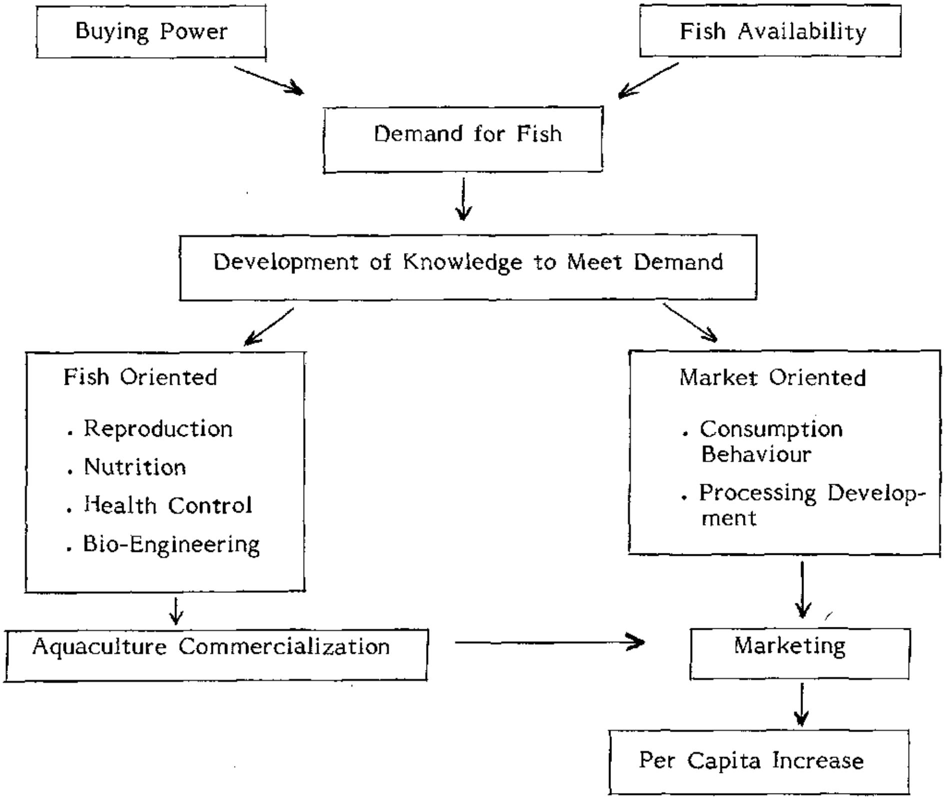

Figure 3. Aquaculture expansion concept

Aquaculture in Africa

Although the first signs of controlled fish production date back to the Pharaohs, there is nothing to suggest that any further developments were made in Africa between then and modern times. The first attempts to farm tilapia date back to 1924 in Kenya, but aquaculture actually made its first enroads after World War II. As a result in the late 1950s about 300.000 fish ponds were in operation mainly for tilapia culture and aquaculture was thought to play a vital role in the food production strategy of many countries (Maar et al., 1966). This development lost its momentum most probably because of the problems inherent in tilapia farming e.g. the prolific reproduction potential of the species, which leads to over-population in ponds and subsequently to poor growth, in other words in too many too small fish. Rational and successful tilapia culture demands great menagerial and enterpreneurial skills, which obviously were found failing.

However, after the World Symposium on Warm-Water Pond Fish Culture in 1966, post-independence aquaculture was revived mostly through externally aided projects, which are still in progress.

Since 1972 some 30 external donors have carried out over 130 short -

Table 4: Present status of aquaculture development in the CIFA region (CIFA, 1983)

Country (* CPCA Member Reference)	Small-scale aquaculture: Status 1982	Small-scale aquaculture: Development Project	Large-scale aquaculture: Status 1982: Pilot	Large-scale aquaculture: Status 1982: Commercial	Large-scale aquaculture: Development Project	Aquaculture research
* Benin	+	+	0	0	0	+
* Botswana						
* Burundi	+	+	0	0	0	+
* Cameroon	++	+++	0	0	+	+
* C.A.R.	+++	+++	0	0	0	++
* Chad			0	0	0	0
* Congo	+	++	0	0	+	+
* Egypt	+++	+++	++		+++	++
* Ethiopia						
* Gabon	+	+	0	0	+	0
* Gambia						
* Ghana	++	++	0	0	+	+
Guinea	+	+	0	0	+	0
* Ivory Coast	++	++	+	+	+	+++
* Kenya	+	++	+	+	+	++
Lesotho	+	+	+	0	+	0
Liberia	+	+	0	+	0	+
* Madagascar	++	++	0	0	+	++
* Malawi	+	+	0	0	+	+
* Mali		+	0	0	0	0
* Mauritius	+	+		+	+	
Mozambique	+	+	0	0		0
* Niger				.	+	+
* Nigeria	++	++	+	+	++	+++
* Rwanda	+	+	0	0	0	+
* Senegal	+	+	0	0	0	0
* Sierra Leone	+	+	0	0	+	+
* Somalia						
* Sudan	+	+	0	0	0	+
Swaziland						
* Tanzania	+	+	0	0	+	+
* Togo	+	+	0	0	0	+
* Uganda	+		0	0	0	
* Upper Volta	+	+	+	+		
* Zaire	++	+	0	0	0	0
* Zambia	+	+	+	+	+	++
Zimbabwe	+	+	0	+	+	++

Ref:
0 development nil
\+ scarcely developed
++ fairly well developed
+++ well developed

Table 5. Present aquaculture objectives in the CIFA region (CIFA, 1983)

Country	Family nutrition	Commercialisation	
		Artisanal	Industrial
Benin	+	+	
Botswana			
Burundi	+		
Cameroon	+	+	
C.A.R.	+	+	
Chad			
Congo	+		
Egypt	+	+	+
Ethiopia			
Gabon	+	+	
Gambia			
Ghana	+	+	
Guinea	+		
Ivory Coast	+	+	+
Kenya	+	+	+
Lesotho	+		
Liberia	+		+
Madagascar	+	+	
Malawi	+	+	
Mali			
Mauritius		+	+
Mozambique	+	+	
Niger		+	
Nigeria		+	+
Rwanda	+		
Senegal	+		
Sierra Leone	+	+	
Somalia			
Sudan	+	+	
Swaziland	+		
Tanzania	+	+	
Togo	+		
Uganda			
Upper Volta	+		+
Zaire	+	+	
Zambia	+	+	+
Zimbabwe		+	+

and/or long-term projects. In 1982 total "on-going" grants and loans amounted to some 60 and 40 million U.S.dollars respectively (CIFA, 1983; Huisman, 1985).

Despite the large effort in public funding, aquaculture obviously has not yet found its "niche" in African society, since Africa's contribution to the global production is insignificant (Table 1), as is the relative percentage of aquaculture in the total fish consumption figures for this region (Table 2). In fact, between 1975 and 1980 aquaculture production in Africa decreased at an average rate of some 13% per annum (FAO, 1984).

In response to this situation the Research and Technology Programme of the Dutch Ministry for Development Cooperation has financed a study on the effectiveness of aquaculture projects in Africa. The study is being executed by Euroconsult (1985).

Other agencies, such as FAO, currently are conducting similar studies to evaluate aquaculture development in Africa (Balarin, 1984a, b, c, d, e & 1985a, b).

The following paragraphs emphasise a few points taken from these and other studies (CIFA, 1983; FAO, 1984; Huisman, 1985; Huisman & Machiels, 1986).

The present continent-wide status of aquaculture as well as the aquaculture development objectives are summarized in Table 4 and 5.

It is striking that the most frequently mentioned objective is family nutrition (subsistence aquaculture), which seems rather contradictory to the very - commercial - nature of aquaculture (Section 4). Although fish protein may seem cheap compared to meat protein, it still needs buying power. The same holds true for increasing fish consumption (Figure 3).

In view of the afore mentioned objective it is not surprising that the most oftcited target group is subsistence farmers. In fact 90% of all funds earmarked for African aquaculture development are used for projects targeting subsistence and artisanal fish farmers, only 6% for the development of commercial aquaculture, and 4% for research.

In view of its present status in Africa, aquaculture still has to be regarded as a novelty. This fact alone justifies the question whether a subsistence farmer can be expected to take the risk inherent in any innovation without adequate financial and menagerial support. It even can be questioned whether a subsistence farmer considers improved family nutrition as a valid incentive for embarking on such an unknown and risky undertaking, especially since such farmers tend to adopt an attitude of risk avoidance.

It is, therefore, advocated that not only technical support should given to the target group, but that financial and marketing support should be combined with it until the local aquaculture industry has reached a stage of autonomous growth (Section 4). It might even be ventured that the latter is of more importance than the traditional discipline-oriented extension components of projects; at the very least they should go hand in hand. Furthermore thought needs to be given too the suitability of subsistence farmers as a key target group. Artisanal fish farmers (or cooperatives) might form a better target group, since aquaculture development unquestionable calls for a private enterpreneurial approach. Consequently in depth socio-economic studies of the society in the target area are mandatory prior to final project formulation and implementation in order to identify projects and strategies that have the best chances of economic viability to the target group. Since a project is a means to an end studies should also be carried out to monitor and evaluate the projects impact during implementation and after completion.

In this context some remarks must be made on the role of governments in aquaculture development. In most aquaculture projects the recipient government plays an active role as counterpart organisation. This is the present situation, and will be difficult to change. But the innovative character of aquaculture in Africa calls for not only governmental cooperation but also - and maybe even more so - private initiative and incentive-based enterpreneurship. Governments, having a regulatory role, are by nature not ideal innovators. It is, therefore, recommended that government involvement be transformed; - instead of serving as an active counterpart, it could be the source of the best "nutrient" for aquaculture to grow on, i.e. good legislation, credit-schemes, infrastructural support, etc.

The donor agencies must realise that aquaculture can only be introduced into Africa through innovative action. If a project is to be a means to achieve on objective, which, in the case of aquaculture, means ultimate attainment of autonomous growth, the time element is crucial. The standard project life of 3 to 4 years is not long enough.

In view of the preceding, an alternative approach to aquaculture development in Africa, should include, apart from longterm technical and extension assistance, longterm financial and marketing assistance directed to well defined and promising target groups. Projects should be chosen on the basis of their commercial feasibility within the target area which is the only realistic way to meet the challenge of commercial aquaculture.

References

Balarin, J.D., 1984a. National reviews for aquaculture development in Africa, 1. Zimbabwe. FAO Fish.Circ.770, 1, 69 pp.

Balarin, J.D., 1984b. National reviews for aquaculture development in Africa. 2. Liberia. FAO Fish.Circ. 770, 2, 49 pp.

Balarin, J.D., 1984c. National reviews for aquaculture development in Africa. 3. Siera Leone. FAO Fish.Circ. 770, 3, 55 pp.

Balarin, J.D., 1984d. Études nationales pour le développement de l'aquaculture en Afrique. 4. Togo. FAO Circ.Pêches. 770, 4, 66 pp.

Balarin, J.D., 1984e. Études nationales pour le développement de l'aquaculture en Afrique. 5. Benin. FAO Circ.Pêches. 770, 5, 52 pp.

Balarin, J.D., 1985a. National reviews for aquaculture development in Africa. 6. Cameroon. FAO Fish.Circ. 770, 6, 88 pp.

Balarin, J.D., 1985b. National reviews for aquaculture development in Africa. 7. Kenya. FAO Fish.Circ. 770, 7, 96 pp.

CIFA, 1983. Aquaculture development. 5th Session of Committee for Inland Fisheries of Africa (CIFA). Cairo, Egypt, 15-20 January 1985. Paper No. CIFA/83/5, 23 pp.

Euroconsult, 1985. The effectiveness of aquaculture projects in Africa. Euroconsult, Arnhem, The Netherlands. 90 pp.

FAO, 1985. A study of methodologies for fore-casting aquaculture development. FAO Fish.Techn.Paper No.249. FAO, Rome, 47 pp.

Huisman, E.A., 1985. Recent advances in aquaculture and their implications in the African region. In: H.Rosenthal (Ed.) Proceedings International Conference on Aquaculture, Aquacoltura '84, Verona, Italy, 11-14 October 1984.

Huisman, E.A. & Machiels, M.A.M., 1986. Fish production for food in the tropics. Proc.XIIIth Int.Congres of Nutrition, Brighton, U.K., 18-23 August 1985 (in press).

Kassim, B.B., A.K.Jee & T.C.Eng, 1979. A review of the status of research and development activities in rice-cum-fish culture in Asia. Universiti Pertanian Malaysia (Faculty of Fisheries and Marine Science). 49 pp.

Maar, A., M.A.E.Mortimer & I.van der Lingen, 1966. Fish Culture in Central East Africa. FAO Fish.Ser.No.20 FAO, Rome.

Pullin, R.S.V. & Z.H.Shehadeh, 1980. Integrated agriculture-aquaculture farming systems. International Center for Living Aquatic Resources Management (ICLARM), Manila, Philippines. 238 pp.
Reich, K., 1975. Multispecies fish culture (polyculture) in Israel. Bamidgeh, 27, 4, 85-99.

AQUACULTURE DEVELOPMENT AND TRAINING IN AFRICA

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Summary

Total aquaculture production for Africa has been reported as of, 23,337 tons in 1975 and 11,552 in 1980, indicating an average decrease 12.83% yet a food production increase of 3.10%, and a fish harvest decrease of 0.60% (FAO, 1984a). A survey of national data for 27 African countries which reported to have aquaculture production indicates that annual per capita production for 1980 varied between 0.85 (Benin) and 235 (Liberia) grams, Mauritius (125), Zimbabwe (108), Egypt (62), Burkina Faso (58), Nigeria (39) and Ivory Coast (37) are among the higher producers. The survey also shows that the overall production decrease was mainly due to a 7,000 ton drop in Nigeria's output between 1975 and 1980. While the reability of these statistics can be questioned in some cases and could account partially for the differences in production figures, factors such as the availability of technology, financial and socio-economic incentive and trained personnel should be reviewed in view of the importance of aquaculture in rural development.

The three levels of core personnel required are senior aquaculturists, aquaculture technicians and extension workers. The majority of technicians and extension workers have to be trained in their own countries with special emphasis on production systems of relevance to those countries and the socio-economic conditions under which they are applied. A smaller number of senior aquaculturists, who need a broad multidisciplinary training in all significant aspects of aquaculture and who would, after training, be able to identify deficiencies, plan and execute aquaculture production schemes at all levels under government or private agencies, have to be trained on a regional or subregional basis. The African Regional Aquaculture Centre (ARAC) established in 1979 under a cooperative arrangement between the UNDP, FAO and the Government of Nigeria and sponsored by all the countries in the region, has, up to now, enrolled 107 participants from 13 anglophone and 11 francophone countries of Africa in 5 one-year courses for senior aquaculturists. 76 Trainees have completed the programme succesfully, 56 of them having received a Master of Technology in Aquaculture from the Rivers State University of Science and Technology (Nigeria), to which ARAC is affiliated. At present 25 participants are undergoing training in the fifth annual course. It is hoped that subregional and national centres will be linked to the aquaculture network for Africa which is being planned, and that this will lead to the provision of adequate numbers of qualified manpower and also to the coordination of other aquaculture development activities such as research and information which are badly needed in the region.

Résumé

La production totale de l'aquaculture en Afrique représentait 23,337 tonnes en 1975 et 11,552 tonnes en 1980 - ce qui indique une baisse de 12.83% par an dans le contexte d'un accroissement de 3.10% pour la production alimentaire et d'une baisse de 0.60% pour la récolte de poissons (FAO,

1984a. Un examen des données nationales pour 27 pays pratiquant activement l'aquaculture montre que la production par habitant en 1980 se situait dans une gamme variant de 0.85 g (Bénin) à 235 g (Libéria). S'il convient, dans certains cas, de ne pas se fier entièrement aux statistiques qui pourraient ne rendre compte que partiellement des chiffres de production, il importe d'étudier des facteurs comme les technologies disponibles, les incitations financières et socio-économiques encore ou le personnel déjà formé, la raison l'importante de l'aquaculture dans le développement rural.

Des aquaculteurs expérimentés, des techniciens en aquaculture et des vulgarisateurs sont les trois catégories professionelles requises pour former le noyau de toute activité aquacole. La majorité des techniciens et des vulgarisateurs doit être formée sur place et l'accent doit être mis sur les systèmes de production applicables à leurs pays et sur les conditions socio-économique de cette application. Aux aquaculteurs spécialisés dont les effectifs sont moindres, il incombe, après leur formation, d'identifier les carences, de planifier et de mettre en oeuvre des projets de développement de l'aquaculture à tous les niveaux des organismes gouvernementaux ou privés; ils doivent donc être formés sur une base régionale ou sous-régionale. Le Centre Régional Africain pour l'Aquaculture (ARAC) a été crée en 1979, sous l'égide de tous les pays de la région, en vertu d'un accord de coopération conclu entre le PNUD, la FAO et le Gouvernement du Nigéria. Il a accueilli jusqu'ici 107 participants en provenance de 13 pays anglophones et 11 pays francophones d'Afrique, qui suivent des cours de formation d'une année (cours organisé chaque année depuis cinq ans) pour devenir aquaculture: 76 stagiaires ont terminé le programme avec succès dont 56 qui ont obtenu le diplôme de maîtrise ès techniques aquacoles (M.Tech.Aquaculture) de la Rivers State University of Science and Technology, Nigeria, université à laquelle l'ARAC est affilié. Un groupe de 25 étudiants suit actuellement les cours de la cinquième période annuelle de formation. On espère que les centres nationaux et sous-régionaux seront rattachés au réseau que l'on prévoit d'établir en Afrique pour l'aquaculture et que cela permettra d'assurer un bon niveau de spécialisation du personnel ainsi que la coordination d'autres activités de promotion de l'aquaculture telles que la recherche et les services d'information nécessaire à la région.

Aquaculture production in Africa

The status of aquaculture development in Africa has been reviewed with special attention to assessing levels of production (Pillay, 1979, 1981; Coche, 1983, FAO, 1984a, Balarin, 1985). The statistics available are far from satisfactory. Commenting on the estimates available Coche (1983) remarks that data are sometimes contradictory and often incomplete and that the presented estimates were subjective, incomplete or erroneous. Balarin (1985) observes that the total aquaculture production for Africa could be in the range of 7 - 144.4 thousand tons per annum, the wide range of which indicates the dubious reliability of the types of data available. It is, however, believed that present aquaculture production does not exceed 10.000 tons per year, consisting exclusively of finfish, most of them raised in fresh water (Coche, 1983). This forms only 0.1% of the world aquaculture production of 8.7 million tons and is low in comparison with the corresponding production values of other continents, which ranged from 1.3 to 84% of the global total (Pillay, 1981; Coche, 1983).

Reviewing the aquaculture production of countries in the CIFA region Coche (1983) points out the need for the countries to establish a viable system for collection of aquaculture statistics necessary for planning of aquaculture development on a national and regional scale.

FAO (1984a) presents aquaculture production figures for 27 African countries (having reported aquaculture production), which are based on earlier estimates available, with some additions and subjective corrections of obviously erroneous values. Allthough the authors advise that the values are to be accepted with caution, it would appear that these data could be taken as a basis for the present purpose. Aquaculture production for the years 1975 and 1980 and estimated per capita production for the 27 countries, taken from FAO (1984a) are presented in Table I.

Table 1. Estimates of Aquaculture Production in Africa. Source: FAO, 1984a.

Country	1975 t/year	1980 t/year	Finfish + Oysters production Gram/ Carp (1980)
Benin	-	3	0.85
Cameroon	137	273	32.33
Central African Republic	43	67	29.21
Congo	15	30	19.52
Egypt	3,500	2,597	61.89
Gabon	5	10	18.25
Ghana	40	120	10.27
Ivory Coast	10	300	37.34
Kenya	400	400	24.29
Lesotho	14	27	20.13
Liberia	350	700	235.06
Madagascar	300	300	34.32
Malawi	46	92	14.93
Mauritius	60	120	125.13
Nigeria	10,000	3,000	38.92
Rwanda	10	19	3.96
Senegal	191 *	191 *	33.74
Sierra Leone	1 *	3 *	0.86
South Africa	300	600	20.49
Sudan	25	50	2.72
Tanzania	1,500	500	27.88
Tunisia	30+30 *	30+30 *	4.72
Uganda	700	350	26.51
Burkina Faso	200	400	57.90
Zaire	5,000	705	24.92
Zambia	29	29	5.03
Zimbabwe	400	800	108.17
Total	23,114 **	11,522 **	Mean 24.98

* Oysters

** Total excludes oysters

It is shown that the total aquaculture production for the continent decreased from 23,337 tons in 1975 to 11,552 tons (finfish, only) in 1980, indicating an annual decrease of 12.83%. It is noteworthy that food production and capture fisheries harvest increased 3.10% and -0.60% respectively over the same period (FAO, 1984a).

A survey of national data indicates that per capita production for 1980 ranged between 0.85 (Benin) and 235 grams (Liberia). Among the higher values are 125 grams (Mauritius), 108 (Zimbabwe), 62 (Egypt), 58 (Burkina Faso), 39 (Nigeria) and 37 (Ivory Coast). It is tempting to consider these values as indicators of aquaculture activity in the countries concerned. But this would have to be confirmated by statistics, the pressing need for which has already been stressed. Information in Table I, suggests that the decline in total aquaculture production for the region was mainly due to a 7.000 ton production drop in Nigeria between 1975 and 1980. Only Senegal, Tunesia and Sierra Leone report production figures for oysters, respectively 191, 3 and 60 tons for 1980. In 16 of the other 25 countries finfish production increased between 1975 and 1980. In Tanzania, Uganda and Zaïre, like in Nigeria, aquaculture production decreased.

Although statistics are of questionable reliability, as was already mentioned it would be worthwhile analysing the reasons for such changes, and thereby stimulating a better appreciation for the need for data collection.

Problems in aquaculture development

The role of aquaculture

The role of aquaculture in development is now accepted widely. The World Conference on Fisheries Management and Development (FAO, 1984b), in its programme of action stated that: "In view of the increasing priority being given to aquaculture (including marine culture) FAO's assistance to its member nations needs further strengthening. While there is a particular interest among countries which are landlocked, or which have restricted access to wild fish resources, nearly all countries, including small island states and many with relatively unused marine resources, are making increasing efforts to develop aquaculture. The reasons include the need to diversify rural production, to provide alternative employment for rural people, especially women, to produce more fish for local consumption, and to increase opportunities of earning foreign exchange".

Commercial and rural or village-level aquaculture are two separate facets of development, the latter being more important in view of its role in improving the quality of life, including the health and economy, of the rural populations. Commercial aquaculture on the other hand is gaining faster recognition in the developed world, and the Wall Street Journal recently referred to aquaculture as one of the ten best investments (Fisheries, 1985). At either level more fish is needed for the protein starved world. It is now becoming obvious that the rate of growth in world fish production has levelled off. However, the demand for fish as food is expected to double over the next fifteen or twenty years.

Constraints in Aquaculture development

It is well known that unlike the countries in Asia the African countries did not have a background and tradition in aquaculture even though aquaculture in certain parts of Africa was as old as anywhere else in the world. The realization of the importance of aquaculture and the hopes given by the "wonder-fish", tilapia, caused many countries in Africa to take up fish culture in the '60s. Apparently most of these ventures were unsuccessful or at least not as successful as expected. One of the causes might have been the handicap of the prolific reproductive potential of the tilapias. Certainly several other factors such as lack of institutional facilities, funding and organization, difficulties in transferring technology, especially due to the absence of trained personnel, lack of understanding of the socio-economic issues connected with setting up aquaculture programmes, inadequate infrastructure, and the absence of an appropriate government policy were also responsible for the slow development of aquaculture. The absence of a properly organized aquaculture extension service slows down development, particularly in the case of small scale rural aquaculture. Loans at reasonable rates combined with adequate technical and material suport could stimulate artisanal aquaculture development in rural areas. The development of large private enterprises would require a sound financing policy including grants, interest free loans and fiscal incentives to attract foreign capital (Pillay, 1981). Aquaculture programmes should also be covered by suitable legislation to develop and protect aquaculture.

Many of these considerations should be taken up at the initial stage of programming aquaculture ventures, and subject to availability of suitable technology, the right choice of the aquaculture systems and the site is of paramount importance. The complexity of the issues to be considered in site selection is indicated in Fig. 1. FAO (1984a) finds that five major factors, e.g. environment, space, technology, production and marketing management, and marketing are important in aquaculture development. The following sub-factors, physical environment, institutional environment, social environment, water space, culture technology and production operations are also closely related to aquaculture development.

A successful form of aquaculture could entail the integration of aquaculture with crop- and live-stock farming, as has indeed been done profitably in China and elsewhere in Asia. This would ease issues on feed and fertilizer supplies and also in general management and optimal use of labour and farm machinery. Indiscriminate grafting of aquaculture ventures can be seen as a common cause for programme failure in Africa and other parts of the world.

General characteristics of aquaculture development in Africa

Species cultivated

The most widely cultivated finfish species is the tilapia, especially Oreochromis niloticus. This species has been introduced into salt water areas as well, in addition to Sarotherodon melanotheron and Tilapia guineensis which naturally occur in brackish waters. The common carp and several Chinese and Indian carps are also being cultured in many countries. Other exotics often cultured are the trouts. The catfishes, Clarias spp. and Chrysichthys spp., the Nile perch and the mullets are the other often cultured finfishes. Among crustaceans the penaeids (Penaeus monodon, P. indicus, P.notiales etc.) and the palaemonids (Macrobrachium rosenbergii and the endemic M.vollenhovenii) are of potential value in African aquaculture. The oysters (Crassostrea spp.) are being successfully cultured in Senegal and Sierra Leone and experimentally in Nigeria and Mauritius.

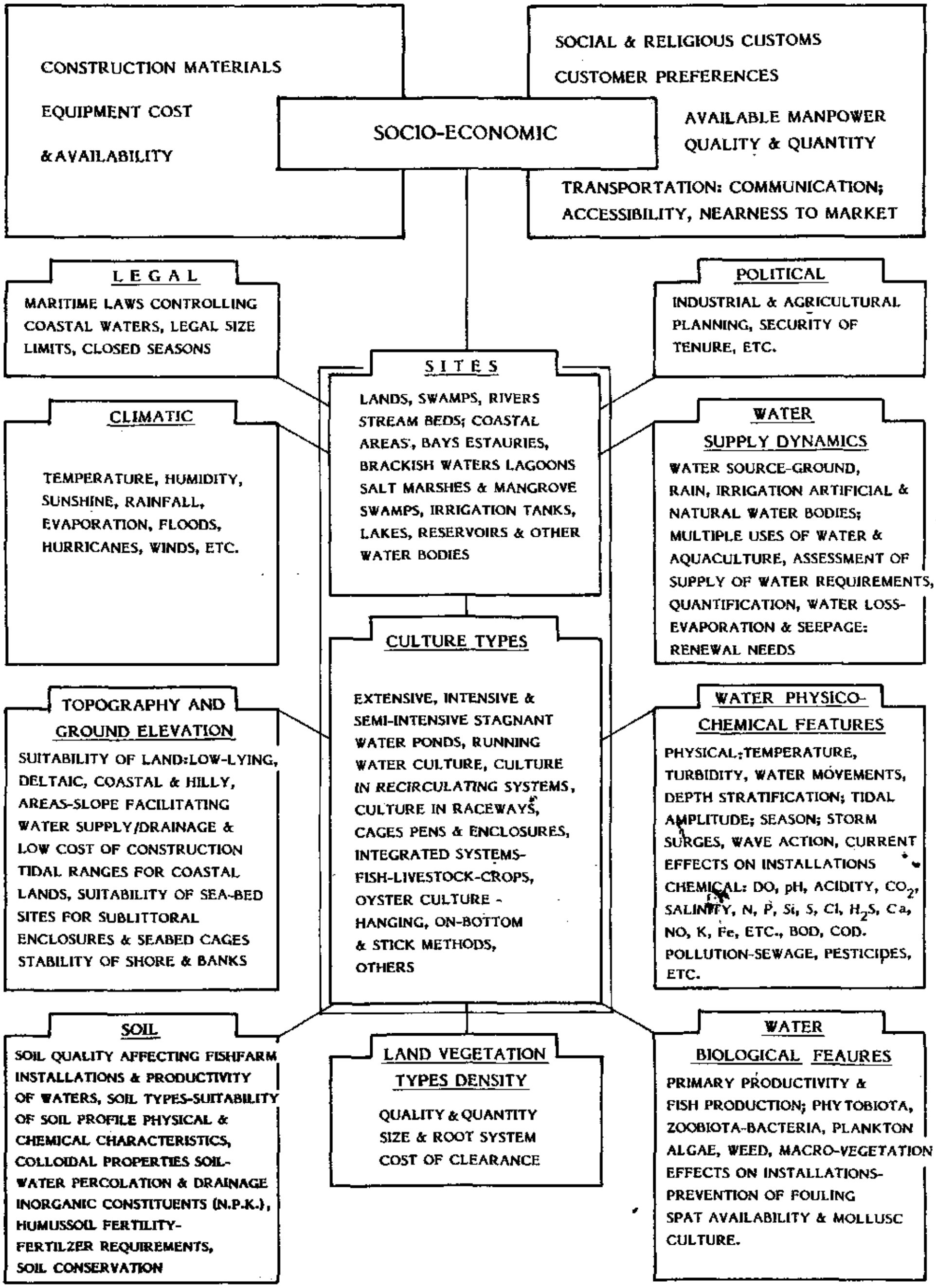

FIGURE 1. FACTORS AFFECTING SITE SELECTION IN AQUACULTURE.

Aquaculture systems

Besides pond culture practised in most African countries, some specific fish farming production techniques have been developed in many parts of Africa (Coche, 1983). Cage culture has been developed in Ivory Coast, Egypt (grass carp), Zimbabwe (trout) and is being experimented in Burkina Faso, Benin and Togo. Pen or enclosure culture has been successfully developed for tilapias and Chrysichthys in Ivory Coast and for tilapia in Benin. Rice-cum-fish culture is another avenue, well developed in Madagascar and now being experimented in Kenya, Liberia and Sierra Leone. Fish culture integrated with animal husbandry has produced good results in Central African Republic and Zambia. There is ample scope for development of this most effective integration in other parts of Africa.

A major problem in aquaculture is adequate supply of fish seed and transport of live fish. These aspects need more attention in order to develop suitable techniques for large-scale application.

Large scale industrial aquaculture development has already reached an advanced stage in some African countries, either through private or public enterprises (Coche, 1983). But only enterprises which are commercially viable will stand the test of time (Pillay, 1977).

Manpower requirements and training personnel

Being an interdisciplinary science, aquaculture calls for expertise in many fields. Since it is not practical or economical to have specialists in every discipline in all enterprises, they will have to depend on some common services for specialisted assistance. The managerial staff, could either be composed of technologists with some training in management or managers with some training in aquaculture technology. The manpower requirements at various levels should be estimated at the national and regional level before organizing training programmes. One could expect a drop out of about 25% or the senior professionals by transfers to other areas; this loss should be taken into consideration on planning training programmes (Pillay, 1977).

Aquaculture training

As mentioned earlier a major constraint to the development of aquaculture in most countries is the scarcity of trained personnel, especially those with broad training and experience in the practical aspects of aquaculture production. The three levels of core personnel required for aquaculture have been identified as senior aquaculturists, aquaculture technicians and extension workers (UNDP/FAO, 1975). The majority of aquaculture technicians and extension workers will have to be trained in their own countries, with special emphasis on appropriate production systems and the attending socio-economic conditions; the senior aquaculturists who are fewer in number will need multidisciplinary training provided at the regional or sub-regional level.

Following the decision of the Ghana workshop (UNDP/FAO, 1975) the African Regional Aquaculture Centre (ARAC) was established in 1979, under a cooperative arrangement between the Government of Nigeria, the United Nations Development Programme and the Food and Agriculture Organization and sponsored by all the countries in the region to provide multidisciplinary training for senior aquaculture personnel, applied, systems- oriented research and information activities.

Training of senior aquaculturists at ARAC

A curriculum of multidisciplinary training for senior aquaculturists for the African region (FAO/UNDP, 1979) was prepared by a Task Force appointed by FAO and serves as the basis for ARAC's one-year training course for senior aquaculturists. The fifth course of this kind is now nearing completion.

Nature and duration of training

The training offered at ARAC is intended to qualify candidates for planning and executing aquaculture programmes in fishery or allied departments of government and semi-government agencies or private industries. It is multidisciplinary and covers all essential aspects of aquaculture, e.g. site selection, construction of aquaculture facilities, breeding and rearing of cultivable organisms, relevant physico-chemical, biological and environmental questions, post-harvest technology, socio-economics and planning.

Instruction covers both theory and practice. Training lasts for one year, (± 1500 hours) consisting of three 13-15 weekterms of academic study and two 3-5 weeks inter-sessional breaks which are spent on projects, and fieldwork, including a study-tour. The schedule is so tight that it should, perhaps, be extended by three months.

Training schedule

The training schedule closely follows the established "Curriculum". The 19 subjects listed in the "Curriculum" are still the major component of the aquaculture course. Since the 4th annual course "Statistical Methods in Aquaculture" has been added. Project work is still a major activity for the trainees who report on both their "Culture trial" and their "Individual research project".

The training is given in both English and French. The lectures are given separately for the anglophone and francophone participants but for the rest, such as practical exercises, field work, seminars, etc. the two linguistic groups work together which encourages interaction among the trainees and stimulates discussions on and comprehension of the variety of aquacultural problems in Africa.

The ARAC Master of Technology diploma in Aquaculture

Successful trainees i.e. those with an average of 60% or over qualify for the ARAC Post-graduate Diploma. They are eligible to apply for the M.Tech.(Aquaculture) degree of the Rivers State University of Science and Technology (RSUST), Port Harcourt to which ARAC is affiliated

All candidates who have a degree in fisheries, biology or allied subjects qualify for admission. A few candidates without a degree, but who possess a lower diploma have been admitted to the ARAC Diploma programme. RSUST carefully examines all applications from trainees before admitting them for the M.Tech.(Aquaculture) degree. So far 56 of the 76 (7 women) candidates who have received the ARAC diploma, have successfully qualified for the M.Tech.(Aquaculture) degree (see Table II); the per country distribution of trainees in the four ARAC courses conducted so far is shown in Fig.2.

Trainees are exposed to certain situations and are required to suggest solutions using the information they have gathered during the course and earlier. They must critically assess each aspect of theory and practical exercises, during the seminars and discussions. Major activities of the programme include pond culture, tilapia culture, culture systems such as those used with catfish, carp and polyculture systems. The trainees' culture trial usually concern tilapias and other local fresh or brackish water species in a pond culture set up. In some cases polyculture and cage culture have tried, using the available facilities.

Table II. National representation of trainees per training course.

Countries	Course					
	1st 1980/81	2nd 1981/82	3rd 1982/83	4th 1983/84	5th 1985	Total
Anglophone						
1. Ethiopia	-	-	-	1	-	1
2. Gambia	-	-	1	1	1	3
3. Ghana	(1[a])	-	1	1.	1	3
4. Kenya	3	-	1	2	5	11
5. Liberia	-	-	-	1.	-	1
6. Malawi	1	-	-	1	-	2
7. Nigeria	6(1[a])	4(2[a])	8	4	10	32
8. Sierra Leone	2	-	1	-	1	4
9. Sudan	2	-	-	-	-	2
10.Tanzania	1	1	1	-	-	3
11. Uganda	-	1	-	1	-	2
12. Zambia	1	1	1	1	1	5
13. Zimbabwe	-	-	-	1	-	1
Francophone						
14. Burundi	-	-	-	-	1	1
15. Cameroun	-	-	-	-	1	1
16. C.A.R.	2	1	1	1	1	6
17. Congo-Brazzaville	-	3	3	-	-	6
18. Ghana	4	2	-	-	-	6
19. Guinea-Conakry	-	1	-	-	3	4
20. Ivory Coast	1	-	-	1	-	2
21. Mali	-	-	-	2	-	2
22. Rwanda	-	-	1	-	-	2
23. Senegal	-(1[a])	-	-	1	-	1
24. Zaire	-	-	-	1	-	1
Number qualified for M.Tech.degree	16	11	15	14	-	56
Drop-outs	(3[a])	(2[a])	(1[a,b])	-	-	
Total completed	23	16	17	20	25	101[(c)] (76)

Note: a - Drop-outs
b - Mauritius - Trainee repatriated for medical reasons
c - Total completed in the first four courses: 76

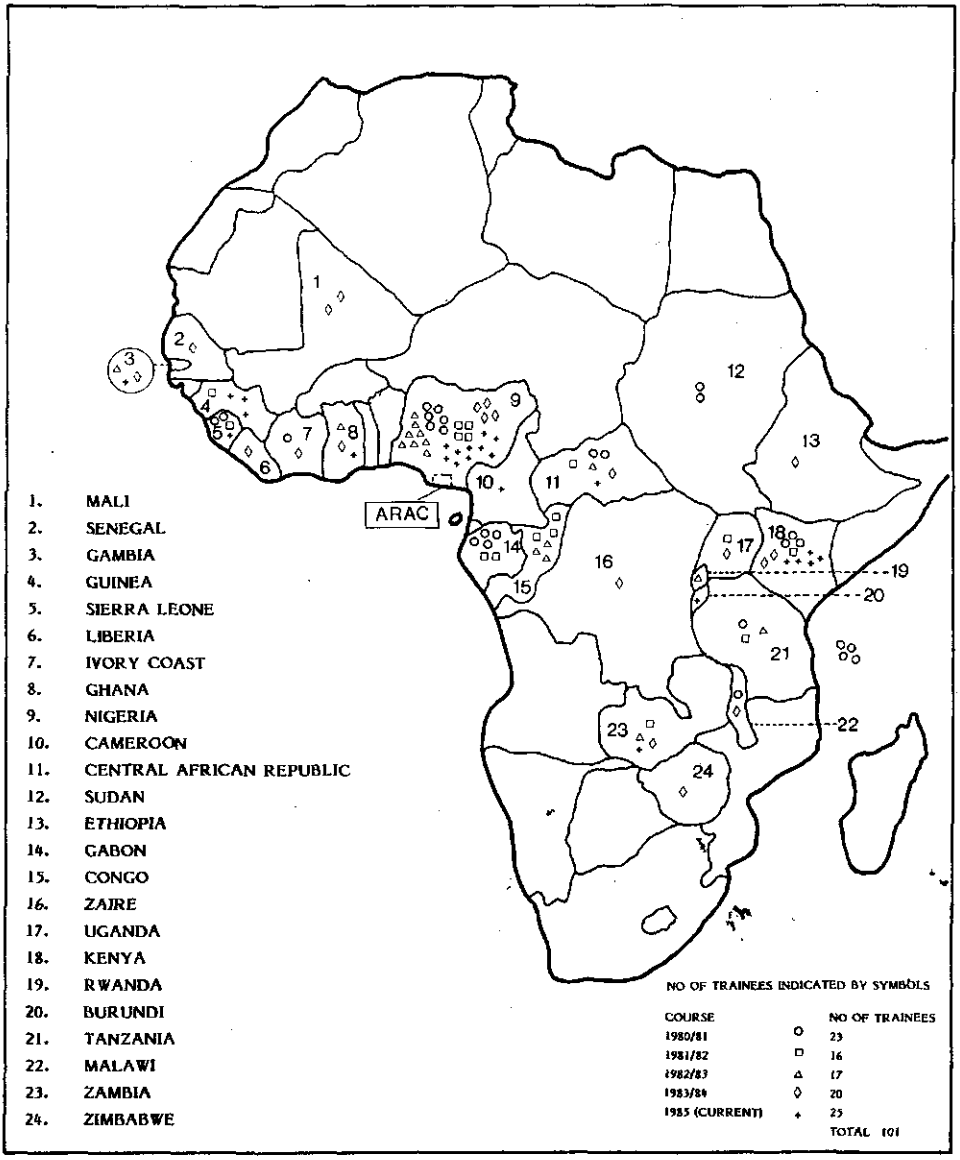

FIGURE 2. AFRICAN REGIONAL AQUACULTURE CENTRE; NATIONAL REPRESENTATION OF TRAINEES.

Other culture systems have been dealt with briefly and mainly from a theoretical point of view to expose the trainees to different forms of aquaculture, as carried out in various parts of the world. This serves as the basis for the introduction of new systems. First-hand information is frequently given by guest consultants; e.g. since pen culture does not exist in Nigeria, Mr.S.Hem from Ivory Coast was invited to conduct a programme on pen culture (Hem, 1979). The present group of trainees went to Benin to study this system and the traditional lagoon culture. Hopefully more study tours outside Nigeria can be organised for future programmes.

Site selection and species selection for culture are discussed in broad detail encompassing the various aspects of socio-economical, geographical, climatological, physico-chemical and biological considerations. Conditions and species relevant to the region and background experiences of trainees are considered.

Trainees gather considerable experience in pond construction by designing a fish farm using data they have collected in the field. The course of nutrition and feed formulation is very detailed, and many students carry out individual projects in this field. The environment species interactions have interested several trainees. While they get insight into the management of the species to be cultured, they also get trained by being confronted with problems in aquaculture and by seeking solutions. Above all, the trainees develop considerable confidence in being able to speak and solve timely problems through research, reports and theses, which are submitted to internal and external examiners (see Annex I for a list of trainee projects).

Post-harvest technology, fish health and hygiene are taught by Centre staff and consultants. The socio-economics of aquaculture and extension are dealt with by using specialists from the Faculty of Agriculture of the Rivers State University of Science and Technology.

ARAC training for senior aquaculturists is considered to be of high level, similar to training given in other international institutions.

Upon return home about 80% of ARAC trainees are fruitfully employed in aquaculture and allied fisheries development activities. ARAC monitors their activities by correspondence. It might be worthwhile to have an independent assessment of the impact of ARAC training on trainees after return home.

Improvements and prospects for the future

Funding

Some 125 trainees out of a targeted 175 (Table II) are expected to be trained by the end of the sixth annual course. This coincides with the end of the second phase of the project. Full enrolment for each annual course is 35 trainees, and although 35 are admitted, only about 20-25 attend annualy because of insufficient financial support. Funding agencies such as ADB, CFTC, USAID, GFID and EEC (EDF) have assisted in supporting the trainees (Table III). ADB fully financed the first course. It is hoped that more international funding can be obtained in the future.

Future programmes

The sixth course at ARAC is scheduled to begin on January 9, 1986. According to the reports from different countries and international groups training in aquaculture in Africa needs to be continued some years to come. Applications for the sixth course are now being processed. The course should have an enrolment of 20-25 participants, subject to funding. The number could be higher if more funds were obtained. The second meeting of the ARAC Advisory Committee is scheduled for November, 1985, when this and other future ARAC programmes will be discussed.

Table III. Details of funds received from various funding agencies and number of trainees funded per course.

	Course 1st 1980/81	2nd 1981/82	3rd 1982/83	4th 1983/84	5th 1985[a]	Total
ADB[b]	26	-	-	7	2[b]	35
UNDP/FAO Field Projects	-	7	5	3	3	18
CFTC	-	3	4	3	5	15
USAID[c]	-	-	1	1	1[c]	3
GFID[d]	-	-	-	-	1	1
Govt.of Gabon	-	2	-	-	-	2
Govt.of Guinea-EEC Conakry[e] (EDF)	-	-	-	-	3	3
Govt.of Mali[e] - EEC (EDF)	-	-	-	2	-	2
Govt.of Nigeria	-	6	8	4	10[f]	28
Total	26	18	18	20	25	107
Number successful						
for ARAC Diploma	23	16	17	20	-	76
for M.Tech.Degree	16	11	15[g]	14[g]	-	56[g]

a - On-going course which commenced on January 7, 1985

b - ADB funds were received in the first year for all trainees; ARAC uses the balance for subsequent courses.

c - USAID awarded 3 fellowships but only 2 fellows joined the course.

d - Funds from GFID, Feldafin received for the first time in the current course for a trainee from Sierra Leone.

e - Funds received from EEC (EDF) through country governments.

f - Funds through various Government (Federal and State) and parastatal agencies in Nigeria - some trainees are on paid leave of absence.

g - In 3rd and 4th courses 2 candidates in each course, who qualified otherwise for the M.Tech.degree, did not submit their revised thesis.

Aquaculture development in relation to capture fisheries and agriculture

Pillay (1977) suggests that marine capture fisheries environments are suitable for aquaculture. Capture fisheries is important because it establishes a market and network to get fish to consumers. However capture fisherman would have difficulty in transferring to culture operations unless the "reward" was worthwhile (FAO, 1984a).

Rewards from the integration of aquaculture with agriculture, which was referred to earlier are many (Kutty, 1977; Pedini, 1982). Aquaculture can borrow technology and expertise from the allied branches of agriculture, such as soil-water management, weed, pest and disease control, genetic manipulations, socio-economics and extension. In spite of some level of competition for space (land and water) and nutritional requirements, the integration of fish-livestock-crop farming is most profitable. The pressure from exploding populations in certain parts of Asia and the long population increase period, have apparently resulted in harmonious evolution of integrated systems, where wastes and wants are minimised.

Coordination of aquaculture development activities

The UNDP/FAO Aquaculture Development Coordination Programme (ADCP) has established six regional centres located in Nigeria, Brazil, China, India, Philippines and Thailand, and an inter-regional centre in Hungary, ARAC forms part of this network. These centres undertake applied research for technology development, senior level training and development of an aquaculture data base. The regional centres are proposed to be linked with national centres for technology testing and adaptation, training of technicians and extension workers and information dissemination. Due to the differences in cultured species and in aquaculture systems and also due to the regional, national and local differences in resources and knowledge available, governments are faced with a major challenge in providing services and technical support to aquaculture, especially with respect to extension. The need for various training activities is acute even in areas where aquaculture has been practiced in traditional ways (FAO, 1984b). In this context it is hoped that the proposed network of national centres linked to ARAC will be able to play a vital role in the development of aquaculture in Africa.

References

Balarin, J.D., 1985. Aquaculture Practices in Africa: Systems in use and species cultivated. A status Report. Paper presented at the Consultative Workshop on Village Level Aquaculture Development in Africa, Freetown, Sierra Leone, 14-20 February, 1985. Commonwealth Secretariat, Food Production and Rural Development Division, London.

Coche, A.G., 1983. Aquaculture Development. Committee on Inland Fisheries of Africa (CIFA). Fifth Session, Cairo, Egypt, 15-20 January, 1983. 23 pp.

FAO, 1984a. Inland-water Resources and Aquaculture Service, Fishery Resources and Environment Division. A study of methodologies for forecasting aquaculture development. FAO Fish.Techn.Pap. (248): 47 p.

FAO, 1984b. Report of the FAO World Conference on Fisheries Management and Development, Rome, 27 June-6 July, 1984. 60 p.

Fisheries, 1985. Current events and announcements. Fisheries Bulletin of American Fisheries Society 10 (4): 39.

Hem, S., 1979. L'aquaculture en enclos- Adaptation au Milieu Lagunaire Ivoirien. Prov.Report No.7: 199 (Aquaculture II). International Foundation for Science. Abidjan, Ivory Coast, November 1979.

Kutty, M.N., 1977. Fish culture in a farm complex. Kisan World. Madras 4 (11): 11-69.
Pillay, T.V.R., 1977. Planning of aquaculture development - an introductory guide. Farnham, Surrey, Fishing News Books Ltd., for FAO, 71 p.
Pillay, T.V.R., 1979. The Status of Aquaculture, 1976. In Advances in aquaculture, Eds. T.V.R.Pillay & W.A.Dill. Farnham, Surrey, Fishing News Books Ltd., pp.1-10.
Pillay, T.V.R., 1981. Status of Aquaculture, 1981. Paper presented at the Twelfth Annual Meeting of the World Mariculture Society, Venice, Italy, 21-25 September, 1981.
UNDP/FAO, 1975. Aquaculture Planning in Africa. Report of the First Regional Workshop on Aquaculture Planning in Africa, Accra, Ghana, 2-17 July, 1975. 114 p.
UNDP/FAO, 1979. Curriculum for the training of the aquaculturists in the African Regional Centre for Aquaculture, Port Harcourt, Rivers State. 34 p.

Appendix 1.

AFRICAN REGIONAL AQUACULTURE CENTRE
Port Harcourt, Nigeria

Topics of project work carried out by ARAC trainees

First course, 1980/81

1. Ectoparasitic (trematode)infection in Tilapia guineensis.
   -Karrar, Miss B.M. (Sudan) and Otenyo, F. (Kenya).
2. Oxygen requirements of the prawn Penaeus notialis and the Cichlid fish Tilapia guineensis.
   -Onamusi, B.C. (Nigeria), Shariff, M.F. (Sierra Leone), Wafula, M. (Kenya) and Kenja, S.R. (Tanzania).
3. Sex reversal in Tilapia guineensis.
   -Rashidi, B.B. (Malawi).
4. Culture trials on Oreochromis niloticus.
   -Gbondo, W. (Sierra Leone), Hassan, H.A.R. (Sudan) and Muguswi, C.T. (Zambia).

Second training course, 1981/82

5. Salinity tolerances of Sarotherodon melanotheron, Tilapia guineensis, O.niloticus and T.zillii.
   -Bangura,A.A. (Sierra Leone) and Jumbo, J. (Uganda).
6. Effects of methyl testosterone on early growth of Tilapia guinnensis.
   -Wangila, B.C. (Kenya).
7. Influence of anaesthetic quinaldine on certain species of Tilapia.
   -Sado, E.K. (Nigeria).
8. Effects of pH on survival of Oreochromis niloticus and Hemichromis fasciatus.
   -Lema, R.E. (Tanzania), Nwokike, S. (Nigeria) and Mutale, J.C. (Zambia).
9. Survival of Oreochromis niloticus and S.melanotheron under varying environmental conditions.
   -Nwadukwe, F.O. (Nigeria).
10. Oxygen regimes and plankton blooms in plastic pools.
    -Ezekoka, Miss N.J. (Nigeria).
11. Studies on the efficiency of artificial feeds of three different compositions on O.niloticus fingerlings grown in plastic pools.
    -Koyaguitrembi, M. (Central African Republic).
12. Comparative growth trials of Oreochromis niloticus using natural and artificial feeds.
    -Mayet, J., Koubakouenda, Miss H. and M'Voula, R.B. (all from Congo Brazzaville).
13. Studies on the use of different numbers of broodfish of T.guineensis in 10% artificial brackishwater.
    -Ngong-Memiaghe, E. (Gabon).

Third training course, 1982/83

14. Food and feeding habits of Tilapia guineensis.
    -Ademakiniva, B.T. (Nigeria).
15. Growth, oxygen consumption and ammonia excretion in Sarotherodon melanotheron and Oreochromis niloticus at different salinities.
    -Ahingwa, G.N. (Ghana).
16. Some aspects of feeding, assimilation and food conversion in the Cichlid fish, Tilapia zillii.
    -Ajibado, S. (Nigeria).

-Ajibado, S. (Nigeria).

17. Some aspects of feeding, assimilation and food conversion in the Cichlid fish, Oreochromis niloticus.
-Banda, K.P. (Zambia).

18. Studies on escape (avoidance) responses of the gastroped mollusc, Tympanotenus fuscatus) to tobacco waste.
-Aleem, S.C. (Nigeria).

19. Tidal and seasonal influence on physico-chemical conditions of the New Calabar River at Aluu.
-Erondu, E.S. (Nigeria).

20. The influence of pH on the survival of Oreochromis niloticus at various ammonia concentrations.
-Kissaka, M.B.S. (Tanzania).

21. Food and feeding habits of Sarotherodon melanotheron in relation to its morphological structures.
-Hamman, J.B. (Nigeria).

Fourth training course, 1983/84

22. Production de zooplancton pour l'etude de la competition de Sarotherodon melanotheron et de Tilapia (Coptodon) guineensis élevés en bacs et essai d'élevage semi-intensif de T.melanotheron en eau saumâtre à laferme piscicole de Buguma.
-Badji, N. (Senegal).

23. Essai d'élevage du O.niloticus en bacs utilisant differents types d'aliments à composition proteinique croissante et élevage semi-intensif du Tilapia melanptheron en eau saumatre à Buguma.
-Blimi, N. (Ivory Coast).

24. Studies of Elops lacerta and other extraneous fishes in brackishwater ponds and culture of T.melanotheron in brackishwwater ponds.
-Bolarinwa, J.B. (Nigeria).

25. Some observations os aspects of biology of T.mario Boulenger and culture of Tilapias in fresh water ponds.
-Bongonyinge, C. (Uganda).

26. Fecondité et maturité du T.mariae (Pelmatotilapia) et essai d'élevage semi-intensif du O.niloticus et T.galilea en polyculture en eau douce à Okigwe.
-Camara, Miss O. (Mali).

27. Predation by Parocephalus obscurus on fry of Oreochromis niloticus, T. zillii and tadpoles of Diroglosuus occidentales and culture of Tilapias in freshwater ponds.
-Chirwa, H.K. (Malawi).

28. Influence of dissolved oxygen on feeding and growth of cichlid fish, Oreochromis niloticus (Linnaeus) and pond culture of Tilapias in fresh water.
-GG/Tsadik, G. (Ethiopia).

29. Influence of two organochloride pesticides, Thiodan and Lindane on survival of fingerlings of Oreochromis (Sarotherodon) niloticus and T.zillii (Gervais).
-Gurure, R.M. (Zimbabwe).

30. Growth studies on Tilapias, Oreochromis niloticus (Linn.), Sarotherodon galinaeus (Linn.) and T.zillii (Gervais) in different salinities and culture of Tilapias in brackish water fish ponds.
-Jallah, J.M. (Liberia).

31. Primary productivity of brackishwater and freshwater fish ponds and culture of Tilapia in brackishwater fish pond.
-Jallow, A.M. (Gambia).

32. Evacuation gastrique et assimilation proteinique chez la O.nilotica et essai d'élevage semi-intensif du O.niloticus et du T.galilaea en polyculture en douce à Okigwe.
-Kaimba, B. (Central African Republic).
33. The food and feeding habits of fry of Tilapia guineensis (Bleeker) and Sarotherodon melanotheron (Ruppel) from brackishwater ponds, and culture of Sarotherodon melanotheron in a brackishwater fish ponds.
-Kasumu, R.A. (Nigeria).
34. Effet de la predation par Hemichromis fasciatus sur les alevins de Tilapias et les tetards de grenouilles, et essai d'élevage semi-intensif du O.niloticus et du T.galilaea en eau douce à Okigwe.
-Mayo, M. (Zaire).
35. Studies on the effects of organic fertilizers on nutrient releases and plankton growth.
-Muntemba, R. (Zambia).
36. Studies on influence of some micronutrients on the growth and survival of Sarotherodon melanotheron (Ruppel) and Oreochromis niloticus (Linnaeus).
-Ofori, J.K. (Ghana).
37. Maturation, hypophysation and larval development in Clarias lazera (C.& V., 1840) and culture of Tilapias in freshwater pond.
-Osuigwe, D.I. (Nigeria).
38. Production of plankton in freshwater and brackishwater type by application of lime and fertilizer and culture of Tilapia in brackishwater pond.
-Ogunsola, Mrs.A.F. (Nigeria).
39. Macrobrachium vollenhovenii, its availability, tolerance of salinity and low pH, and an assessment of its use as a predator in polyculture.
-Thiga, B.M. (Kenya).
40. Etude préliminaire du Régime Alimentaire de Tilapia (Pelmatotilapia) mariae (Boulenger, 1899) dans son milieu naturel et élevage semi-intensif de O.niloticus (L) et T.galilaea (A) en polyculture en eau douce.
-Traore, D. (Mali).
41. Feeding habit and food spectrum of Sarotherodon melanotheron (Ruppel) in brackishwater ponds.
-Wakai, G.K. (Kenya).

A REVIEW OF AQUACULTURE PRACTICES IN TANZANIA

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Summary

This review of aquaculture practices in Tanzania estimates that there are 3000 fish ponds in Tanzania yielding about 150 tons of fish per annum, over 80% of which are hardly managed. After these ponds are stocked the farmers wait for a year or two to harvest them. The yields from such ponds are very small and discouraging. In well managed ponds yields are good. As for marine culture attempts to propagate rabbitfish, Siganus canalicullatus and algae in the coastal waters of Tanzania have been most successful. Work carried out up to present sofar indicates that Tanzania has a good potential for aquaculture.

Resumé

Cette communication décrit les pratiques d'aquaculture en Tanzanie. En estime qu'il y a 3000 étangs d'aquaculture en Tanzanie qui donnent un rendement de quelque 150 tonnes de poisson par an. Plus de 80% de ces étangs ne sont l'objet d'aucun soin. Ce sont des étangs qui ont été creusés, remplis d'eau puis mis en charge. Les pisciculteurs attendent un ou deux ans avant de procéder à la récolte. Les rendements de ces étangs sont très faibles et décourageants. En revanche, les quelques étangs qui sont correctement exploités donnent de bons rendements. Des tentatives de culture de Siganus canalicullatus et d'algues dans les eaux côtières de Tanzanie ont connu un réel succès et les travaux réalisés montrent que l'aquaculture en Tanzanie offre un potentiel élevé.

Introduction

Fish culture has been practised in many parts of both developed and developing countries for a long time. For example, South East Asia cultures tilapia, milkfish, catfish and prawns, the United States cultures clams, Mercenaria mercenaria, and oysters, Crassostrea americana, whereas European culture practices include salmon, trout, oysters and clams. On the African continent aquaculture has also played a role to provide fish protein for the population.

New techniques are always being developed in fish culture as a result of technological progress. For example, it is now possible to induce sex reversal and sterility successful. Such technologies can be used to reduce overpopulation of fish.

In Tanzania, fish culture practice, though widely spread, has not kept pace with technological progress. Most farmers dig ponds or dams and after stocking, just wait one or two years and then harvest their fish. Returns from such practices are usually un-attractive. Recently, attempts to cultivate rabbitfish, Siganus canalicullatus, in the coastal waters of Tanzania have been successful (Bwathondi, 1981, 1982a). Attempts to culture Oreochromis niloticus, imported from the Baobab Farm, Mombasa, are, now in progress.

The present-day aquaculture practices in the Tanzania can be divided into unmanaged pond culture and managed pond and cage culture. It is estimated that Tanzania has a total of 3000 ponds of about 0.25 hectares on the average, yielding about 150 tons annually (Bwathondi, 1985).

Of these ponds, more than 80% can be considered as unmanaged. Fishermen/ fish farmers are constantly advised to care for their fish. This includes feeding the fish and removing dead or weak individuals. The feed used is mainly locally available feed-stuffs from farms such as rice bran and food left-overs from households and institutions.

A survey on existing fish farms in Tanzania indicated that the majority of fish farms were concentrated in the southern zone of the country, e.g. Lindi, Mtwara, Ruvuma and Mbeya Regions. Second was the north-east zone, including the Kilimanjaro, Arusha and Tanga Regions. The coastal and western zones do not support much fish culture. The reasons for such a concentration of aquaculture sites in the southern zones of Tanzania include availability of land and water and the fact that fish protein is used to supplement beef protein in the southern regions where cattle are scarce. Furthermore, the absence of cattle in this zone, leaves enough land for farmers to construct ponds. The central and the north-western parts of the country (except Kagera region) are too arid for fish farming.

The culture of freshwater fish in Tanzania has progressed somewhat, far more than marine fishes and organisms. The first attempts to culture marine animals in Tanzania date back to the late '60s, with lobsters and oysters being added in the mid '70s. Subramaniam (1980) studied the prawns of Tanzania and designed a prawn culture project which was not implemented due to his departure from Tanzania. Other attempts to culture marine organisms in Tanzania include Jiddawi's project (1984) for Zanzibar oysters and Mshigeni's(unpublished) research - which is progressing well - on algae. The most intensively explored marine fish culture in Tanzania concerns the rabbitfish, Siganus canalicullatus, reared in floating cages. Bwathondi (1982b) reported on the potential of polyculture of rabbitfish and oysters. This was the result of work done by Bwathondi and Ngoile (1982) on the growth of bivalves - including oysters and Pinctada spp. - on floating cages. In attempting to advise on the use of floating cages in fish culture in Tanzania Bwathondi (1982c), lists the following drawbacks: bouyancy, fouling, siltation and socio-economic factors.
Any attempts to introduce floating cage culture should address the above problems first.

Finally, recent work by Mndeme (1985) has revealed that oysters of Dar es Salaam belong to the genus Crassostrea and that those growing on rock surfaces (usually submerged most of the time) grow faster and to bigger sizes yielding more meat than those growing on the mangrove trunks and roots (which are submerged for a shorter duration). Integrated fish(grass carp)-cum-duck culture is being carried out in a project, based in Morogoro Region. More time is needed to evaluate results from the project.

In conclusion it is worth mentioning that aquaculture in Tanzania, though developing at a slow pace, especially freshwater aquaculture holds great promise for the near future.

References

Bwathondi, P.O.J.,1981. The culture of rabbitfish, Siganus spp. in Tanzania. IFS, Stockholm, Sweden. 35 pp.

Bwathondi, P.O.J., 1982a. Preliminary investigations on the rabbitfish, S. canalicullatus cultivation in Tanzania. Aquaculture, 27: 205-210.

Bwathondi, P.O.J., 1982b. The potential of marine polyculture in developing countries: Case study in Tanzania. Atlantica Vol. 5.

Bwathondi, P.O.J., 1982c. The aquaculture of rabbitfish Siganus canaliculatus Park 1797 and Problems of cage culture in Tanzania. Univ.Dar.Sc. Journal Vol.8 (1 & 2): 43-53.

Bwathondi, P.O.J., 1985. Fish culture as means of aleviating protein deficiency in Tanzania. Paper presented at a seminar on the utilization of food: Morogoro, Tanzania, 27-31 May 1985.

Bwathondi, P.O.J. & Ngoile, M.A.K., 1982. Bivalves fouling floating cages used in aquaculture. Indian J.Mar.Sciences II (3): 282-285.

Jiddawi, N.S., 1984. Preliminary investigation on growth and settlement of oysters on cultches in the harbour area of Zanzibar (mimeo).

Mndeme, E.E., 1985. Determination of optium meat yield of commercially important oysters in Dar es Salaam and vicinity. MSc.Thesis, University of Dar es Salaam.

Subramaniam, S.P., 1980. Studies on penaeid prawns with special reference to the nursery environment. Ph.D.Thesis, University of Dar es Salaam.

THE STATUS OF AQUACULTURE IN MAURITIUS

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Summary

Coastal aquaculture or more precisely the fattening of marine fish and shellfish have been practised within sea enclosures since the year 1800 and at present the culture methods have not changed. Fish fingerlings are seasonally collected from the wild and transferred into the enclosures locally called 'barachois', similarly spats of oysters or baby oysters are collected and fattened using suitable submerged structures. All species under culture feed on the organisms found naturally in the water. However in some instances chicken entrails or cow manure is applied to enrich natural productivity. The production of this type of culture is low.

Inland aquaculture development was initiated on sound principles with the introduction of the giant freshwater prawn Macrobrachium rosenbergii in 1972 and of the Chinese and Indian major carps: - Ctenopharyngodon idella (Valenciennes), Hypophthalmichthys molitrix (Valenciennes), Catla catla (Hamilton), Labeo rohita (Hamilton), Cirrhinus mrigala (Hamilton), as well as the common carp (Cyprinus carpio, Linnaeus), in the mid seventies.

Post larvae of M.rosenbergii have been produced in the hatchery using the green and clear water techniques as has been carp fingerlings using hypophysation. Prawn and carp culture is well established and promising.

Resumé

L'aquaculture côtière ou, plus précisément, le grossisement des poissons de mer et des crustacés, se pratique en enclos marins depuis le 19ème siècle et les méthodes de culture actuelles restent les mêmes que celles d'antan. Les alevins sont périodiquement collectés dans la mer et transférés dans des enclos marins connus localement sous le nom 'barachois'; les naissans d'huîtres ou jeunes huîtres sont pareillement collectés et engraissés dans des structures immergées adaptées. Toutes les espèces cultivées se nourrisent des organismes qui se trouvent naturellement dans l'eau. Dans certains cas, toutefois, on complète cette alimentation pas des entrailles de poulets ou de la bouse de vache. La productivité de ce type d'élevage est faible.

Le développement de l'aquaculture à l'intérieur des terres, sur des bases solides, a commencé par l'introduction de la crevette géante d'eau douce, Macrobrachium rosenbergii en 1972 et des carpes chinoises et indiennes : Ctenopharyngodon idella (Valenciennes), Hypophthalmichthys molitrix (Valenciennes), Catla catla (Hamilton), Labeo rohita (Hamilton), Cirrhinus mrigala (Hamilton) ainsi que Cyprinus carpio (Linnaeus), aux environs de 1975.

On a produit en écloseries des post-larves de M.rosenbergii en eaux claires enrichies en algaes, et des alevins de carpes par hypophysation.

L'élevage de crevettes et de carpes est bien établi et tout à fait prometteur.

Introduction

Fish farming in the marine and estuarine environment is confined to 'Barachois' which are permeable drystone wall enclosures in small bays, estuaries or indentations along the coat. Fish culture practice is not very highly developed and consists of capturing finfish fingerlings from the open lagoon, which are transferred to the "Barachois" for fattening.

Although Mauritius is an island, major aquaculture development has taken place in the fresh water fisheries sector. The culture of the giant fresh water prawn Macrobrachium rosenbergii is developing into an industry, locally known as the 'Camaron Industry'. The aquaculture of Indian major and Chinese carps is also developing fast.

Camaron culture

Since the successful transplatation in Mauritius of the giant fresh water prawn Macrobrachium rosenbergii in 1972 (Ardill et al., 1973), two permanent camaron hatcheries have been constructed to provide prawn seed i.e. camaron post-larvae. One, the Camaron Hatchery Co Ltd. belongs to the private sector, the other, Albion Fisheries Research Centre Hatchery, is Government owned.

The private sector hatchery started operationing in 1976 and is run on a purely commercial basis. It has a floor area of 966 m^2 with 32 poured concrete tanks having a total production volume of 768 m^3 (Thompson, 1979). The technique employed is that of mass larval culture (Fujimura, 1974), utilizing phytoplankton-enriched or 'green' water with 15 o/oo salinity in large rectangular concrete tanks. The hatchery has an annual production capacity of about 10 million camaron juveniles, but at present produces between 3.5 and 4 million juveniles per year.

The Albion Fisheries Research Centre Hatchery started in 1983 is smaller (a floor area of 240 m^2). It has ten 2.000 liter conical reinforced fibreglass tanks for mass larval rearing. The larvae are cultured in clear water at 13-15% salinity using modern techniques developed by CNEXO of France in Tahiti. Hatchery acticities include applied research in the field and production of prawn post-larvae for the Government-owned fresh-water fish farm at La ferme.

As the result of steady expansion since 1973 the prawn growing pond area now covers about 25 ha, and produces 35 tons of camaron per annum. The commercial ponds are earthen ones, rectangular in shape, with a size range of 0.2-0.6 ha. The 0.2 hapond is recommended as the optimum size for the farmers. A private company has just embarked on a project for the construction of a 20 ha pond complex for camaron production. When this farm becomes operational the annual camaron production is expected to increase to 75 tons.

The private hatchery sells the camaron post-larvae at Mauritian Rupee (MR.) 0.50 per unit. The present stocking rates for 0.2 ha growout ponds range from 30.000 to 40.000 camaron post-larvae. The culture period is generally limited to one year. However, after seven months of culture, the large prawns are culled using drag seine nets, with a stretch mesh size of 5 cm. The partial culling of the large size prawns is practised on a monthly basis from the 7th to the 11th months after which the pond is completely drained and the remaining camaron harvested. In general experienced farmers record a 70% survival of camaron with an average standard length of 12 cm (Goorah and Parameswaran, 1983) and 35 grams in weight. The farm gate wholesale price for camaron is MR. 90 per kilogramme.

The camaron are fed on a specially formulated camaron feed with 30-35% protein. The feed computed on the basis of 3% bodyweight per day is provided daily. The special formula feeds that have been developed locally are the camaron crumbles and the camaron pellets manufactured by Livestock Feed Factory Ltd. During the first two to three months period, the camaron are fed with the crumbles which is afterwards replaced by the pellets. The ex-factory sale price for the camaron feed is about MR. 5.700 per ton.

Carp culture

During 1975 and 1976 three species of Indian major carp namely Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) and the Chinese carp Ctenopharyngodon idella (Valenciennes) and Hypohthalmichthys molitrix (Valenciennes) and the common carp Cyprinus carpio (Linnaeus) were successfully transplantated into the country from India. These species were selected for culture in fresh-water ponds because of the following characteristics (Parameswaran et al., 1977).

(I) Carp are fast growing and have a very efficient feed conversion.
(II) They feed at primary and secondary trophic levels and hence energy losses in fish-flesh production are low.
(III) They are neither predatory nor territorial
(IV) The various species of carp have different and somewhat compatible feeding habits and, therefore use most pond resources optimally. They readily accept cheap supplementary feeds.
(V) Carp are hardy, withstand handling, and tolerate fluctuations in temperature and oxygen and other dissolved gasses in water.
(VI) Unlike Tilapia, they (except for common carp to a limited extent) do not breed in ponds, reservoirs or fast flowing streams.
(VII) They have firm and palatable flesh.

Carp culture is widely practised by the farmers either under extensive or under semi-intensive conditions. Intensive carp culture is not practised because of the prohibitive feed costs. The type of ponds used for extensive culture are irrigation water holding tanks and fallow ponds. However, compatible species of carp are generally cultivated in the camaron ponds. Four species of carp, namely rohu, catla, grass carp and silver carp can be used satisfactorily for polyculture in the camaron ponds. Some farmers prefer to rear camaron as a monoculture but may maintain a small population of grass and silver carp in the pond as biological control agents. In the summer months the camaron ponds invariably develop either macro-vegetation or filamentous algae on the pond bottom, or thick phytoplankton blooms. If these are not controlled, nighttime oxygen deficiency may develop and kill all the camaron in the pond. To avoid such dangers the camaron ponds are stocked with grass carp to control filamentous algae and macrophytes and with silver carp to control the phytoplankton bloom in the pond. Prior to the introduction of carp, the camaron farmers suffered endless crop losses. Furthermore, this system saves on one hand manual labour for removing filamentous algae and submerged vegetation from the ponds and on the other hand saves water for dilution or flushing of the phytoplankton

In order to meet national carp seed requirements in 1983 the Government constructed the La Ferme Fish Farm a 28 pond fresh-water fish farm covering a total water area of 4.0 ha, described in Table 1 hereinunder.

Table 1. Pond details of La Ferme Fish Farm.

Category of ponds	Area (ha)	No.of ponds	Dimensions (m)	Total area (ha)
Nursery	0.0495	9	15.0 x 33.0	0.445
Rearing	0.10	6	22.0 x 45.5	0.6
Stocking	0.20	11	30.0 x 66.7	2.2
Stocking	0.40	2	530 x 75.0	0.8

The strategic objective of the La Ferme Fish Farm is to produce some 500.000 carp fingerlings annually in order to meet the national fish seed demand. Another activity involves research on the polyculture of finfish and camaron designed to improve culture techniques and optimize yields. The major carps are reproduced by hypophysation during the breeding season which extends from November to March. The spawn produced is reared in nursery ponds for three to four months until they reach fingerling size i.e. an average of 9 cm. They are then distributed free to all fish farmers for eventual stocking of their ponds.

The fingerlings produced in excess of the farmers' demand are stocked in fresh-water reservoirs. There are seven domestic water supply and irrigation reservoirs with a total surface of 460 ha (Motwani, 1971). Four of these reservoirs are gradually being stocked with carp fingerlings; a reservoir fishery will probably be established in a few years. Preliminary results show that carps grow well in reservoirs.

Mariculture

The culture of economically important finfish and shellfish species is practised in sea enclosures locally called 'barachois'. These are water bodies situated in suitable bays, coastal indentations and estuaries, which are fenced from the lagoon by a man-made permeable dry stone wall with sluice gates at distances calculated to allow for water exchange during tidal fluctuations. There are 22 'barachois' ranging from 0.5 to 50 ha, covering a total area of 392 ha.

Finfish culture

Cultivated finfish species include Siganus sp., Valamugil sp., Chanos chanos, Lethrinus sp., Upeneus sp. and other species common to the lagoon.

Fish seeds (fingerlings) used for stocking purposes are collected seasonally from the wild between December and March by seining operations in waist deep coastal waters. After quick sorting they are transported to the 'barachois' in a floating box made of plastic mesh towed behind a boat. The number of fingerlings are then estimated and released in the 'barachois'.

The availability of fingerlings is not quaranteed and the numbers collected have always varied from year to year. It is often difficult to obtain the adequate species mix. The culture methods have essentially remained traditional. 'Bacharois' are periodically fertilized with cow manure to favour the growth and bloom of macroalgae, phytoplankton and zooplankton, on which the fingerlings and yearlings feed. In general no supplemental feed is applied, but some 'barachois' owners who have the facilities, add chicken entrails to improve production.

After a culture period of about 2 years the fish are harvested, or partial harvests are carried out periodically which enables elimination of some predatory species at the same time. The average production in 'barachois' is about the same as that in the lagoon i.e. 36 kg/ha/yr, which is low.

The principal problems in this type of fish culture are the presence of many predatory fish (like sharks, Barracuda, Sphyraena sp., needle fish, Tylpsorus crocodilus, trumpet fish Fistularia serrata and Synaceichthys sp.) which find their way into the 'barachois' and take a heavy toll on the population under culture, the insufficient availability of natural food in the water, and poaching.

Shell fish and crustacean culture

Cultivated non finfish species include oysters and crabs, viz., Crassostrea sp. and Scylla serrata respectively.

Oyster culture is practised in a few 'barachois' particularly in the North Eastern and the South Eastern region of the island because of the suitability of the sites.

Baby oysters of the local species Crassostrea cuculata are purchased by culturists from collectors and fattened in suspended trays or trays placed on the sea bed. Several techniques and materials have been tested to maximise growth and quality but have not given satisfactory results.

Attempts have also been made to grow exotic species such as C.gigas, C.virginica and Ostrea edulis (Brusca and Ardill, 1974), but mortality ratio have been high due to rapid temperature fluctuations, lack of feed (phytoplankton) to sustain growth, and parasitic attacks by the Polydora worm.

The culture of the local oyster is preferred because of its adaptability to the environment, but it has a slow growth rate, taking 3-4 years to attain marketable size.

There are no annual production figures but surveys conducted in hotels and information from oyster growers, indicate that about half a million oysters are consumed annually.

Crab culture is practised on a very small scale in a few 'barachois'. Small crabs, collected along the coast, are transferred into 'barachois' or in cages which are placed in 'barachois', where they are fattened using chicken entrails as supplementary feed.

On the whole mariculture has not departed much from its past status. However, presently several projects are underway at research level to develop mariculture as for instance a pilot project for the culture of penaeid shrimps.

Aquaculture extension services

In order to promote the development of and the interest in aquaculture to meet the growing demand for fish protein and reduce imports, Ministry officials organize talks and discussions at village levels, give lectures to students, undergraduates and teachers and offer certain facilities and technical assistance to fish farmers in the following fields:

- Site and species selection,
- Feasibility analysis of projects for the future,
- General guidance on pond layout, design and construction,
- Supply of marine fish fingerlings from the lagoon and carp fingerlings,
- Supply of giant fresh water prawn post-larvae (if available),
- Management principles,
- Technical advice,
- Monitoring water quality and growing crops,
- Crop harvesting.

References

Ardill, D., R.Jenson, B.Jugnarain & R.K.Thompson, 1973. The introduction of the giant freshwater prawn Macrobrachium rosenbergii (De Man) into Mauritius. Revue Agricole et Sucrière de l'Ile Maurice, 52, 6-11.

Brusca, G. & D.Ardill, 1974. Growth and survival of the oysters Crassostrea gigas, C.virginica and Ostrea edulis in Mauritius. Revue Agricole et Sucrière de l'Ile Maurice, 1974, 53, 111-131.

Fujimura, T., 1966. Notes on the development of a practical mass culture technique of the giant fresh-water prawn (De Man) Macrobrachium rosenbergii. Indo-Pacific Fisheries Council, 12th Session. IPFC/C66/WP 47, 4 pp.

Goorah, D., & S.Parameswaran, 1983. Maturation and fecundity of the giant camaron, Macrobrachium rosenbergii (De Man) in ponds in Mauritius. Revue Agricole et Sucrière de l'Ile Maurice, 62, 84-90.

Motwani, M.P., 1971. Techno-Economic Survey of Mauritius. 3. Fisheries. Techno-Economic Mission, Government of India, New-Delhi, 128 p.

Parameswaran, S., M.I.Jehangeer & J.D.Ardill, 1977. Introduction of Indian and Chinese carps and preliminary observations on polyculture in Mauritius. Revue Agricole et Sucrière de l'Ile Maurice, 56, 124-140.

Thompson, R.K., 1979. Aquaculture of the fresh-water prawn, Macrobrachium rosenbergii in Mauritius, its status and potential. Proceedings of the National Agricultural Production Conference, University of Mauritius, 435-459.

L'AQUACULTURE EN TUNISIE

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Resumé

L'aquaculture a commencé en 1969 en Tunisie avec l'installation de parcs à moules et à huitres japonaises dans la région de Bizerte.

Les naissans d'huîtres sont importés. Le production totale est faible et entièrement consommé localement.

La pisciculture a debuté en 1975 avec la création par Brunel, un coopérant francais, d'une écloserie de loups (Dicentrarcus labrax) et de daurades (Chrysophys aurata) à Ghar el Behl dans le nord du pays. Cette installation a été vendue à l'INSTOP (Institut National Scientifique et Technique d'Océanographie et de Pêche) de Salambôo à Tunis.

Summary

Aquaculture started in Tunesia in 1969 with the establishment of Pacific Oyster and mussel culture grounds north of the Bizerte region.

Spats of oysters are imported. Since the total production is small, it is all consumed locally.

Farming of finfish started in Tunesia in 1975 when Brunel, a French Technical Assistant, started a hatchery for seabass (Dicentrarchus labrax) and gilt-head bream (Chrysophys aurata) in Ghar el Belh in the north of the country. The facility was sold to INSTOP (Institut National Scientifique et Technique d'Océanographie et de Pêche) in Salambôo Tunis.

L'aquaculture en Tunesie

L'aquaculture a débuté en Tunisie en 1969 avec l'installation des parcs à moules et à huîtres japonaises dans le nord du pays, à Bizerte. Les naissans d'huîtres sont importés. La production des ces coquilles, bien que peu importante, est entièrement consommée localement.

La pisciculture a commencé en Tunisie en 1975 avec la création d'une d'ecloserie de loups (Dicentrarchus labrax) et de daurades (Chrysophya aurata) par Brunel, un coopérant francais, à Ghar El-Melh dans le nord du pays. Cette installation a été ensuite en 1978 vendue à l'INSTOP (Institut National Scientifique et Technique d'Océanographie et de Pêche Salambôo Tunis).

En 1976 une station de grossissement de muges a été mise en place au Lac de Khéniss à Monastir (centre du pays); 12000 alevins ont été élevés jusqu'à la taille commercialisable et alimentés par les déchets de cantines d'école. Ce centre d'élevage est aussi dirigé par l'INSTOP.

Au début les résultats obtenus à Ghar El Melh et à Khéniss n'étaient pas très satisfaisant du fait des maladies parasitaires et bactériennes, qui se déclaraient de temps à autre dans les deux stations. Cette situation doit être attribuée en premier lieu du manque de personnel scientifique compétent dans ces deux stations qui sont très éloignées des Universités de Tunis et de Sfax. Aucun chercheur à plein temps n'est engagé pour y travailler. La deuxième cause de cet "échec" est d'ordre budgétaire, mais la MEDRAP vient d'afforter une aide assez importante au développement de l'aquaculture à Khéniss. De grands bassin d'élevage et une écloserie sont en cours d'aménagement.

Actuellement 3 ingénieurs halieutes à plein temps font fonctionner la station de Khéniss en collaboration avec l'écloserie de Ghar El Melh mais il fait attendre encore quelque temps avait de pouvoir se prononcer sur l'efficacité de ces élevages.

Une station de piscisulture qui à donné de bons résultats est la station de grossissement de l'Oued El Akarit à environ 80 km au Sud de Sfax. On a creusé dans la terre pour créer des bassins communiquants et alimentés par un puit artésien en bord de mer ayant une salinité de l'ordre de 7 à 8 g/l. La réussite de cette station est dûe à plusieurs facteurs:

- renouvellement continu de l'eau;
- oxygénation parfaite dûe à la dénivellation des bassins (disposés en escalier);
- la salinité (7-8 g/l) ne favorise ni les parasites d'eau douce ni ceux d'eau de mer;
- pas de gros investissements. Un seul gardien s'occupe de l'alimentation des poissons (2 sacs de 50 kg de concentrés pour volaille, par semaine).

Le grossissement dure environ 18 mois. Les alevins de loups, daurades et muges sont collectés par les pêcheurs sur la plage. Laproduction est d'environ 2 tonnes tous les 6 mois.

Il est à signaler également que la Banque Mondiale en collaboration avec certains pays du Golfe Arabique, a prévu des installations d'aquaculture dans le sud du pays, dans la mer de Bougrara. Une étude préliminaire du terrain a été faite en 1983 mais à ce jour, les travaux n'ont pas encore commencé.

Dans le Golfe de Gabès aucun essai de pisciculture n'a été fait jusqu'a présent alors que le milieu semble réunir plusieurs éléments favorables à une aquaculture (extensive, du moins). En effet, à Sfax, les marées sont importantes (environ 1 m) mais les vagues ne sont jamais très violentes; la température de l'eau descend très exceptionnelement en dessous de 10°C. En outre, non loin de la ville de Sfax, à Thyna, il existe des marais salants abandonnés qui pourraient être exploité de cette façon.

Sensibilisés par toutes ces données, nous avons décidé à l'E.N.I.S. (École Nationale d'Ingenieurs de Sfax) de développer des activés d'aquaculture à Sfax. Avec l'aide de la FIS en 1982, nous avons essayé de mettre sur pied une station expérimentale d'élevage de loups (Dicentrarchus labrax et D.punctatus), de daurades et de Muges.

Vu l'éloignement de la mer (3 ou 4 km), nous étions obligés de travailler en circuit fermé. Nos installations prêtes en janvier 1985, n'ont connu aucune défaillance notable et nous ont permis d'obtenir des résultats très encourageants lors des premiers essais que nous avions démarré 3 mois auparavant, sur les Muges.

A l'E.N.I.S. nous sommes actuellement 5 chercheurs dont 3 Maitres de conférence et 2 Maitres assistants représentant 3 spécialités: Physiologie, Biologie et Parasitologie des poissons.

D'autre part nous bénéficions d'un projet subventionné par l'INRST (Institut National de Recherche Scientifique en Tunisie) pour les essais de grossissement de poissons en cages à Kerkennah. Le site est déjà choisi et les cages sont en cours de préparation.

Nous comptons réaliser le prégrossissement des larves dans les installations expérimentales à l'E.N.I.S. puis le grossissement en cages des alevins jusqu'à la taille commercialisable, à Kerkennah.

L'aquaculture n'en est qu'à ses débuts en Tunisie mais devrait prendre un grand essor dans ce pays où le potentiel scientifique ne manque pas. Il reste à encourager la collaboration entre les organismes responsables et les chercheurs dans ce domaine en favorisant les communications et les échanges d'idées et d'expériences.

PRESENT STATUS OF AQUACULTURE IN ZAMBIA

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Summary

Fish farming in Zambia started in the early 1940s in order to supply protein to protein deficient areas. At present there are over 3000 fish ponds of about 0.25 ha each with production levels upto 3-4 tonnes/ha/yr. Species cultivated are Tilapia rendalli, Oreochromis andersonii, O.macrochir, O.mossambicus, Cyprinus carpio, Clarias spp., Serranochromis rebustus and Haplochromis mellandi, the latter two being used as predators.

The Government supplies fry for stocking and conducts research on modern methods to develop fish farming. Excellent scope for commercial fish farming exists, and the Government, with assistance from FAO/UNDP, is giving full support to fish farm development. In the rural sector other international agencies are assisting peasants in aquaculture development.

Resumé

L'élevage piscicole a été introduit en Zambie au début des années 40 pour fournir des protéines à des régions qui en manquaient. Il existe aujourd 'hui 3000 étangs piscicoles d'environ 0.25 ha chacun et dont les niveaux de production sont de l'ordre de 3 à 4 tonnes par hectare et par an. Les espèces cultivées sont Tilapia rendalli, Oreochromis andersonii, O.macrochir, O.mossambiques, Cyprinus carpio, Clarias spp. ainsi que Serranochromis rebustus et Haplochromis mellandi, utilisés comme prédateurs.

Le gouvernement fournit des alevins pour l'empoissonnement des étangs et conduit aussi des recherches sur l'utilisation de méthodes modernes de développement de la pisciculture. Les perspectives d'élevage commercial sont bonnes et le gouvernement développe la pisciculture avec l'aide de la FAO et du PNUD. Dans le secteur rural, d'autres institutions internationales aident les paysans à promouvoir leurs activités d'aquaculture.

Introduction

Zambia, though a land-locked country, is blessed with vast water resources covering an area of 53,680 km² during the rainy season in other words 7% of the total area of the country. Fish is regarded as the most important source of animal protein, current consumption being over 80,000 metric tonnes. The total production of the Zambian fisheries as of 1984 was 62,000 metric tonnes. Fish Culture has contributed over 700 tonnes per year to the total fish production, the shortfall being met by imports from neighbouring countries.

Fish culture is not new in Zambia as it started in the mid '40s with the construction of six ponds in Chilanga. During the years 1958-60 the Department of Fisheries constructed more ponds in Chilanga station which became a demonstration unit. Later pond construction spread to other areas with the sole aim of supplying protein to protein deficient areas. By the end of 1965 there were 1231 ponds with an area of approximately 100 ha. Most of the ponds were owned by subsistence farmers who grew fish for their own consumption. Although fish farming activities have been going on for many years, serious attempts to develop commercial fish farming have only been made during the past 5-6 years.

Area and scope

The Government, through the Department of Fisheries, is responsible for the development of fish farming in the country. It has 19 demonstration fish farms scattered in various parts of the country. Some of these fish farms are used as research centres where new fish farming technologies are tested before they are introduced to the fish farmers. The research centres are located at Chilanga near Lusaka, Mwekera near Kitwe, and Chipata (Fig.1).

The government, with the assistance of the United Nations Development Programme and the Food and Agriculture Organization (UNDP/FAO), has now embarked on a programme to improve the management and, thus, per hectare yields of fish farms. As a result of the success of this programme in developing management practices for both commercial and village level fish farming, there are now eight large private fish farms with a total area of 70 hectares and 20 moderate sized fish farms which together produce 75-100 tonnes of fish annually.

Present data on fish ponds indicate that there are over 3169 (349 ha) ponds and 545 (432 ha) dams in use for fish farming. Most of the ponds are no larger than 0.25 ha. It has been demonstrated that with good management using intensive fish farming practices, production levels of 3-4 tonnes per hectare per year are possible. The present level of production amounts to 710 tonnes, 621 tonnes more than in 1967.

Species cultivated and culture practices

Early fish culture programmes included Tilapia rendalii (T.melanopleura), Oreochromis macrochir, O.andersonii, O.mossambicus, Cyprinus carpio, Serranochromis robustus, Haplochromis mellandi and Clarias spp. which were introduced mainly in dams for sport fishing and in ponds as predators to control the prolific reproductive potential of tilapia species. H.mellandi was also introduced to control snails in case of bilharzia outbreaks in ponds and dams. The common carp, the only exotic fish, was brought in from Malawi as fry in 1980.

Polyculture of these species was recommended to utilize all the nichés available. It was only through intensive fertilization and feeding that productions of up to 6.6 tons/ha/year were achieved under experimentel conditions.

The Government and FAO have been trying to identify local species suitable for fish culture and the appropriate management practices. The results obtained so far indicate that the three spotted bream (Oreochromis andersonii), is suitable because of its good growth rate, whereas this species does not reproduce as fast as other species. Various farming systems have experimented with this species e.g. integrated fish farming using fish-cum-pig culture, fish-cum-duck culture, and fish culture using supplementary feeding. Maximum production levels achieved are 9.8 tonnes/ha/year with pigs, 7.0 tonnes/ha/year with ducks and 3.6 tonnes/ha/year under intensive feeding with a mixture of 50% maize bran and 50% sunflower cake, at stocking rates of 2.5 fish/m^2. Fingerlings for stocking weighed between 20 and 25 g, and fish were harvested after six months having obtained a marketable size (100-150 g).

The mirror carp is being reared in Government fish farms for intensive fish farming experiments. It has adapted favourably to the prevailing conditions in Zambia and has shown an impressive growth rate of 143 g/month using intensive feeding. Natural spawning takes place in ponds. Private farmers have also acquired the carp for their own experimentations.

Though no definite feed has been formulated, a number of agricultural by-products are being used as fish feed, e.g. maize bran, rice bran, vegetables, chicken litter, sunflower cake, brewery waste, slaughter house waste, soyabean cake, and even poultry feeds used at 5 percent body weight per day.

Conclusion

Due to the inability of natural fisheries to fill the widening gap between supply and demand, the Department of Fisheries is placing great emphasis on large-scale commercial fish farming through an effective fish culture development programme. In former times the Government supplied fingerlings for stocking free of charge, but industry at present needs an estimated 10 million fingerlings annually to stock the existing dams and ponds, which demand the Fisheries Department in unable to meet. This increased demand prompted the Fisheries Department with the Fish Culture Development Project (FAO) at Chilanga to establish a Pilot Tilapia Fish Seed Production and Distribution Centre using modern fish farming technologies. This programme is still in progress.

A seed production strategy will contribute significantly to the development of the industry. It is hoped that in future the Government will turn its present demonstration fish farms into seed production and distribution centres to enhance fish farming since each year Zambia consumes more fish than it produces. The difference, currently being met by imports, could be produced through integrated and intensive fish farming on the 3500 hectares and 200 hectares the private and the public sector respectively are considering financing and farming.

At present international agencies such as FAO/UNDP, UNHCR and ICMC, are actively assisting the Government of Zambia in furthering the development of fish culture.

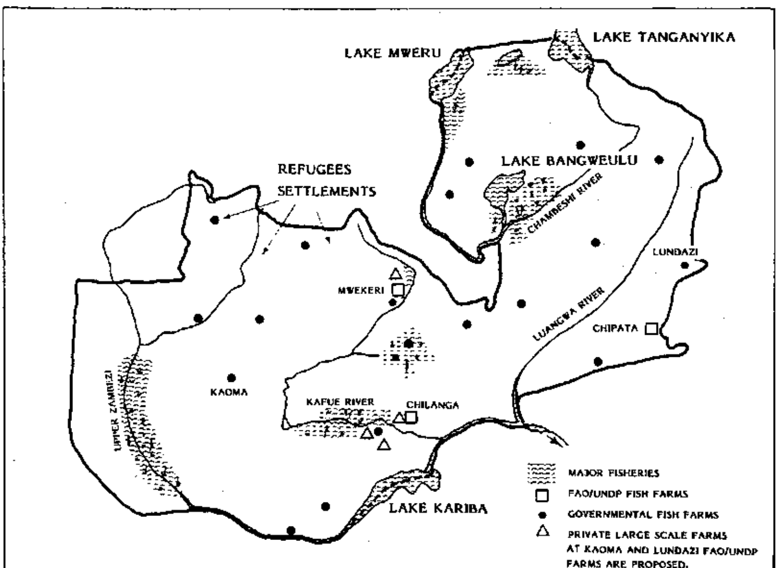

Figure 1. Map of Zambia showing fishery areas and fish farms under GRZ and FAO management and other private farms.

INOCULATION OF BRINE SHRIMP, ARTEMIA SALINA, IN KENYA; EXPECTED IMPACT ON AQUACULTURE DEVELOPMENT

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Summary

Populations of the brine shrimp, Artemia salina, are found in hundreds of salt lakes and salt farms (salinas) all over the world. Its distribution however, is not continous and several countries as for instance Brazil, Thailand, and Philippines have inoculated the species. Although several ideal biotopes for this brine shrimp exist in Kenya (Rift Valley and Coastal saltworks)A.salina is not indigenous in this country. Inoculation in two coastal saltworks took place in 1984. This paper reviews the expected impact of this inoculation of the brine shrimp on the farming of fish and crustaceans, and on the general economy of the country.

Resumé

On trouve des populations d'Artemia salina dans des centaines lacs et des salines du monde entier. Elles ne se répartissent cependant pas uniformément et certains pays comme le Brésil, la Thailande, les Philippines et d'autres, ont dû avoir recours à l'inoculation. Bien que le Kenya présente plusieurs biotopes très favorables à Artemia salina (dans la Vallée du Rift et les salines côterières) il n'en abrite toutefois aucune population naturelle. On a procédé à l'inoculation de cette espèce dans deux salines côtières en 1984 et on étudie ici les effets que cette inoculation pourrait exercer sur l'élevage des poissons et des crustacés ainsi que sur l'économie du pays en géneral.

General introduction

The brine shrimp, A.salina belongs to the class Crustacea and to the order Anostraca. It has two modes of reproduction e.g. oviparous reproduction whereby the female produces cysts, and ovoviviparous reproduction whereby the female produces free swimming naupliae of 0.4 mm in size (Fig.1).

The cysts, which are miniscule (200-300 µm diameter) and brown in colour usually float at the water surface and are transported by wind and waves to the edges of the waterbodies. The embryo inside is in a state of metabolic dormancy and upon immersion on sea water the cyst hydrates and becomes spherical. The metabolism of the embryo is activated, which leads to the hatching of a 0.4 mm nauplius. The nauplius differentiates through about fifteen molts to become an adult of 8-10 mm long. The adult A.salina can live for several months and the female produces a batch of eggs every five days.

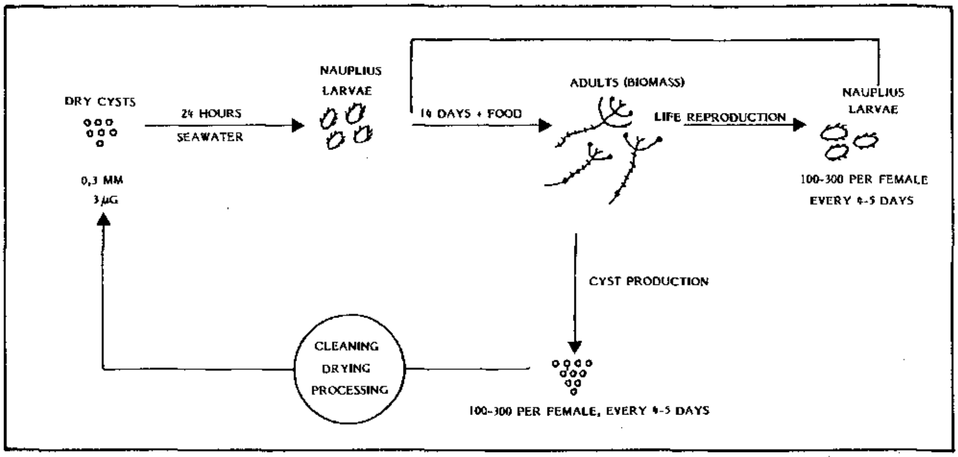

FIGURE 1. ARTEMIA LIFE CYCLE.

During the '30s' it was discovered both in the U.S.A. and in Nórway that the nauplii of A.salina constitute an excellent source for exogenous feeding of fish and crustacean larvae. The fact that A.salina cysts could be stored for many years, if kept dry, was a significant breakthrough in aquaculture. Other types of live feed organisms exist for hatchery and nursery operations of fish and crustaceans e.g. Brachionus (Rotifera) Daphnia (Cladocera). Inert feeds such as pelletized diets are also used, however A.salina is still the best feed for nursery and hatchery operations because it has the following advantages over all other feeds:

- the nauplii have a very high protein content (± 40%)
- the cysts can be stored for many years, and if appropriately packed can be sent all over the world
- from the cysts live larvae i.e. nauplii are easily and quickly obtained by hatching them in seawater.

The fresh hatched nauplii of A.salina are most commonly fed to crustacean and fish larvae. The pre-adult and adult A.salina constitute an even better feed since the protein content is usually higher. This biomass is harvested, washed and fed directly to fish and crustaceans or is harvested and frozen, or is just dried. The thickness of the exoskeleton is only 1 µm which means the whole A.salina can be consumed without any processing.

The brine shrimp occurs naturally in salt lakes and salt ponds with salinities ranging from 60 ppt to 300 ppt which illustrates their adaptive capacity in salinity levels that are mortal to many plant, and animal species. In salt ponds where A.salina occurs naturally or has been introduced, the salt farmers have enjoyed relatively good salt harvests both in terms of quantity and quality. The quality of the salt is enhanced by the particulate filter feeding habits of the brine shrimp which helps in cleaning the brine and the quantity is improved thanks to inhibitions of the algal blooms which prevent early precipitation of gypsum and, in extreme situations, may hemper salt crystallization. The metabolites of the brine shrimp provide a suitable substrate for Malobacterium, which assures the red water coloration, thus enhancing heat absorption, which in turn promotes the production of bigger and finer salt crystals.

Because of the general-uneven-distribution of A.salina in most countries inoculation has been required. In North-east Brazil there was no natural A.salina in the more than 20,000 ha of salinas in the Rio Grande de Norte; it had to be introduced by man. In South-east Asia there are thousands of hectares of salt ponds during the dry season but no natural A.salina. And because all the salt ponds are turned into fresh-water ponds during the mansoon season A.salina inoculations have to be repeated at the beginning of every dry season.

The presence of A.salina in Kenya

Although A.salina has been reported in literature to occur in Lake Elementaita in the Kenya Rift Valley a survey carried out along the Kenyan coast (1983/84) by staff of the Kenya Marine & Fisheries Research Institute, to verify the presence of local strains of A.salina in Kenya (Fig.2) proved to be invain.

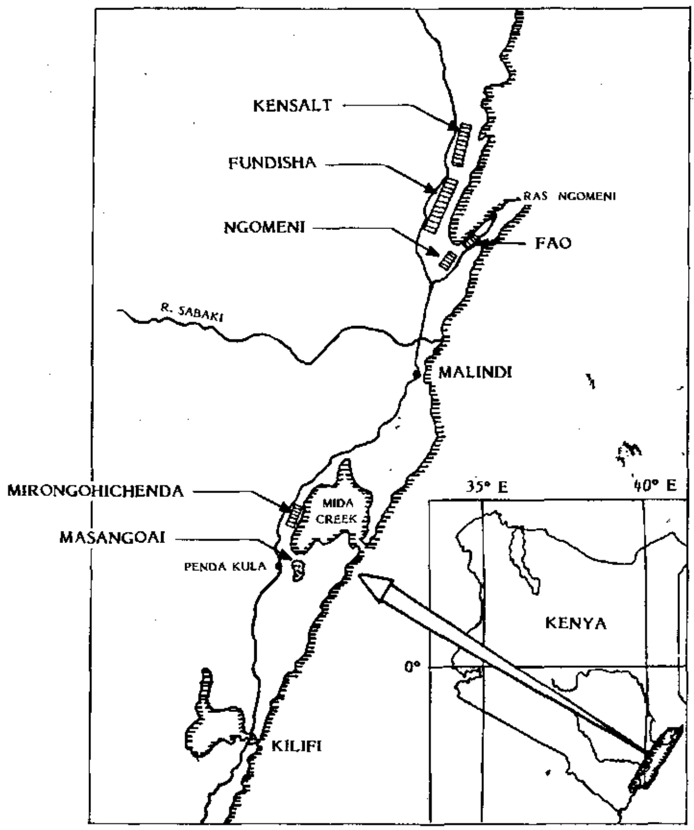

FIG. 2 NORTH COAST OF KENYA: AREAS VISITED ON ARTEMIA SURVEY

However, the physical, biological and chemical parameters determined in the saltworks of Fundisha, Kensalt (Kenya Salt Manufacturers) and Kurawa all indicated that the area was ideal for A.salina. Both Kurawa and Fundisha saltworks were, therefore, inoculated in early 1984. At the moment both Artemia cysts and adults are being produced in these salinas. Further inoculation is planned for the Rift Valley saline lakes i.e. Magadi, Simbi, Sonachi Crater, Bogoria and Elementaita (Fig.3), which are all potential A.salina habitats.

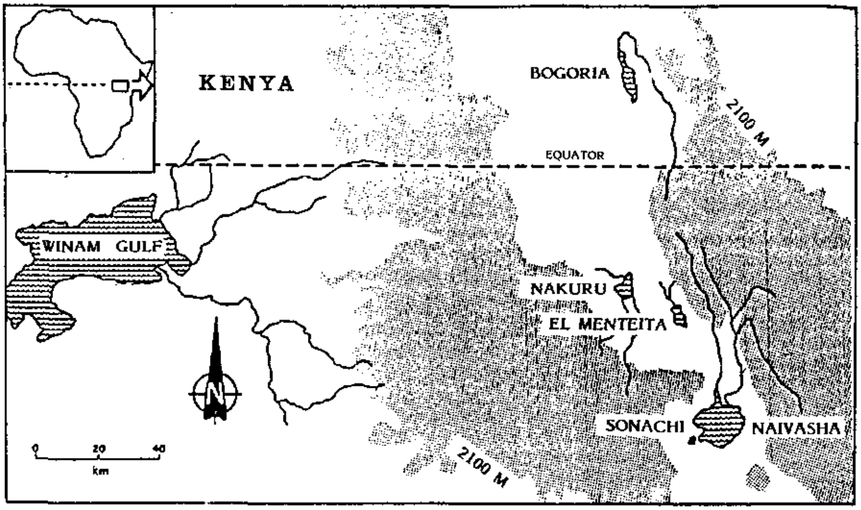

FIGURE 3. MAP OF CENTRAL KENYA WITH LAKES NAMED AND MAJOR RIVERS SHOWN. AREAS ABOVE 2100 M (STIPPLED) DELIMIT THE RIFT VALLEY; HORIZONTAL LINE BISECTING MAP IS THE EQUATOR. RECTANGLE IN INSERT LOCATES MAP ON AFRICAN CONTINENT.

The aim is to bring Kenya into the world cysts market. Initially the commercial supply of cysts, first from the salt ponds in the San Francisco Bay Area (California, USA) and later also from Great Salt Lake (Utah, USA) and Little Manitou Lake (Saskatchewan, Canada) seemed to be unlimited. The global demand for cysts, however, has increased and the price of good quality cysts ranges from US $20-40/kg. Inoculation of the brine shrimp has been accomplished succesfully in various parts of the world where it never existed before. As a result Brazil has joined the world cysts market as a commercial producer and Thailand, Philipines, Indonesia and Vietnam are able to produce cysts for their own local shrimp and fish farms. Other countries are mass culturing the brine shrimp in order to lessen the import of cysts that for instance in Japan currently stands at 3.8-4.0 tonnes/yr.

The future impact of A.salina production for Kenya aquaculture

According to the Kenya Development Plan, 1984-1988, the level of fish production from capture fisheries and aquaculture by 1988 is expected to be 120,000 metric tonnes of which coastal aquaculture is to contribute 6,000 metric tonnes. Shrimp farming is to be intensified to earn more foreign exchange (Table 1).

Table 1. a) Prices of marine fishes in Kenya (shs/kg).*

Group of fishes	Prices in Kenya (cold storage)	Prices of Kenya fishing industry
Sharks and Rays	0.50	1.00 - 3.00
Snappers	4.50	-
Grunters	4.50	-
Groupers	3.00	4.50
Emperors	4.50	-
Pamasba	4.50	-
Chana	2.50	-
Shrimps	25.00	-
Lobsters	15.00	20.00 - 30.00
Crab	-	-
Small commercial fishes	1.50	0.50 - 1.60

b) Penaeid prawn species caught in Kenya.

Penaeus indicus (Milne Edwards)	70 - 90% of total
Metapenaeus monoceros (Fabricius)	15 - 20% of total
P.semisulcatus (De Haan)	5 - 10% of total
P.monodon (Fabricius)	5 - 10% of total
P.japonicus (Bate)	2 - 5% of total

*Adapted from Mutagyera W.B. (proceedings of the Norad-Kenya Seminar to review the marine fish stocks and fisheries in Kenya, Mombasa, 1984).

Up to now crustacean farmers stock their ponds with juveniles captured from the wild in the estuaries (Fig.4).

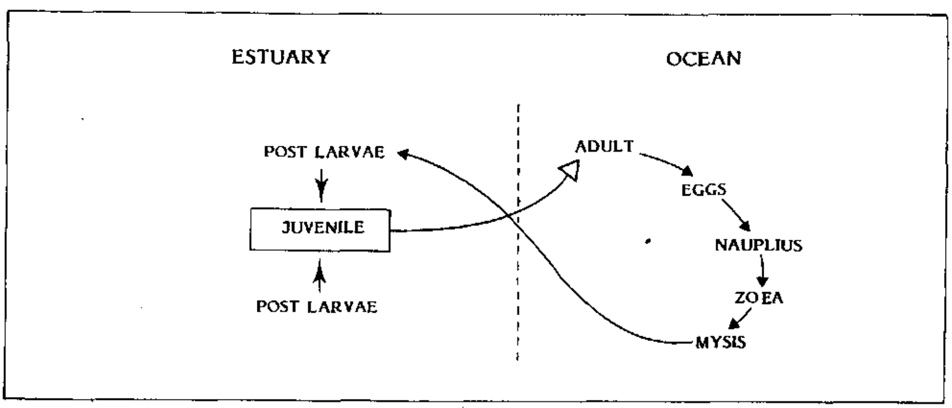

FIGURE 4. LIFE CYCLE OF PENAEID SHRIMP

This is a very primitive method which eventually leads to the depletion of the wild stock, as evidenced by the collapse of the shrimp industry in Ecuador. A feasibility study by the Kenya Government/FAO/UNDP has shown that the coastal region of Kenya has a high potential for crustacean farming. Only by ensuring farmers of a safe and abundant supply of post-larvae for stocking will the target figure of 6,000 metric tonnes by 1988 be reached. The establishment of a local production of brine shrimp cysts and biomass, will lower the operational costs of hatcheries and nurseries and enable them to supply postlarvae to the farmers regularly. It has also been shown that there is a vast potential for vertically integrated aquaculture in which the various A.salina products can be used in a single operation, viz, the cysts are harvested, processed, stored or hatched as the need may be for prawn or fish larvae reared in the hatcheries and the Artemia biomass collected from the evaporation ponds are fed to post-larval shrimps in nurseries and grow-out ponds. Such approaches are quite appropriate for both government-owned salt operations like Kenya Salt Manufacturers and for private firms.

Conclusions

By referring to other countries where A.salina inocualtion has been practised the following conclusions can be drawn for Kenya.

- Local production of A.salina cysts and biomass will be instrumental in ensuring a constant supply of prawn postlarvae for stocking in grow-out ponds. Increased production of highly priced crustaceans will develop exports and bring in more foreign earnings for the country.

- Cyst production after inoculation in the numerous potential A. salina habitats in Kenya, may produce a surplus cyst production which could be sold on the world cyst market. This is another source of foreign exchange.

- The activities outlined above will create more jobs.

ALIMENTATION DU JEUNE TILAPIA, APPLICATION AU DÉVELOPPEMENT DE SON ÉLEVAGE INTENSIF

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Résumé

Depuis quelques années, des recherches sont développées pour l'utilisation optimale des ressources naturelles des étangs en vue de l'alimentation des jeunes Tilapias, du stade larve au stade fingerling.

Le présent travail est une revue bibliographique des connaissances actuelles et un exposé des travaux en cours au laboratoire d'Ichtyologie appliqué. Trois types de nourriture sont étudiés: les végétaux supérieurs aquatiques comme la lentille d'eau, Lemna minor, produite en continu sous serre solaire, le phytoplancton pour lequel plusieurs espèces notamment les Chlorella sont couramment cultivées, enfin le zooplancton constitué essentiellement de Daphnia.

La valeur nutritive de ces types de nourriture ainsi que les performances de croissance sont étudiées pour permettre une évaluation des possibilités d'éviter les distributions de nourriture artificielle en écloserie.

Quelques dispositifs expérimentaux et les premiers résultats sont exposés et les axes de recherches possibles pour le futur sont présentés. Ils concernant surtout les observations à effectuer en vrai grandeur dans le cadre de stations de pisciculture intensive.

Le terme usuel de Tilapia est souvent employé, pour des raisons de commodité et d'habitude, pour désigner indistinctement les genres: Tilapia Smith, Sarotherodon Rüppel, Oreochromis Günther (Trewavas 1982).

Summary

For the last few years research has been conducted on using natural pond productivity to feed young tilapia from the larval to the fingerling stage.

This paper presents a bibliographical review of relevant data and work currently underway in applied ichtyological laboratories.

Three types of food have been studied, viz. higher aquatic plants such as Lemna minor (duckweed) produced throughout the year in greenhouses, phytoplankton (depending on the culture medium, various species, esp. Chlorella, are selected and zooplankton, mainly Daphnia.

The nutritional value of these types of feed and resulting growth rates are studied in order to assess the possibility of avoiding feeding of artificial diets in hatcheries.

This paper sets out experimental designs, preliminary results and possible lines of research for the future. It emphasises observations that need to be made on a live size scale at intensive fish culture stations.

Introduction

D'origine africaine, les Tilapias ont été introduits dans plus de 100 pays en raison de leurs grosses potentialités aquacoles (Balarin & Hatton, 1979; Moreau, 1983).

Ce sont des poissons très peu exigeants pour les conditions du milieu, se reproduisant facilement et présentant des taux élevés de survie chez l'alevin. Les Tilapias sont parmi les poissons d'élevage ceux qui requièrent le moins d'énergie pour la production de protéines animales (Edwardson, 1976). De même, ils nécessitent une faible infrastructure en hommes et matériel (Bell & Canterbery, 1976) et ils présentent des croissances et des productions élevées en milieu naturel et en pisciculture extensive (Bowen, 1980, Fernando & Holcik, 1982). L'élevage de ces poissons es donc parfaitement indiqué pour les pays intertropicaux ayant des problèmes d'approvisionnement en protéines (Ruwet et al., 1975) et un trop faible niveau technologique et économique pour prétendre au développement d'une aquaculture intensive (Balarin & Hatton, 1979).

7 espèces se sont révélées jusqu'a présent intéressantes pour l'élevage, selon Pullin (1983) et Schoenen (1982):

Oreochromis (Nyassatilapia) macrochir (Boulenger 1872)
Oreochromis aureus (Steindachner 1864)
Oreochromis mossambicus (Peters 1852)
Oreochromis niloticus (Linnaeus 1757)
Sarotherodon galileus (Hamelquist 1757)
Tilapia rendalli (Boulenger 1896)
Tilapia zillii (Gervais 1848)

En vue de l'extension de la pisciculture en étangs pour les pays en voie de développement, de nombreuses recherches ont été effectuées sur la nutrition des Tilapias. Les régimes alimentaires des adultes sont bien connus, au moins pour les espèces susceptibles d'être utilisées en aquaculture (Balarin, 1979; Bowen, 1982). Les Tilapias sont des consommateurs primaires (macro et microphytes) à tendance omnivore. Les adultes du genre Tilapia sensu stricto sont pour la plupart des macrophytophages, mangeant préférentiellement des macrophytes ainsi que des algues filamenteuses. Oreochromis et Sarotherodon sont des poissons au régime alimentaire souvent plus diversifié incluant notamment du zooplancton et du zoobenthos (Spataru & Zorn, 1978) et éventuellement des oeufs ou des larves de poissons.
Ainsi, par exemple, on donne classiquement pour exemple certains régimes alimentaires:

O.aureua = omnivore
S.galilaeus = phytoplanctophage
T.rendalli = herbivore

Toutefois les spectres alimentaires ne sont pas étroits. Les Tilapias possèdent des facultés permettant d'expliquer leur facilité de production et les croissances enregistrées: ils peuvent notamment digérer les algues bleues (Moriarty, 1973), et assimiler détritus et bactéries (Bowen, 1976a, 1976b, 1979, 1980a, 1980b, 1981, 1982). En fait les régimes alimentaires dépendent beaucoup de la disponibilité des différentes sources d'alimentation du milieu et de la compétition interspécifique; cela tend à reduire les spectres alimentaires des différentes espèces sur les ressources qui leur conviennent le mieux.

Tout ce qui vient d'être dit du milieu naturel est également vrai de la nourriture naturelle disponible en étang de pisciculture qui doit être valorisée au mieux par le poisson et, de là, par le pisciculteur lui-même. Ce sont ces considérations jointes au coût sans cesse croissant de l'alimentation des poissons en élevage intensif, amenant celui-ci à perdre toute rentabilité économique dans certains pays tropicaux, qui ont amené notre équipe à s'intéresser à l'alimentation du jeune Tilapia (stade larve à fingerling) à partir de nourritures naturelles disponibles en abondance dans certaines régions.

Ainsi, trois types de nourriture ont été prises en compte: les végétaux supérieurs sous la forme de lentilles d'eau (duckweed en anglais) le phyto-

Tableau 1. Aliments consommés par les Tilapias adultes en milieu naturel (Bowen, 1982)

ESPECES	ALIMENTS	REFERENCES
T. guineensis	Algues, détritus, invertébrés	FAGADE (1971)
T. kottae	Phytoplancton, détritus invertébrés	CORBET et al (1973)
T. mariae	Phytoplancton, invertébrés	CORBET et al (1973)
T. shirana	Macrophytes, algues, zooplancton	BOURN (1974)
T. rendalli	Macrophytes, périphyton	FISH (1951, 1955) CAULTON (1976, 1977) DENNY et al (1978)
T. sparrmanii	Périphyton	BOWEN (1983)
T. zillii	Macrophytes, invertébrés benthiques	ABDEL-MALEK (1972) BUDDINGTON (1979)
O. aureus	Zooplancton, détritus	SPATARU et GOPHEN (1983)
O. esculentus	Phytoplancton	DENNY et al (1978)
S. galilaeus	Phytoplancton	CORBET et al (1978) SPATARU et ZORN (1978)
S. jipi	Periphyton	DENNY et al (1978)
O. leucostictus	Phytoplancton, détritus	MORIARTY et al (1973)
S. melanotheron	Algues, détritus, invertébrés	FAGADE (1971)
O. mossambicus	Macrophytes, algues benthiques, phytoplancton, périphyton, zooplancton, détritus, alevin et oeuf de poisson	BOWEN (1979, 1980) MAN et HODGKISS (1977) MUNRO (1967), NAIK (1973) WEATHERLEY et COGGAR (1977)
O. niloticus	Phytoplancton	MORIARTY et MORIARTY (1973)
O. pangani	Périphyton	DENNY et al (1978)
O. variabilis	Algues, sédiments benthiques	FISH (1955)

plancton, essentiellement les algues du genre Chlorella, et le zooplancton, principalement le genre Daphnia.

Après une revue des connaissances sur l'alimentation du jeune et de l'adulte, le présent travail expose les premiers résultats obtenus au laboratoire sur la croissance du jeune.

L'alimentation du jeune et de l'adulte

A - Généralités sur le régime alimentaire

Comme montré au tableau 1et à la figure 1, l'alimentation des tilapias est très diversifiée, ils se nourrissent de phytoplancton, de zooplancton, de periphyton, de détritus, d'invertébrés, de macrophytes, d'algues benthiques, d'alevins et d'oeufs de poissons. La larve, l'alevin et le juvénile se nourrissent d'invertébrés, surtout des Crustacés (Le Roux, 1965). La transition de ce régime vers celui de l'adulte est fréquemment brutale (Brown, 1976; Moriarty et al., 1973) mais, dans certains cas, elle peut durer un an ou plus (Whitfield & Blaber, 1978).

Les poissons adultes du genre Tilapia sensu stricto surtout T.rendalli, T.zilli, T.sparmanii et T.tholloni sont macrophages. Les adultes se nourrissent préférentiellement d'algues filamenteuses, de macrophytes aquatiques et de matières végétales d'origine terrestre. Cette spécialisation inclut les alevins à certaines époques (hiver). Dans certaines eaux pauvres en végétation aquatique, ces espèces se nourrissent d'aliment animal comme montré par Spataru (1978), chez T.zillii dans le lac Kinneret (Israel). Moreau (1979) a également montré que, faute de végétaux supérieurs, T.rendalli recherche la nourriture animale au lac Isaty et lac de Mantasoa (Fig.1). Ces observations s'accordent avec celles de Munro (1967) et de Fryer (1959) selon lesquels T.rendalli consommerait une quantité notable d'oeufs et de jeune alevins, éventuellement les siens.

Certaines espèces des genres Sarotherodon et Oreochromis, souvent espèces lacustre, sont des consommateurs très spécialisés, notamment O.variabilis du lac Victoria (sédiments benthiques, Fryer & Iles, 1972), O.alcalicus grahami du lac Magadi (algues épilitiques), O.esculentus (phytoplancton) et O.macrochir (phytoplancton et algues épilithiques). Plusieurs espèces ont des régimes alimentaires très variés où dominent les composantes végétales: algues épilithiques, épiphysiques, algues filamenteuses, phytoplancton. O. aureus (Spataru & Zorn, 1978), S.galilaeus (Lauzanne & Iltis, 1975) et S. niloticus (Moriarty, 1973) se nourrissent de Cyanophycées. O.aureus (Spataru & Zorn, 1978), O.shiranus chilwae (Bourn, 1974) et O.mossambicus (Bruton & Boltt, 1975; Man & Hodgkiss, 1977) sont également capables de manger des débris végétaux et des macrophytes.

Les composants animaux: zooplancton et organismes benthiques, peuvent également intervenir: les larves d'insectes, Crustacés, Mollusques. Dans certaines eaux, O.mossambicus mange les insectes terrestres flottant en surface et des poissons (lac Sibaya, Bruton & Boltt, 1975).O.andersonii, O.aureus, O.mossambicus et O.niloticus paraissent omnivores, comparés à S.galilaeus et O.macrochir qui ont un spectre alimentaire limité. Dans le lac Kinneret, Spataru (1976), Spataru et Zorn (1978) montrent que le spectre alimentaire est plus restreint chez S.galilaeus (Pyrrophytes, Peridinium sp.) que chez O.aureus (zooplancton quand celui-ci est abondant).

B - Principales sources de variations de l'alimentation

Les variations de régime alimentaire sont un des éléments de la remarquable plasticité écologique des Tilapias; le régime alimentaire dépend de différents facteurs:

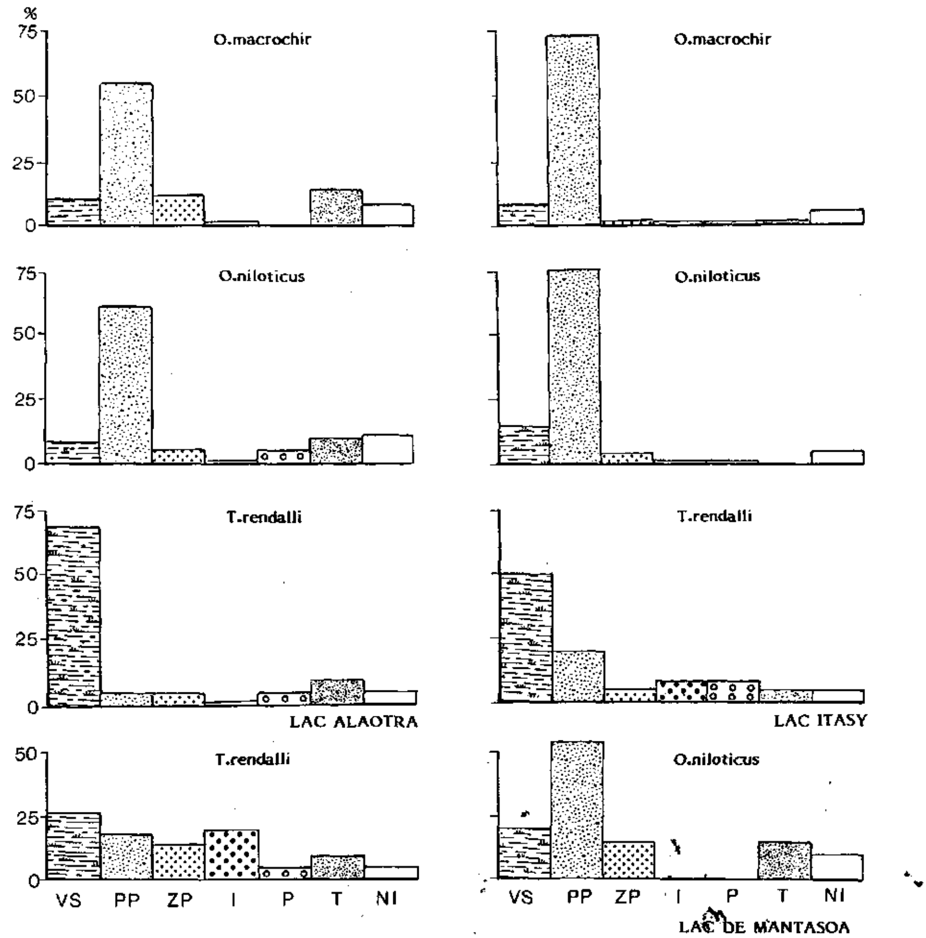

FIGURE 1. PROPORTIONS RELATIVES DES DIFFÉRENTS CONSTITUANTS DU RÉGIME ALIMENTAIRE CHEZ LES POPULATIONS DE TILAPIAS DE CERTAINS LACS MALGACHES.
VS=VÉGÉTAUX SUPÉRIEURS, PP=PHYTOPLANCTON, ZP=ZOOPLANCTON ET BENTHON, I=INSECTES OU LEURS LARVES, P=POISSONS (OEUFS, ALEVINS), T= TERRE, NI= ÉLÉMENTS NON IDENTIFIÉS.

1. le type d'organismes vivants présents qui est fonction de la physico-chimie des eaux étudiées.
2. l'accessibilité de la nourriture selon sa localisation; par exemple, dans certains lacs et réservoirs, quelques nourritures sont en eau trop profonde et sont inaccessibles au Tilapia qui n'est pas capable d'aller en eau profonde (Caulton & Hill, 1973).
3. la présence de compétiteurs qui forcent chaque espèce à changer de nourriture.

Les alevins sont généralement un régime alimentaire varié, composé de petites particules organiques, de phytoplancton, Diatomées, périphyton, zooplancton, organismes benthiques (Bruton & Boltt, 1975; Gophen, 1980; Whyte, 1957; Moreau, 1979).Dans le lac Sibaya, en Afrique du Sud (Bruton & Boltt, 1975), les adultes O.mossambicus capturés dans la zone de végétation marginale se nourrissent de Diatomées, de débris végétaux, mais ceux capturés en eaux libres se nourrissent d'insectes aériens (Coléoptères et Hémiptères). Dans le lac Kinneret (Spataru, 1978), T.zillii adulte exploite la nourriture de surface de l'eau libre et rarement celle du fond; mais, jeune, il se nourrit d'organismes benthiques (larves de chironomides, ostracodes, nématodes et gemmules d'éponges).

Les variations saisonnières de l'alimentation ont été étudiées chez T.zillii, S.galilaeus et O.aureus dans le lac Kinneret (Spataru, 1976, 1978; Spataru & Zorn, 1978), chez O.mossambicus dans le réservoir Plover Cove, Hong Kong (Man & Hodgkiss, 1977) chez T.rendalli et O.niloticus des lacs d'altitude de Madagascar (Moreau, 1979; résumé sur les figures 2 et 3). Au printemps, O.aureus du lac Kinneret se nourrit plus ou moins sélectivement de zooplancton qui est très abondant. Lorsque la production de zooplancton diminue à cause de la prédation piscivore, O.aureus se nourrit sélectivement de phytoplancton: Pyrrophytes et Péridinium sp. T.zillii se nourrit principalement de Coléoptères, de pupes de chironomides et de Péridinium sp. en hiver et au printemps, et de zooplancton (Cladocères) en été et automne (Spataru, 1978).

L'activité alimentaire des Tilapias varie selon la saison en fonction de facteurs tels que la température, la reproduction, la compétition interspécifique. Dans le réservoir Plover Cove, Hong Kong, le cycle saisonnier de l'activité alimentaire suit le cycle de la température: celle-ci est minimale en janvier-février (16-17°C) et maximale en juillet-septembre (27-30°C). Dans le lac Kinneret, Israël (Spataru & Zorn, 1978), l'activité alimentaire de O.aureus est maximale en été et automne (max.t°=30°C), tandis que celle du T.zillii est maximale au printemps et relativement constante aux autres saisons (Spataru, 1978).

Pendant la période de reproduction, T.zillii modifie ses habitudes alimentaires et recherche la nourriture benthique. En effet, l'activité alimentaire n'est pas interrompue pendant la garde des jeunes chez T.zillii (Spataru, 1978), mais elle l'est chez des femelles incubatrices, même si de la nourriture est quelquefois trouvée dans l'estomac comme chez O.alcalicus grahami (Coe, 1966; in Fryer & Iles, 1972, p.124).

C - Ration jounalière et comportement alimentaire

Plusieurs auteurs ont estimé laration journalière des poissons parmi ceux-ci, il faut citer Noble (1972) ainsi que Fortin et Magnin (1972) pour Perca flavescens, Lauzanne (1969), pour Alestes baremoze, Lewis et al.(1974), pour Micropterus salmoïdes, Thorpe (1977), pour Perca fluviatilis. Chez O.niloticus (Moriarty & Moriarty, 1973), la ration en plancton est une fonction Y = 271 + 13.3 X où X est le poids du poisson en grammes. Caulton (1982) a énoncé une relation entre la ration journalière de T.rendalli et la température lorsque celle-ci est comprise entre 18 et 34°C; M est le

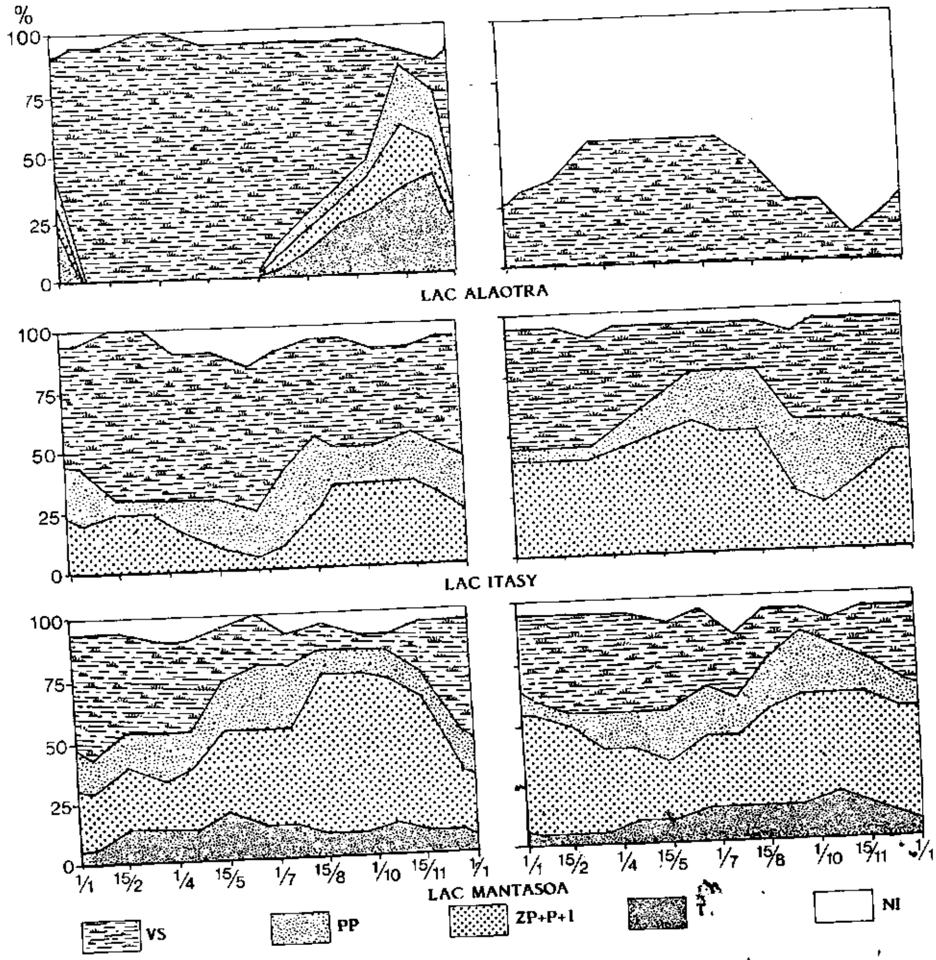

FIGURE 2. VARIATIONS CYCLIQUES ANNUELLES DU RÉGIME ALIMENTAIRE CHEZ T.RENDALLI ADULTE (A GAUCHE) ET CHEZ LES ALEVINS (A DROITE).

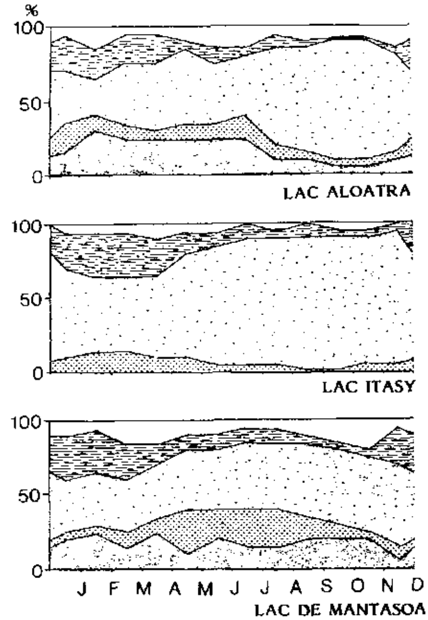

FIGURE 3. VARIATIONS CYCLIQUES ANNUELLES DU RÉGIME ALIMENTAIRE CHEZ LES ESPÈCES PLANCTONOPHAGES; LÉGENDES SUR LA FIGURE PRÉCÉDENTE.

poids frais des poissons et C la ration étudiée.

C 18°C = 0.0667M - 1.061
C 22°C = 0.0709M - 0.261
C 26°C = 0.1097M + 0.278
C 30°C = 0.1169M + 0.683
C 34°C = 0.1205M + 0.868

Selon Man et Hodghiss (1977) au Réservoir de Plover Cove, Hong Kong, O.mossambicus se nourrit le jour surtout de 12:00 h à 15:00 h; l'estomac est vide de 0:00 h à 3:00 h. Une alimentation diurne à été observée chez O.shiranus chilwae (Bourn, 1974), O.alcalicus grahami (Coe, 1966, 1967), O.niloticus dans le lac Bosumtwi (Whyte, 1975), plusieurs espèces mangent la nuit, notamment T.discolor et S.multificiatus du lac Bosumtwi (Whyte, 1975).

D - La digestibilité de la nourriture

La digestibilité de la nourriture ingérée en milieu naturel a attiré très tôt l'attention et, pour s'en tenir aux seuls Tilapias, quelques observations au lac Victoria montrent qu'ils ne digèrent pas certaines Cyanophycées.

Au lac George, Moriarty (1973) montre que le pH de l'estomac de O. niloticus doit être très acide pour permettre la digestion des Cyanophycées qui, de toute façon, seraient moins bien digérées que les Bacilloriophycées mais mieux que les Chlorophycées ou les végétaux supérieurs riches en cellulose.

Moriarty et Moriarty (1973) précisent ces derniers travaux et font remarquer qu'en général les genres Sarotherodon et Oreochromis ne digèrent pas les Cyanophycées. La population de O.niloticus du lac George constituerait une exception car elle digèrait à 70% les Bacilloriophycées, à 50% les Chlorella (Chlorophycées) et à 45% environ les Cyanobactéries.

Moriarty et Moriarty (1973), Lowe (1958) et Harbott (1975) concluent, chez O.niloticus du lac Rodolphe, à une certaine digestion des Cyanophycées qui est variable pour une même espèce d'un lac à l'autre; pour Lowe (1958), comme pour Fryer et Iles (1972), les facteurs phisico-chimiques de l'eau seraient en cause; Fryer et Iles pensent même que c'est la basicité des eaux du la Rodolphe et du lac George et plus particulièrement le rapport $(Na^{+})/(Ca^{++})$, très élevé au lac Rodolphe, qui y faciliterait la digestion des Cyanophycées devenues moins résistantes aux enzymes digestifs des poissons.

De ces éléments, on retient que les Bacillariophycées sont toujours digérées, les Cyanophycées irrégulièrement, mais moins difficilement les Chlorophycées.

Bowen (1982) a étudié la digestion chez O.mossambicus dans le lac Victoria, Vénézuela. Il montre que les protéines et les lipides sont assimilés plus efficacement que la matière organique totale ou l'énergie alimentaire. Le même résultat a été obtenu par Kirilenko et al. (1975).

De plus, les nombreux essais réalisés sur l'alimentation en laboratoire à l'aide des végétaux supérieurs (Tabthipwon, 1985), ou à l'aide de phytoplancton (Reid, 1984) montrent qu'un régime uniquement végétal ne permet pas une bonne croissance. Lauzanne (1978) indique que la mauvaise utilisation des algues pas des poissons phytoplantonophages est due à la faible digestion de celles-ci. De même, la digestibilité des macrophytes est faible. Ainsi, toujours en laboratoire, la digestibilité de Najas guadalupensis par T.zilli n'atteint que 29.3% chez une espèce pourtant phytophage (Buddington, 1979). L'assimilation des protéines d'Elodée est de 53% et celle des fibres brutes de 49% chez T.rendalli (Mann, 1966).

Utilisation des lentilles d'eau (Lemna minor)

La mise en valeur à des fins de pisciculture intensive d'une nourriture naturelle suppose une bonne connaissance de celle-ci, de sa valeur nutritionnelle et des besoins essentiels des poissons. C'est dans cet esprit qu'ont été réalisés les travaux sur les lentilles d'eau qui sont les plus avancés.

A - Les lentilles d'eau

Les Lemnaceae sont des plantes de l'ordre des monocotylédones flottant à la surface d'eaux relativement fraîche. Il existe environ 40 espèces réparties en 4 genres (Rusoff et al., 1980): Lemna, Spirodela, Wolffiella et Wolffia.
Parmi celles-ci, Lemna minor a été la plus étudiée. Elle est caractérisée par sa très faible teneur en cellulose (11% en moyenne). Par ailleurs, des essais effectués sur lisier de porc par Chaubard (1980) et Gervais (1982) ont montré que Lemna minor pouvait notamment assimiler les composés minéraux azotés et phosphatés. Ces plantes font l'objet de nombreuses études pour une utilisation dans l'épuration des eaux usées d'origine industrielle ou agricole (Harvey & Fox, 1973).
Les teneurs en protéines des lentilles d'eau varient selon le milieu de culture. Lorsque des plantes sont cultivées sur des eaux riches en azote, leur valeur nutritionelle augmente. Elle varie aussi selon l'âge de la plante (Hillman & Culley, 1978; Culley & Epps, 1973). Rusoff et al. (1980) montrent que le taux de protéines est compris entre 10% et 30% dela matière sèche dans les conditions naturelles (moyenne: 25%); Myers, en 1977, rapporte qu'il peut atteindre 42.6% chez la jeune plante. La composition en acides aminés de ces protéines est donnée dans le tableau 2. La lentille d'eau comporte 4 à 5% de son poids frais sous forme de matière sèche et 3% de celle-ci sous forme de lipides (tableau 3).

Tableau 2 : Composition en acides aminés de *Lemna minor*.
Résultats exprimés en % de la matière sèche.
(Saint-Salvy 1983)

Acide aspartique	3.167 ± 0.41
Sérine	1.163 ± 0.06
Acide glutamique	3.101 ± 0.15
Proline	1.362 ± 0.08
Glycine	1.535 ± 0.09
Alanine	1.894 ± 0.27
Cystine	0.417 ± 0.07
ACIDES AMINES ESSENTIELS	
Arginine	1.957 ± 0.17
Histidine	0.533 ± 0.03
Isoleucine	1.314 ± 0.06
Leucine	2.375 ± 0.11
Lysine	1.686 ± 0.11
Méthionine	0.378 ± 0.08
Phénylalanine	1.518 ± 0.08
Thréonine	1.244 ± 0.04
Tryptophane	0.916 ± 0.08
Valine	1.707 ± 0.06
Total des acides aminés	24.63

Tableau 3 : Constituants de *Lemna minor* (% de matière sèche)

Protéines	26.7 % ± 1.2
Lipides	3.3 % ± 0.4
Cellulose	11.4 % ± 1.2
Matières minérales	14.1 % ± 0.8
Protéine/Energie = P/E=	78.2 mg/Kcal

Boyd (1970) a trouvé une valeur énergétique s'élevant en moyenne à 4.1 kcal. par gramme de matière sèche. Cette valeur très élevée confère à Lemna minor une haute valeur nutritive déjà révélée plusieurs fois en aquaculture. Ainsi, selon Cross (1969) Lemna minor est l'une des plantes aquatiques que la carpe chinoise Ctenopharyngodon idella consomme le plus facilement. Shireman et al.(1977 & 1978) ont utilisé Lemna minor en élevage intensif de carpe chinoise et ont montré que la lentille d'eau donne une croissance individuelle de 1.15 g/jour chez des poissons d'environ 65 g. Rifai (1980) a employé 3 espèces de plantes aquatiques, Hydrilla, Lemna et Chara pour nourrir en cage O.niloticus ayant un poids moyen individuel initial de 170.8 g. Lemna donne les meilleurs résultats (Fig.4).

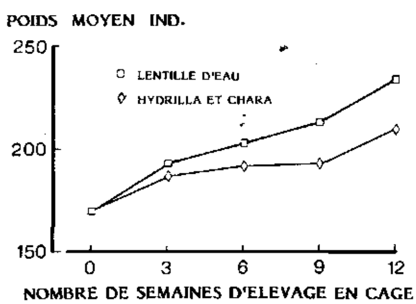

FIGURE 4. COMPARAISON DES PERFORMANCES DE CROISSANCE DE O.NILOTICUS ALIMENTÉ AVEC DIFFÉRENTS TYPES DE NOURRITURE VÉGÉTALE D'APRÈS RIFAI(1980).

B - Les besoins nutritionnels des Tilapias

Les besoins sont d'abord des besoins de quantité de nouirriture fraîche à absorber par jour. La ration journalière est exprimée en pourcentage du poids des poissons (Figure 5). Les juveniles ont besoin d'un pourcentage plus élévé que les adultes. Les facteurs à considérer pour déterminer la ration alimentaire sont le pourcentage de protéines dans la nourriture, les espèces des poissons et la température de l'eau (Balarin & Haller, 1982).

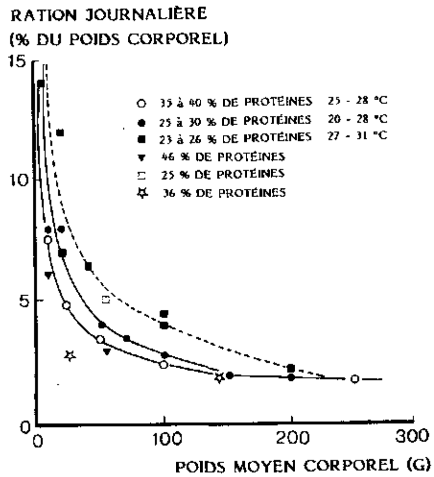

FIGURE 5. RELATION ENTRE LE POIDS MOYEN INDIVIDUEL ET LA RATION JOURNALIÈRE NECESSAIRE POUR UNE CROISSANCE OPTIMALE CHEZ LES TILAPIAS D'APRÈS BALARIN ET HALLER (1982). CE GRAPHIQUE EST LA SYNTHÈSE DE PLUSIEURS EXPÉRIENCES EN ÉTANG ET EN CAGE.

Au sujet des acides aminés et des protéines, les besoins de O.niloticus sont les mêmes que ceux d'autres espèces de poissons (Mazid et al., 1979) notamment pour les acides aminés essentiels et sont rappelés en annexe. Par ailleurs, d'après De Silva et Perreira (1984) les alevins d'O.niloticus ont besoin pour la croissance de 35% de protéines au lieu des 26.7% contenus dans le lentilles d'eau employées ici, qui sont donc un peu moins riches que théoriquement nécessaire.

C - Matériel et méthodes

Les O.niloticus utilisés ont été placés dans des aquariums de 100 litres (110, 30, 33 cm) alimentés par l'eau de la ville. L'eau de chaque aquarium a été chauffée à la température de 25 ± 2°C par une résistance électrique thermostatée de 200 watts. L'oxygénation de l'eau a été assuré par une de diffuseurs d'air. Les aquariums ont été nettoyés une fois par semaine. La photopériode est fixée à 12HJ-12H. Les Tilapias ont été nourris 6 jours par semaine à raison de trois repas par jour (9h, 13h, 17h). A chaque repas, la distribution à refus des lentilles d'eau a été effectuée par petites quantités, pour éviter les pertes de nourriture et vérifier la quantité réellement consommée.

Les pesées ont eu lieu à intervalle régulier d'une semaine. Les poissons ont été pesés après environ 24h de jeûne; en effet, le temps d'évacuation des aliments du tube digestif chez les Tilapias serait d'environ 10h à 25°C

(Ross & Jauncey, 1981).

La durée des élevages a été de deux mois. Les paramètres physico-chimiques des eaux des bacs ont été les suivants:

N.NH3 (mg/L)	0.62 à 0.71
N.NO2 (mg/L)	0.06 à 0.07
N.NO3 (mg/L)	2.20 à 2.40
Alcalinité totale (mg/L)	156.00 à 157
Dureté totale (mg/L)	164.00 à 165
pH	7.30 à 7.40

La digestibilité des protéines a été calculée par méthode indirecte. Le principe de cette méthode est la présence d'un marqueur inerte, non digestible dans l'aliment. De ce fait, cette substance est retrouvée en totalité dans les fèces. Elle transite avec le bol alimentaire et les variations de sa concentration parrapport aux constituants du repas indiquent nécessairement la digestion et l'absorption de ces derniers.

Les marqueurs faisant partie intégrante de l'aliment et utilisés pour les études de digestibilité chez le poisson sont la silice (Hickling, 1966), la cellulose (De Silva & Perreira, 1984) et les cendres résistantes à l'hydrolyse (Bowen, 1981).

Nous avons utilisé, comme marqueur, la cellulose normalement peu digérée dans les conditions de laboratoire (Van Dyke & Sutton, 1977; Stickney & Shymway, 1974; Cowey & Sargent, 1979; Prejs & Blaszczyk, 1977). La quantité de cellulose est donc inchangée après passage dans le tube digestif (Buddington, 1979). Les lentilles d'eau contiennent de 9.4% à 11.0% de matière sèche sous forme de cellulose (Russof et al., 1980), ce qui est suffisant pour permettre l'emploi de la méthode.

La digestibilité des lentilles d'eau et des protéines a été calculée d'après les formules suivantes:

Digestibilité apparente des lentilles d'eau:

$$100-100 \frac{\%\ \text{Cellulose Lemna}}{\%\ \text{Cellulose fèces}}$$

Dgestibilité apparente des protéines:

$$100-100 \frac{\%\ \text{Cellulose Lemna}}{\%\ \text{Cellulose Lemna}} \times \frac{\%\ \text{protéines fèces}}{\%\ \text{protéines Lemna}}$$

La méthode de récupération des fèces ne permet souvent qu'une récolte partielle des échantillons et la quantité de fèces disponibles (matière sèche) est souvent trop faible pour permettre d'effectuer plusieurs dosages. De plus, il existe des problèmes de dissolution de fèces et de perte de protéines solubles dans l'eau (Windell et al., 1972).

Enfin, on a mesuré les deux paramètres suivants:

- le quotient nutritif (Qn) : poids sec d'aliment ingéré par unité de gain de poids frais (aliment ingéré/gain de poids).

- le coefficient d'efficacité protéique :

$$\text{C.E.P.} = \frac{\text{Gain de poids (g)}}{\text{Protéines ingérées (g)}}$$

D - Résultats

La lentille d'eau est bien acceptée par les alevins d'Oreochromis niloticus et chaque repas est consommé en moins d'une heure. A la ration de 40%

à partir de la deuxième semaine, on a constaté des refus. On a aussi pu mesurer que les poissons consomment chaque jour des lentilles d'eau jusqu'à concurrence d'environ 36% du poids vif.

De façon plus détaillée, la consommation journalière selon le poids des poissons est conforme au tableau suivant:

Poids des poissons (g)	Consommation des lentilles d'eau (g/j/i)	% poids vif (%/j/i) *	QN	C.E.P.
5 - 10	1,9	36	2,34	1,62
11 - 15	2,6	33	2,43	1,59
16 - 20	4,9	28	2,18	1,72
21 - 25	6,3	25	2,23	1,68
26 - 30	6,8	27	2,40	1,50

* Calculé avec le poids frais des lentilles d'eau.

La tendance générale est une augmentation de la consommation individuelle avec la taille dans l'intervalle étudié mais le pourcentage du poids vif diminue. Les valeurs de Qn et E.C.P. montrent que les lentilles d'eau sont utilisées aux mieux par des individus de 16 à 25 g.

Les résultats détaillés de essais de croissance sont donnés dans les tableaux 4 et 5 et sur les figures 6 et 7. Ils montrent que, dans un premier temps les croissances sont analogues chez les poissons dont les tailles de depart sont différentes (2 g et 8 g); en effet, dans les deux cas, au bout de 6 semaines, les biomasses sont pratiquement un peu plus que doublées. Les valeurs de Qn et E.C.P. sont très proches. Elles laissent penser que l'utilisation des protéines est la même quelle que soit la taille, au moins jusqu'à 20 g. Les présents résultats ont incité à rechercher la charge maximale de poissons que pouvaient supporter les bacs dans les conditions de l'expérience.

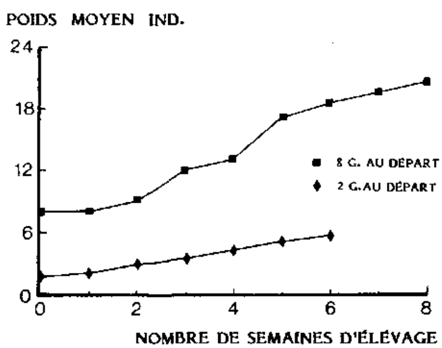

FIGURE 6. CROISSANCE DE POISSONS DE DIFFÉRENTES TAILLES NOURRIS À REFUS AVEC LEMNA MINOR, D'APRÈS TABTHIPWON (1985).

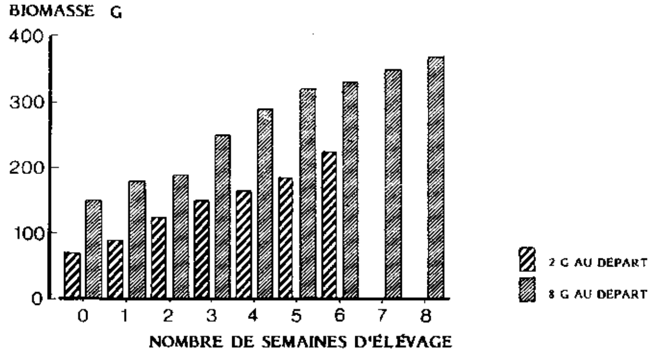

FIGURE 7. EVOLUTION DE LA BIOMASSE DES POISSONS AU COURS DE L'ÉLÉVAGE AVEC DES LENTILLES D'EAU À REFUS, D'APRÈS TABTHIPWON (1985).

Tableau 4 : Croissance au cours des deux essais avec des individus de tailles différentes sur une durée de 2 mois

	Poissons de 2 g au début	Poissons de 8 g au début
DEBUT		
Poids total (g)	75.0	168.2
Nombre d'individus	40	20
Poids moyen initial (g)	1.87	8.40
FIN		
Poids total (g)	230.9	387.6
Nombre d'individus	38	19
Poids moyen final	5.75	22.88
Accroissement de la biomasse	156.0	219.40
Croissance individuelle journalière (g/j/i)	0.09	0.18
% survie	92.5	95

Tableau 5 : Quotient nutritif et coefficient d'efficacité protéique au cours des 2 mêmes essais

	Poissons de 2 g au début	Poissons de 8 g au début
Aliment sec total ingéré (g)	362,0	489.0
Protéines ingérées (g)	96.6	130.9
Augmentation de la biomasse (g)	156.0	219.4
Quotient nutritif	2.32	2.23
C.E.P. (Coefficient d'efficacité protéique)	1,61	1.67

Nous avons constitué deux lots à différentes densités de poissons et même biomasse de 200 g au départ. Le premier lot (Lot T1) est de 15 poissons par aquarium (poids moyen: 13.73 g) et l'autre (Lot T2) est de 31 poissons (poids moyen: 6.35 g).

Les poissons se nourrissaient de lentilles d'eau seulement. Ils en consommaient à refus, c'est-à-dire environ 25 à 35% de leur biomasse en poids frais comme exposé plus haut.

Les résultats de cette expérience sont présenté dans les tableaux 6 et 7 et les figures 9 et 10.

Le fait important à noter est que la biomasse des poissons cesse pratiquement d'augmenter dès la 8ème semaine. Les individus ont alors 13 g dans un cas et 25 g dans l'autre. A ces tailles, une écloserie peut fort bien commercialiser ces jeunes poissons auprès de pisciculteurs pour des élevages intensifs. Des installations à grande échelle peuvent prévoir la production de fingerlings uniquement en lentilles d'eau sur environ 2 mois jusqu'à concurrence de 400 g pour 0.33 m^2 soit 12.12 t/ha. Ceci impose de travailler avec des bassins de faible profondeur (30-40 cm) comme les aquariums ayant servi pour cette étude, au risque de voir la température de l'eau s'élever fortement comme cela à lieu sous les tropiques.

Pour voir à quelle taille s'observe la meilleure digestibilité des lentilles d'eau, nous avons effectué une étude sur des poissons de poids différents.

Tableau 6 : Croissance au cours de l'évaluation de la charge maximale

	T1	T2
DEBUT		
Poids total (g)	209,3	196,8
Nombre d'individus	15	31
Poids moyen initial (g)	13,73	6,36
FIN		
Poids total (g)	405,9	413,0
Nombre d'individus	15	29
Poids moyen final (g)	24,9	13,1
Accroissement de la biomasse (g)	196,6	216,2
Croissance journalière moyenne (g/j/i)	0,155	0,093
% survie	100	93,5

Tableau 7 : Quotient nutritif et coefficient d'efficacité protéique lors de l'évaluation de la charge maximale

	T1	T2
Aliment sec total ingéré (g)	436,5	550,6
Protéines ingérées	116,3	147,0
Augmentation de biomasse (g)	196,6	216,2
Quotient nutritif	2,22	2,54
C.E.P.	1,69	1,72

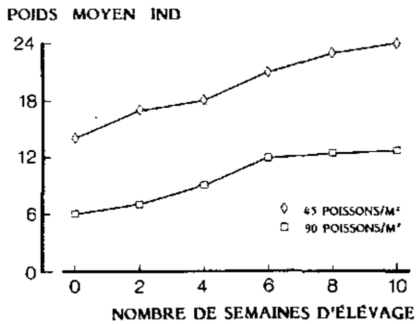

FIGURE 8. CROISSANCE INDIVIDUELLE MOYENNE DE O.NILOTICUS SOUS DIFFÉRENTES DENSITÉS; ALIMENTATION À REFUS AVEC LES LENTILLES D'EAU.

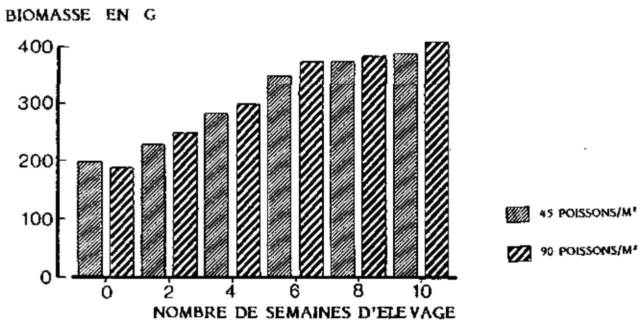

FIGURE 9. EVOLUTION DE BIOMASSE DU STOCK DE POISSONS ÉLEVÉS SOUS DIFFÉRENTES DENSITÉS: ALIMENTATION À REFUS AVEC DES LENTILLES D'EAU, D'APRÈS TABTHIPWON (1985).

Nous avons donné un seul repas par jour à 9 heures du matin à la ration de 20% de la mise en charge, mesurée en poids frais des lentilles d'eau. Les résultats figurent ci-dessous.

Mise en charge		Poissons de 15 à 20 g	Poissons de 25 à 40 g	Moyenne
Nombres d'individus		15	15	
Poids moyen (g)		17.8 + 1.9	32.4 + 4.3	
Poids total (g)		268.2	501.5	
Digestibilité	Protéines	62.8 ± 1.9	61.8 ± 1.61	62.3 ± 1.82
	Totale (matières sèches)	53.7 ± 1.57	52.8 ± 1.76	53.2 ± 1.56

La première remarque à faire est que la digestibilité est très élevée. Par ailleurs il n'y a pas de différence selon la taille. Ce résultat est à rapprocher du fait que, lors des premiers essais, les valeurs de Qn et de E.C.P. étaient proches chez des poissons de tailles pourtant différentes.

E - Discussion

La consommation de lentilles d'eau

Les poissons herbivores consomment les plantes aquatiques en grande quantité, en raison de la haute teneur en eau des plantes (Gaigher et al., 1984; Edwards, 1980). La teneur moyenne en eau des lentilles d'eau est de 94.6%.

Chez la carpe chinoise Ctenopharyngodon idella, Bhatia (1970) a rapporté que les poissons de 1 à 1.25 kg consomment de 100 à 174% de leur poids vif par jour sous forme de certaines plantes aquatiques. Venkatesh et Shetty (1978) montrent que ce poisson consomme Ydrilla et Ceratophyllun à raison respectivement de 100 et 125% de son poids vif par jour. Shireman et al. (1978) ont cité les travaux de Opuszynski (1972) selon lesquels la carpe chinoise consomme chaque jour de plus en plus de lentilles d'eau quand la température augmente, 50% de son poids à 20°C et 100 à 120% à 22°C.

Chez les hybrides O.niloticus * O.aureus, Gaigher et al. (1984) ont rapporté que les poissons de 125 g de poids moyen consomment les lentilles d'eau Lemna gibba (31.5% de protéines) à raison d'environ 25% de poids vif par jour. Nos propres résultats (25 à 36% du poids vif par jour) sont légèrement différents. Les poissons étaient, il est vrai, un peu plus petits et la souche de lentilles d'eau, un peu moins riche en protéines.

Les croissances observées

Les croissances individuelles sont de 0.09 g/j pendant l'alevinage (entre 1 et 10 g) et de 0.18 g/j pendant le prégrossissement (entre 10 et 30 g), chez les lots nourris avec les lentilles d'eau à refus. Le rapport "protéines sur énergie" (P/E) des lentilles d'eau employées ici est de 78.2 mg de protéines par kcal. Le taux de protéines est de 26.7%. la croissance des alevins (0.09 g/j) est un peu plus élevée que celle des alevins de Tilapia zillii de même poids nourris avec un aliment artificiel contenant autant de protéines (21.7%) pour une valeur de P/E de 81.32 (0.076 g/j) (Mazid et al., 1979).

Chez les alevins de Tilapia zillii, on a aussi rapporté une croissance de 0.18 g/j avec une nourriture contenant 34.7% de protéines, et dont le P/E= 95.3.

Chez O.mossambicus de 1.83 g alimenté avec une nourriture artificielle à 24% de protéines et dont P/E= 74.1, Jauncey (1982) a obtenu une croissance individuelle de 0.117 g/j/i.

En conséquence, les lentilles d'eau sont une nourriture de qualité équivalente à celle des aliments employés par les autres auteurs pour des Tilapias de même taille.

La digestibilité

La digestibilité des aliments varie selon leur source et selon les espèces de poissons. L'équipement enzymatique des poissons joue alors un rôle très important (Cowey & Sargent, 1973; Van Dyke & Sutton, 1977; Stickney & Shumway, 1974). La digestibilité des plantes est normalement faible à cause de la cellulose et d'autres composants non digestibles.

Les fibres végétales sont, en général, non digestibles à moins qu'une bactérie du tube digestif ne les transforme préalablement par la cellulose. Chez la carpe (Cyprinus carpio), Smith (1971), Stickney & Shumnway (1974) pensent que l'activité cellulosique dépend de la microflore intestinale Prejs et Balsczyh (1977), Niederholzer et Hofer (1979) estiment que cette activité dépend uniquement de la nature de l'aliment consommé.

Si on admet que les celluloses sont exogènes, leur présence implique une origine alimentaire. Dans ce cas, il faut que, dans le tube digestif, existe une flore bactérienne cellulotique. Niederholzer et Hoffer (1979) ont montré que cette flore bactérienne est présente dans la plante ingérée.

Si l'activité de la cellulose existe, le pH de l'estomac et la vitesse de transit alimentaire chez Tilapia diminuent (Buddington, 1979). En effet, chez les Tilapias, le pH de l'estomac pendant l'alimentation est très acide: moins de 2.0 d'après Bowen (1976); cette acidité est carctéristique de Tilapia (Moriarty, 1973; Caulton, 1976). Chez d'autres poissons, le pH est normalement voisin de 4 (Barrington, 1957; Smith, 1971).

La digestibilité totale et celle des protéines des lentilles d'eau observées ici sont de 53.2% et 62.3% respectivement. Les différences de digestibilité avec celles évoquées plus ba montrent que la lentille est mieux digérée par O.niloticus que d'autres plantes aquatiques par des poissons réputés mycrophytophages: Tilapia zillii et Tilapia rendalli.

Kirilenko (1975) montre que, chez Oreochromis mossambicus âgé de 15 à 18 mois, la digestibilité de Chlorella (algue verte) est de 59.24 à 56.85%. Chez Tilapia zillii d'un poids moyen de 60 g élevé à 24°C, Buddington (1979) a determiné la digestibilité de Najas guadalupensis (15.7% de protéines,27.8% de cellulose); la digestibilité totale et celle des protéines sont de 29.3% et 72.1% respectivement. Les digestibilités des protéines de Spirodela polyrrhiza (96.7% d'eau, 18.18% de protéines et 1.03% de fibres) et Elodea canadensis chez Tilapia rendalli sont de 42% et 43% respectivement (Mann, 1967).

La digestibilité totale de Lemnia minor est, ici, plus haute que celle observée par Buddington (1979) chez Tilapia zillii avec Najas guadalupensis. Ceci peut s'expliquer car la cellulose est peu abondante dans la lentille d'eau (11.4% au lieu de 21.7% chez Najas). En pareil cas, Moriarty (1973) montre que c'est le pH très acide de l'estomac de O.niloticus qui permet la digestion de nourriture végétales pauvres en cellulose.

Chez O.niloticus, la digestibilité des lentilles d'eau ne varie pas avec la taille, tout au moins jusqu'à 40 g. Kirilenko (1975) montre que chez O. mossambicus, il n'y a pas différence de digestibilité de Chlorella avec la taille du poisson. Une différence de digestibilité selon l'âge des poissons a été trouvée en nourrissant avec de l'algue bleue Microcystis. La digestibilité est plus haute chez le poisson de 15 mois que chez celui de 8 mois.

Rélation entre Tilapia et phytoplancton

A - Données bibliographiques

A la suite de Melack (1976), Almazan et Boyd (1978), Biro et Vörö (1982), la mesure de la production primaire peut être utilisée pour prédire le rendement piscicole des lacs et réservoirs tropicaux et tempérés. Des études ont été accomplies dans 9 lacs africains (Melack, 1976). Des observations ont aussi été faites en étang chez O.aureus par Almazan et Boyd (1978), chez O.niloticus par Edwards et al. (1981) et Aquino et Nielsen (1983).

Almazan et Boyd (1978) montrent que dans des étangs fertilisés avec des engrais inorganiques, la biomasse du phytoplancton conditionne en partie la production de O.aureus (Fig.10), par exemple; $Y = -166.64 + 354.60X$ ($R^2 = 0.79$) où Y est la production de O.aureus en kg/ha et X la production primaire en $gC/m^2/J$.

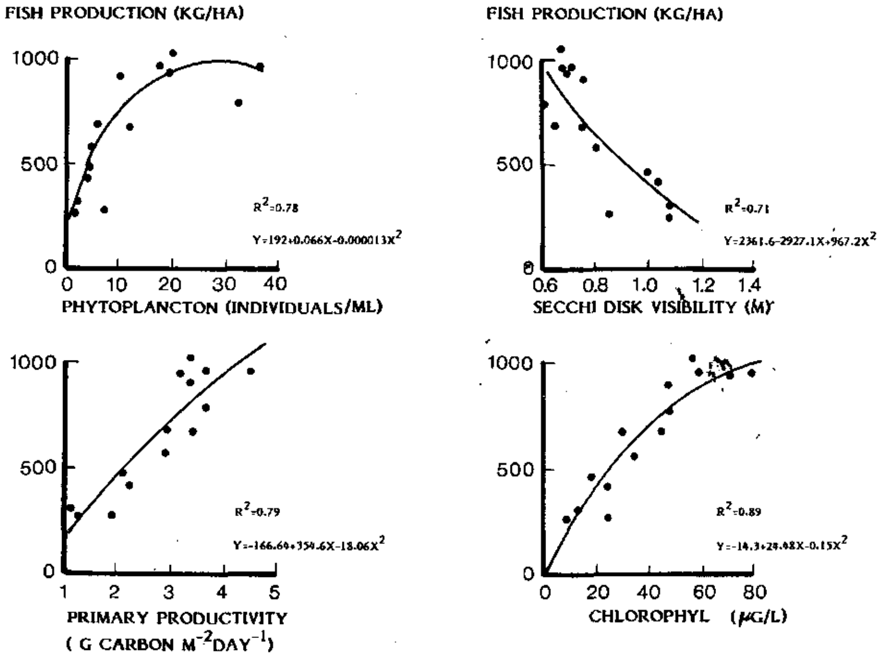

FIGURE 10. RELATION ENTRE LA DENSITÉ DE PHYTOPLANCTON ET LA PRODUCTION DE S.AUREUS EN ÉTANG. LES RELATIONS ONT ÉTÉ ÉTABLIES AU NIVEAU DE PROBABILITÉ P = 0.01.

En Thailande, où régulièrement a été renouvelé l'engrais organique, Edwards et al. (1982) énoncent une relation linéaire entre la production de O.niloticus, élevé dans des étangs de 200 m² et l'abondance de phytoplancton en mg/l.

Au lac Sampalac (Fig.11), aux Philippines, O.niloticus atteint en 3 mois la taille de 110 g en cage. Sa croissance est en relation étroite avec la production primaire : $Y = 0.74 + 2.18 \log X$ ($R^2 = 0.69$) où Y est le gain de poids en g/ind/j et X = la production $gC/m^3/j$ (Aquino & Nielsen, 1983).

La quantité et la qualité de nourriture jouent un rôle important pour la croissance des poissons phytoplanctonophages (Bowen, 1982). Les études sur la digestibilité du phytoplancton par O.niloticus font comprendre le rôle de celui-ci dans sa croissance. Ainsi, dans le lac George où il digère les Cyanophycées qui sont très abondantes (Moriarty, 1973), la production de O.niloticus atteint 157 kg/ha/an (Schlesinger & Regier, 1982). Inversement, la croissance de O.niloticus nourri principalement de Cyanophycées non digérées dans le lac Alaotra est plus basse que dans le lac Itasy où O.niloticus se nourrit de Bacillariophycées qui sont digérées, contrirement aux Cyanophycées (Moreau, 1979).

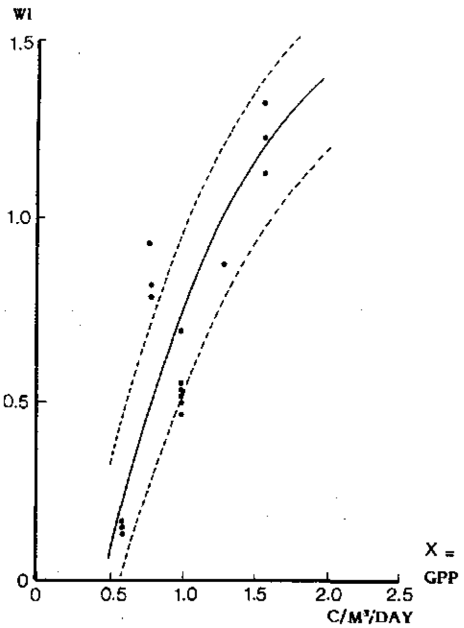

FIGURE 11. RELATION ENTRE LA PRODUCTION PRIMAIRE (GPP) ET LA CROISSANCE PONDÉRALE DE O.NILOTICUS (WI) . r^2 = 0.89 et WI = 0.74 + 2.18 LOG (GPP).

B - Premiers résultats expérimentaux

Des expériences sur la croissance de O.niloticus nourri au phytoplancton ont été accomplies chez O.niloticus par Pantastico (1984), Reid (1984), Orachunwong (1985). A cause de leur petite taille les Chlorelles sont peu retenues et, selon Moriarty et Moriarty (1973), O.niloticus ne consomme que 25% de la quantité donnée. Pantastico (1984) montre qu'une concentration de Chlorella de 150 - 170*10^3 ind/ml ou de 90 - 120*10^3 ind/l est nécessaire pour obtenir 93% de survie chez l'alevin de O.niloticus, mais il ne dit rien sur la croissance. A des concentration de 150 à 170 * 10^3 ind/ml de Chlorella sp dans les conditions de laboratoire (t = 30°C), il se révèle que les jeunes O.niloticus (0.5 g) meurent après deux semaines et ne grandissement pas comme montré sur la figure 12. En plus, le coefficient de condition diminue, traduisant une dégradation de l'état physiologique des poissons (Orachunwong, 1985). L'élevage de O.niloticus (5 g) dans un milieu riche en Scenedesmus sp amène aussi une diminution du coefficient de condition (Fig.13, Reid, 1984). De plus, pour une bonne croissance avec Chlorella sp et Scenedesmus sp, une nourriture animale supplémentaire est requise (Reid, 1984; Orachunwong, 1985).

A partir des ces résultats, on peut penser que O.niloticus est capable d'assimiler les algues vertes, mais cela ne suffit pas. Il est donc souhaitable d'étudier d'autres aliments: les détritus, les Cyanophysées, par exemple.

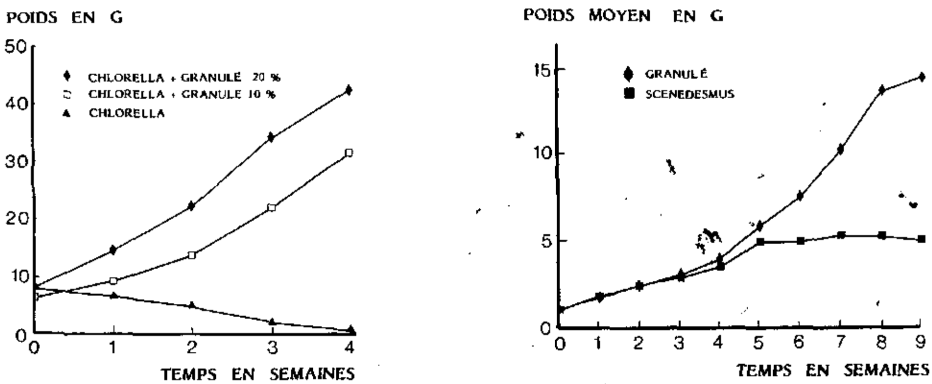

FIGURE 12. CROISSANCE COMPARÉE DE O.NILOTICUS NOURRI AVEC DIFFÉRENTS ALIMENTS Y COMPRIS UNE RATION UNIQUEMENT DE SOURCE VÉGÉTALE, D'APRÈS ORACHUNGWONG (1985) ET REID (1984).

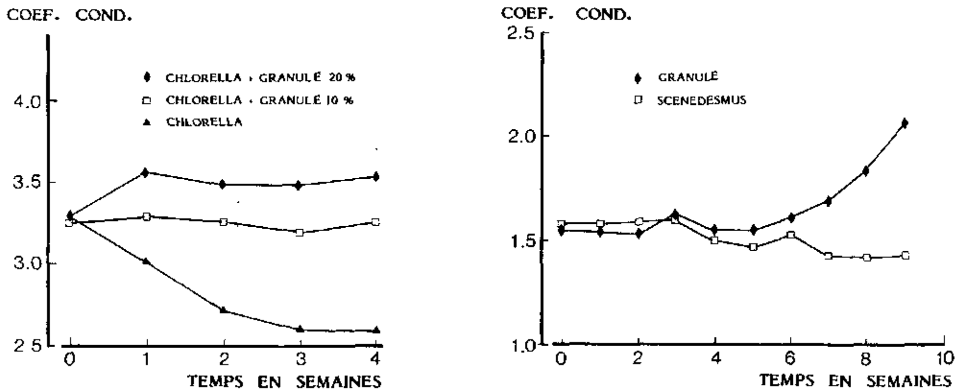

FIGURE 13. EVOLUTION DU COEFFICIENT DE CONDITION DE O. NILOTICUS JEUNE LORSQU'IL EST NOURRI AVEC DES ALIMENTS UNIQUEMENT VÉGÉTAUX (PHYTOPLANCTON), D'APRÈS ORACHUNGWONG (1985) ET REID (1984).

Relation entre les Tilapias et le zooplancton

A - Données bibliographiques

Peu d'auteurs se sont intéressés aux relations existant entre le zooplancton et les Tilapias, alors que de nombreux indices indiquent que la prédation des Tilapias sur le zooplancton est loin d'être négligeable. Ainsi Moreau (1979) indique que le pourcentage représente dans le bol alimentaire par le zooplancton et le benthos chez T.rendalli Boulenger du lac de Mantasoa (Madagascar), oscille au cours de l'année entre 20% (mars) et 65% (août/septembre). Schroeder (1973) estime que le zooplancton est la source de nourriture la plus importante pour les carpes et les Tilapias.
Les travaux réalisés au Costa Rica (Dickman, 1982), sur la relation entre la densité de O.mossamcbicus en étang et la densité de zoo et phytoplancton, montrent d'une part que la prédation très importante sur le zooplancton se porte sur les espèces disponibles (Copépodes adultes ou Diaphanosoma) et, d'autre part, que l'évolution des peuplements zooplantoniques et phytoplanctoniques varie avec la densité des Tilapias. Oreochromis mossambicus se nourrit préférentiellement sur les grands copépodes, ceux-ci sont éliminés à haute densité de prédateur. Ainsi, à une densité de 0.5 Tilapia par m^2, il y a une domination de Mesocyclops leukartii. Entre 0.5 et 1-2 Tilapias par m^2, les rotifères sont dominants. Au delà de 1-2 adultes par m^2, le zooplancton est peu développé alore que le phytoplancton atteint 2.10^6 cellules par litre.

De plus, les nombreux essais montrent qu'un régime uniquement végétal ne permet pas une bonne croissance sans supplémentation de protéines animales.Balarin et Hatton (1979) suggèrent l'apport d'environ 10% de matières animales pour obtenir une bonne croissance chez un poisson herbivore.

La relation la plus étroite existant entre les Tilapias et le zooplancton est notée chez l'alevin et le juvenile. En effet, la vie de la plupart des poissons débute par un stade zooplantophage. Les Tilapias de taille inférieure à 5 cm montrent une préférence pour le zooplancton puis ils deviennent plus omnivores jusqu'à 7.5 cm, les poissons de tailles supérieures ont leur régime alimentaire propre (Le Roux, 1956). McBay (1961) indique que le zooplancton forme une partie importante du bol alimentaire des juvéniles de Oreochromis niloticus (2.5 cm). Landau (1979) rapporte que les adultes de S.galilaeus se nourrissent sélectivement sur du phytoplancton, Peridinium sp., alors que les alevins présentent un régime alimentaire plus varié dont les crustacés forment une grande proportion en volume du contenu intestinal et stomacal. Balarin et Hatton (1979) indiquent que les Tilapias sont zooplanctophages jusqu'à la taille de 5-6 cm. Certains auteurs montrents que le changement de régime alimentaire entre l'alevin et l'adulte peut être brutal (Moriarty et al., 1973; Bowen, 1976). Drenner et al. (1982) précisent le comportement alimentaire des juvéniles de S.galilaeus. Ainsi jusqu'à la taille de 2 cm, l'alevin absorbe des particules, principalement du zooplancton qu'il repère individuellement; puis, cette tendance diminue avec la taille et la filtration devient prépondérante au delà de 6 cm. Cette étude permet d'aprécier la prédation de S.galilaeus et les effets de cette prédation sur la dynamique du peuplement zooplanctonique. Le pourcentage de succès des attaques sur les différentes espèces zooplantoniques montre que la sélection se porte sur les proies de grande taille et de faible mobilité (Daphniidae, Ceriodaphnia) et non de faible taille et très mobiles (Cyclopoïdes et nauplii). La distance de réaction du prédateur augmente linéairement avec la taille de la proie.

DR = 8.33 TP - 3.15 (R^2 = 0.74)

DR = distance de réaction (cm)

TP = taille de la proie (mm)

L'un des faits importants qui ressort de cette étude est que cette sélection préférentielle sur le zooplancton tend à modifier la composition du peuplement zooplantonique du lac favorisant la prolifération des taxons de petites tailles. Drenner et al. trouvent que la digestion par Sarotherodon galilaeus du zooplancton est plus rapide que celle du phytoplancton (Peridinium sp.) et indiquent que ceci doit être pris en considération pour éviter une sous-estimation du rôle du zooplancton dans l'alimentation des Sarotherdodon galilaeus du lac Kinneret. Chez Oreochromis mossambicus élevé dans des étangs recevant différents taux de fertilisation, l'importance de la prédation sur le zooplancton augmente avec sa disponibilité (Dendy et al., 1968). Dans les étangs non fertilisés, 44.4% des animaux examinés contenaient du zooplancton, alors que 75% des poissons examinés contenaient du zooplancton dans les étangs fertilisés. Dendy et al. indiquent que le zooplancton est très bien digéré sauf les ostracodes.

Selon Fernando (1983), la faible productivité piscicole des milieux intertropicaux serait due aux faibles disponibilités en zooplancton. Les alevins étant zooplanctophages, la disponibilité en zooplancton est facteur limitant pour le recrutement, quelle-que soit l'espèce. Les Tilapias produisent peu de jeunes à la fois; il en résulte de leur part une faible consommation de zooplancton. Fernando suppose de plus que l'une des raisons de la forte productivité des Tilapias pourrait provenir de l'utilisation par les alevins avec une efficacité optimale du zooplancton disponible.

Ceci montre combien il est nécessaire d'entreprendre une série d'études sur la création zooplancton/Tilapias, afin de mieux gérer la culture des Tilapias en étangs notamment en utilisant la fertilisation pour augmenter la production secondaire du milieu; une bonne croissance résultant de la disponibilité simultanée des protéines animales et végétales.

B - Premiers résultats expérimentaux

a) Performances de croissance

Le laboratoire a étudié la croissance d'alevins d'Oreochromis niloticus en fonction de quatre rations de zooplancton frais.
Des alevins d'O.niloticus ont été élevés pendant 35 jours à 28°C, dans des cages de 2 litres de volume placées dans un aquarium de 200 litres alimenté en eau par un circuit fermé. La maille des cages est de 50 m. Dix alevins ont été placés dans chaque cage. De jeunes daphnies (Daphnia magna, 300-400 ·m) ont été distribuées 3 fois par jour (10h-14h-18h), 7 jours par semaine. Les poissons ont été mesurés (à 0.1 mm près) et pesés (à 0.0001 g près) chaque semaine, avant la distribution matinale de nourriture. La ration de zooplancton a été alors ajustée pour la semaine en fonction de la biomasse des poissons de chaque cage.
Les résultats de la croissance linéaire et pondérale sont représentés sur la figure 14 et le tableau 8, ci-dessous.

Tableau 8. Résultats de la croissance d'alevins de Oreochromis niloticus nourris avec du zooplancton frais (Daphina magna) à 28°C pendant 35 jours.

Ration	Poids initial (g)	Poids final (g)	Croissance relative (%)	Taux de crois-specifique (%/j)
3.33	0.113	0.134	18.58	0.488
8.33	0.103	0.210	103.88	2.056
16.67	0.110	0.405	268.18	3.8
33.33	0.108	1.103	921.30	6.864

(Ration : * 1000 proies / g.alevins / jour)

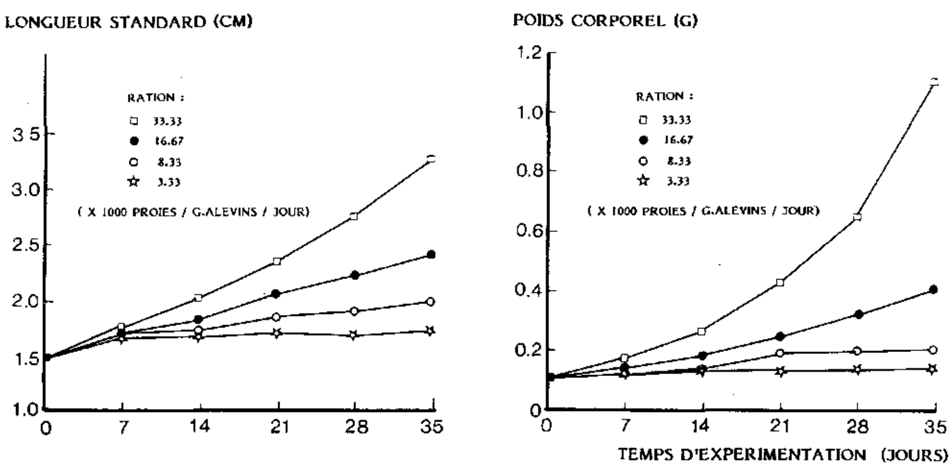

FIGURE 14. CROISSANCE DES JEUNES O.NILOTICUS NOURRIS UNIQUEMENT AVEC DU ZOOPLANCTON, D'APRÈS SEGURA (1985).

Dans nos conditions expérimentales, nous obtenons pour la ration maximale (33330 proies/g. alevins/jour) un taux de croissance spécifique de 6.9%/J. Dans les mèmes conditions, des alevins d'O.niloticus (4 cm) nourris à 9% de leur poids vif avec des granules pour carpes (32% de protéines) présentent un taux de croissance spécifique de 4.3%/J.
Par ailleurs, à 26°C, des alevins de O.niloticus (0.1 g) nourris ad libitum avec des granulés pour truites (45% de protéines) et des granulés pour carpes (32% de protéines) présentent après 35 jours d'élevage des taux de croissance spécifique de 7.5% par jour. A titre de référence il faut citer Gophen (1980) qui a montré que le zooplancton est préférable pour l'alevin au phytoplancton, et que les aliments riches en protéines, zooplancton ou aliments artificiels, permettent des croissances supérieures à celles en registrées avec du phytoplancton.

De même, comptenu des résultats comparés obtenus avec du zooplancton et des aliments artificiels, il est sans doute possible d'élever à moindre coût des alevins jusqu'au stade "fingerlings" aussi de commercialisation bon marché , auprès des pisciculteurs. Les étangs nurserie ou de prégrossissement employés devront être choisis en fonction de caractéristiques assurant une productivité élevée en zooplancton (étangs peu profonds,...); de plus, il faut veiller à l'absence d'autres espèces de poissons ou de géniteurs pouvant entrer en compétition avec les alevins. Cette voie est actuellement choisie dans certains pays pour l'élevage d'alevins de carpe commune (Cyprinus carpio) (Fotis et al., 1985).

b) Modalités de prédation sur le zooplancton

Pour analyser la prédation sur le zooplancton, nous avons mesuré 2 paramètres: la taille maximale des proies ingérables en fonction de la taille de l'alevin, et la taille maximale des proies ingérées lors de alimentation.

Le premier paramètre a été mesuré en donnant des proies calibrées (Daphnia magna) à des alevins. Pour obtenir le second paramètre, des alevins on été placés dans des curves de 1 m³ et nourris avec du zooplancton de taille hétérogène. 30 mn après la distribution de nourriture, les alevins ont été sacrifiés et le contenu du tube digestif a été analysé. Le zooplancton a été mesuré sous loupe binoculaire de 15 ' m près. Les résultats sont donnés dans la figure 15.

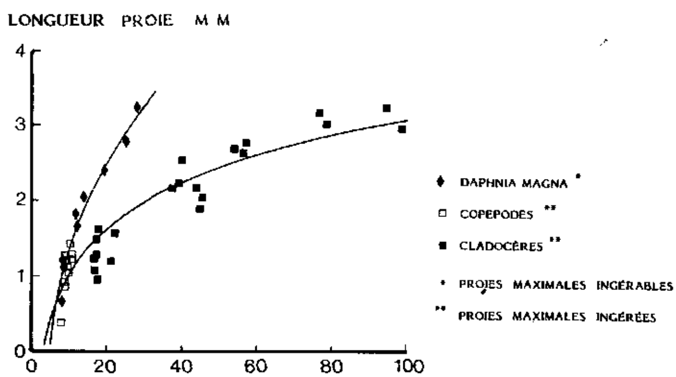

FIGURE 15. RELATION ENTRE LA TAILLE DE L'ALEVIN ET LA TAILLE MAXIMALE DES PROIDS INGÉRÉES.

Nous voyons qu'un animal de 28 mm est capable d'ingérer une proie de 3.5 mm (taille maximale disponible). Dans le cas où l'animal choisit ses proies, nous trouvons des proies supérieures à 3 mm chez des alevins de plus 70 mm. La sélectivité des proies de grandes tailles (Drenner et al., 1982) ne suit donc pas parfaitement les potentialités morphologiques de l'alevin car le pourcentage relatif des proies de tailles différentes intervient également.

c) Hypothèse sur le transit alimentaire

Le rapport longueur de l'intestin/longueur standard (LI/LS) varie avec la taille de l'animal. Ainsi, pour des animaux de 10 mm, ce rapport est de 1 alors qu'il atteint 6.5 chez des animaux de 100 mm (Figure 16).

D'une manière générale, l'efficacité de l'appareil digestif est en partie lié à la longueur de l'intestin; LI/LS est plus élevé chez les animaux herbivores que les carnivores. Dans notre cas, les variations de LI/LS peuvent traduire l'évolution du régime alimentaire ente le jeune et l'adulte.

Chez les alevins, le temps de passage dans l'estomac est faible; certains aliments n'étant pas retenus par l'estomac se retrouvent directement dans l'intestin (Hofer & Newrkla, 1983). Dans nos expériences, 30 mn après le début du repas, l'intestin contient 79.7% des proies intactes du tractus digestif chez des alevins de 10 mm; chez des alevins de 22 mm ce pourcentage passe à 52.4%, puis à 0% chez des alevins de 38 mm.

Nous pouvons voir ici une des raisons possibles de la non-utilisation des matières végétales chez l'alevin, l'attaque des végétaux se faisant dans l'estomac où le pH est très acide (2.0) (Moriarty, 1973; Bowen, 1980, 1982). Où, chez des poissons de moins de 20 mm, tout semble se passer comme si l'estomac n'était pas "physiologiquement fonctionnel".

Conclusion

Les présents résultats, encore très fragmentaires laissent pourtant espérer des applications intéressantes en pisciculture intensive. Toutefois, une difficulté majeure surviendra lorsqu'il faudra passer des travaux de laboratoire à ceux en étang de pisciculture grandeur nature. En effet, dans ces derniers, plusieurs sources de nourriture naturelle seront normalement disponibles et les études concernant l'une d'entre elles en particulier ne sauraient faire abstraction de l'influence possible des autres même si elles sont peu abondantes. Ce problème a pu quelquefois conduire à des interprétations discutables de données expérimentales obtenues en station de pisciculture. C'est pourquoi il faut suggérer que des recherches en laboratoire et sur le terrain soient menées simultanément; c'est d'ailleurs ce que fera notre équipe dans les années qui viennent.

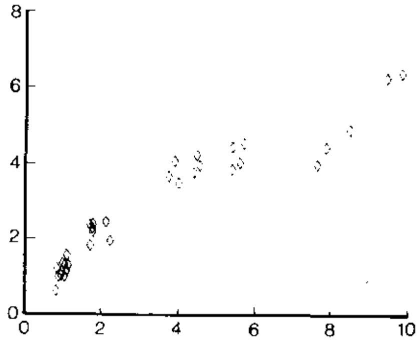

FIGURE 16. EVOLUTION DU RAPPORT LONGUEUR INTESTIN/LONGUEUR STANDARD AVEC LA TAILLE DES ALEVINS DE O.NILOTICUS, D'APRÈS SEGURA (1985).

REFERENCES

ALKHONY , A.A. et S.A. ABDEL MELEK 1972. Food and feeding habits of some fishes in Lake Quarum. Part I, Tilapia zillii (Gervais) according to different localities. Bull. Inst. Oceangr. Fish, U.A.R. 2 : 185-201.

ALMAZAN , G. et C.D. BOYD 1978. Plankton production and Tilapia yield in ponds. Aquaculture 15 : 75-77.

ANDERSON J., A.J. JACKSON, A.J. MATTY et B.S. CAPPER 1984. Effects of dietary carbohydrate and fibre on the Tilapia , Oreochromis niloticus (Linn.). Aquaculture 13 : 265-272.

AQUINO, L.V. et B.H. NIELSEN 1983. Primary production and growth rate of Tilapia nilotica in cage in Sampalac Lake, Philippines. International Symposium on Tilapia in Aquaculture. Nazareth, Israel 3-13 Mai 1983 : 455-463.

BALARIN, J.D. et A.D. HALLER 1982. The intensive culture of Tilapia in tanks, raceways and cages. In MUIR, J.F. et R.J. ROBERTS (eds.), Recent advances in Aquaculture. Westview Press, Boulder, Colorado.

BALARIN, J.D. et J.P. HATTON 1979. Tilapia, a guide to their biology and culture in Africa. Unit of Aquatic Pathobiology, University of Stirling Scotland. 174 p.

BARRING, E.J.W. 1957. The alimentary canal and digestion, p. 109-161. In BROWN M.E. (ed.), The physiology of fishes, vol. I. Academic Press, London.

BELL, F.W. et R.E. CANTERBERY 1976. Aquaculture for the developing countries : A feasibility study. Ballington Publishing Company, Cambridge, Massachusetts. 266 p.

BIRO, P. et L. VOROS 1982. Relationships between phytoplankton and fish yields in Lake Balaton. Hydrobiologia 97: 3-7.

BOURN, D.M. 1974. The feeding of three commercially important fish species in lake Chilwa, Malawi. Afr. J. Trop. Hydrobiol. Fish. 3(2) : 35-145.

BOWEN, S.H. 1976a. Feeding ecology of the Cichlid fish Sarotherodon mossambicus in Lake Sibaya, Kwazulu. Ph.D. Dissertion, Rhodes University, Grahamstown. 135 p.

BOWEN, S.H. 1976b. Mechanism for digestion of detrital bacteria by the Cichlid fish Sarotherodon mossambicus (Peters). Nature (London) 260 : 137-138.

BOWEN, S.H. 1979. A nutritional constraint in detrivory by fishes : the stunted population of Sarotherodon mossambicus in Lake Sibaya, South Africa. Ecol. Monogr. 49(1) : 17-31.

BOWEN, S.H. 1980. Detrital nonprotein amino acids are the key to rapid growth of Tilapia in Lake Valencia, Venezuela. Science 207 : 1216-1218.

BOWEN, S.H. 1981. Digestion and assimilation of periphyton detrital aggregate by Tilapia mossambica. Tran. Amer. Fish. Soc. 110 : 241-247.

BOWEN, S.H. 1982. Feeding, digestion and growth qualitative considerations, p.141-156. In PULLIN, R.S.V. and R.H. LOWE-McCONNELL (eds.), The biology and culture of Tilapias. ICLARM Conference Proceeding 7, 432 p. Internationa Center for Living Aquatic Resources Management, Manila, Philippines.

BOYD, C.E. 1970. Amino acid, protein and caloric content of vascular aquatic macrophytes. Ecology 51 : 902-906.

BRUTON, M.N. et R.E. BOLTT 1975. Aspects of the biology of Tilapia mossambica (Peters) (Pisces:Cichlidae) in a habitat freshwater lake (Lake Sibaya, South Africa). J.Fish.Biol. 7 : 423-446.

BUDDINGTON, R.K. 1979. Digestion of aquatic macrophyte by Tilapia zillii. J. Fish Biol. 15(3) : 449-456.

CAULTON, M.S. 1976. The importance of pre-digestive food preparation to Tilapia rendalli (Boulenger) when feeding on aquatic macrophytes. Trans. Rhodesia. Sci. Assoc. 57(3) : 22-28.

CAULTON, M.S. 1982. Feeding, metabolism and growth of tilapias: some quantitative considerations, p.157-180. In PULLIN, R.S.V. and R.H. LOWE-McCONNELL (eds.), The biology and culture of Tilapias. ICLARM Conference Proceeding 7, 432 p. International Center for Living Aquatic Resources Management, Manila, Philippines.

CAULTON, M.S. et B.J. HILL 1973. The ability of Tilapia mossambica to enter deep water. J.Fish.Biol. 5 : 783-788.

CHAUBARD, J.P. 1980. Valorisation des effluents oxydés de lisier de porc par culture de plantes aquatiques. D.E.A. Ecole Nationale Supérieure Agronomique. Toulouse.

COCHE, A.G. 1976. A general review of cage culture and its application in Africa. FAO Tech. Conf. on Aquaculture, Kyoto, Japan. FIR: AQ/CONF/76E. 72 : 33 p.

COE, M.J. 1966. The biology of Tilapia grahami (Boulenger) in lake Magadi, Kenya. Acta.Trop. 23 : 146-177.

COE, M.J. 1967. Local migration of Tilapia grahami (Boulenger) in lake Magadi, Kenya in response to diurnal temperature changes in shallow waters. East. Afr. Wild J. 5 : 171-174.

CORBET, S.A.,J. GREEN, J. GRIFFITH et E. BETNEY 1973. Ecological studies on crater lakes in West Cameroun : Lakes Kato and Maoandorg. J. Zool. 170(3) : 309-324.

COWEY, C.B. et J.R. SARGENT 1979. Fish nutrition. In HOAR, W.S. et D.J. RANDALL (eds.), Fish physiology, vol. VIII. Academic Press, New York.

CROSS, D.G. 1969. Aquatic weed control using grass carp. J. Fish Biol. 1 : 27-3

CRUZ, E.M. et L.L. LAUDENCIA 1977. Protein requirement of Tilapia mossambica fingerlings. Kalikasan Philipp. J. Biol. 6 : 177-182.

CULLEY, D.D. et E.A. EPPS. 1973. Use of duckweed for waste treatment and animal feed. J. Water. Pollut. Contr. Fed. 45 : 337-347.

DAVIS, A.T. et STICKNEY, R.R. 1978. Growth responses of Tilapia aurea to dietary quality and quantity. Trans. Amer. Fish. Soc. 107(3) : 479-482.

DE SILVA, S.S. et M.M. PERERA 1984. Digestibility in Sarotherodon niloticus fry dietary protien level and salinity with further observation on variability in daily digestibility. Aquaculture 38 : 293-306.

DENDY, J.S., V. VARIKUL, K. SUMAWIDJAJA et M. POTAROS 1966. Production of Tilapia mossambica (Peter), plankton and benthos as parameters for evaluating nitrogen in pond fertilizers. FAO World Symposium on Warm-Water Pond Fish Culture, Rome 18-25 Mai 1966. FR: II/E-12 : 226-239.

DENNY, P.,D.W. BOWKER et R.G. BOILEY 1978. The importance of littoral epi--phyton as food for commercial fish in the recent African man-made lake Nyumba ya Munger reservoir, Tanzania. Biol. J. Linn. Soc. 10(1) : 139-150.

DICKMAN, M. 1982. La production of Tilapia en la provincia de Guanacaste, Costa Rica. Rev. Lat. Acui., Mexico 13 : 20-30.

DRENNER, R.W., G.L. VINYARD, M. GOPHEN et S.R. McCOMAS 1982. Feeding behavior of the cichlid, Sarotherodon galilaeum : selective predation on Lake Kinneret zooplankton. Hydrobiologia 87 : 17-20.

EDWARDS, P., O-N. SINCHUMPASAK et M. TABUCANON. 1981. The harvest of microbio-algae from the effluent of a sewage fed high rate stabilization pond by Tilapia nilotica. Part 2 : Studies of the fish ponds. Aquaculture 23: 107-147.

EDWARDSON, W. 1976. Energy demands of aquaculture : a worldwide survey. Fish Farming Int. 3(4) : 10-13.

FAGADE, S.O. 1971. The food and feeding of Tilapia species in the Lagos Lagoon. J. Fish Biol. 3 : 151-156.

FERNANDO, C.H. 1983. Zooplankton and fish production, with special reference to the Tilapias. International Symposium on Tilapia in Aquaculture, Nazareth, Israel 3-13 Mai 1983 : 95-104.

FERNANDO, C.H. et J. HOLCIK 1982. The nature of fish communities. A factor influencing fishery potential and yields in lakes and reservoirs. Hydrobiolgia 97 : 127-140.

FISH, G.H. 1951. Digestion in Tilapia esculenta. Nature (London) 167 : 900-901.

FISH, G.H. 1955. The food of Tilapia in East Africa. Uganda. J. 19 : 85-89.

FORTIN, R. et E.MAGNIN 1972. Quelques aspects quantitatifs et qualitatifs de la nourriture des Percidés , Perca flavescens (Mitchell) dans la grande anse de l'ile Penat, au lac Saint-Louis. Ann. Hydrobiol. 3(1) : 79-91.

FOTIS, G., Th. KOUSOURIS, S. KILIKIDIS et A. KAMARIANOS 1985. The exploitation of zooplankton from lake Vistonis Greece in the culture of carp fry (Cyprinus carpio L.). J. Environ. Biol. 6 : 115-127.

GAIGHER, I.G.,D. PORATH et G. GRANOTH 1984. Evaluation of duckweed Lemna gibba as food for Tilapia (Oreochromis niloticus * O. aureus) in a recirculating unit. Aquaculture 41 : 235-244.

GERVAIS, B. 1982. Adaptation et productivité de la lentille d'eau (Lemna minor L.) ; application à la valorisation du lisier de porc. Mémoire. Ecole Supérieure d'Agriculture de Purpan, Toulouse, 126 p.

HARBOTT, B.J. 1975. Preliminary observations on the feeding of Tilapia nilotica (L.) in lake Rudolf. Afr. J. Trop. Hydrobiol. Fish. 4(1-3) : 27-38.

HARVEY, R.M. et J.L. FOX 1973. Nutrient removal using Lemna minor. J. Water Pollut. Contr. Fed. 75 : 1928-1938.

HICKLING, C.F. 1966. On the feeding process in the white amur Ctenopharyngodon idella. J. Zool. 148 : 408-419.

HOFER, R. et P. NEWRKLA 1983. Determination of gut passage time in Tilapia fry (Oreochromis mossambicus) under laboratory and field conditions. International Symposium on Tilapia in Aquaculture, Nazareth, Israel 3-13 Mai 1983 : 323-327.

JACKSON, A.J. et B.S. CAPPER 1982. Investigation into the requirements of Sarotherodon mossambicus for dietary methionine, lysine and arginine in semi synthetic diets. Aquaculture 20 : 289-297.

JACKSON, A.J., B.S. CAPPER et A.J. MATTY 1982. Evaluation of some plant protein diets for the Tilapia (Sarotherodon mossambicus). Aquaculture 27 : 97-109.

JAUNCEY, K. 1982. The effects of varying dietary protein level on the growth, food conversion, protein utilisation and body composition of juvenile Tilapia (Sarotherodon mossambicus). Aquaculture 27 : 43-54.

JAUNCEY, K. et B. ROSS. 1982. A guide to Tilapia feeds and feeding. Institute o Aquaculture, University of Stirling, Scotland. 111 pp.

KIRILENKO, N.S. et al. 1975. The digestibility of the crude protein and neutral fat of some microalgae by Tilapia mossambica. J. Ichtyology 15 : 151-155.

LANDAU, R. 1979. Growth and population studies on Tilapia galilaéa in Lake Kinneret. Freshwater Biol. 9 : 23-32.

LASHER, C.W. 1967. Tilapia mossambica as a fish for aquatic weed control. Prog. Fish Cult. 29 : 48-50.

LAUNDAU, R. 1983. Factors influencing tilapia biomass in lake Kinneret. International Symposium on Tilapia in Aquaculture. Nazareth, Israel. 3-13 Mai 1983 : 8-17.

LAUZANNE, L. 1969. Etude quantitative de l'alimentation des Alestes baremaze. Cah: O.R.S.T.O.M. sér. Hydrobiol. 3(2) : 15-27.

LAUZANNE, L. 1978. Etude quantitative de l'alimentation de Sarotherodon galilaeus (Pisces : Cichlidae) du lac Tchad. Cah. O.R.S.T.O.M. Sér. Hydrobiol. 12 : 71-81.

LAUZANNE, L. et A. ILTIS 1975. La sélection de la nourriture chez Tilapia galilaea (Pisces, Cichlidae) du lac Tchad. Cah. O.R.S.T.O.M. sér. Hydrobiol. 9(3) : 193-199.

Le ROUX, P.J. 1966. Feeding habits of the young of four species of Tilapia. S. Afr. J. Sci. 53(2) : 33-37.

LEWIS, Z.M.,R. HEIDNGER R.,W. KIRK, U.CHAPMAN et D. JOHNSON 1974. Food intake of the Largemount Bass. Trans. Amer. Fish. Soc. 103 : 277-280.

LOWE, R.H. 1958. Observation on the biolgy of Tilapia nilotica (Linn.) in East African Waters. Rev. Zool. Bot. Afr. 57(1-2) : 129-170.

MANN, H.S.H. et I.J. HODGKISS 1977a. Studies on the ichthyo-fauna in Plover Cave reservoir, Hong Kong, I. Sequence of population change. J. Fish Biol. 11 : 1-13.

MANN, H.S.H. et I.J. HODGKISS 1977b. Studies on the ichtyo-fauna in Plover Cave reservoir, Hong Kong, feeding and food relations. J. Fish Biol. 11 : 1-13.

MANN, M. 1966. The utilization of food by Tilapia melanopleura. FAO World Symposium on Warm-Water Pond Fish Culture, Rome 18-25 Mai 1966 , FR : III/E-8 : 408-410.

MAZID, M.A., Y. TANAKA, T. KATAYAMA, M.A. RAHMAN, K.L. SIMPSON et C.O. CHICHESTER 1979. Growth response of Tilapia zillii fingerlings fed with caloric diets with variable protein levels. Aquaculture 18 : 115-122.

McBAY, L.G. 1961. The biology of Tilapia nilotica Linn. Proceeding of the 50 th Annual Conference, Southeastern Association of Game and Fish Commissioners. October 22-25 : 208-218.

MELARD, Ch. et J.C. PHILIPPART 1981. Pisciculture intensive du Tilapia, Sarotherodon niloticus, dans les effluents thermiques d'une centrale nucléaire en Belgique. Proc. World Symp. on Aquaculture in Heated Effluents and Recirculation Systems. Stavanger 28-30 May, 1980. vol. I, Berlin.

MESCHAT, A. 1967. The status of warm-water fish culture in Africa. FAO Fish. Rep. 44(2) : 88-122.

MIRONOVA, N.J. 1975. The nutritive value of algae as food for Tilapia mossambica. J. Ichtyol. 15(3) : 510-514.

MOREAU, J. 1979. Biologie et évolution des peuplements de Cichlidés (Pisces) introduits dans lacs Malgaches d'altitude. Thèse Doc.Etat INP Toulouse 38 : 345 p.

MOREAU, J. 1983. A review of introductions of Tilapia in opened inland waters of Africa, their influence on ecology and fisheries. International Symposium on Tilapia in Aquaculture, Nazareth, Israel 3-13 Mai 1983 : 77-85.

MORIARTY, C.M. et D.J.W. MORIARTY 1973. Quantitative estimation of the daily ingestion of phytoplankton by Tilapia nilotica and Haplochromis nigripinnis in Lake George, Uganda. J. Zool. Lond. 171(1) : 15-23.

MORIARTY, D.J.W. 1973. The physiology of digestion of blue green algae in the cichlid fish Tilapia nilotica. J. Zool. Lond. 171 (1) : 25-39.

MORIARTY, D.J.W. et C.M. MORIARTY 1973. The estimation of carbon from phytoplankton by two herbivorous fishes : Tilapia nilotica and Haplochromis nigripinnis. J. Zool. Lond. 171(1) : 41-55.

MORIARTY, D.J.W.,J.P.E.C.DARLINGTON, I.G. UNN, C.M. MORIARTY et TEVLIN, M.P. 1973. Feeding and grazing in lake George, Uganda. Proc.R.London.B. 184:299-319.

MUNRO, J.L. 1967. The food of a community of East African freshwater fishes. J. Zool. 151(3) : 389-415.

MYERS, R.W. 1977. cité par RUSOFF, et al. 1980. A comparative study nutrient composition and growth of selected duckweeds, Lemnaceae, on dairy waste lagoons. M.S. Thesis. Louisiana State Univ. 74 p.

NIEDERRHOLWER, R. et R. HOFFER. 1979. The adaptation of digestive enzymes to temperature, season and diet in roach Rutilus rutilus L. and rudd Scardinius erythrophthalmus L. J. Fish Biol. 15 :411-416.

NOBLE, R.L. 1967. A method of direct estimation of total food consumption with application to young yellow perch. Prog. Fish Cult. 34(4) : 191-194.

NOSE, T. 1979. Summary reports on the requirements of essential amino acids for carp, p. 145-154. In J. HALVER and K. TIEWS (eds.), Finfish nutrition and fishfeed technology, vol. I.

OGINO, C. 1980. Protein requirement of carp and rainbow trout. Bull. Jap. Soc. Fish. 46(3) : 385-388.

ORACHUNWONG, C. 1985. Les besoins alimentaires de Sarotherodon niloticus nourri avec Chlorella sp. Rapport de Stage, ENSAT, Toulouse. Doc. Multig. nn pp.

PAGAN, P.A. 1969. Cage culture of tilapia. FAO Fish Cult. Bull. 2 : 6.

PREJS, A. et M. BLASZCZYK. 1977. Relationships between food and cellulase activity in freshwater fishes. J. Fish Biol. 11 : 447-452.

PULLIN, R.S.V. 1983. Choice of Tilapia species for aquaculture. International Center for Living Aquatic Resources Management, Manila, Philippines. ICLARM Contribution No. 140. 15 p.

REID, T. 1984. Growth of the african freshwater Cichlid fish Tilapïa, Sarotherodon niloticus in Scenedesmus enriched water. Doc. Multiq., ENSAT, Toulouse. 9 p.

RIFAI, S.A. 1981. Control of reproduction of Tilapia nilotica using cage cultur Aquaculture 20:117-185

ROSS, B. et K. JAUNCEY. 1981. A radiographic estimation of the effect of temperature on gastric emptying in Sarotherodon niloticus * S. aureus hybrids. J. Fish Biol. 19 : 333-344.

RUSOFF, L.L., E.W. BLAKENEY et D.D. CULLEY 1980. Duckweeds (Lemnaceae Family) : A potential source of protein and amino acids. J. Agric. Food Chem. 28 : 848-850.

RUWET, J. Cl., J. VOSS, L. HANON et J. Cl. MICHA 1975. Biologie et élevage des Tilapias. Symposium FAO/CPCA, Accra, Ghana, 30 Sept. - 6 Oct. 1975, CIFA/75/SR 10

SAINT SALVY, A. 1983. Production de lentille d'eau Lemna minor dans un système intégré. Mémoire ENSAT, Toulouse. 89 p.

SCHROEDER, G.L. 1973. Factors affecting feed conversion ratio in fish ponds. Bamidgeh 25(4) : 104-113.

SHIREMAN, J.V., D.E. COLLE et R.W. ROTTMANN 1978. Growth of grass carp fed with natural and prepared diets under intensive culture. J. Fish Biol. 12 : 457-463.

SHIREMAN, J.V., D.E. COLLE et R.W. ROTTMANN 1977. Intensive culture of grass carp Ctenopharyngodon idella in circular tank. J. Fish Biol. 11 : 267-272.

SMITH, R.R. 1977. A method for measuring digestibility and metabolizable energy of fish feeds. Prog. Fish Cult. 33(3) : 132-134.

SPATARU, P. 1976. The feeding habits of Tilapia galilaea (Artedi) in lake Kinneret (Israel). Aquaculture 9:47-59.

SPATARU, P. 1978. Food and feeding habits of Tilapia zillii (Gervais) (Cichlidae) in lake Kinneret (Israel). Aquaculture 14 : 327-338.

SPATARU, P. et M. ZORN 1976. Some aspects of natural feed and feeding habits of Tilapia galilaea (Artedi) and Tilapia aurea (Steindachner) in Lake Kinneret. Bamidgeh 28 : 12-17.

SPATARU, P. et M. ZORN 1978. Food and feeding of Tilapia aurea (Steinachner) (Cichlidae) in Lake Kinneret (Israel). Aquaculture 13 : 67-79.

STICKNEY, R.R. et S.E. SHUMWAY 1974. Occurence of cellulase activity in the stomach of fishes. J. Fish Biol. 6 : 779-790.

TABTHIPWON, P. 1985. Utilisation de la lentille d'eau Lemna minor en aquaculture, application au Tilapia, Sarotherodon niloticus. Thèse Doct. 3ème cycle, INP, Toulouse. 106 p.

THORPE, J.E. 1977. Daily ration of adult perch Perca fluviatilis (L.) during summer in Loch Leven, Scotland. J.Fish Biol. 11(1):55-68.

TREWAVAS, E. 1982. Tilapias : taxonomy and speciation, p. 3-12. In PULLIN, R.S.V. and R.H. McCONNELL (eds.), The biology and culture of Tilapias. ICLARM Conference Proceeding 7, 432 p. Tnternational Center for Living aquatic resources Management, Manila, Philippines.

UCHIDA, R.N. et J.E. KING 1962. Tank culture of tilapia. U.S. Fish. Wild Serv. Fish Bull. 62 : 21-51.

VAN DYKE, J.M. et D.L. SUTTON 1977. Digestion of duckweed Lemna spp. by the grass carp Ctenopharyngodon idella. J. Fish Biol. 11 : 273-278.

WEATHERLEY, A.H. et B.M.G. COGGER 1977. Fish culture : problems and prospects. Science 197(4302) : 427-430.

WHITFIELD, A.K. et S.J.M. BLABER 1978. Resource segregation among iliophagous fish in Lake St. Lucia, Zululand. Environ. Biol. Fishes 3(3) : 293-296.

WHYTE, S.A. 1975. Distribution, trophic relationships and breeding habits of the fish population in a tropical lake basin (Lake Basumtri, Ghana). J. Zool. 177 : 25-56.

WINDELL, J.J., J.W. FOLTZ et J.A. SAROKON 1978. Methods of fecal collection and nutrient leaching in digestibility studies. Prog. Fish Cult. 40(2) : 51-55.

WINFREE, R.A. et R.R. STICKNEY 1981. Effects of dietary protein and energy on growth, feed conversion efficiency and body composition of Tilapia aurea. J. Nutr. III(6) : 1001-1012.

Annexe 1 : Besoins en acides aminés de quatre espèces de poissons, exprimés en gramme/100 g d'aliments[*]

	CARPE[a]	CARPE[b]	TRUITE[b]	*S. mossambicus*[c]
ARGININE	1,6 (4,3)	1,52 (3,8)	1,4 (3,5)	1,59 (4,0)
HISTIDINE	0,8 (2,1)	0,56 (1,4)	0,64 (1,6)	-
ISOLEUCINE	0,9 (2,5)	0,92 (2,3)	0,96 (2,4)	-
LEUCINE	1,3 (3,3)	1,64 (4,1)	1,76 (4,4)	-
LYSINE	2,2 (5,7)	2,12 (5,3	2,10 (5,2)	1,62 (4,1)
METHIONINE	0,8-1,2 (2,1-3,1)	0,64-1,16 (1,6-2,9)	0,72 (1,8)	0,53 (1,33)
PHENYLALANINE	1,3-2,5 (3,4-6,5)	1,16 (2,9)	1,24 (3,1)	-
THREONINE	1,5	1,32 (3,3)	1,36 (3,4)	-
TRYPTOPHANE	0,3	0,24 (0,6)	0,20 (0,5)	-
VALINE	1,4	1,16 (2,9)	1,24 (3,1)	-

(a) NOSE (1979) (b) OGINO (1980) (c) JACKSON et CAPPER (1982).

* Le chiffre entre parenthèses indique le pourcentage nécessaire de l'acide aminé sur l'ensemble des protéines du régime alimentaire (mg/100 mg de protéines).

Annexe 2 : Evolution du quotient nutritif au cours des deux essais avec des individus de tailles différentes, à densité constante

	Période expérimentale (en semaines)								
	1	2	3	4	5	6	7	8	Moyenne
poissons de 2 g au départ	2,45	2,11	2,56	2,33	2,25	2,23	-	-	2,32
	(46,21	(41,17)	(48,30)	(43,90)	(42,41)	(42,10)	-	-	(43,80)
poissons de 8 g au départ	2,34	2,32	2,15	2,22	2,04	2,30	2,28	2,33	2,23
	(46,80)	(42,00)	(40,50)	(41,80)	(38,50)	(43,40)	(43,00)	(43,90)	(42,40)

* Entre parenthèses figurent les valeurs de Qn calculées avec le poids frais des lentilles d'eau.

Annexe 3 : Evolution du quotient nutritif au cours du test de mise en charge

LOTS	Période expérimentale (en semaine)					
	2	4	6	8	10	Moyenne
T1	1,92 (35,50)	2,03 (37,60)	2,11 (39,10)	2,48 (45,90)	2,59 (47,90)	2,22 (41,10)
T2	2,23 (41,30)	2,52 (46,60)	2,60 (48,10)	2,67 (49,40)	2,63 (48,70)	2,53 (46,80)

* Entre parenthèses figurent les valeurs de Qn calculées avec le poids frais des lentilles d'eau

EFFETS DU TAUX DE NOURRISSAGE (SON DE RIZ) ET/OU DE FERTILISATION (FIENTES DE VOLAILLE) SUR LA CROISSANCE PONDÉRALE DE OREOCHROMIS NILOTICUS EN ÉTANG - ÉTUDE DE LA RENTABILITÉ FINANCIÈRE DE L'OPÉRATION

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Resumé

Cette étude porte sur l'utilisation de deux déchets agro-alimentaires (son de riz et excréments de volaille) individuellement puis en association dans la pisciculture de Oreochromis niloticus.

L'expérimentation a été réalisée en trois tests dans des étangs de 5 ares avec une mise en charge de 500 alevins de 12 g par are. La durée de chaque test a été de 6 mois.

Les résultats obtenus ont été très satisfaisants dans la mesure où les tailles et les quantités de poisson obtenu conviennent à l'autoconsommation rurale (leurs petites tailles ne permettant pas de les vendre en ville).

L'étude de la rentabilité financière de l'opération a révélé qu'il se dégage toujours un profit pour le pisciculteur même si, dans le pire des cas, celui-ci doit acheter les intrants (son de riz, excréments de volaille).

Summary

This study concerns the use of two agro-food wastes (rice bran and chicken droppings) in Tilapia culture.

The experiment was divided into three tests using 5 are ponds stocked with 500 12g fingerlings per are. Each test lasted six months.

Considering the size and production level, the results of this study indicate that this type of management is fashioned for application in backyard fish farming. However, sizes were too small to be sold on urban markets.

A study of the financial profitability showed that the fish farmers earned a profit even when they had to pay for the inputs (rice bran and poultry droppings), which was seldom the case.

Introduction

Au Burkina Faso, une des possibilités pour venir à bout de la malnutrition consiste à produire des protéines animales de bonne qualité et de faible coût. La pisciculture de type villageois ou familial permettrait d'atteindre cet objectif et, en même temps, de réduire le chômage (surtout en saison sèche) et les migrations. Les eaux de surface et les sous-produits et déchets agro-alimentaires (son de riz, excréments de volaille, etc) disponibles en milieu rural s'en trouveraient également valorisés.

L'expérimentation réalisée, objet de cette publication, avait donc pour but de jeter les bases d'une pisciculture rurale adaptée au Burkina Faso.

Methodes et matériel utilisés

L'expérimentation a été conduite dans des étangs d'une surface de 5 ares chacun, avec une mise en charge par are de 500 alevins de Oreochromis niloticus ayant un poids moyen individuel de 12 g. Elle a consisté en trois tests d'une durée de 6 mois chacun: avec fertilisation, avec nourrissage et avec une combinaison fertilisation et nourrissage.

Pendant toute la durée de ces tests, la biomasse totale et les paramètres de qualité physico-chimique des eaux ont été contrôlés tout les 15 jours. Dans le cas du nourrissage les rations étaient aussi réajustées tous les 15 jours. Le protocole expérimental est résumé dans le Tableau 1.

Tableau 1. Protocole expérimental.

Test 1.	Fertilisation	20 kg de fientes de volaille par are et par mois.
Test 2.	Nourrissage	Ration quotidienne de son de riz répartie en 4 prises. - 20% de la biomasse pendant les 2 premiers mois - 10% de la biomasse pendant les 2 mois suivants - 5% de la biomasse pendant les 2 derniers mois
Test 3.	Fertilisation et Nourrissage	- 10 kg de fientes de volaille par are et par mois - Ration quotidienne de son de riz répartieen 4 prises . 10% de la biomasse les 2 premiers mois . 5% de la biomasse les 2 mois suivants . 2.5% de la biomasse les 2 derniers mois

Résultats

Le tableau 2 indique les valeurs extrêmes des paramètres de qualité physico-chimique de l'eau mesurés en cours d'expérimentation. La figure 1 illustre les courbes de croissance pondérale individuelle, la notation R signalant les cycles de reproduction naturelle (selon la pratique normale en élevage de tilapias).

Tableau 2. Valeurs extrêmes de paramètres physico-chimiques.

Paramètre	Température °C		pH		O_2(mg/l)		Conductivité (µs/cm)	
Test	6h	14h	6h	18h	6h	16h	6h	14h
Test 1. Août-Janvier	19	34	6.8	10	1.5	20	82.2	125.8
Test 2. Août-Janvier	19	34	5.6	8	0.2	10	93	145
Test 3 Février-Juillet	18	37	6.5	9	0.2	18	163	186

Les récoltes obtenues en fin d'expérimentation sont présentées dans le tableau 3.

Tableau 3. Récoltes obtenues en fin d'expérimentation.

Test 1. Fertilisation	
- Poissons de grande taille:	137 kg à 70 g
- Poissons de taille moyenne:	15 kg à 15 g
- Frai	-
Test 2. Nourrissage	
- Poissons de grande taille	162 kg à 85 g
- Poissons de taille moyenne:	36 kg à 50 g
- Frai	30 kg à 7 g
Test 3. Fertilisation et nourrissage	
- Poissons de grande taille:	159 kg à 75 g
- Poissons de taille moyenne:	49 kg à 30 g
- Frai	27 kg à 7 g

Discussion

L'examen des 3 courbes de la figure 1 montre que le nourrisśage bien mené profite plus aux poissons que le nourrissage combiné avec la fertilisation seule.

De même, l'action combinée nourriture - engrais est plus bénéfique que l'action isolée de la fertilisation.

Ceci étant, on pourrait penser à augmenter la part de la nourriture dans le test 3 afin d'obtenir de meilleurs résultats qu'à présent. Cependant, les données relatives à la qualité physico-chimique des eaux nous enseignent que, dans pareil cas, on aurait une qualité des eaux plus mauvaise que celle obtenue dans les tests 1 et 2; de ce fait, les résultats ne seraient pas meilleurs.

Sur le plan de la reproduction, les poissons du test 3 ce sont reproduits plus tôt. Ceci est sans doute dû au fait que le test s'est déroulé à une période particulièrement sèche, ce qui a entraîné le pompage de l'eau d'alimentation des étangs (insuffisante de surcroît). On a donc assisté à un échauffement exagéré (37°C) des eaux, ce qui a conduit à une reproduction prématurée.

Dans le même temps et, pour les mêmes raisons, il y a eu trois cycles de reproduction et non pas deux comme dans les tests 1 et 2.

Les présentes expérimentations ayant pour but de jeter les bases de la pisciculture rurale de type villageois ou familial au Burkina Faso; il est nécessaire d'évaluer le coût des intrants en fonction de la production.

Une des lignes politiques agricoles actuelles du Faso est d'encourager les paysans à produire de façon à mener le pays vers l'autosuffisance et l'indépendance alimentaire. Pour le volet pisciculture rurale, les paysans seront techniquement encadrés pour la construction des étangs. Ils devront apporter les intrants (son de riz, de mil ou de sorgho et excréments de volaille) mais les alevins leur seront fournis par l'Administration.

Si, dans le pire des cas, ils sont tenus d'acheter les intrants comme nous l'avons fait pour les besoins de l'expérimentation, la situation se présentera comme illustré dans le tableau4.

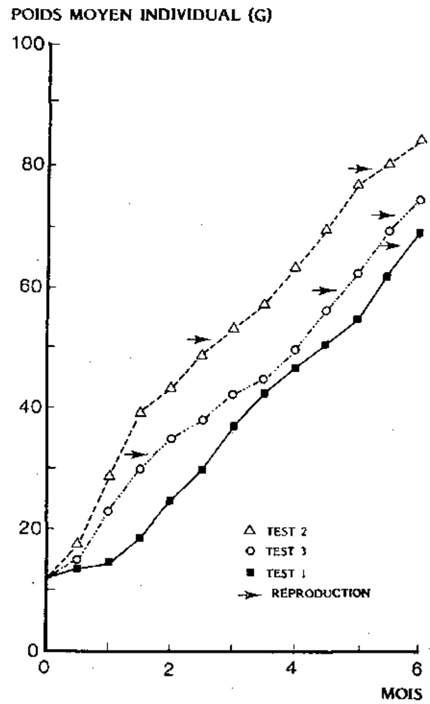

FIGURE 1. CROISSANCE PONDÉRALE DE OREOCHROMIS NILOTICUS DANS UN ÉLÉVAGE EN UNE PHASE DE 6 MOIS.

Les récoltes obtenues en fin d'expérimentation sont présentées dans le tableau 3.

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- Poissons de grande taille	162 kg à 85 g
- Poissons de taille moyenne:	36 kg à 50 g
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Une des lignes politiques agricoles actuelles du Faso est d'encourager les paysans à produire de façon à mener le pays vers l'autosuffisance et l'indépendance alimentaire. Pour le volet pisciculture rurale, les paysans seront techniquement encadrés pour la construction des étangs. Ils devront apporter les intrants (son de riz, de mil ou de sorgho et excréments de volaille) mais les alevins leur seront fournis par l'Administration.

Si, dans le pire des cas, ils sont tenus d'acheter les intrants comme nous l'avons fait pour les besoins de l'expérimentation, la situation se présentera comme illustré dans le tableau 4.

Tableau 4. Récapitulatif des éléments de la rentabilité financière des opérations.

Intrant	Son de riz 20F/kg		Fientes de volaille 10F/kg		Poisson consom. 300F/kg		Profit
Test	kg	CFA	kg	CFA	kg	CFA	CFA
1	0	0	600	6000	137	41100	± 35100
2	2050	41000	0	0	198	59400	± 18400
3	850	17000	300	3000	207	62100	± 42100

A l'examen du tableau 4, on peut se rendre compte qu'il se dégage toujours un profit (entre 18400 et 42100 F) pour le pisciculteur au cas où toute la production serait vendue.

Sur le plan financier, le test 3 est plus rentable que le test 1 et, ensuite, que le test 2. On peut aussi constater que le prix de revient du son de riz a une influence déterminante sur la rentabilité financière, même si cet aliment permet d'obtenir de bons résultats tant en poids moyen individuel qu'en biomasse.

Conclusions

Dans une pisciculture rurale conduite comme dans les tests 1, 2 et 3, seuls les résultats des tests 2 et 3 permettent de démarrer un, sinon deux autres cycles d'élevage du même genre. On remarque qu la croissance est plus importante à mesure que la part de la nourriture augmente (jusqu'à 20% de la biomasse au premier stade). Cependant, on peut noter le rôle non négligeable de la fertilisation dans l'accroissement des biomasses.

Du point de vue de la production de poisson de consommation en milieu rural, le test 3 (fertilisation et nourrissage) est plus performant que les test 2 (nourrissage sans fertilisation) et, ensuite, test 1 (fertilisation sans nourrissage).

Du point de vue financier, si l'on considère que le pisciculteur (paysan) doit, dans le pire des cas, acheter les intrants (son de riz, excréments de volaille), il devra adopter le test 3 qui donne plus de profit que les tests 1, en premier lieu, et test 2, ensuite.

Pour terminer, disons que les trois tests sont tous bons pour le paysan qui produit lui-même les intrants de sa production. Par conséquent, ils peuvent être retenus comme méthodes de production de poisson en milieu rural pour autant qu'ils contribuent à la valorisation des sous-produits et déchets agro-alimentaires et des eaux de surface, mettant ainsi à la disposition des masses rurales, des protéines animales de bonne qualité et de faible coût.

RÉSULTATS PRÉLIMINAIRES DE L'ALIMENTATION ARTIFICIELLE DE TILAPIA GUINEENSIS (BLEEKER) ET SAROTHERODON MELANOTHERON (RUPPEL) EN ÉLEVAGE

A.Cissé

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Résumé

On a procédé à la station experimentale de Layo, à des essaies d'alimentation de Tilapia guineensis et Sarotherodon melanotheron, auxquels des rations protéiniques de 25%, 20% et 37% ont été administrées sous forme de granulés. L'empoissonnement des bassins en ciment de 4 m^2 s'est effectué avec des alevins de 35-40 g de poids moyen à une densité de 10 poissons/m^2 à raison de deux bassins par formule alimentaire pas espèce. Pendant six jours par semaine des aliments en granulés ont été jetés à la volée en surface au taux de 3% de la biomasse estimée durant une période de 8 mois (240 jours). Le gain quotidien de poids individuel et les quotients nutritifs alimentaires ont été calculés pour les trois formules. A la récolte des différents traitements nous avons en les résultats suivants:

T.guineensis mâle (poids moyen: 185 g) et S.melanotheron femelle (poids moyen: 172 g) avaient les meilleurs croissance en élevage mixte avec respectivement l'aliment à 25% de protéine totale riche en matières lipidiques et 20% de protéine totale riche en matières glucidiques.

Summary

Feeding trials were conducted in Layo (C.R.O. Aquaculture experiment station), feeding 25%, 20% and 37% protein rations in pelleted form to Tilapia guineensis and Sarotherodon melanotheron. Fish of 35 to 40 g mean weight, were stocked at a density of 10/m^2 in 4 m^2 concrete tanks. Two tanks were used per treatment per species. Pelleted feed were broadcast on the tank surface six days a week at a rate of 3% of the estimated body weight during an eight month growing period. Production, daily individual weight gain and feed conversion were different for the three rations. T. guineensis male (mean weight: 185 g), and S.melanotheron female (mean weight: 172 g) showed better results with respectively 25% protein ration supplemented with lipids, and 20% protein ration supplement with carbohydrates.

Introduction

Depuis quelque années, des essais sont menés par le Centre de Recherches Océanographiques (C.R.O.) concernant les possibilités d'élevage de Tilapia guineensis et de Sarotherodon melanotheron. Ces deux espèces de Cichlidés sont de type estuarien et supportent des salinités très élevées allant de 0 à plus de 35‰. Elles sont présentes dans toutes les lagunes Ivoiriennes et dans les lagunes ouest-Africaines en général (Daget & Iltis, 1965; Bardach et al., 1972; Balarin, 1979). Elles sont par ailleurs très appréciées et de consommation courante. Dans le milieu naturel, leur régime alimentaire est omnivore à tendance herbivore. Constitué surtout de plantes macrophytes chez T.guineensis qui est benthophage "brouteur" et de phytoplancton chez S.melanotheron qui est filtreur.

La faisabilité économique de tout élevage repose, en grande partie, sur la disponibilité d'aliments composés à des prix élevés et stables. Pour tenter de s'affranchir le plus possibles des importations toujours onéreuses d'ingrédients ou de produits finis, un certain nombre de tentatives ont eu pour objet de metter au point des aliments composés réalisés en majeure partie à l'aide de produits ou sous-produits locaux.

L.expérimentation en cages flottantes en lagune Ebrié de S.melanotheron a révélé une croissance moyenne journalière de 0,64 g avec un aliment titrant 15% de protéine totale (Magnet & Kouassi, 1979) ce qui semblait très intéressant chez cette espèce. Malheureusement, pour des raisons de disponibilités d'alevins, les recherches n'ont pas pu être poursuivies.

Legendre (1983) a fait également des essais d'alimentation chez S.melanotheron en enclos sur des durées restreintes. D'une part, il a obtenu un taux de croissance satisfaisant avec un aliment composé titrant 35% de protéine totale. D'autre part, l'auteur pense que la nourriture utilisée n'est pas peut-être pas l'aliment le plus souhaitable pour la nourriture de cette espèce, malgré sa richesse. Donc pour lui un gros effort doit être fait en vue de mettre en évidence un aliment mieux adapté aux besoins des "tilapias lagunaires".

A notre connaissance il n'existe aucun résultat disponible se rapportant à l'étude des besoins nutritionnels de T.guineensis.

Par le présent travail nous nous proposons de définir une formule alimentaire équilibrée et peu coûteuse, les critères étant la croissance et le quotient nutritif (Qn). Ce dernier se définit comme le rapport entre le poids de nourriture distribuée et l'accroissement du poids de poisson correspondant.

Matériel et méthodes

Des alevins de T.guineensis et S.melanotheron pesant en moyenne 35-40 grammes ont été récoltés des étangs de la station puis stockés dans des bassins carrés de 2 m de côté et 1 m de profondeur. L'alimentation en eau de ces structures se faisait par gravité à partir d'un château-d'eau qui était lui-même rempli par pompage dans la lagune. L'e suivi journalier de certains paramètres physico-chimiques de l'eau des bassins a été effectué durant toute la période d'élevage. Les fluctuations moyennes minimales et maximales ont été enregistrées. Ainsi salinités observées ont été de 5‰ en saison sèche et de 0‰ en saison des pluies. La température a varié de 27°C à 32°C, le pH de 6 à 8,5, et l'oxygène de 4,5 mg/l à 7 mg/l.

Avant de commencer le test de nutrition proprement dit, les alevins ont été placés en stabulation et nourris avec un même aliment standard pendant deux semaines. Après cette période d'adaptation des poissons aux nouvelles conditions, trois lots, repliqués une fois chacun, ont été constitués au hasard à raison de 10 poissons par mètre carré par bassin (sex ratio: 1/1). Différentes formules alimentaires leur ont été attribuées. Un groupe de poissons a été nourri avec un aliment titrant 37% de protéine totale (formule N°II proposée par Legendre, 1983), deux autres groupes ont été nourris avec des aliments ayant respectivement 20% et 25% de protéine totale. La nourriture a été régulièrement distribuée quatre fois par jour pas bassin à raison de 3% de la biomasse des poissons.

L'introduction d'une quinzaine d'Hemichromus fasciatus mâle (p.m. 50 g) dans chaque bassin avait pour but d'assurer le contrôle de la population de T.guineensis et de S.melanotheron par élimination de tous les alevins produits en cours d'élevage, et permettre ainsi aux poissons mis en charge de croître de façon satisfaisante, en l'absence de toute surpopulation. Les échantillonnages mensuels ont permis, en fonction du gain en poids enregistré, de tenir compte du poids des Hemichromis dans le calcul des nouvelles rations. Les essais ont porté sur une période de 240 jours. Pour l'analyse statistique, nous avons utilisés le test X^2 pour l'estimation du taux de survie

Tableau I. Composition chimique des matières premières utilisées pour la fabrication des aliments de poissons (% de matière sèche). Ce tableau représente la moyenne de plusieurs analyses chimiques réalisées par le Laboratoire Central de Nutrition Animale de l'Ecole Normale Supérieure Agronomique d'Abidjan (ENSA) pendant la période de l'expérimentation.

Matières premières	Matière minérale	Matière cellulosique	Matière azotée brute	Matière grasse	Extrait non azoté	P	Ca
Farine de poisson	26,08	0,00	59,51	6,04	8,37	3,33	6,26
Tourteaux de soja	7,72	7,61	52,35	1,33	30,99	0,91	0,71
Tourteaux de coton	6,94	14,54	47,23	5,48	25,81	1,22	0,20
Tourteaux de palmiste	3,28	26,03	17,43	10,59	42,67	0,64	0,27
Tourteaux d'arachide	5,50	11,12	49,62	6,22	27,54	0,75	0,18
Son de blé	6,40	11,25	17,25	4,69	60,41	0,93	0,15
Maîs	0,81	2,30	8,01	1,99	86,89	0,10	0,06

dans les différentes populations de poissons, puis l'analyse de variance et le test de Tukey pour voir s'il existe une différence significative entre les alimenst.

Préparation des aliments

Nous avons recensé les potentialités locales en matières premières puvant entrer dans la composition des aliments. Ensuite nous avons procédé à leurs analyses systématiques au Laboratoire de Nutrition Animale (LACENAENSA d'Abidjan) (Tab.1). Les mélanges farineux obtenus à partir des formules mises au point on été longuement malaxés à la main puis passés au travers d'un hachoir électrique à viande équipé de filières de 3 mm de diamètre. Les granulés ainsi formés ont été exposés au soleil pendant 7 à 8 h (en saison sèche) ou dans une étuve à 50°C (pendant la saison des pluies). Une fois séchés, ils ont été mis en sachets plastiques. Les aliments ont été fabriqués tous les trois jours. La composition et l'analyse chimique des aliments testés sont présentées dans les tableaux II et III.

Tableau II. Composition des régimes alimentaires (% de matière sèche).

Composants	Aliment Expérimental X_1	Aliment Expérimental X_2	Aliment Témoin T.N°2(*)
Farine de poisson	10	5	20
Tourteaux de soja	20	10	15
Tourteaux de coton	10	20	-
Tourteaux de palmiste	15	15	-
Tourteaux d'arachide	5	10	20
Son de blé	20	30	25
Maïs	15	6	20
Vitamine C	1	1	-
Premix (a)	2	1	2
Farine de manioc cuite (b)	2	2	2
Prix de revient de l'aliment en FCFA/kg(c)	83,25	69,90	104,75

a) - Le composé vitamine (Premix) contient par kg; vit A 35.000.000 Iu, vit D3 10.000.000 Iu, vit B2 2 g, vit B6 5 g, Ca-panthothenate 10 g, Acide folique 1 g, vit B12 0,02 g, vit E 5.000 Iu, vit PP 10 g, DL Methionine 20 g, Biotine 0,01 g, Choline 15 g, vit K3 10 g.

b) - La farine de manioc cuite ou amidon sert de liant.

c) - Les coûts des aliments ne tiennent pas compte ici des frais d'usinage.

(*)- T.N°2 : tilapia N°2.

Tableau III. Caractéristiques analytiques des formules alimentaires (% de matière sèche).

	X_1	X_2	T.N°2
Matière minérale	7.87	5.70	16,01
Matière cellulosique	5,66	6,40	3,34
Protéine brute (N x 6,25)	24,60	20,30	36,70
Matière grasse	13,94	5,27	4,32
Extrait non azoté	47,93	62,27	39,63

Résultats et observations

T.guineensis

A la fin de l'expérience, un X^2 effectué sur la survie ne montre pas d'effet significatif entre les trois aliments. La survie moyenne est de 80%. L'analyse de variance effectuée sur les poids inividuels ne met pas en évidence d'effet bassin, mais un effet aliment significatif. La comparaison des résultats de croissance dans les différents lots montre que l'aliment X_2 a une efficacité significativement moindre que celle des aliments X_1 et T.N°2 ($p < 0,01$). Ces derniers conduisent à des résultats équivalents. Les Qn moyens calculés sur l'ensemble de la période d'essai dans les différents lots nous ont donné les résultats suivants: 6,38 pour le lot A nourri avec l'aliment X_2; 3,50 pour le lot B nourri avec l'aliment T.N°2; et 3,32 pour le lot C qui a reçu l'aliment X_1. Les Qn des lots B et C sont très proches ce qui confirme que les aliments X_1 et T.N°2 ont une même efficacité (Tab.IV).

Tableau IV. Résultats des élevages de Tilapia guineensis nourris avec les différents aliments testés *.

Type d'aliment (teneur en protéines)	Début de l'expérience		Fin de l'expérience			Quantité d'aliments ingérés (kg)	Gain individuel journalier (g/j)	Quotient nutritif (Qn)
			♂	♀				
	P.M. (g)	P.T. (kg)	P.M. (g)	P.M. (g)	P.T. (kg)			
X_1 = 25%	36,50	1,460	185,20	111,50	6,370	16,314	0,61	3,32
T.N°2 = 37%	38,35	1,534	175,60	107,70	5,505	13,920	0,58	3,50
X_2 = 20%	38,80	1,552	145,05	99,50	4,424	18,330	0,44	6,38

* Les chiffres présentés correspondent à la moyenne des résultats obtenus avec les deux replicats.

PM = Poids Moyen

PT = Poids Total

Nous constatons cependant que ces Qn sont élevés. Une des raisons semble être que l'aliment distribué ne serait pas consommé ou très peu consommé pendant la maturation et surtout au moment de la saison de reproduction. Les résultats obtenus permettent d'établir le graphique (Fig.1) des poids moyens individuels atteints selon l'aliment testé. Une différence de croissance liée au sexe a été mise en évidence. En effet, les mâles ont une croissance plus rapide que les femelles dans les mêmes conditions expérimentales et pour le même temps d'élevage.

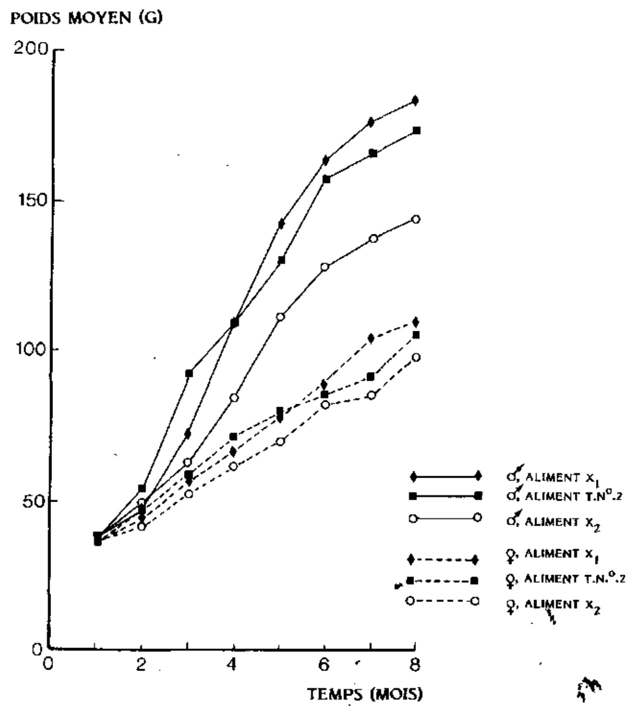

FIGURE 1. CROISSANCE EN POIDS DE TILAPIA GUINEENSIS EN ÉLÉVAGE MIXTE NOURRIS AVEC LES ALIMENTS X_1, X_2 et T.N°.2.

S.melanotheron

Un raisonnement analogue a été fait pour S.melanotheron en élevage mixte. La survie moyenne en fin de manipulation a été ici de 60%. Cette moins bonne performance a été due à une mortalité assez importante surtout chez les mâles. Les résultats présentés dans le tableau V montrent que les aliments X_2 et T.N°2 donnent un rendement équivalent.

Tableau V. Résultats des élevages de Sarotherodon melanotheron nourris avec les différents aliments testés*.

Type d'aliment (teneur en protéine)	Début de l'expérience		Fin de l'expérience			Quantité d'aliments ingérés (kg)	Gain individuel journalier (g/j)	Quotient nutritif (Qn)
	P.M. (g)	P.T. (kg)	P.M. (g)	P.M. (g)	P.T. (kg)			
X_1 = 25%	39,20	1,568	91,30	130,07	3,390	14,197	0,37	7,80
T.N° 2 = 37%	37,35	1,494	109,75	168,10	3,994	10,200	0,54	4,08
X_2 = 20%	38,72	1,548	98,55	172,60	4,075	12,485	0,56	4,95

* Les chiffres présentés correspondent à la moyenne des résultats obtenus avec les deux replicats.

P.M. = Poids Moyen

P.T. = Poids Total

Par contre l'aliment X_1 donne une efficacité significativement moindre à celle des aliments précédents ($P < 0,01$). Les Qn sont encore élevés et méritent amélioration. Cependant ils confirment encore une fois nos résultats statistiques. Nous observons également (Fig.2) que chez S.melanotheron, ce sont les femelles qui ont une croissance pondérale supérieure à celles des mâles quel que soit l'aliment reçu. Situation contraire à ce que nous avons constaté chez T.guineensis. Legendre (1983) attribue cette faible performance des mâles à l'incubation buccale pratiquée par ces derniers. En effet durant cette période ils ne se nourrissent pas.

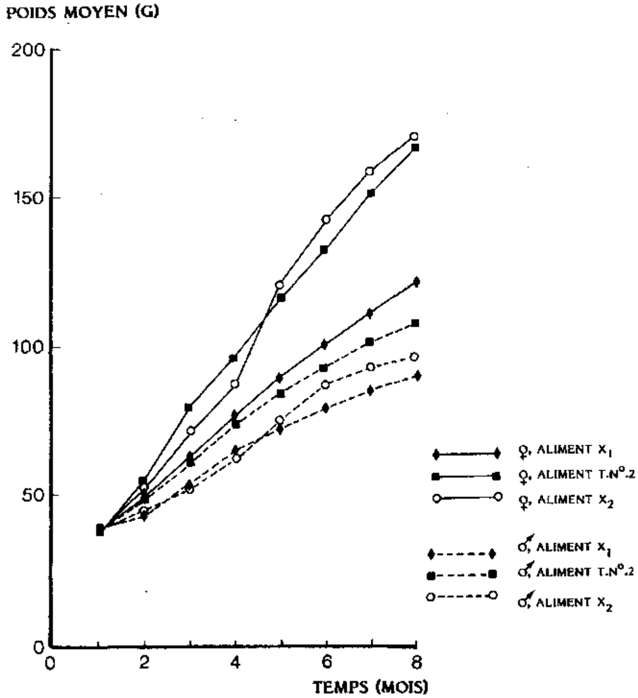

FIGURE 2. CROISSANCE EN POIDS DE S.MELANOTHERON EN ÉLÉVAGE MIXTE NOURRIS AVEC LES ALIMENTS X_1, X_2 et T.N°.2.

Conclusions

- L'aliment T.N°2 donne des résultats équivalents à X_1 ou à X_2 qui sont les plus performants suivant l'espèce. Mais le choix de X_1 ou X_2 apparaît préférable dans la mesure où ces aliments sont moins onéreux que T.N°.2
- Le fait que X_1 marche mieux pour T.guineensis, alors que c'est X_2 qui donne les meilleurs résultats chez S.melanotheron, suggère des différences de besoins alimentaires de ces deux espèces, en particulier différences de besoins lipidiques et glucidiques.
- Pour la suite de notre travail, un équilibre est à trouver entre les deux aliments (X_1 et X_2) en tenant compte des besoins essentiels des espèces-cibles pour qu'on puisse aboutir un jour à un "aliment-tilapia" fiable. Aussi l'accent sera mis particulièrement sur la détermination des meilleures conditions de distribution de l'aliment, telles que la ration quotidienne, et la fréquence de distribution.

References

Balarin, J.D., 1979. Tilapia: a guide to their biology and culture in Africa. University ofStirling, Stirling, G.B., 174 p.

Bardach, J.E., J.H.Ryther, W.O.McLarney, 1972. Aquaculture. The farming and husbandry of freshwater and marine organisms. N.H.Wiley - Interscience, 808 p.

Daget, J., A.Iltis, 1985. Poissons de Côte d'Ivoire (Eaux douces et saumâtres). Mémoires 17An, n° 74, 385 p.

Legendre, M., 1983. Observations préliminaires sur la croissance et le comportement en élevage de Sarotherodon melanotheron et de Tilapia guineensis en lagune Ebrié (Côte d'Ivoire).Thèse Doc.Sc.,Cent.Rech.Océanogr., Abidjan, 9 (2): 1-36.

Magnet, C.& Y.S.Kouassi, 1979. Essai d'élevage de poissons dans les lagunes Ebrié et Aghien: Reproduction en bac cimentés, élevage en cages flottantes. Publication du Centre Technique Forestier Tropical, 70 p.

DEVELOPMENT AND RESEARCH OF AQUACULTURE IN KENYA

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Summary

Although modern fish farming is relatively new to Kenya, fish production from natural resources has been going on for generations. Current production from this source is a standing 80,000 tonnes, with production from inland waters accounting for more than three-quarters of the total landings. Production from aquaculture is still small though of increasing importance, Totalling approximately one percent of the total fish prouction in the country, the bulk coming from the trout farms.

Although aquaculture practice is widespread throughout the country, much is concentrated along the coastal and in the central part of the country. Major species of fish cultured include common carp, Cyprinus carpio, shrimp species and the Tilapia species. More recently the brine shrimp, Artemia salina has been cultured on an experimental basis.

The major problems affecting fish culture development in Kenya are the insufficient supply of fry and supplementary food. Fish diseases do not as yet pose a major problem fo aquaculture in Kenya, except as concerns trout.

Résumé

Bien que l'aquaculture moderne soit introduite depuis relativement peu de temps au Kenya, la production de poisson obtenue à partir des ressources naturelles est une activité qui existe depuis plusieurs générations déjà et atteint actuellement 80.000 tonnes. La production des eaux intérieures représente plus de trois quarts des prises totales. La production aquacole reste faible quoique gagnant en importance, et correspond approximativement à un pour cent de la production totale de poisson du pays, l'essentiel provenant des élevages de truites.

Les activités aquacoles existent dans tout le pays mais sont davantage concentrées sur le littoral et dans la région centrale. Parmi les espèces aquacoles principales, on trouve la carpe commune (Cyprinus carpio), diverses espèces de crevettes et tilapias et on cultive depuis peu la crevette Artemia salina à une échelle expérimentale seulement.

Les problèmes majeurs affectant le développement de l'aquaculture au Kenya sont un approvisionnement insuffisant en frai et en nourriture supplémentaire. Les maladies ne constituent pas encore de problème majeur chez le poisson, en aquaculture au Kenya, à l'exception de la truite.

Introduction

Although the total annual production of fisheries amounts to about 80,000 which is likely to be doubled as a result of the full utilization of all the aquatic resources, including the recently acquired two hundred mile exclusive economic zone within the Kenya coastal waters, the need to grow fish for food is constantly increasing due to the growth of the population. Consequently, much attention has been given to the development of aquaculture, and as a result, the practice has progressed a great deal in the last few years.

Fish culture is a recent development in Kenya. There is no evidence that it was ever practised in Kenya before the advent of colonialism (1890-1963). As in most African countries, aquaculture was introduced into Kenya in years following the first world war. In 1928,, Black bass, Micropterus salmoides, was first introduced into Lake Naivasha and the dams around Mt.Kenya to satisfy the needs of European adventurers who came to Kenya intent upon big game hunting. At the same period, trout, S.trutta and S. gairdneri, were introduced into rivers in the upper reaches of Mt.Kenya, again for the same purpose, i.e. to meet the angling aspirations of the European community in Kenya.

The years following the end of the second world war saw different motivations and aspirations. The end of the war was witnessed by a decline of protein food supply and in Kenya, as in most other countries, the cry went out for intensification of efforts to increase protein food supply. Aquaculture development was seen as a cheap and ready means to reach the objective. As a result many ponds were dug all over the country, particularly in the Central Province and Western Kenya, and by the end of 1960, aquaculture practice, though rudimentary and rather haphazard, had become rooted in Kenya society.

Ten years earlier the Inland Fish Culture Research Station at Sagana was established to study and undertake research into various aspects of aquaculture including integrated rice-cum-fish culture methods at the newly established irrigation scheme at Nwea-Tabere. Afterwards development and research of aquaculture in Kenya for a long time remained centred around this research station, but with increased interest in aquaculture both research and development activities spread throughout the country, and more especially in the coastal areas and in western Kenya.

Status and scope of aquaculture

About five thousand fresh-water fish ponds covering an area of about 250 hectares are at present scattered all over the country. Most of these are owned by individual homesteads, schools, communities and various institutions. The majority are built through the construction of simple earthen dams across, or along streams, and riverlets. Recently however, improved practices have given rise to different systems as indicated by the concrete constructed running water system at the famous Baobab Farm and by the FAO Shrimp Culture Station at Malindi. In Western Kenya also pond construction improved under the impetus of the Lake Basin Development Authority.

Manpower in Aquaculture

The development of aquaculture depends on the availability of cheap labour as well as of qualified personnel for research and extension services. Kenya is well endowed with cheap labour to undertake mannual work in fish pond construction, but lacks sufficient numbers of trained aquaculturists. There are at this moment ten fully trained scientists working on research and extension services in the countries, in addition to numerous technicians seconded to fish farming projects across the country.

Species cultured

As indicated earlier, the species cultured include rainbow and brown trout, various Penaeus shrimp species, tilapia species (O.niloticus and others), Black bass (M.salmoides), common carp (C.carpio), and more recently and still on an experimental scale, Artemia salina, cultured as feed for prawn and shrimp.

One other species, Cichlica ocellaris introduced in 1970 has taken to the wild waters and although a few are still found at the Sagana station it has not found its way into pond culture. Also grass carp (Ctenopharyngodon idella) because of its breeding problems apparently died out.

Aquaculture Research Facilities

The Inland Fish Culture Research Centre mentioned earlier fell into disrepute by 1964, soon after Independence, and by 1969 all research there has ceased. The station became - and still is - more of a centre for fry production, with research work being carried out at the newly established Gechaga Institute in Nairobi.

At present The Kenya Marine and Fisheries Research Institute with headquarters at Mombasa has a well established aquaculture research division with centres at Sangoro, for diadromous species and tilapia species, at the Mombasa Laboratory for shrimp, oyster and Artemia culture, and at the Kisumu Laboratory soon to be provided with facilities for cage and other culture practices including rice-cum-fish.

The Department of Fisheries, in conjunction with FAO has a well established shrimp culture station at Ngomeni near Malindi, where research work is also undertaken. The Lake Basin Development Authority, a statutory board of the Kenya Government has a fish fry production centre at Kibos near Kisumu, where research work on fry production is being conducted.

Aquaculture problems in Kenya

Problems facing aquaculture are many, but the following appear critical and need immediate attention.

1. Rehabilitation of the existing ponds. As already indicated, there are about five thousand earthen ponds which were built in the early years of aquaculture development in Kenya, and many of these need careful rehabilitation. In addition, now that there is a organized supply of fry at both Sagana and Kibos, some of these ponds will need stocking material from these stations. Owners of these ponds need to be familiarized with basic aquaculture practices and methods so as to improve fish pond production.
2. The problem of supplementary feeds is equally of greatest importance, and the improvement of aquaculture in Kenya will depend very much on the availability of suitable supplementary feeds.
3. Although fish fry production has been improved recently, it is still not adequate to meet the demand, and this particularly applies to shrimp fry, carp fry and trout fry. It should be noted that shrimp culture at Ngomeni in Malindi draws on natural collections of shrimp juveniles. Although there is no evidence that this practice affects the natural shrimp fishery, there is a need to improve the artificial hatchery production of shrimp fry in order to adequately supply the shrimp farmers of Kenya.

STUDIES ON THE FEEDING OF TILAPIA DISCOLOR IN FLOATING CAGES IN LAKE BOSOMTWI (GHANA)

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Summary

Feeding trials were conducted in floating cages in Lake Bosomtwi in April and May of 1985.

Two different diets (A) and (B) containing animal and plant protein sources respectively were tested on fingerlings of Tilapia discolor. Diet (A) contained fishmeal, brewery waste and maize bran. In diet (B), the fishmeal was replaced by cowpea and groundnut cake.

Three cages each containing 100 fish were used for each diet test. Fish were fed at the rate of 10% of total body weight per cage per day, seven days a week for 5 weeks.

The specific growth rates recorded for diet A (3.19) and diet B (3.06) at the end of the experiment showed no significant difference.

Though diet A recorded a better feed conversion ratio value (2.8) than diet B (3.2) there was no significant difference between the values. Similarly the protein efficiency ratio values recorded for diet A (1.06) and diet B (0.90) showed no significant difference.

Resumé

On a procédé à des essais d'alimentation en cages flottantes dans les eaux du lac Bosomtwi d'avril à mai 1985.

Deux rations différentes (A) et (B) composées, l'une d'aliments protéinés d'origine animale et l'autre, d'aliments protéinés d'origine végétale, ont été administrés aux alevins de Tilapia discolor. La ration (A) contenait de la farine de poisson, des drèches de brasserie et du son de maïs. Dans la ration (B), on avait remplacé de poisson de la ration (A) par du niébé et du tourteau d'arachide.

Trois cages dont chacune renfermait 100 poissons ont été utilisées par l'étude des deux rations alimentaires. Les poissons recevaient une dose de nourriture équivalent à 10% de leur poids vif total par cage et par jour, sept jours par semaine pendant cinq semaines.

A la fin de l'expérience, on n'a constaté aucune différence notable entre les taux de croissance obtenus avec la ration (A) (3,19) et ceux résultant de la distribution de la ration (B) (3.05).

Bien que le taux de conversion de la nourriture soit plus favorable pour la ration (A) (2,8) que pour la ration (B) (3,2), la différence ne portait pas réellement à consequence. Elle n'avait pas davantage de portée dans le cas des coefficients d'efficacité protéique enregistrés pour la ration (A) (1,06) et la ration (B) (0,90).

Introduction

Interest in the use of cages for fish culture has increased recently because of ease of management. Cage culture is presently being practiced in Japan (Maruyama et al., 1976), Puerto Rico (Pagan-Font, 1975), Ivory Coast (Coche, 1977), and in several other countries.

In cage culture the growth of fish depends primarily on the quantity and quality of the feed supplied by the farmer (Chua & Teng, 1978). Coche (1976) estimates that up to 60% of the production costs in cage culture are feed costs, therefore it is important to reduce this costs.

Fishmeal, which serves as the main protein source in commercial fish feeds, is expensive. Attempts to find cheaper sources of protein for fish feeds have led to studies on plant protein sources (Kamara, 1982; Appler & Jauncey, 1983).

The present experiment concerns the substitution of fishmeal by a combination of cowpea and groundnut cake in diets of Tilapia discolor fingerlings kept in cages in Lake Bosomtwi. The effects of this substitution on growth and feed utilization were determined.

Materials and methods

Culture cages

Cages used for this experiment were one cubic metre (1x1x1 m). The cage frame was made up of 24 pieces of hard wood joined by nails to form the cubic metre structure, (Fig.1 and 2).

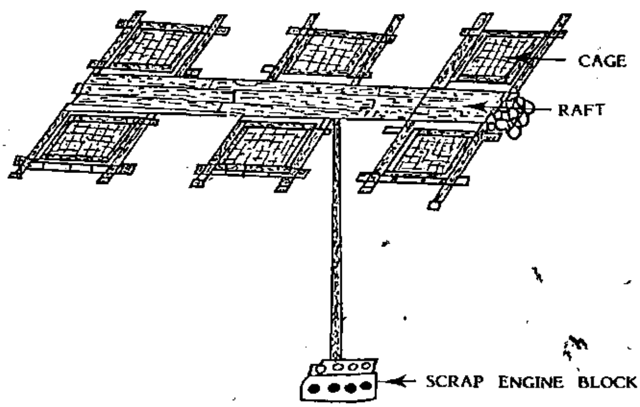

FIGURE 1. FLOATING MAT CAGES USED FOR THE FEEDING EXPERIMENT.

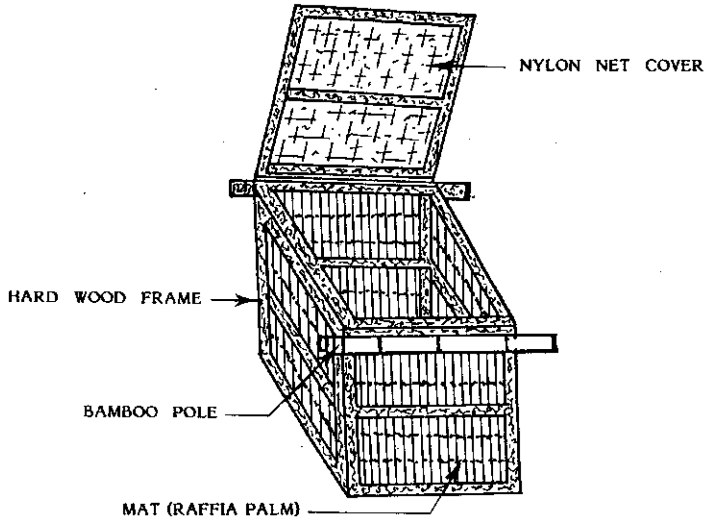

FIGURE 2. A MAT-CAGE ($1\ M^3$)

Each cage had five mats made of raffia palm main vein splits and were waterproofed by tar. The splits forming the mat have been spaced 4 mm apart from each other using a polythelene fibre. The spacing facilitated free water movement through the cage. The five mats were fixed onto five sides of the wooden frame to form the four walls and bottom. The roof of the cage, was covered by a 2 mm mesh size nylon net piece attached to the wooden frame.

Six cages were used for this experiment, three for each diet formulation. They were suspended from a floating raft made of wood and bamboo poles. The whole unit was anchored using a scrap engine block.

Diet formulation and preparation

The two diets A and B, were formulated to ensure protein levels of 35% (Eyeson & Ankrah, 1975; Jackson et al., 1982) using locally available materials. Diet A was prepared from fishmeal, brewery waste and maize bran. Diet B contained cowpea, groundnut cake, brewery waste and maize bran with the cowpea and grounnut cake in diet B replacing the fishmeal in diet A.

The percental composition and the proximate analysis of the two diets are shown in Table 1.

Table 1. Composition of experimental diets.

Ingredient	Diet A %	Diet B %
Fishmeal	45.00	-
Brewery waste	19.00	12.16
Maize bran	31.00	20.27
Cowpea	-	43.92
Groundnut cake	-	18.92
Starch	5.00	4.73
Total	100.00	100.00
Proximate analyses of the experimental diets (%).		
Components		
Crude protein (dry weight)	34.93	34.02
Lipid (dry weight)	2.25	0.82
Moisture	17.50	15.80

The feed ingredients which were obtained from the local market were sundried and milled to powder form. In the case of cowpea treatment against antinutritional factors involved soaking the cowpea and then boiling it for 10 minutes (Owusu-Domfer, 1972) before milling.

Using cooked cassava starch as a binder, the ingredients of each diet were mixed and stirred until crumps were formed. The crumps were sundried, and broken to the required sizes for feeding.

Feeding trial

One hundred fingerlings were stocked, in each cage, Before stocking, the length and weight of the individual fingerlings were recorded. The fingerlings were acclimatized for one week after which the feeding trial was started. The feeding was done at the rate of 10% of the total wet body weight per day to make provision for feed loss through the cage walls. The daily feed ration was divided into three equal parts and fed at 9 a.m., 1 p.m. and 5 p.m.

The fishes were sampled every seven days for individual measurement of length and weight and for determination of the amount of feed to be supplied over the following seven days. The feeding trial was carried out over a period of 35 days.

Regular observations were made of the cages for fouling and fish mortality.

During the trial water samples from inside the cages were taken for pH, ammonia (-N), temperature and dissolved oxygen determinations (A.O.A.C., 1970).

Data analysis

The data collected during the feeding trial were analysed as to differences in specific growth rate, feed conversion and protein utilization due to differences in diet composition.

All statistical analysis were carried out using the students T test at 5%

significance.

Results

During the experiment, the fish accepted the two diets readily. The strong winds and water currents observed during the experimental period may have caused feed losses through the cage walls.

Growth

The growth response of fish during the experimental period is shown in Table 2 as mean initial and final weights and mean specific growth rates (S.G.R.). Diet A produced a non-significant higher S.G.R. than diet B.

Table 2. Growth and protein utilization results of the pooled replicates of diets A and B.

Parameter	Diet A	Diet B
Mean initial Wt.(g)	3.00	3.40
Mean final Wt.(g)	9.18	9.93
Average initial length(cm)	4.34	4.76
Average final length(cm)	4.86	5.33
Specific growth rate (%)	3.19	3.06
Feed conversion ratio	2.80	3.20
Protein efficiency ratio	1.06	0.90

Food conversion

The feed conversion ratios (FCR) recorded for the two diets (Table 2) show a better feed conversion for the fishmeal based diet. The values are however not significantly different.

Protein utilization

The protein efficiency ratio (PER) value for diet A (1.06) is better than for diet B (0.90). The values are however not significantly different.

Hydrology of culture site

Water analysis carried out during the trials (Table 3) show the lake to be very alkaline with pH values ranging between 8.9 and 9.1. Low ammonia - N values ranging between 0.06 and 0.10 mg/l were recorded. Oxygen values ranging between 6.0 mg/l and 7.0 mg/l were recorded during the experiment.

Table 3. Dissolved oxygen, temperature, pH and ammonia - N in the cages during the experimental period.

Week	O_2 (mg/l)	temp (°C)	pH	ammonia - N (mg/l)
1st week	6.0	29	9.0	0.06
2nd week	7.0	28	8.9	0.08
3rd week	6.1	30	9.0	0.06
4th week	6.2	29	9.1	0.09
5th week	6.2	30	9.0	0.10

Discussion

Cage culture of fishes relies entirely on feeding since the fishes do not obtain any of their diet from natural fish food organisms, as under pond farming conditions. The economics of cage culture therefore will depend largely on the cost of the feed.

Attempts to find cheap sources of protein for use in fish feeds have led to the study of plant protein sources (Jauncey & Ross, 1982; Jackson et al., 1982). Kamara (1982) working with groundnut cake fed to Oreochromis niloticus recorded poor fish growth when groundnut cake was used as the sole protein source. The methionine level was 0.21% of the diet. Similar work in this field using sunflower seed meal and rapeseed (Ayeni, 1981; Jackson et al., 1982) also produced poor growth when the plant protein sources were used at higher levels.

The present experiment, which involved the combination of various plant protein sources, however, gave promising results when compared to the control fishmeal based diet. The SGR, FCR and PER obtained for both diets fed to T.discolor showed no significant differences. The good growth produced on the plant protein based diet may be attributed to the combination of the different plant protein sources which might have served to improve the amino acid profile of the diet (Appler, 1983).

The FCR and PER values recorded for both diets in the present experiment are however poorer than values recorded by other workers in similar experiments. Cruz and Laudencia (1978) obtained an FCR of 1.53 when Oreochromis niloticus fingerlings were fed a 30% protein diet in which 50% of the protein was supplied by copra meal and the remaining 50% by fishmeal. Appler (1983) also recorded better FCR values, between 1.26 and 2.09, for fishmeal - alga substituted diets. The poorer FCR values of 2.80 and 3.20 recorded for the fishmeal and the plant protein based diets respectively in the present experiment may be attributed to the loss of feed from the cages during strong winds and currents.

The cost analysis of the diets used in the experiment (Table 4) shows that for the production of 1 kilogram of T.discolor, 210.30 and 137.80 will be required for the fishmeal based and the cowpea and the groundnut cake substituted diets respectively. The experiment however showed no significant difference between the growth rates resulting from the two diets. Since 65.5% of the cost of the fishmeal based diet will be needed to produce the same weight of fish using the cowpea and groundnut cake substituted diet the conclusion is that replacing fishmeal by a combination of cowpea and groundnut cake in T.discolor diets is economically valid.

Table 4. Cost estimates of diets used in the experiment.

Feed	Amount of feed fed per fish (g)	Cost of feed fed per fish (Cedish)	Average weight increase (g)	Cost of feed to produce 1 kg of fish (Cedis)
A	17.06	1.30	6.18	210.36
B	19.87	0.9	6.53	137.83

Acknowledgments

This project was carried out as part of a major investigation of Tilapia culture at the University of Science and Technology, Kumasi, funded by the International Foundation for Science.

References

Appler, H.N., 1983. Green algae as protein source for Oreochromis niloticus and Tilapia zillii. PhD.Thesis. University of Stirling, Stirling, 243 pp.

Appler, H.N. & Jauncey, K., 1983. The utilization of filamentous alga (Cladophora glomerata L.Kutzin) as a protein source in pelleted feeds for Oreochromis (Tilapia) niloticus fingerlings. Aquaculture 30: 21-30.

A.O.A.C., 1970. Official methods of analysis of the association of official analytical chemists. Horwitz, W. (Editor). 11th Edition. Publ.by Association of Official Analytical Chemists, Washington D.C.

Ayeni, G.I., 1981. Plant protein substitution in diets for juvenile Tilapia (Sarotherodon mossambicus). M.Sc.Thesis University of Stirling, July 1981.

Chow, K.W. & J.E.Halver, 1978. Carbohydrates, In Fish Feed Tech. Chow, K.W. (Editor) ADCP/REP/80/11 FAO, Rome.

Chua, T.E. & S.K.Teng, 1978. Effects of feeding frequency on the growth of young estuary grouper, Epinephelus tauvina (Forskal), cultured in floating net cages. Aquaculture, 14 (1978) 31-47.

Coche, A.G., 1977. Preliminary results of cage rearing Tilapia nilotica (1) in Lake Kossou, Ivory Coast. Aquaculture, 10 (2): 109-140 (in French, with English summary).

Coche, A.G., 1976. A general review of cage culture and its application in Africa. FAO Tech.Conf.on Aquaculture, Tokyo, Japan. FIR: AQ/CONF/76/E.72, 33 p.

Cruz, E.M. & I.L.Laudencia, 1978. Screening of feedstuffs as ingredients in ration of Nile 'Tilapia' Kalikasan, Philippines. J.Biol.7 (2): 159-163.

Eyeson, K.K. & E.K.Ankrah, 1975. Composition of foods commonly used in Ghana, published by Food Research Institute, C.I.S.R. Ghana.

Jackson, A.J., B.S.Capper & A.J.Matty, 1982. Evaluation of some plant proteins in complete diets for the tilapia, (Sarotherodon mossambicus). Aquaculture, 27: 97-109.

Jauncey, K. & B.Ross, 1982. A guide to Tilapia feeds and feeding. Inst. of Aquaculture, University of Stirling, FK9 4LA, Scotland.

Kamara, B.K.A., 1982. Evaluation of some oilseed meal proteins in complete diets for the tilapia Oreochromis niloticus. M.Sc.Thesis, Univ.of Stirling.

Maruyama, T., Tamezo & Rikizo Ishida, 1976. Effect of water depth in net cages on growth and body shape of Tilapia mossambicus. Bull.Freshwater Fish Res.Lab.Tokyo, 26, (1): 11-19. (in Japanese with English summary).

Owusu-Domfer, K., 1972. Trypsin inhibitor activity of cowpeas (Vigna unquiculata) and Bambara beans (Voandzuia subterranea), Ghana, J.Agric. Sci. 5, 99-102.

Pagan-Font, F.A., 1975. Cage culture as mechanical method for controlling reproduction of Tilapia aurea.(Steindachner). Aquaculture, 6, (3): 243-247.

STUDIES TO DETERMINE THE POSSIBLE VALUE OF NOTOPTERIS AFER AS PREDATOR IN OREOCHROMIS NILOTICUS PONDS

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Summary

The prevalance of riverine Notopterus afer in the fresh water rivers of Sierra Leone has been observed during river fisheries surveys. Investigations on the possibilities of culturing this riverine species as a predator to control Oreochromis niloticus were carried out at Makali Fish Farm Station.

Two sets of 400 Oreochromis niloticus of both sexes with an average length of 5 cm and an average weight of 20 grams were stocked with two sets of 40 Notopterus afer with an average lenght of 10 cm and an average weight of 45 grams in two earthen ponds. There was considerable reduction of O.niloticus fry in the ponds. A daily growth rate of 0.7 g for O.niloticus and of 1.3 for N.afer were recorded.

Résumé

On a constaté la prédominance de Nopterus afer dans les cours d'eau du Sierra Leone lors d'enquêtes réalisés sur la pêche fluviale. Des recherches ont été effectuées à la station piscicole de Makali sur la possibilité de cultiver ce poisson de rivière afin de l'utiliser comme prédateur pour contrôler Oreochromis niloticus.

Deux lots de quatre cents O.niloticus (des deux sexes) de 5 cm de longueur moyenne et d'un poids moyen de 20 g ont été mis en charge dans deux étangs en même temps que deux lots de quarante Notopterus afer d'une longueur moyenne de 10 cm et d'un poids moyen de 45 g. Il en est résulté une très grande diminution du nombre d'alevins de O.niloticus. On a enregistré une croissance journalière moyenne de 0.7 g pour O.niloticus et de 1.3 g pour N.afer.

Introduction

There is a general notion that the major constraint in Tilapia culture in intensive and semi-intensive systems is the problem of uncontrolled spawning which results in stunted populations. Several methods used in overcoming this problem include monosex culture (raising all-male populations) through hybridization (Pruginin & Kanyike, 1968; Pruginin, 1968; Lovshin et al., 1974) or sexing Tilapia fingerlings using the genital papillae sex differentiation method (Lovshin & Da Silva, 1976). These methods have produced unsatisfactory results because of the difficulty encountered with manual sexing of fingerling. The introduction of a predator to control Tilapia populations in ponds, thereby providing space for growth of both species seems eminent. As a result, efforts are being made to investigate Notopterus afer, an indigenous predatory species with great acceptability as food fish, which could be easily cultured with Tilapia in village fresh water ponds in Sierra Leone.

N.afer belongs to the family Notopteridae (knife-fishes). It is a rather large, elongated, and strongly compressed species. The anus is situated very far forward. The anal fin is long-based and narrow which unite with the small caudal one into a single long fringing fin that acts as chief propulsive organ of the body. By rhytmic wave like movements of this fin the body is directed forwards, or by waves passing in the opposite direction, backwards. The fish can swim almost equally well in either direction, which allows for instant retreat from a predator without any body movement. The mouth is large with numerous small teeth. Scales are very small and the lateral line is complete. The geographical distribution of N.afer is limited to the west coast of Africa, from The Gambia to Zaire. Very little is known about its biology.

Material and methods

The study was sited at the Government Fisheries Station at Makali, Tonkolili District, Northern Province. It used excavated earthen ponds, 250 quare meters in size with depths of between 0.75 and 1.2 m.

O.niloticus and N.afer fingerlings were taken from other ponds at the Makali Fish Farm Station. Fingerlings of the two species were obtained by spawning under normal pond conditions. Two sets of 400 fingerlings of O.niloticus of an average length of 5 cm and an average weight of 20 g were stocked with 40 fingerlings of N.afer of an average length of 10 cm and average weight of 45 g.

Before stocking, the ponds were completely drained and exposed to the sunlight for about one week to ensure the elimination of any predatous and competitive animal life before being refilled with screened water. Two compost piles were constructed along the longer borders of the ponds and 4 kg of chicken manure was used in each compost pile. An additional 2 kg of chicken manure was added every month to each compost pile. Decomposition in the compost was anaerobic. The fish were fed twice daily, in the morning and evening, with rice bran, cassava and fish meal made out of surplus dried fry and fingerlings at the station. The daily ration was approximately 5% of the total body weight of the fish stocked; the feeding level was adjusted every month after samples were taken. The experiment was conducted for 180 days from October 2, 1984 to April 5, 1985.

During the experiment length frquencies and weights of both species were recorded. Water quality parameters measured every 14th day in the ponds included temperature, hydrogen ion concentration (pH), dissolved oxygen (DO), total alkalinity, secchi disk readings and pond water colour, and a monthly average was determined. All measurements were taken between 7 and 5 a.m.

Results and observations

The results of the experiments conducted at Makali Fish Farm Station, are presented in Tables 1, 2 and 3 and Figures 1 and 2. They indicate a potential growth rate of 0.7 g/day by O.niloticus and 1.3 g/day by N.afer (Table 2.).

It was also observed by stomach content analysis that N.afer starts to prey on O.niloticus fry at about 18-20 cm length. At 16-18 cm both fish start to increase in weight, N.afer reducing the O.niloticus. There was also an increased weight gain for N.afer when predatory activity starts. Eggs of N.afer were observed to be deposited under the substrate of compost piles. They were large and oval, deposited in clusters of about 50-70 eggs. Very small quantities of O.niloticus fry were observed when harvesting the ponds. N.afer was quite peaceful to large O.niloticus and it proved very easy to seine and handle this species.

Table 1.Growth data for polyculture of Oreochromis niloticus (O.n.) and Notopterus afer (N.a.).

Date	Average length (cm)		Average weight (g)		Number sampled	
	O.n.	N.a.	O.n.	N.a.	O.n.	N.a.
2-10-84	5	10	20	45	400	40
3-11-84	-	-	-	-	-	-
4-12-84	-	-	-	-	-	-
5-1-85	12	18	68	175	50	20
6-2-85	16	27	83	210	100	25
7-3-85	20	35	110	245	60	20
5-4-85	24	42	145	280	70	20

Table 2. Growth potential for polyculture of O.niloticus and N.afer.

Species	Number	Duration (days)	Average weight gain (g)	Daily weight gain per fish (g)
O.niloticus	400	180	120	0.7
N.afer	40	180	235	1.3

Table 3. Monthly average values of water parameters in the rearing ponds.

Month	Atmospheric temp. (°C)	Water temp. (°C)	Dissolved oxygen (mg/l)	Secchi disk (cm)	Water colour (*)	Total alkalinety (ppm)	pH
Oct. 1984	26	28	8	30	lg	70	6.5
Nov. 1984	25	28	6	22	dg	80	6.5
Dec. 1984	24	26	6	23	g	70	6.5
Jan. 1985	23	25.5	5	20	dg	70	7.0
Feb. 1985	24	26	7	25	g	80	7.0
Mar. 1985	27	29	6	25	g	80	6.5
Apr. 1985	26	28	6	23	g	80	6.5

*

kg = light green g = green dg = dark green

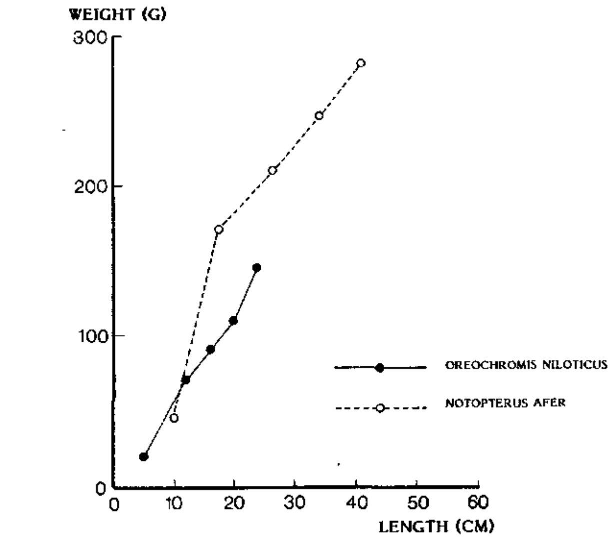

FIGURE 1. LENGTH/WEIGHT RELATIONS OBTAINED IN A 180 DAYS POLYCULTURE EXPERIMENT WITH OREOCHROMIS NILOTICUS AND NOTOPTERUS AFER.

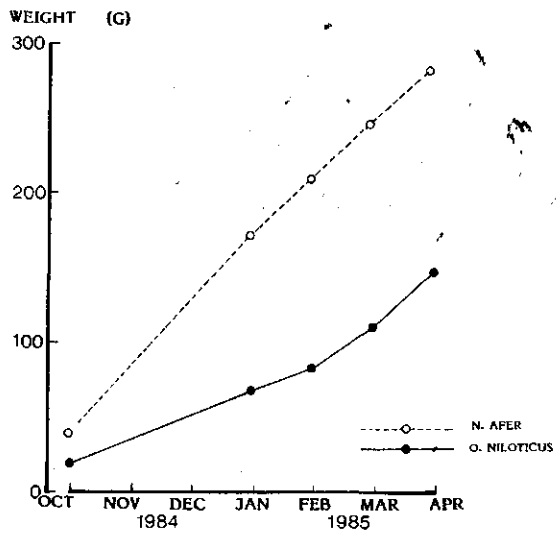

FIGURE 2. GROWTH CURVES OBTAINED IN A 180 DAYS POLYCULTURE EXPERIMENT WITH OREOCHROMIS NILOTICUS AND NOTOPTERUS AFER.

Discussion

The results of the experiment indicate the potential of this polyculture. In density control experiments using *Tilapia* species and the predator *Nile* perch, Lates niloticus, FAO (1965) reported a daily weight gain of 0.7 g for O.niloticus, and 0.36 g for T.zillii. Also in another experiment, using only O.niloticus and L.niloticus a growth rate of 0.42 g/day was achieved.

Density control of O.niloticus populations by predators is not as thoroughly researched as other culture methods aiming at solving the problems of stunting of O.niloticus. Polyculture is now practised in many African countries . Several combinations have been proposed by different authors depending on quantitative and qualitative availability of natural and supplemental food. Carnivorous species are used as predators in polyculture system, especially when culture species reproduce prolifically in rearing ponds. For example, in tilapia culture, Clarias sp., L.niloticus, Bagrus docmac, Micropterus salmiodes, Hemichromis faciatus, and Cichlasoma managuene were used as predators.

The optimal ratio of predator to prey is determined by comparing the size of prey with the size and voracity of the predator (Balarin & Hatton, 1979). The less voracious the predator, the higher its stocking rate needs to be. In Tilapia culture, for example, 2-3% of the total stock usually consist of predators like H.faciatus and L.niloticus (Huet, 1975; Pruginin, 1975); Clarias species are used as predators, the effective ration is 5-10% (Meecham, 1975). In this experiment with O.niloticus, N.afer were used as predators at a rate of 10%.

The polyculture of O.niloticus and N.afer as predator appears to be feasible. The predation capacity of N.afer needs to be quantified to determine optimum stocking rates of both predator and prey. A strict stocking schedule will be necessary to gain maximal benefit from this predator/prey culture. More research and development is needed to maximize the pond production using these two species in a polyculture system.

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References

Balarin, J.D. & J.P.Hatton, 1979. Tilapia: A Guide to their Biology and Culture in Africa. University of Stirling, Scotland, 174 pp.

FAO, 1965. Report to the Government of Uganda on the experimental fish culture project in Uganda, 1965-66. FAO/UNDP Report No. TA2446, Rome, 16 pp.

Huet, M., 1975. Textbook of fish culture; breeding and cultivation of fish. West Byfleet, Surrey, Fishing News Book Ltd.

Lovshin, L.L. & A.B.Da Silva, 1976. Culture of monosex and hybrid Tilapia. In: Symposium on Aquaculture in Africa. Accra, Ghana, 30 September-20 October, 1976. FAO/CIFA/T4 (Suppl.1) Rome, pp. 548-562.

Lovshin, L.L., A.B.Da Silva & J.A.Fernandes, 1974. The intensive culture of the all-male hybrid of Tilapia hornorum (male) X T.nilotica (female) in Northeast Brazil. FAO/CARPAS Symposium on Aquaculture in Latin America, Rome 18 pp.

Meecham, K., 1975. Aquaculture in Malawi, FAO/CIFA Symposium on Aquaculture in Africa, Accra, Ghana. CIFA/75/SC1. 6 pp.

Pruginin, Y., 1968. The culture of Carp and Tilapia hybrids in Uganda. Paper presented to the Symposium on Fish Farming, OAU, Nairobi.

Pruginin, Y., 1975. Species combination and stocking density in Africa. FAO/CIFA Symposium on Aquaculture in Africa.

Pruginin, Y. & E.S.Kanyike, 1968. Monosex culture of Tilapia through hybridization. Paper presented to the Symposium on Fish Farming, OAU, Nairobi.

AN ANALYSIS OF FACTORS AFFECTING INDIVIDUAL FISH GROWTH AND POND FISH PRODUCTION

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Summary

Factors affecting growth and production of fish from an autecological (individual fish) and synecological (fish in ponds) point of view have been enumerated and discussed. While there is much complementarity and agreement in the two approaches, certain concepts such as optimal growth and ration lack correspondence in the known models of the two systems. It appears that a double-log plot of growth rate against mean weight of fish in pond taken at intervals during the culture period would enable estimation of critical standing crop and carrying capacity, but the growth rate in such a study by Hepher corresponds to maximal growth. Since growth rate and culture period can be regulated to obtain a desired yield the fish farmer perhaps should keep fish in ponds at the desired growth rate (near optimal) and harvest at the stage of critical biomass (optimal standing crop) in accordance with the cost-benefit ratio. While in a simplified situation stocking density, size at stocking and culture period of fish with a certain growth rate can be manipulated (simultanueously with the control of other factors) to obtain desired production levels, under practical conditions feeding and growth of fish in ponds is much more complex. This may be ascribed to the multiple level supply (sources) of food for fish in managed ponds and the medium itself becoming the carrier of nutrients and food besides being the regulator of growth and survival of stocked fish, which is so markedly different from terrestrial animal production.

Résumé

L'auteur énumère et analyse toute une série de facteurs qui influençent la croissance et la production du poisson au niveau de l'individu et à celui du groupe (cultivé en étangs). Si croissance et production sont abordées en pisciculture comme disciplines ayant de nombreux points communs, certains concepts comme ceux de croissance optimale et de ration alimentaire ne peuvent se fonder sur un même dénominateur dans aucun des modèles connus des deux types de croissance. Il semble qu'en traçant une courbe en coordonnées logarithmiques du taux de croissance en fonction du poids moyen du poisson en étang, mesuré pendant l'élevage, on pourrait évaluer les niveaux critiques de la récolte et de la capacité de charge à tout moment. Toutefois, le taux de croissance dans une telle étude faite par Hepher correspond à le croissance maximale. Comme on peut agir sur la croissance et le temps de culture pour obtenir le rendement souhaité, il serait bon que le pisciculteur maintienne le taux de croissance proche de l'optimum et aussi uniforme que possible pour le poisson élevé en étangs et le récolte au stade où la biomasse devient elle-même optimale compte tenu de la rentabilité économique. Pour obtenir les niveaux de production desirés il est possible d'agir, lors de la mise en charge, sur la taille des poissons ayant taux de croissance déterminé (ainsi que, simultanément, sur d'autres facteurs). Il est beaucoup plus complexe de planifier, dans la pratique, l'alimentation et la croissance des poissons. Cette difficulté

pourrait provenir des multiples sources d'alimentation offer aux poissons dans les étangs aménagés et du milieu lui-même qui, d'agent régulateur de la croissance et de la survie des poissons, devient en outre le véhicule des éléments nutritifs et des aliments toutes choses qui diffèrent notablement de ce qu'on observe dans l'élevage des animaux terrestres.

Introduction

Fish growth and consequently increase in fish biomass in water bodies are of major interest to the fish culturist, the fish nutritionist and the fishery biologist. As implied in the title of this paper there are two separate aspects: fish growth, largely studied using the individual fish to understand the mechanisms involved, and, fish production in ponds. Correlating these observations helps explain the mechanisms of production, eventually regulate the various inputs and management practices and to obtain optimum production from the pond. While there is no complete study on a specific species, most of the information on individual fish growth required can be obtained in Brett's exhaustive analysis (Brett, 1979). For the purpose of studying fish production the presentation of fish growth in ponds by Hepher and Pruginin (1981) is used. This analysis by Hepher and Pruginin is largely based on Hepher's earlier studies (Hepher, 1975; 1979) and those of Walter (1934). Sockeye salmon, a temperate species studied by Brett, is the most well studied species of fish as far as growth is concerned. The results obtained with this species will be used in this presentation as an example of a growth potential analysis in individual fish and of the factors influencing this potential. Hepher's analysis is mainly based on data obtained using common carp in Israel.

These sets of data will be used on the assumption that the basic principles involved will also be valid for tropical aquaculture.

Considerable information on growth of tropical species, especially tilapias is available (Pullin & Lowe-McConnel, 1982 ; Fishelson & Yaron, 1983). Balarin (1979), Balarin & Haller (1983) and Beveridge (1984) also provide much information on growth and production of tilapias. Perhaps there is more information available on Sarotherodon mossambicus than on the other tilapia species, mainly because of the more cosmopolitan distribution of this species. Feeding, growth and metabolism of S.mossambicus have been investigated in detail (Job, 1969a; 1969b; Kutty, 1972; Kutty et al., 1972; Kutty & Sukumaran, 1975; Karuppannan, 1972; Karuppannan & Kutty, 1978; Ananthakrishnan & Kutty, 1974; Pandian & Raghuraman, 1972; Mohamed & Kutty, 1981). Other quotations on S.mossambicus can be obtained from Balarin (1979) and Beveridge (1984). Considerable information is also available on metabolism and growth of other tilapia species (Beamish, 1970; Moriarty, 1973; Bowen, 1982; Caulton, 1978, 1982; Hepther et al., 1983). Studies on this subject have also been initiated at the African Regional Aquaculture Centre at Port Harcourt, Nigeria (Ahingwa, 1983; Ajibade, 1983; Tsadik, 1984).

Unfortunately systematic information on metabolism and growth as available for salmonids (sockeye salmon most elaborately) is not available for any of the tropical species. As mentioned earlier some generalizations in this presentation are, therefore, derived from the temperate species (Brett, 1979).

Factors influencing growth

Brett (1979) gives a vivid description of the factors influencing growth. Figure 1, based on Kutty (1981), gives a graphic presentation of the energy utilization by fish and the various related extrinsic and intrinsic factors.

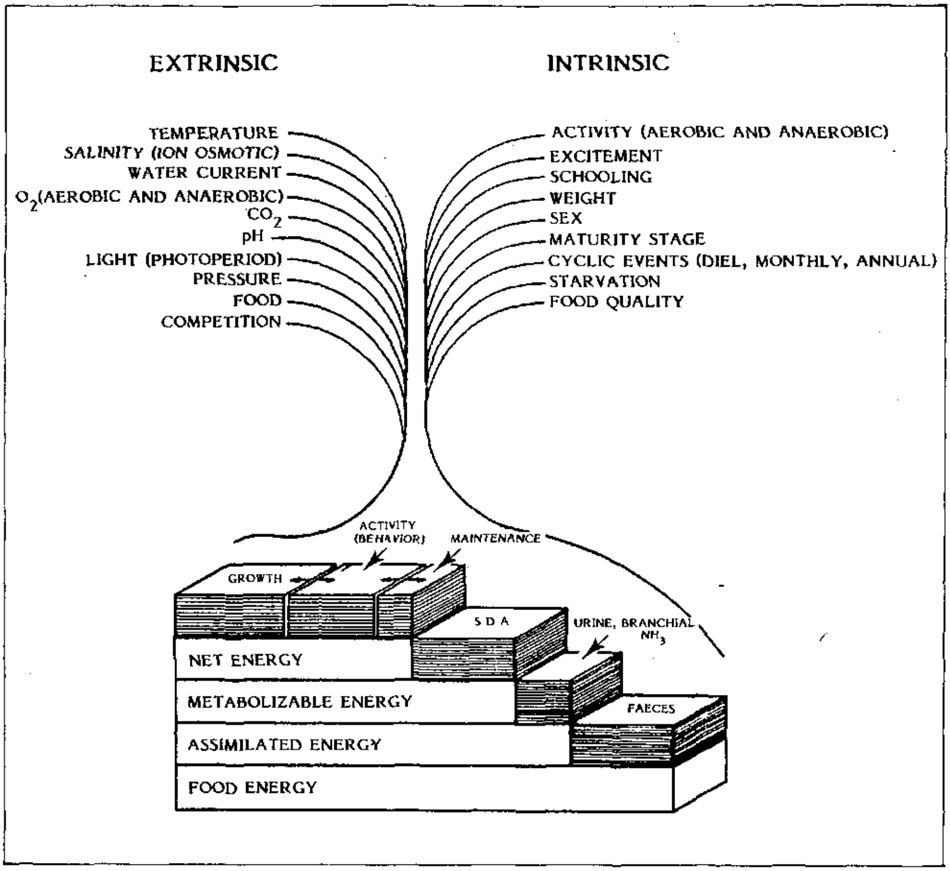

FIGURE 1. FACTORS REGULATING ENERGY UTILIZATION OF FISH (AFTER KUTTY, 1981).

An aspect of interest here is the relation between energy utilization (energy metabolism) and growth (increase in biomass). As the figure shows only a minor portion of the gross energy intake (food) is deposited in growth (including gonadal, the major portion being lost at various steps (faeces, branchial nitrogen, specific dynamic action (SDA), maintenance ("standard metabolism"), and activity and behaviour (swimming, aggression etc.)) For further explanation see *Fry, 1947, 1971*. It can thus be stated that there is competition for energy between growth and activity - locomotion, behaviour etc. - (Brett, 1970; Kutty, 1980). In pond fish farming it must be the fish culturist's objective to have the maximum/optimum amount of energy deposited as growth, taking into account overall production economics.

The following enumeration is derived from Brett's presentation of the metabolic system in so far as it is involved in fish growth.

Metabolic system involved in growth:	Standard metabolism Active metabolism Digestion Regulation Storage (gonads) Morphogenic Metabolites
Input sources:	Food and oxygen
Output products:	Growth, work and excrements
External factors affecting the system:	Abiotic: Pressure, temperature, salinity, O_2, CO_2, NH_3, pH, light, season Biotic: Food abundance, availability, composition, digestibility, competition
Internal factors:	Weight, sex, age, maturity, health, growth rate, exercise, acclimation, transforming, group activity, O_2 debt.

Hepher and Pruginin (1981) also list the intrinsic and extrinsic factors separately. The internal machinery of the fish such as genetics, sex, size, maturation etc. fall under the former category and would set limits for fish growth. But there are certain extrinsic (environmental) factors such as those hereinunder listed by Hepher and Pruginin which are also of prime importance in regulating growth.

1. Chemical characteristics of water and soil
2. Water temperature
3. Metabolic levels
4. Available oxygen
5. Available food

Of these the first two are considered density-independent (not affected by the change in fish density) and the latter three density-dependent. Perhaps only temperature is strictly density-independent, since many chemical characteristics of water such as nitrogen in various form, pH, CO_2 etc. would change with density.

Metabolite load (excretory wastes) certainly increases with density, and oxygen and food could be depleted faster with increase in density. Making more food available in the pond (fertilization, feeding) would remedy the food problem, and aeration of pond water could solve the oxygen problem.

Reducing the metabolite load is a costly venture, since water exchange (flow) through the rearing system has to be increased to remedy the situation, and this could raise other problems.

But of all the factors temperature, size and food are most important in determining the growth rate of fish (Brett, 1979). Under brackishwater conditions, salinity also could be assumed to be of major importance.

Temperature (rather temperature change) can generally be ruled out as a major factor in tropical fish culture systems since it is often uniformly high. Extreme temperature with reference to latitudes and altitudes can however influence survival and growth markedly. It is of interest that the metabolic rate of many tropical fish continues to increase with increasing temperature almost untill the lethal point has been reached. This was shown to apply to S.mossambicus (Karuppannan, 1972; Ananthakrishnan & Kutty, 1974; Kutty & Sukumaran, 1975). It can be taken that in such cases the metabolic scope and consequently growth rate increases with increasing temperature almost up to the point of death (Fry, 1957). For many tropical fish species the upper thermal regimes seems to affect survival more seriuosly than growth.

Size has a major effect - both relative and absolute - on growth rate. With increasing size fish will show a decreasing growth rate (expressed relatively as a percentage of the body weight per unit of time), but with increasing size fish will gain more weight (expressed in absolute terms as increase in weight per unit of time). This difference has a basic biological reason; a smaller fish metabolises or utilizes energy much faster than a larger fish and consequently proportionally more tissues are deposited (growth) by a smaller fish; resulting also in a relatively higher energy waste (heat dissipation). Also a smaller fish consumes relatively more food.

This phenomenon will become apparent in feeding tables. The amount of food required to feed 1 kg of carp hatchlings, will be much larger than that required to feed a single carp of 1 kg weight, provided in both cases feed is administrated at the same level (for instance maintenance level). This difference will only be large if expressed in absolute weight units. However, this difference will be absent if expressed in relation units, i.e. in grams of food per "metabolic" weight (Fry, 1957).

Since fish metabolism is related to fish body weight to the 0.8 power ($g^{0.8}$ or $kg^{0.8}$) the relative units are expressed as $g/g^{0.8}$ (grams per "gram metabolic weight") or $g/kg^{0.8}$ (grams per kilogram metabolic weight").

Size also interacts with temperature, salinity and other ecological factors. Size and numbers determine the biomass of fish in a culture system, and density combined with stocking size and culture period, serve the basis for controlling fish production.

Food indeed is the major factor regulating growth. As explained earlier this effect is best studied by analysing information obtained experimentally on individual fish e.g. Brett's sockeye salmon (Fig.2). It is seen from the figure that by increasing the food ration from zero to over 8%, the growth rate increased to an asymptote i.e. maximum growth rate (G max) corresponding to maximum ration (R max). At a ration of 1% the growth rate is "zero". This ration of 1% is adequate only for the maintenance of the fish (no loss or gain in weight) and is called maintenance ration (R maint). Below this ration level the fish loses weight and survival becomes a function of available energy in the fish and rate of utilization. In the case of fish, survival time is much higher than that for mammals, since the basal energy requirements are much lower than those for warm-blooded animals. A starving fish at low temperature has a low metabolism and can survive for months without food. However in small fish, say hatchlings or fry, energy dissipation is much higher, and their survival without food would be much more critical than for large fish.

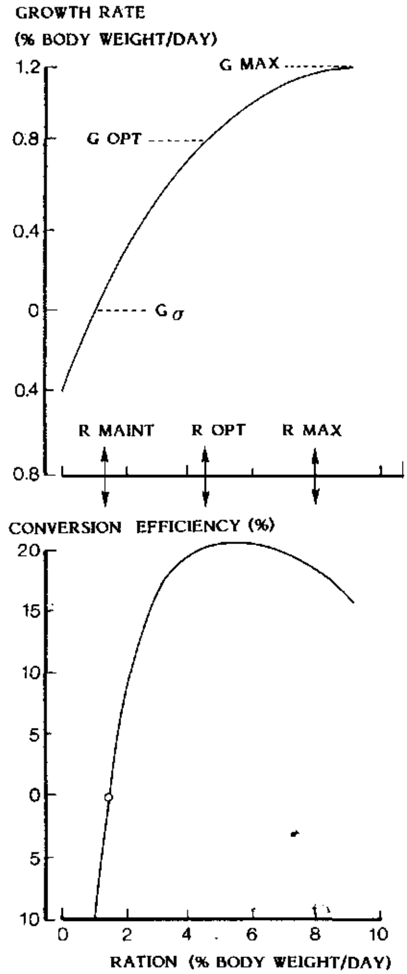

FIGURE 2. INFLUENCE OF RATION (FOOD QUANTITY) ON GROWTH RATE (UPPER PANEL) AND ON CONVERSION EFFICIENCY (LOWER PANEL) IN FISH. THE CURVES ARE BASED ON DATA OF SOCKEYE SALMON FROM BRETT ET AL. (1969).

Furthermore Fig.2 shows the optimum food ration provided for the most efficient growth or in other terms provided for maximum conversion efficiency (C.E.)[1]. The aquaculturists should endeavour to grow fish at optimum ration/growth, again subject to certain economic considerations. As Brett (1979) points out there can be the same conversion efficiency value for two different rations (C.E.curve is "dome" shaped), which may create confusion in interpretation in the case of inadequate experimentation.

Correlation of food/ration and growth rate in fish pond

The feeding level mainly determines the growth rate of fish in a pond, as shown clearly by Hepher (1975) and Hepher and Pruginin (1981). In Fig.3 (based on Hepher's study) it is indicated that weight gain -$\mathring{W}$-(g/day) rose in proportion to fish weight -$\bar{W}$-, and feeding levels. The feeding levels indicated change in "quantity" and in "quality", at the different phases (listed below):

I	natural productivity only (no fertilization and no supplementary feeding
II	natural productivity and fertilization
III	natural productivity and fertilization and supplementary feeding with maize
IV	natural productivity and fertilization and pelleted high protein feed.

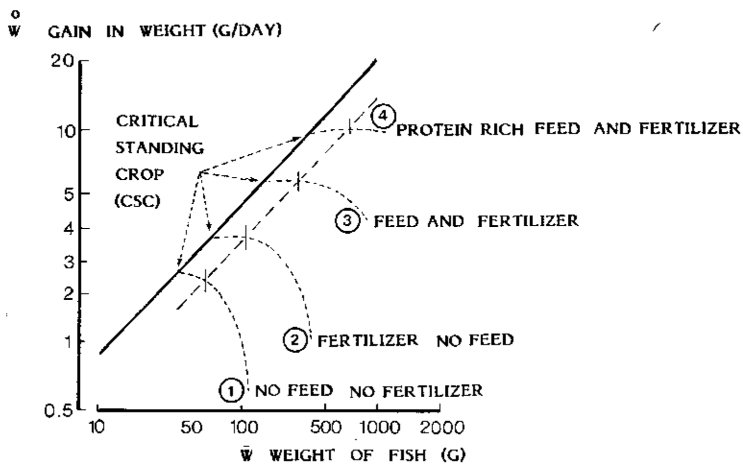

FIGURE 3. RELATION OF FISH SIZE ($\bar{W}$) AND GAIN IN WEIGHT ($\mathring{W}$) OF INDIVIDUAL FISH WITH INCREASED LEVELS OF FEEDING IN A FISH POND. DATA PRESENTED ARE FROM COMMON CARP, HEPHER (1975). THE UPPER STRAIGHTLINE (CONTINUOUS) CORRESPONDS TO G MAX BASED ON RELATIONSHIP OF $\mathring{W}$ AND $\bar{W}$ GIVEN BY HEPHER AND THE LOWER LINE (DASHED) CORRESPONDS TO G OPT FIXED ARBITRARILY (SEE TEXT). THE VERTICAL BARS ON THE DECREASING $\mathring{W}/\bar{W}$ CURVES SUGGEST "OPTIMAL STANDING CROP" FOR EACH FEEDING LEVEL.

The results in Fig.3 apply to common carp in Israel for a specific set of conditions and feeding levels. A fish pond has a limit in the total weight of fish (standing crop) it can support. When this limit is reached the growth rate being becomes zero. In such conditions, the maximum biomass attainable, is referred to as the carrying capacity of the water body (Yashouv, 1959). This maximum biomass is referred to as maximum standing crop by Hickling (1962). Before reaching this phase a certain time after stocking, the weight gain steadily increases linearly up to a point at which the corresponding biomass in the pond is referred to as the "critical standing crop (CSC)" (Hepher & Pruginin, 1981). The curve for a decreasing growth rate almost touches the X-axis indicating a point of zero growth and this corresponds to the carrying capacity (CC) of the pond.

Thus each feeding level has its own CSC and CC. At the first feeding level where growth was based on natural productivity of the pond only, the CSC and CC are lowest. With addition of fertilizer the growth rate picks up again and the linear increase of W continues to reach a higher CSC. Again when "saturation of the productivity" (feed exhaustion) is reached in the pond there is a fall in growth rate. This fall is remedied by adding artificial feed. Here Hepher added maize so that sufficient energy-yielding carbohydrates enabled "protein sparing action". Then both CSC and CC reached another higher level. When formulated pelleted feed (balanced diet with high protein) was added maximal CSC was reached. The quantity of feed (when quality was adequate) was the prime factor for growth in the first two feeding levels. In the third and fourth feeding levels quality improvement was the main reason for the increase in CSC.

Subtle improvements in quality, like adding vitamins and minerals and other essential factors would further improve fish production. We could thus perhaps visualise a situation in which we can combine the individual fish growth vs. ration (Fig.2) and the pond growth vs. feeding level (fig.3) relation, as shown in (Fig.4). Hepher et al. (1983) demonstrated this with reference to dietary proteins in red tilapia.

In Fig.4 it is graphically illustrated that both feed quantity (R maint, R_1, R_2, etc.) and feed quality (RQ_1, RQ_2, etc.) influence growth rate. In the pondfish growth study by Hepher the distinction between G opt and G max has not been made, and since maximum food conversion efficiency is obtained at the optimum ration, it is important to conceptualise the role of G opt vs. R opt in pond production. Hepher's model now indicates only production from the point of view of G max vs. R max.

$$(CE)^1 = \frac{\text{Gain in weight of fish}}{\text{Weight of food eaten (Ration)}} \times 100$$

The food and fish (flesh) should be expressed in the same units - dry weight or calories - to be meaningful.

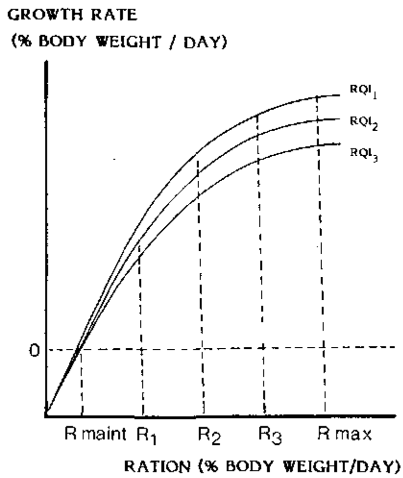

FIGURE 4. RELATION OF QUANTITY AND QUALITY OF FEED (RATION) ON GROWTH RATE OF FISH.

In the growth rate vs. ration curve shown in Fig.2, G opt is reached at a ration (R opt) of about half the maximum ration (R max). At R opt, quite obviously, the fish would not grow at the maximum rate, but at this ration level conversion efficiency (CE) will be maximal. In Fig.3, presenting the mean weight gain ($\dot{W}$) versus mean weight ($\bar{W}$) of fish in the pond, ($\dot{W} = 0.176\bar{W}^{0.68}$, Hepher & Pruginin, 1981) the growth rate has to be the maximal rate (G max), with which the critical standing crop (CSC) apparently coincides. As already pointed out the increase in $\dot{W}$ with increase in $\bar{W}$ corresponds to the lapse of time after stocking, and it appears that fixing R opt for the period is quite complicated. Balarin and Haller (1982) discuss a similar though not identical situation in intensive culture of tilapias.

To provide for optimal feeding levels in pond fish farming under different menagerial levels, as indicated by the numbers (1) to (4) in Fig.3 requires quite some experimentation in order to assess the natural productivity and its equivalence with the feeds used (Tang, 1970, Hepher, 1975). In this way a value could be obtained for the increase in fish biomass by using a conversion factor for the primary productivity of the pond (Beveridge, 1984). Moreover the extent of the effect of fertilization on the productivity of the pond should also be known. The supplementary feed then given should be only enough to reach R opt.

It thus becomes obvious that if the stocking rate (initial biomass of fish) is less than CSC in (1) and (2) of Fig.3 (Hepher, 1975) there would be food in excess during the initial period of culture, even assuming that the rate of fertilization could be regulated to maintain the feeding level at R opt. With increase in biomass of fish, either by growth or by increase in stocking density (see also discussion below and Fig.5) the food available would decrease from the level R>max to R max (growth rate remaining continuously at G max over this period) and then at the point of CSC the growth rate would drop as explained and the food available would pass through R opt and reach the stage of R maint, corresponding to CC and G_o.

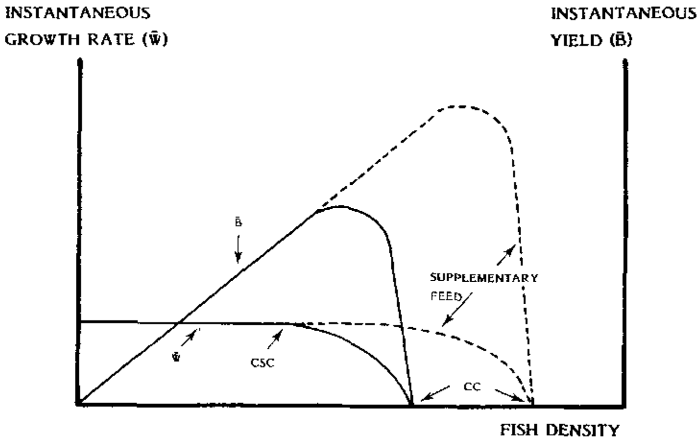

FIGURE 5. RELATION OF FISH DENSITY AND INSTANTANEOUS GROWTH RATE (W̄) AND YIELD (B̄) IN A FISH POND (AFTER HEPHER AND PRUGININ, 1981).

Under conditions (2) and (4) the G opt/R opt can be maintained provided the productivity of the pond remains at the same level during the culture period, but this need not be so, as the food organisms would be affected by feeding pressure and environmental changes which would alter their turn-over (Beveridge, 1984).

It is important that the CC, if not CSC, of the pond be fixed either by direct studies of fish production at various feeding levels, as shown by Hepher (Fig.3), and also by others (Yashouv, 1959; Kovalec, 1957) or indirectly by using values of primary productivity (Beveridge, 1984). Excess feeding, quite common in many cases among fish culturists, could be reduced either by the regulation of feed, or by the regulation of standing crop (thinning or by additional stocking).

In Fig.3, a straight broken line drawn lower than Hepher's continuous line relating W and W̄ (corresponding to G max/CSC) might correspond to G opt (and optimal standing crop) but the slope of this line would be subject to the relative effect of size discussed previously. In the present case the G opt line is drawn assuming G opt to be 2/3 G max. It is significant that the shift in food available with reference to changes in W and W̄ indicated above, passes from R max to R maint through R opt, but it must be clarified that each point in time refers to a different W̄, and in this case the R opt (marked by vertical lines on the dropping W/curve) will correspond to the optimal standing crop for the specific W and time. The yield at this point will be higher than at CSC (Gmax), because the specific W̄ at optimal standing crop (OSC) would be larger. Thus one could obtain the same yield by maintaining fish in a pond either at G max/R max or at G opt/R opt; the advantage of the former is a reduction in culture period while that of the latter is saving in ration. So far G opt is discussed as a biological optimum, but there will also be an economical optimum considering the cost-benefit relation of the total operation (Hepher, personal communication).

In order to reap maximum benefit from a fish pond two levels of feed manipulation can be considered in pond-fish management. One is the "saturation" of the productivity potential of the pond, in terms of the quantity of food it can supply to the stocked fish, i.e. by way of increase in productivity through nutrients already available and added (fertilization). When this stage has been reached further increase in fish production is possible only by adding feed (supplementary feed), which is strictly outside the productivity potential of the pond. The second level of feed manipulation would encompass the latter aspect i.e. improvement of pond fish production by improvement of the nutritional quality of the supplementary feed given. For the optimal yield of fish from a pond, however, the quantity of food should be regulated to maintain fish at optimal growth through the culture period.

Feed quantity and quality cannot be the only constraints to obtain maximum production from a pond. As has already been pointed out it would be possible to increase fish production from a given water body by improving water quality e.g. air supply would increase oxygen supply and fish growth. The next step would be to renew the water in the pond, thus tending to change the static water status of the pond to a moving or running water status - or perhaps at some level to use recycled and reconditioned water. At this stage there is also a risk that when pond water is renewed to improve water quality the nutrients and the basic feed organisms so carefully nurtured to this point are lost. These latter suggestions would markedly change the cost-benefit structure of the venture.

Manipulation of stocking size, density and culture period

As mentioned previously the maximum biomass (standing crop) i.e. carrying capacity of a water body, under a certain set of conditions (fertilization, feed etc.) is fixed. Depending on the rate of utilization of energy (food) in the pond and the density of fish species stocked, the time required to reach carrying capacity - or better, critical standing crop/optimal standing crop - could be mainly a function of the size of fish stocked and their number (density). Since the growth rates ($\mathring{W}$) (maximal and optimal) of the fish are known under the given set of conditions, size and density of fish at stocking can be manipulated to obtain the required harvest size in a given culture period. Within limits this can be worked out on the basis of a linear relation of growth rate and fish size as shown in Fig.3. This allows for direct control of the culture period by choosing the stocking size of fish. Having determind the CSC/OSC of the pond as corrected to accommodate mortality and exact growth rate most of the conditions to attain the full productivity potential of the pond can be manipulated. For an example of estimations of pond production with actual values of growth rate for common carp and stocking size, densities and culture period, refer to Hepher and Pruginin (1981).

The relationship between stocking density, growth rate and yield shown by Hepher (1975) is illustrated in Fig.5. Initially, at increasing fish density, growth rate may remain at the maximum level, since the pond provides a surplus of food, untill CSC is reached. Beyond this fish density growth rate will decline and will become zero at a density that corresponds to the carrying capacity of the pond. Alongside this growth rate/density relation, the yield (B) increases gradually with increase in density, and peaks at a point between CSC and CC; beyond this point the yield plummets. With changing food availability in the pond, e.g. through supplementary feed, the growth rate/density and yield/density curves shift to the right, but the general pattern remains the same (Fig.5). Density and OSC have the same relationship as that of CSC; the difference is that for OSC the growth rate (G opt) is lower, the limit being determined by the regulation of R opt. The supplementary feed given should then be adjusted to maintain optimal growth of stocked fish.

The fish pond production would thus be subject to control through manipulation of the following factors (see also Fig.6):

- Physical and chemical features of the water body and productivity of the pond, at the various levels of feeding, as explained (feed, fertilizer)
- Growth rate (G max and G opt) of the species to be cultured
- Stocking size
- Stocking density
- Harvest size
- Culture period

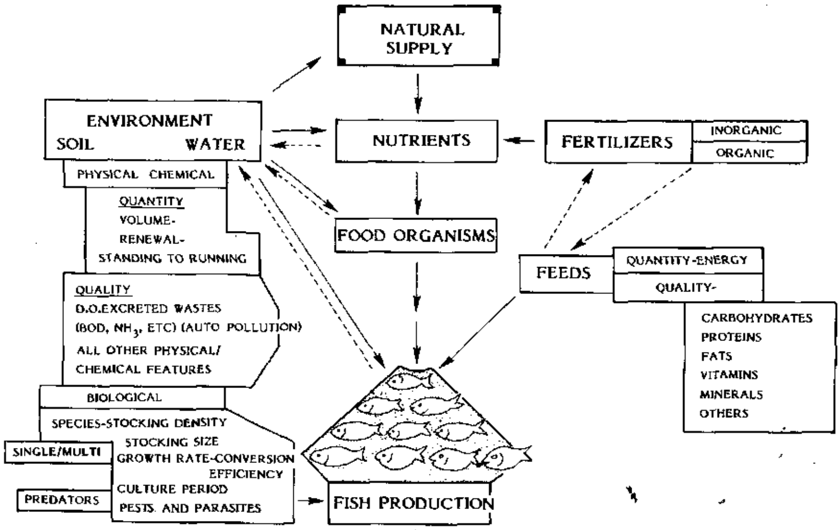

FIGURE 6. FACTORS AFFECTING FISH PRODUCTION IN A POND.

In spite of having all this information pond conditions must be monitored to avoid fish mortality due to diseases/environmental causes and maintain fish health through appropriate pond management measures. The present discussion concerns fish which do not reproduce in the pond. If reproduction could not be avoided in the pond, for instance in tilapia, yield predictions have to use other methodologies (Pauly & Hopkins, 1985).

Although the approach described in this paper is simplified it may help in developing better pond management procedures.

References

Ahingwah, G.N., 1983. Growth, oxygen consumption and ammonia excretion of *Sarotherodon niloticus* at different salinities. M.Tech.(Aquaculture) Thesis, ARAC/Rivers State University of Science and Technology, Port Harcourt, Nigeria.

Ajibade, S., 1983. Some aspects of feeding, assimilation and food conversion in the cichlid fish, *Tilapia zilli*. M.Tech.(Aquaculture) Thesis, ARAC/Rivers State University of Science and Technology, Port Harcourt, Nigeria.

Ananthakrishnan, K.R. & M.N.Kutty, 1974. Mortality and breathing rate at high ambient temperature in the cichlid fish, Tilapia mossambica. Indian J.Exper.Biol., 12: 55-59.

Balarin, J.D., 1979. Tilapia. A guide to their biology and culture in Africa. Unit of Aquatic Pathobiology, University of Stirling, Scotland.

Balarin, J.D. & R.D.Haller, 1982. Intensive culture of Tilapia in tanks, raceways and cages. In: Recent Advances in Aquaculture Ed. J.D.Muir and Roberts, p. 265-356. Croom Helm, London and Canberra and Westview Press, Boulder, Colorado.

Beveridge, M.C.M., 1984. Cage and pen fish farming. Carrying capacity models and environmental impact. FAO Fish.Tech.Pap., 225: 131 p.

Beamish, F.W.H., 1970. Influence of temperature and salinity acclimation on temperature preferenda of the euryhaline fish, Tilapia nilotica. J.Fish. Res.Bd.Can.27(7): 1209-1214.

Bowen, S.H., 1982. Feeding, digestion and growth - qualitative consideration, p. 141-156. In: The biology and culture of tilapias. Ed. R.S.V.Pullin & R.H.Lowe-McConnel. ICLARM Conference Proceedings 7, p. 432. International Center for Living Aquatic Resources Management, Manila, Philippines.

Brett, J.R., 1970. Fish - the energy cost of living. In: Marine Aquaculture. Ed. W.J.McNeill, pp. 37-52. Oregon State University Press.

Brett, J.R., 1979. Environmental factors and growth Chap.10. In: Fish Physiology. Vol.8. Ed. W.S.Hoar, D.J.Randall & J.R.Brett, pp. 599-675. Academic Press, London and New York.

Caulton, M.S., 1982. Feeding, metabolism and growth of tilapias: some qualitative considerations, p. 157-180. In: The biology and culture of tilapias. Ed. R.S.V.Pullin & R.H.Lowe-McConnell. ICLARM Conference Proceedings 7, p. 432. International Centre for Living Aquatic Resources Management, Manila, Philippines.

Fishelson, L. & Z.Yaron, 1983. Proc.International Symposium on Tilapia in aquaculture. Nazareth, Israel, 8-13 May 1983. Tel Aviv University, Tel Aviv, Israel.

Fry, F.E.J., 1947. Effects of environment on animal activity. Univ.Toronto Stud.Biol.Ser. 55, 1-62.

Fry, F.E.J., 1957. The aquatic respiration of fish. In: Physiology of fishes, Vol.1. Ed. M.E.Brown, pp. 1-63. Academic Press, New York.

Fry, F.E.J., 1971. The effect of environmental factors on the physiology of fish. In: Fish Physiology, Vol. 6. Ed. W.S.Hoar & D.J.Randall, pp. 1-98.

Fry, F.E.J., 1971. The effect of environmental factors on the physiology of fish. In: Fish Physiology, Vol. 6. Ed. W.S.Hoar & D.J.Randall, pp. 1-98. Academic Press, London and New York.

Hepher, B., 1967. Some biological aspects of warm-water fish pond management. In: The biological basis of freshwater fish production. Ed. S.B. Gerking, pp. 417-428. Balckwell Scientific Publications, Oxford & Edinborough.

Hepher, B., 1975. Supplementary feeding in fish culture. Proc. 9th Int. Congr.Nutrition, Mexico 1972, 3: 183-198, Karger, Basel.

Hepher, B., 1979. Supplementary diets and related problems in fish culture. Proc.World Symp.on Finfish Nutrition and Fish Feed Technology, Hamburg, 20-23 June, 1978, 1: 343-347 (Berlin).

Hepher, B. & Y.Pruginin, 1981. Commercial fish farming with special reference to Israel. John Wiley & Sons.

Hepher, B., I.C.Liao, S.H.Cheng & C.S.Hsieh, 1983. Food utilization by red tilapia - effects of diet composition, feeding level and temperature on utilization efficiences for maintenance and growth. Aquaculture, 32: 255-275.

Hickling, C.F., 1962. Fish culture: 295 p. Faber & Faber, London.

Job, S.V., 1969a. The respiratory metabolism of Tilapia mossambica (Teleostei). I. The effect of size, temperature and salinity. Mar.Biol.(Berl.) 2(2): 121-126.

Job, S.V., 1969b. The respiratory metabolism of Tilapia mossambica (Teleostei). II. The effect of size, temperature, salinity and partial pressure of oxygen. Mar.Biol.(Berl.) 3: 222-226.

Karuppannan, N.V., 1972. Studies on the locomotory metabolism of Tilapia mossambica (Peters), Ph.D.Thesis, Madurai University, India.

Karuppannan, N.V. & M.N.Kutty, 1978. Excretion of lactic acid in exercised fish, Tilapia mossambica. Proc.Indian Acad.Sci., (Animal Sciences). 8B: 169-172.

Kovalec, J., 1975. Effect of fertilization and food on the production of Tilapia by fish culture in Zambia. FAO/CIFA Symp.on Aquaculture in Africa, Accra, Ghana. CIFA/75ISE 24, 14 p.

Kutty, M.N., 1972. Respiratory quotient and ammonia excretion in Tilapia mossambica. Mar.Biol. (Berl.) 16(2): 126-133.

Kutty, M.N., 1981. Energy metabolism of mullets. In: Aquaculture of Grey Mullets. Ed.O.H.Oren, pp. 219-264. International Biology Programme, 26, Cambridge University Press.

Kutty, M.N., N.V.Karuppannan, M.Narayaran & M.P.Mohamed, 1971. Maros-Schulck technique for measurement of carbon dioxide production in fish and respiratory quotient in Tilapia mossambica. J.Fish.Res.Board Can. 28: 1342-1344.

Kutty, M.N. & N.Sukumaran, 1975. Influence of upper and lower temperature extremes on the swimming performance of Tilapia mossambica. Trans.Amer.Fish.Soc. 104(4): 755-761.

Mohamed, M.P. & M.N.Kutty, 1981. Respiratory quotient and ammonia quotient in Tilapia mossambica with special reference to hypoxia and recovery. Hydrobiologia. 76: 3-9.

Pandian, T.J. & R.Raghuraman, 1972. Effects of feeding rate on conversion efficiency and chemical composition of the fish Tilapia mossambica. Mar.Biol. (Berl.), 12,(2): 129-136.

Pauly, D. & K.D.Hopkins, 1985. A method for the analysis of pond growth experiments. ICLARM News letter, 6(1): 10-12.

Pullin, R.S. & R.H.Lowe-McConnell, 1982. The biology and culture of tilapias. ICLARM Conf.Proc. 7, 432 p. International Centre for Living Aquatic Resources, Manila, Philippines.

Tang, Y.A., 1970. Evaluation of balance between fishes and available fish foods in multi species fish culture ponds in Taiwan. Trans.Amer.Fish. Soc. 99(4): 708-718.

Tsadik, G.G., 1984. Influence of dissolved oxygen on feeding and growth of cichlid fish Oreochromis niloticus (Linnaeus). M.Tech.(Aquaculture) Thesis ARAC/Rivers State University of Science and Technology, Port Harcourt, Nigeria.

Walter, E., 1934. Grundlagen der allgemeinen fischereilichen Produktionslehre. Hb.Binnenfisch. Mitteleureuropa. 4: 481-662 (cited inHepher, B., 1975).

Yashouv, A., 1959. Studies on productivity of fish ponds. I. Carrying Capacity. Proc.Tech.Pap.Gen.Fish.Coun.Meditterr., 5: 409-419.

BREEDING STRATEGIES IN FRESHWATER FISH

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Summary

In the growing industry of aquaculture future development will depend largely on building up a genetically promising seed supply. High fecundity and high genetic variability in almost all key performance parameters may well pave the way to extraordinary selective improvement in aquatic animals.

Prior to any breeding work, the breeding goals must be clearly defined which means, specifying selection traits and their importance in the selection process, e.g. growth performance, disease resistance and maturing age. These programs should start with a systemic screening of genetic resources, in other words comparing strains from which first generation stock is to be selected.

Because of the medium to low heritability of nearly all traits involved, selection should be based on family rather than on individual selection. This again requires separate family rearing until the family members can be used in common testing: these concepts have been tested in trout and tilapia breeding. For example in trout, selection responses from family breeding are expected to be about 3 times as high as from mass selection.

Crossbreeding strategies might be advantageous in case of antagonistic trait constellations. Non additive effects can only be profitably exploited in species with a longer domestication tradition especially in less intensive production environments. In future fish breeding, modern biotechnical methods may focus increased attention on the production of triploid seed stock, by combining tetraploid with diploid lines and on the development of special gynogenetic lines within complementary crossbreeding programs.

Résumé

Dans le développement de l'aquaculture intensive, tout progrès futur dépendra largement de sources de potentiel génétique bien adaptées. Les possibilités d'amélioration sélective des animaux aquatiques sont considérables étant donné les fécondités élevées et la forte variabilité génétique de presque tous les paramètres importants mesurant la performance.

Toute sélection doit nécessairement reposer sur la détermination de l'objectif, c'est-à-dire la définition des caractéristiques de sélection comme la vitesse de croissance, la résistance aux maladies et l'age de maturité et leur importance relative. On commencera par un examen systématique des resources génétiques, c'est-à-dire par comparer les souches qui permettront de sélectionner les lignées parentales.

En raison de la faible héritabilité de presque toutes les caractéristiques, la sélection devrait être réalisée par famille plutôt que par individu. Il faudra ensuite élever séparément chaque famille jusqu'à ce que les individus la constituant puissent être utilisés dans des tests analogues à ceux pratiqués pour la reproduction de la truite et du Tilapia. Chez la truite, par exemple, les effets résultait d'une sélection par famille devraient être trois fois plus élevés que ceux obtenus après une sélection massale.

Des stratégies d'hybridation pourraient être favorables dans les cas de

combinaison de caractéristiques antagonistes. Les possibilités offertes par l'exploitation d'effets n'ajoutant pas de variation génétique ne sont bonnes que dans le cas d'espèces traditionellement domestiquées, notamment lorsque les systèmes de production sont peu intensifs. Il semble qu'on pourrait prêter davantage attention à l'avenir à deux méthodes biotechniques de sélection: l'une vise à la production de triploïdes en combinant des lignées tétraploïdes avec des lignées diploïdes; l'autre vise au développement de lignées gynogénétiques spéciales dans le cadre de programmes d'hybridation complémentaires.

Introduction

During the recent decades remarkable improvement of productivity has been achieved for all important species of livestock. In the Federal Republic of Germany for example the average milk and beef yield per cow has been doubled since 1950. The same improvement has been observed in the number of eggs per hen and in the growth performance of broilers. In pigs the back fat was reduced to 1/3 of that in 1960, when pig testing on station was introduced on a large scale (Table 1).

Table 1. Development of performance in livestock production in the FRG (Langholz, 1985).

		1950-1960	1984
Cattle			
Milk yield/cow and year	kg	2560	4824
Beef produced/cow and breeding heifer	kg	93	239
Pig			
Age of 100 kg pig	days	187	169
meat/fat ratio (at 13th rib)	1:	1.26	0.38
Feed conversion (kg feed/kg gain)	kg	3.33	2.68
Poultry			
Eggs/hen and year		120	251
Slaughter age of broiler,	days	68	44
(at ... kg final weight)	kg	(1.49)	(1.88)
Feed conversion (kg feed/kg gain)		2.80	1.90

Enhanced by a favourable economic environment these improvements were only possible by focussing on systematic breeding research based on theoretical population genetics. The main features of an advanced breeding strategy in farm animals are strong selection pressures within integrated breeding plans, consistent utilization of artifical insemination and testing facilities, as well as introduction of crossbreeding programs to overcome genetic antagonism between important traits and to exploit heterosis. In the growing aquaculture industry future development will also largely depend on the genetic potential of the stock used. It is surprising that up to now integrated breeding and selection programs rarely have been practised even though in some regions fish farming has a long tradition. The main reasons for failures in aquaculture breeding strategies have been unsuccessful artificial reproduction of some farmed species, technical difficulties in applying sophisticated testing procedures, and also inflexible aquaculture traditions.

This contribution deals with the encouraging prospects for selective improvement of aquaculture candidate species and sets out principles for developing avanced breeding and selection strategies in fresh-water fish.

Breeding prospects in fish

Compared with farm animals fishes have a number of advantages. The most important are:

- a high fertility in most species, enabling very accurate evaluation of breeding values by sib- or progeny testing and high selection intensities among the brood stock tested,
- a pronounced genetic variability in most traits, especially in growth traits, which is significantly higher than in farm animals indicating the chance for high selection responses (Table 2),
- the extrauterine fertilization, which in combination with the high fertility, is of great advantage for crossbreeding programs, and facilitates genetechnology, the latter being of special importance to fish breeding.

Table 2. Genetic variability in farm animals and fish.

		$\bar{x}$	Sp	h^2	S_G	V_A%
Cattle						
milk	kg	5000	800	.25	400	8.0
daily gain	g	1000	120	.20	54	5.4
Pigs						
daily gain	g	600	60	.20	27	4.5
backfat	mm	12	2.0	.30	1.1	9.2
Poultry						
number of eggs		250	30	.25	15	6.0
body weight broiler		1350	108	.30	59	4.4
Fish						
body weight German trout	g	200	55	.20	25	12.5
body weight, Norwegian salmon	kg	4.75	1.33	.35	.79	16.6

The long generation interval, as observed in some cultured species from temperate zones, however, is rather disadvantageous e.g. the Atlantic salmon (up to 5 years). Furthermore family breeding in fish requires separate rearing of the individual families under standardized environmental conditions until the family members can be marked and released for common testing. Thus family breeding in fish requires fairly sophisticated technical and organisational arrangements.

The few selection experiments made in fish and shellfish breeding so far confirm the good chances for selective improvement in both growth and disease resistance. Kinghorn (1983) evaluated Gjerde's results on one generation selection for slaughter weight in Atlantic salmon and arrived at 3.6% resp. 2.7% genetic improvement per year. Three generation selection for early growth (147 day post-fertilization weight) in rainbow trout by Kincaid et al.(1977) resulted even in a selection response of close to 6%.

Variability and heritability are the two main parameters used to evaluate the breeding prospects of different species and their traits of interest. The estimates on these parameters have been recently reviewed by Gjedrem (1983) and are listed in Table 3. Except for rainbow trout, Atlantic salmon and channel catfish, information on the genetic structure of quantitative traits of aquaculture species is rather scarce. Nevertheless estimates indicate that:

- varability in body weight is very high in all species, higher in younger than in older animals,
- heritability for juvenile body weight is rather low except in channel catfish and oysters. For adults, weight heritability estimates are somewhat higher,
- the meatiness and fat percentage derived from carcass traits are indicative of satisfactory heritability. The variability in fat percentage is somewhat lower,
- inhereted disease resistance, compared to farm animals is remarkable,
- age at sexual maturation although fairly heritable, especially in salmon, is highly variable.

In conclusion the coincidence of moderate heritability and high variability for most of the parameters indicates very good prospects for selection programs in aquatic animals.

Breeding goals

Prior to breeding activities the breeding goal including all traits of economic importance and the selection criteria must be clearly defined.

In livestock breeding the economic weight, assigned to the different selection criteria, is derived from the marginal profit generated by further production improvements, e.g. from the difference between increase in returns caused by a further improvement of a certain trait and the cost of the input required to obtain that trait improvement.

Economic studies on aquaculture systems are scarce and calculations on marginal profits even for the main traits are non-existent. Increased attention to the economics of aquaculture research is therefore, highly recommended, since at present only rough assessments on the economic value of the different traits can be made.

Growth rate, feed conversion efficiency and survival rate are of major economic importance in most livestock production systems and likely also in aquaculture systems. Growth rate, i.e. comparative body weight at a fixed age, can be accurately and easily recorded, and the prospects of selective improvements are extraordinarily good for all species. Thus growth performance should be one of the first traits to consider in breeding research. The growth performance has to be tested by covering as close as possible the growing period as applied under practical farming conditions especially in case marketing weights approach the mature phase of the fish. Furthermore breeding should be based on weight measurements and not on body length, even though genetic correlations between weight and length are close to unity and the phenotypic correlations around $r = 0.9$

Table 3. Average values for coefficients of variation (CV) and heritabilities (h^2) based on sire component for economically important traits in fish and shellfish (Gjedrem, 1983).

Economically important trait	Rainbow trout		Atlantic salmon		Common carp		Channel catfish		Tilapia		Oysters		Prawns	
	CV	h^2_s	CV	h^2_s	CV	h^2_s	CV	h^2_s	CV	h^2_s	CV	h^2_s	CV	h^2_s
Body weight juveniles	33^{7}	0.12^{4}	78^{1}	0.08^{1}		0.15^{1}	46^{1}	0.42^{4}	26^{5}	0.04^{1}		0.36^{3}		0.12^{3}
Body weight adults	22^{7}	0.17^{2}	27^{2}	0.36^{3}	22^{1}	0.36^{2}	27^{3}	0.49^{4}						
Body length juveniles	14^{3}	0.24^{3}	23^{1}	0.14^{2}				0.12^{1}	8^{1}	0.06^{1}		0.47^{2}		
Body length adults	9^{2}	0.17^{2}	8^{2}	0.41^{4}			8^{2}	0.61^{3}						
Mortality/ resistance		0.14^{1}		0.11^{4}	28^{1}									
Carcass traits: Meatiness	20^{1}	0.14^{1}	19^{1}	0.16^{1}										
Meat color	23^{1}	0.06^{1}	16^{1}	0.01^{1}										
Fat-%	10^{1}	0.47^{1}				0.14^{1}	8^{2}	0.23^{3}						
Dressing-%	6^{1}	0.01^{1}	4^{1}	0.03^{1}			2^{2}	0.00^{2}						
Age at maturation		0.18^{1}		0.41^{2}										

Superscripts give number of estimates involved.

(Gjerde & Gjedrem, 1984). As a rule the fish farmer is paid for fish weight (gutted or ungutted) and the direct selection strategy should always be preferred.

Feed conversion efficiency, of vital economic importance in case of artificial feeding, is not easy to record as a routine. Routine testing is only possible on a family basis throughout the rearing period in the event of family breeding with separate rearing of full sib groups. But exact feed intake remains unknown, since the feed supply depends on weight. Thus, it is not surprising that gross feed efficiency was found to be low in heritability and highly correlated with growth both genetically and phenotypically for early growth in trout by Kinghorn (1983), who concluded that to consider feed conversion efficiency apart from growth is of little or no value when selecting young rainbow trout, this most likely applies to fish breeding in general.

Survival rate is of great economic importance especially in later growth stages. Although there are many reasons for losses, direct selection for lower mortality rate is probably not very effective as has been indicated by - rather low - heritability estimates. Selection activities aimed at improved disease-resistance are much more promissing, provided a standardized testing procedure is used.

Fillet percentage and fat content might have to be included in the breeding work as parameters of carcass and meat quality. In trout an antagonistic tendency between growth performance and percentage of fillet was found (Morkramer et al., 1985). A certain fat content might be required in the processing procedures. Furthermore the development of meat firmness should be carefully considered when selecting for fast growth, since intensive selection for lean growth in pigs and chickens leads to severe problems in meat quality, if quality is not included in selection.

Finally, selection for delayed sexual maturity is always of significant importance for fish that only reach their market weights when nearly mature e.g. salmon and heavy trout or when maturity is very early and causes stunted growth in pond farming e.g. for Tilapia.

Development of breeding plans

After defining the production and thus the breeding goal, breeding plans should abide by a consistent strategy, e.g. Skjervold's (1976) strategy for Norwegian salmon breeding (Fig.1).
This strategy can be generalized for genetic improvement of most cultivated species and shall be followed in the discussion below.

Selection of breeding base

Any breeding activity should start with a very careful selection of the foundation stock on which production and further breeding shall be based. This concerns the selection of both the most promissing species and the most productive strains within the species, either from the wild or from hatcheries with different production environments and/or foundation stocks.

Species selection is basic and depends largely on specific market requirements and on the basic features of the production environment to be exploited. Strain selection aims at the exploitation of genetic differences as adapted to controlled - mostly also confined - production environments and genetic differences in converting high feed inputs.

These differences can be quite pronounced and can siginificantly influence the overall economics of production. Different strains of cage-cultured salmon from rivers in Norway after three years of growth weighed between 2.1 and 5.1 kg (Table 4).

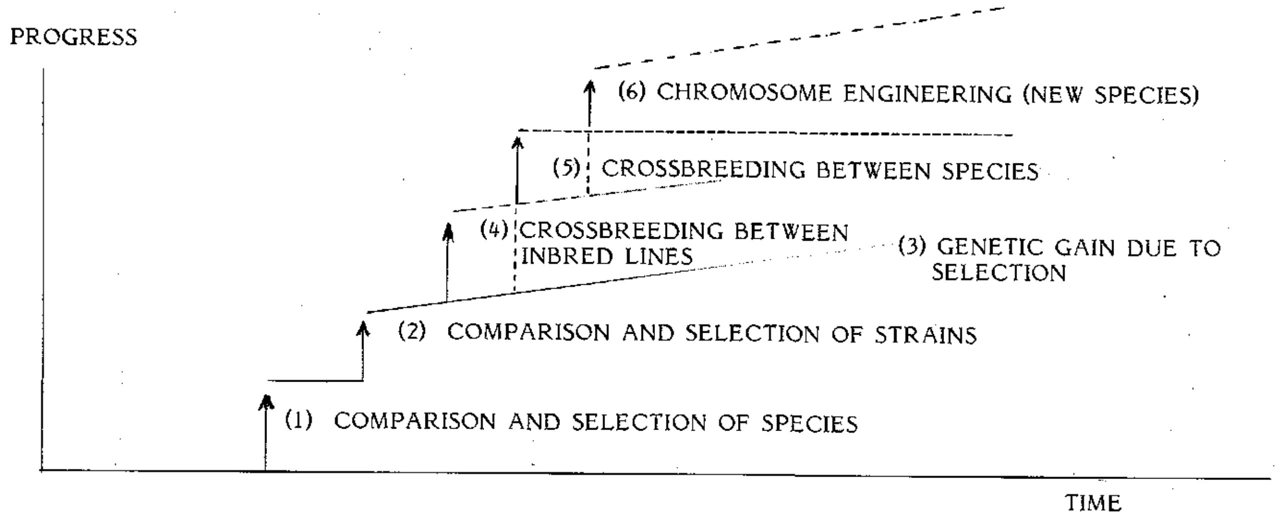

FIGURE 1. STRATEGY FOR DEVELOPING BREEDING PLANS FOR SALMONIDS (SKJERVOLD, 1976).

Table 4. Weight of cage-cultured salmon strains originating in different rivers (Skjervold, 1976) after three years of growth.

River	Weight	River	Weight
Jordalsgrenda	5.1	Laerdalselva	4.4
Namsen	4.9	Alta	4.3
Rauma	4.7	Sandvikselva	4.1
Surna	4.7	Loneelva	3.9
Fosen	4.7	Driva	3.6
Gaula, Sunnfj.	4.6	Luleå	3.1
Etne	4.6	Usma	2.1
Målselv	4.5		

Even between domestic trout strains differences can be very pronounced the top strain reaching a market weight about 25% higher than the average of a strain collection of European trout hatcheries. A wild strain which was carried out in the 1st and 5th series of the trial only obtained half the final weight of the cultivated strain.

Table 5. Least squares constants (c) of fish weight (g) of European trout strains at marketable weight (Morkramer et al., 1985).

Spring spawners						Autumn spawners			
1st series		3rd series		5th series		2nd series		4th series	
No.[a]	$\hat{c}$	No.	$\hat{c}$	No.	$\hat{c}$	No.	$\hat{c}$	No.	$\hat{c}$
1	53.8	8	62.0	8	48.6	14	24.4	14	73.8
17	45.5	3	28.5	3	13.4	12	23.9	12	-0.5
3	32.5	1	21.8	1	0.3	13	-12.5	13	-10.4
16	18.2	7	13.9	7	-3.0	11	-35.7	15	-26.6
10	4.4	5	10.8	5	-6.4			11	-36.3
5	-4.2	2	-25.1	2	-11.3				
2	-7.6	4	-31.1	4	-41.7				
4	-22.3	6[b]	-80.8						
6[c]	-120.2								
μ	236.9		214.9		199.6		246.8		205.2

a) No. = Number of strain;

b) Range of standard error of constants (s(c)) 7 - 18;

c) Wild population.

Preliminary results indicate that polymorphic gene markers e.g. polymorphic serumproteins, enzymes, blood groups, can be employed to ascertain whether strains of different genetic evolution will have entered into the foundation stock, provided a certain quantitative performance has been reached in the production systems (Keese & Langholz, 1974). Studies on polymorphic serum proteins in German trout populations indicate that some strains clearly differ in evolutionary backgrounds.

It can be concluded that selection of the foundation stock is a most essential component to successful systematic breeding in fish with promising selection prospects.

Selection procedures

As mentioned earlier the high genetic variability of almost all traits of interest indicate very good chances for improvement through selection. The efficiency of selection very much depends on the accuracy with which the genetic potential of the breeding animals can be evaluated. This again is a function of the heritability and the amount of information available on a certain trait either from the proband itself or from its relatives (ancestors, sibs, progency).

In fish breeding, selection has been predominantly based on the individual merits of a single parameter e.g. live weight at a certain age. This procedure, called individual or mass selection, is satisfactory only if the selection criteria range from medium to high, because the accuracy of an evaluation based on only one individual record is directly expressed by the heritability. In case of medium to low heriatibility for most of the quantitative traits mass selection alone is of limited prospective value in fish breeding. According to present knowledge mass selection may yield satisfactory results in selection for weight at higher ages or for delayed maturity only.

For traits with the range of heritability as found in aquatic animals, complementary or even replacing mass selection by family selection is usually preferred.

Model calculations on breeding responses to selection based on the growth rate of rainbow trout using family studies in our Institute indicate that a change from mass to family selection can increase the selection response/year by a factor of about 3. The large family sizes of sibs or progency quarantee a high accuracy in estimating breeding values even if the heritability is very low. Group sizes of 300 individuals in family testing improve the accuracy in breeding values to 90% when heritability values amounts to $h^2 = 0.10 - 0.15$, which for example occurred with early growth.

On the other hand the high technical, organisational and also financial input required for family breeding should be taken into account.. It is of utmost importance that the rearing conditions for the separate families be kept as uniform as possible in the various tanks to avoid having a special tank effect bias the (genetic) family effect. Even though it used high technical standards the Norwegian research group on quantitative genetics in Salmonids estimated a tank effect in fingerling weight of 4.5% in salmon and 4.3% in trout (Gjedrem, 1983). Therefore, principles of random with design with at least one replicate are highly recommended for family testing. Figure 2 gives an example of the family testing procedure, which has been developed for testing rainbow trout for German market and production conditions. A corresponding system is under development for family testing (maturing age and growth) in Tilapia in a recycling unit at Göttingen University and under field conditions at the Baobab Farm in Kenya. The test as it stands now is illustrated in Figure 3.

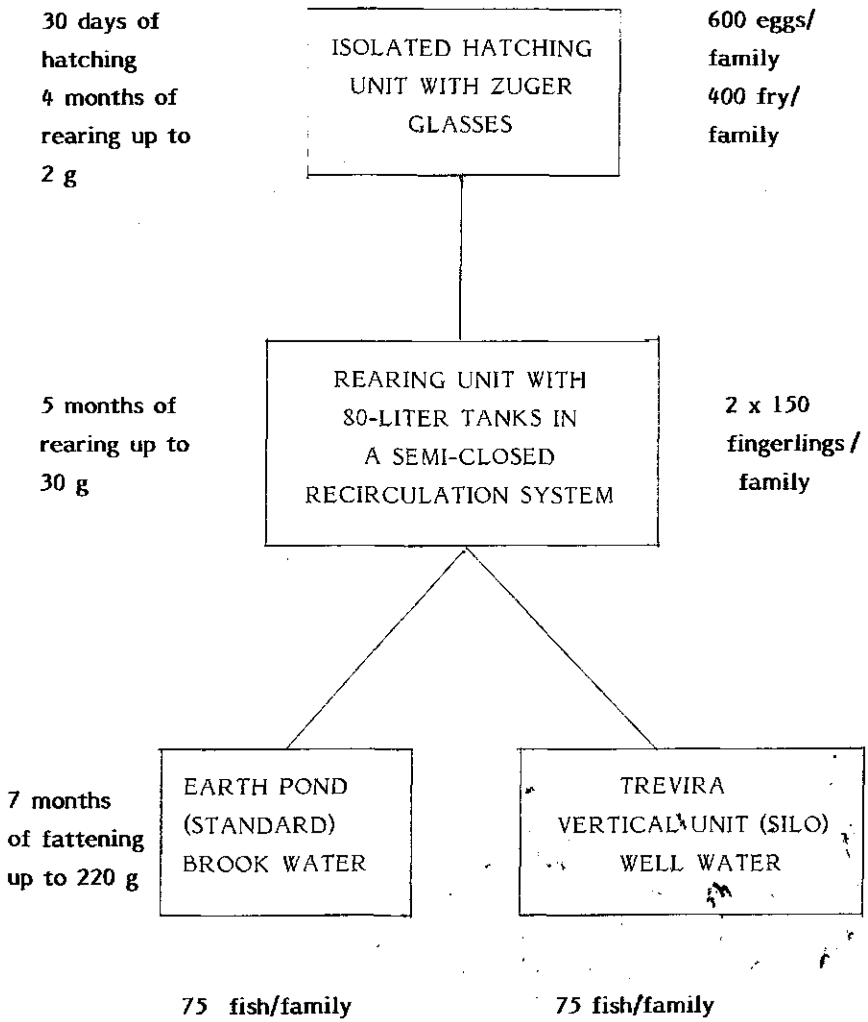

FIGURE 2. STANDARDIZED FAMILY TESTING PROCEDURE "RELLIEHAUSEN" IN RAINBOW TROUT.

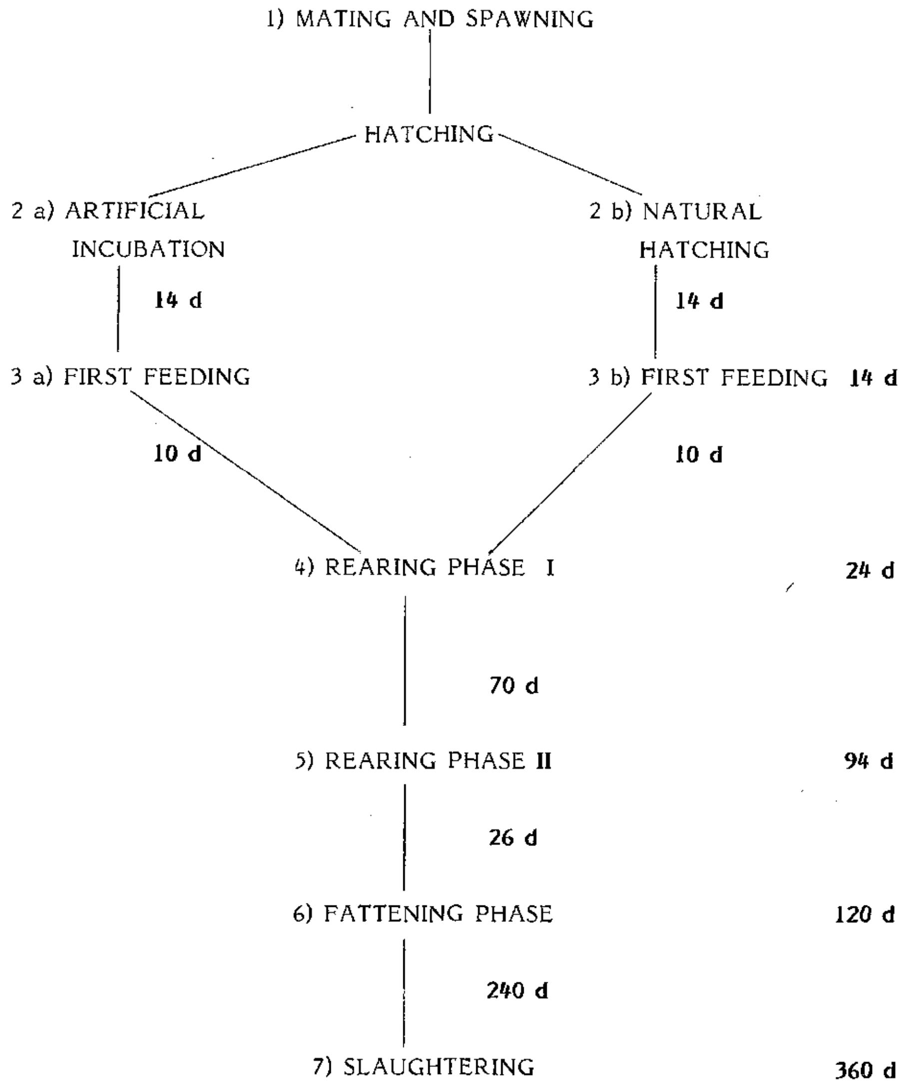

FIGURE 3. PRELIMINARY FAMILY TESTING PROCEDURE "GOTTINGEN" IN TILAPIA.

The results from family testing as a rule should be incorporated as sib tests and not as progeny tests in future breeding plans to avoid prolongation of the generation interval and thus reduction of possible annual genetic progress. This is especially valid in species with long generation intervals as for example in Salmonids.

When defining a selection strategy for breeding programs a general decision has to be taken on the principal breeding method to be applied:

- either "universal" selection within one or more populations (strains) for seed production by straight multiplication procedures
- or special selection of different strains or within lines to be combined for crossbred stock production by special cross-breeding strategies.

Furthermore, to what extent inbreeding can be applied in both situations in order to obtain more uniform seed stock for production needs to be clearly understood. Up to now inbreeding has only been systematically included in breeding plans in poultry and laboratory animals where inbred lines have been established. In other farm animals inbreeding is applied, with great caution; continued inbreeding can seriously reduce performance and vitality. In fish the genetic load seems to be fairly high, and inbreeding strategies may not be advisable, as was indicated by Kincaid's (1983) in-breeding trials with trout (Table 6).

Table 6. Effect of inbreeding on performance in rainbow trout (Kincaid, 1983).

Trait	Inbreeding coefficient					
	F = 0.25 (16 pairs)			F = 0.50 (13 pairs)		
	Inbred	Outbred	% depression[a]	Inbred	Outbred	% depression[a]
Hatchery performance						
Hatchability (%)	69.1	83.5	17.2	84.2	84.0	- 0.2
Fry survival to 84 days (%)	89.2	94.7	5.8	89.3	89.7	0.4
Weight (g), 147 days	3.4	3.4	0.0	3.0	3.6	16.0
Feed conversion 147 days	2.3	2.2	-6.7	2.1	2.0	- 5.0
Weight (g), 364 days	68.0	91.0	25.0	85.1	145.9	41.7
Field performance						
6 months weight (g)	72.4	79.9	9.4	65.2	74.5	12.5
12 months weight (g)	150.7	173.2	13.0	132.6	187.0	29.1

a) Percent depression is calculated as outbred mean minus inbred mean divided by outbred mean.

Thus straight selection procedures with low inbreeding coefficients might become the predominant method for selective improvement both for multi-purpose strain improvement and specialized lines in crossbreeding programs.

Crossbreeding prospects

From a few systematic crossbreeding experiments based on simultaneous test diallels the effects of special crossbreeding seems to be of secundary importance. This is especially true in in Salmonids as it results from inter-strain diallels in Norwegian salmon (Gjerde & Refstie, 1984) and in European trout (Hörstgen-Schwark et al., 1985). As an example, the fattening results obtained from the purebred strains and their reciprocal crosses are listed in Table 7, showing that the general strain effect is stronger than the non additive crossbreeding effects.

Table 7. LSQ means of fattening weight in different strains of rainbow trout and their reciprocal crosses (Fricke, 1984).

	♂	♀ Strain no. 2	3	4	5
Strain no.	2	221.0	231.5	227.1	230.9
	3	231.2	235.1	226.3	223.6
	4	222.8	227.7	211.9	209.8
	5	221.3	216.4	213.8	211.6

Purebred mean = 219.9 g
Crossbred mean = 223.5 g

These results obviously are an indication of a high degree of heterozygocity which is found in, e.g. breeding populations not exposed to systematic selection over an extended period of time. Only in the case of outcrossing inbred lines or crossbreeding diiferent carp strains with long and different domestication histories can non additive effects of greater siginificance be expected (Kincaid, 1976; Gjerde et al., 1983; Brody et al., 1980). However, even in carp breeding for production in more controlled environments, strain selection and selective improvement have to be given priority.

A crossbreeding system of selected strains i.e. breeding lines will probably be needed for simultenous improvement of antagonistic traits. In trout an antagonistic relation has been observed between growth performance and fillet percentage in the carcass which lead to drastic changes in strain ranking and their reciprocal crosses for trait improvement (Table 8). An antagonistic relation might also develop between growth and specific meat quality as the result of intensive selection for faster liveweight gain.

Special interest has been devoted to crosses between species for the purpose of delaying or even suppressing maturity and thus producing heavier fishes. None of the species crosses with salmonid species has been of commercial value, because the crossbred performance never exceeded the purebred performance of the superior species. Only interspecies crosses in Tilapia e.g. O.niloticus x O.aureus have been introduced on a broader scale for producing predominantly male progency.

Table 8. Ranking of different strains of rainbow trout and their reciprocal crosses for fattening weight, percentage of fillet and fat (Fricke, 1984).

Rank	Strain comb.	Fattening weight $\hat{c}$	Strain comb.	Percentage of fillet $\hat{c}$	Strain comb.	Percentage of fat $\hat{c}$
1	3 x 3	12.4	5 x 2	.93	5 x 2	.67
2	2 x 3	8.8	4 x 5	.42	2 x 5	.44
3	3 x 2	8.6	5 x 4	.34	2 x 3	.22
4	2 x 5	8.3	5 x 5	.27	2 x 4	.14
5	4 x 3	5.1	3 x 5	.23	3 x 3	.13
6	2 x 4	4.5	2 x 3	.20	3 x 2	.13
7	3 x 4	3.7	3 x 2	.13	4 x 3	.12
8	3 x 5	.9	2 x 5	.10	5 x 5	.05
9	4 x 2	.2	5 x 3	.04	2 x 2	.02
10	5 x 2	- 1.3	2 x 4	- .26	5 x 3	.00
11	2 x 2	- 1.6	2 x 2	- .28	5 x 4	- .05
12	5 x 3	- 6.2	3 x 4	- .35	4 x 2	- .34
13	5 x 4	- 8.8	4 x 2	- .40	3 x 4	- .34
14	4 x 4	- 10.8	4 x 4	- .41	3 x 5	- .35
15	5 x 5	- 11.0	4 x 3	- .47	4 x 5	- .40
16	4 x 5	- 12.9	3 x 3	- .50	4 x 4	- .45
y_t		226.6		68.55		6.91

y_t = overall mean; $\hat{c}$ = LSC constant.

Impact of biotechnology

Two biotechnological measures might get broader application in future fish breeding:

- production of sterile triploid populations for production,
- development of "pure" gynogenetic breeding lines to produce crossbred populations for production.

Triploid production can be induced directly by subjecting fertilized eggs to mutagenic procedures (e.g. shock by heat, cold or pressure). This direct induction of polyploidy, however, is uncertain and only moderately successful, and thus still far from being applicable on a large scale. The indirect approach of producing triploids by combining tetraploid with diploid breeding animals is much more promising. Contrary to triploids, induced tetraploids are fertile and can be used for building up breeding lines which again guaratee an off spring of triploids in normal breeding procedures.

In case of antagonistic trait constellation it might be advantageous to build up special lines from outstanding individuals by gynogenesis. In this technique normal eggs are fertilized by sperm, inactivated by radiation and then subjected to cold shock. The subsequent retention of the second polar body induces meiotic parturition. Due to crossing over at this stage the offspring is not fully identical to the female parent. Gynogenesis has been succesfully applied in various species and has been introduced in carp line breeding in Hungary. This technique may well be tried in breeding strategies for other species in the near future. The outcome of such a strategy very much depends on the genetic load and the inbreeding effects connected to it in the cultured species.

In the future specific gene transfer might be included in fish breeding plans as a major stap in improving disease resistance.

Conclusion

Additive genetic variation constitutes the greatest genetic resource available for stock improvement. Thus, unwavering priority has to be given to screening and selection of potential strains and to subjecting the best strains to consistent selection programs. Although some heterosis can be expected, especially in species with longer domestication complementary additive effects in crossbreeding programs should lead to major improvements such as greater uniformity and overall performance.

References

Brody, T., N.Storch, D.Kirsht, G.Hulata, G.Wohlfarth & R.Moav, 1980. Application of electrophoretic genetic markers to fish breeding. III. Diallel analysis of growth rate in carp. Aquaculture 20, 371-379.

Fricke, H., 1984. Die Leistungserwartung von Zuchtlinienkreuzungen in der Forellenzucht. Diss.Göttingen.

Gjedre, B., K.Gunnes & T.Gjedrem, 1983. Effect of inbreeding on survival and growth in rainbow trout. Aquaculture 37, 327-332.

Gjedre, B., & T.Refstie, 1984. Complete diallel cross between five strains of Atlantic salmon. Livest.Prod.Sci.11, 207-226.

Gjedre, B. & T.Gjedrem, 1984. Estimates of phenotypic and genetic parameters for carcass traits in Atlantic salmon and Rainbow trout. Aquaculture 36, 97-110.

Gjedrem, T., 1983. Genetic variation in quantitative traits and selective breeding in fish and shellfish. Aquaculture 33, 51-72.

Hörstgen-Schwark, G., H.Fricke & H.-J.Langholz, 1985. The effect of strain crossing on the production performance in rainbow trout. 2nd International Symposium on Genetics in Aquaculture, Davis Ca., 23-6 - 28-6-1985.
Keese, A., & H.-J.Langholz, 1974. Elektrophoretische Studien zur Populationsanalyse bei der Regenbogenforelle. Z.f.Tierz.u.Zübiol. 91, 109-124.
Kincaid, H.L., 1976. Inbreeding in rainbow trout (Salmo gairdneri). J.Fish. Res.Board Can. 33, 2420-2426.
Kincaid, H.L., W.R.Bridges & B.von Limhac, 1977. Three generations of selection for growth rate in fall spawning rainbow trout. Trans.Am.Fish. Soc. 106, 621-629.
Kincaid, H.L., 1983. Inbreeding in fish populations used for aquaculture. Aquaculture 33, 215-227.
Kinghorn, B., 1983. Genetic variation in food conversion efficiency and growth in rainbow trout. Aquaculture 32, 141-155.
Langholz, H.-J., 1985. Tierhaltung und Fischwirtschaft. Vortragung "Existenzsicherung in der Landwirtschaft durch Erweiterung der Tätigkeitsfelder in Produktion, Dienstleistung und Vermarktung" des Dachverbandes wissenschaftlicher Gesellschaften der Agrar-, Forst-, Ernährungs-, Veterinär- und Umweltforschung e.V., 15/16 April 1985 in München.
Morkramer, S., G.Hörstgen-Schwark & H.-J.Langholz, 1985. Comparison of different European Rainbow trout populations under intensive production conditions. Aquaculture 44, 303-320.
Skjervold, H., 1976. Genetic improvement of salmonids for fish culture. In: "Aspects of fish culture and fish breeding". (ed.) E.A. Huisman, Misc. Paper LH, no.13: p. 7-27.

INDUCED SPAWNING AND EARLY GROWTH OF MPASA (OPSARIDIUM MICROLEPIS) AND NCHILA (LABEO MESOPS) IN TANKS AND EARTHEN PONDS

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Summary

The initial study of Mpasa (Opsaridium microlepis) failed to provide any applicable information on fry production using induced spawning techniques. Partial spawning of 500-2000 eggs was demonstrated through egg deposition in hapas and was later confirmed by determination of an ova-diameter frequency chart. Both carp and Mpasa pituitary suspension proved effective. 66.3% Of the eggs were successfully fertilised. The number of eggs produced per fish was generally higher than hitherto recorded, varying from 37,000 eggs for fish of 54.5 cm total length to 67,000 eggs for fish of 57 cm total length. The diameter of the ova ranges from 0.25-2.5 mm and showed several size modes in each gonad. Survival of fry in indoor tanks was rather low (46.9-68.8%. Influence of water quality rather than food and vulnerability to predation as a result of delayed scale formation appeared to have been responsible for this low survival. Fishes were fed up to 1 g with mainly Artemia salina nauplii and zooplankton. To some extent pelleted feed was supplied in addition. Individual growth of fry in tanks amounted to 11-19 mg day^{-1}.

Hypophysation of Nchila (Labeo mesops) was successfully conducted from January to April. Effective dosage with carp hormones was 0.64-3.0 mg per 100 fish; males responded to lower dosages. Fertilised eggs were bigger, (3-7 mm), than for Mpasa, however fry accepted the same type of food as Mpasa. Maturity of females was attained at a smaller size (25 cm) than reported before (30 cm). Preliminary experiments with fingerlings in manure loaded ponds proved promissing in view of the growth rates obtained.

Résumé

Les études préliminaires sur le Mpasa (Opsaridium microlepis) n'ont pas fourni d'informations pouvant être utilisées dans l'alevinage par ponte induite. Le dépôt de quelque 500 à 2000 oeufs dans les hapas a fait la preuve qu'une ponte fractionnée s'était produite, constatation corroborée ensuite par l'examen d'un tableau de fréquence du diamètre des ovocytes. Les hormones de carpes ainsi que les extraits hypophysaires ont joué un rôle actif et on a enregistré une fertilisation réussie pour 66.3% des oeufs. Le nombre d'oeufs produits par poisson était supérieur en général à ce qui avait été enregistré jusqu'à présent et varait de 37000 oeufs par poisson ayant une longueur totale de 54,5 cm à 67000 oeufs par poisson de 57 cm de longueur totale. Le diamètre des ovocytes variait de 0,25 à 2,5 mm et plusieurs catégories de tailles étaient représentées dans les gonades.

Les taux de survie des alevins en bac à l'intérieur variait de 46,9% à 68,8% - ce qui est assez médiocre. Il semble qu'il faille attribuer ce faible taux de survie davantage à la qualité de l'eau qu'à la nourriture, sans oublier la vulnérabilité aux prédateurs résultant d'une formation tardive

des écailles. On a donné aux poissons pesant jusqu'à 1 g une nourriture composée essentiellement d'Artemia salina nauplii et de zooplancton. Certaines quantités de nourriture ont aussi été fournies sous forme de granulés. La croissance pondérale du frai élevé en bac a atteint 11-19 mg par jour^{-1}.

L'hypophysation des Nchila (Labeo mesops) a été effectuée avec succès de janvier à avril. Un dosage de 0,64 à 3,0 mg d'hormones de carpes pour 100 g de poisson s'est avéré efficace, les mâles réagissant toutefois à un dosage plus faible. Les oeufs fertilisés, de 3 à 7 mm, étaient plus gros que ceux du Mpasa, les alevins acceptant toutefois le même type de nourriture que celle qui était donnée aux Mpasa. Les femelles arrivaient à maturité à une taille plus petite (25 cm) que celle qui avait été enregistrée précédemment (30 cm). Des essais préliminaires réalisés sur des alevins élevés dans des étangs enrichis en fumier se sont avérés prometteurs au vu des vu des taux de croissance obtenus.

Part 1. Mpasa

Introduction

The Mpasa (Opsaridium microlepis) is one of the favorite food fish species in Malawi, fetching premium prices in local markets. In recent years, catches have shown major declines (Jackson et al., 1963; Willoughby, 1979; Tweddle, 1981) mainly as a result of heavy fishing pressure but possibly also due to a change of the riverine environment from excessive siltation. The Mpasa fishery in permanent rivers north of Linthipe (Lowe, 1952) was especially important to the Central and Northern regions of Malawi.

The feeding habitats of the fish are completely predatory, consuming zooplankton during the fry and fingerling stages and Engraulicypris sardella and Haplochromis sp. during the adult stage. Breeding takes place over an extended period, February to September, in the Northern and Central regions, although the fishes seem to be adaptable to the flood regime in their particular river of migration. While most fish ascend affluent rivers to spawn, fry has been observed far from any rivers suggesting that spawn might also occur in the main lake. During spawning fishing is heavy using gillnets, traps, weirs and scoop nets.

Data by Lowe (1952) and Tweddle (1983) show that growth is relatively fast during the first three years with an annual increase in length of some 10 cm, until maturity is attained at about 30 cm in the third year. Studies of potential fecundity are generally of limited value unless obtained from prespawning females (Vogele, 1981). Tweddle (1983) showed that spawners contained large numbers of oocytes; 1,381 to 22,077, from fish of 19 to 55.5 cm total length.

Attempts by Soma (1979) to induce the fish to spawn had limited success and most fry were deformed. The present study was initiated to investigate induced spawning with carp hormones and subsequent rearing of fry in an effort to develop rearing techniques for possible culture under controlled conditions. Supplementary data were collected on aspects of fish biology with respect to fecundity, spawning frequency and growth.

Material and methods

Capture of spawners

Fishing was conducted three times from May to July 1983 in Bua River (Nkhota Kota) which is the closest river to Domasi with a reliable Mpasa fishery. Since the river has a rocky bottom with scattered pools, rods oocytes (Alvarez-Lajonchere et al., 1981).

Egg counting was done in three replications of 10 g each from the anterior, mid and posterior section of the gonad to determine eventual differences in egg size due to their position in the gonad. All the ova in the sub-samples were counted. One hundred ova from each sub-sample were measured for diameter to the nearest 0.01 mm, using an ocular and stage micrometer magnifier.

Results and discussion

Previous studies have indicated that Mpasa runs occurred in almost all permanent rivers north of Linthipe (Lowe, 1952), but at present the only reliable fisheries are in Bua River (Nkhota Kota) and North Rukuru (Karonga). Bua River being closer to Domasi offered the better opportunity for this study although this might have biased the data since Mpasa from North Rukuru are reported to be of smaller size (Tweddle, 1981).

Most fishes caught developed serous fluid in the body cavity suggesting that the method of fishing by hook and line, may stress the fish. Normally spawning activity was observed 6 hours after injection with pituitary suspension and involved vigorous movement of the caudal fin as described in more detail by Tweddle (1983). Carp pituitaries were just as effective as Mpasa ones, although in the absence of weight data on Mpasa pituitaries dosage comparison was not possible. As shown in Table 1, only a few eggs ovulated, usually 500-2,000 per spawn. The average fertilization percentage was 66.3% (Table 2).

Table 1. The response of Mpasa female fish to carp and Mpasa pituitary.

Initial weight (kg) of fish	Final weight (kg) of fish	Loss of weight (g) (including ovulated eggs)	Dosage (mg/1,000 g)
2.0	1.98	20	4.05 *
1.60	1.60	-	1.41 *
1.70	1.70	-	1.66 *
1.85	1.84	10	3.00 *
1.20	1.20	-	3.16 *
1.35	1.34	10	2 pituitaries **
1.45	1.43	20	2 pituitaries **

* carp pituitary

** Mpasa pituitary of donor fishes having the same weight as the recipient.

Table 2. Fertilization of Mpasa eggs.

No.of eggs	No.of fertilized eggs	% fertilization
20	13	65
20	15	75
20	10	50
20	15	75
Average		66.3

Diameters of preserved ova ranged from 0.25 mm to 2.5 mm, which implies the existence of different size modes (Fig.1).

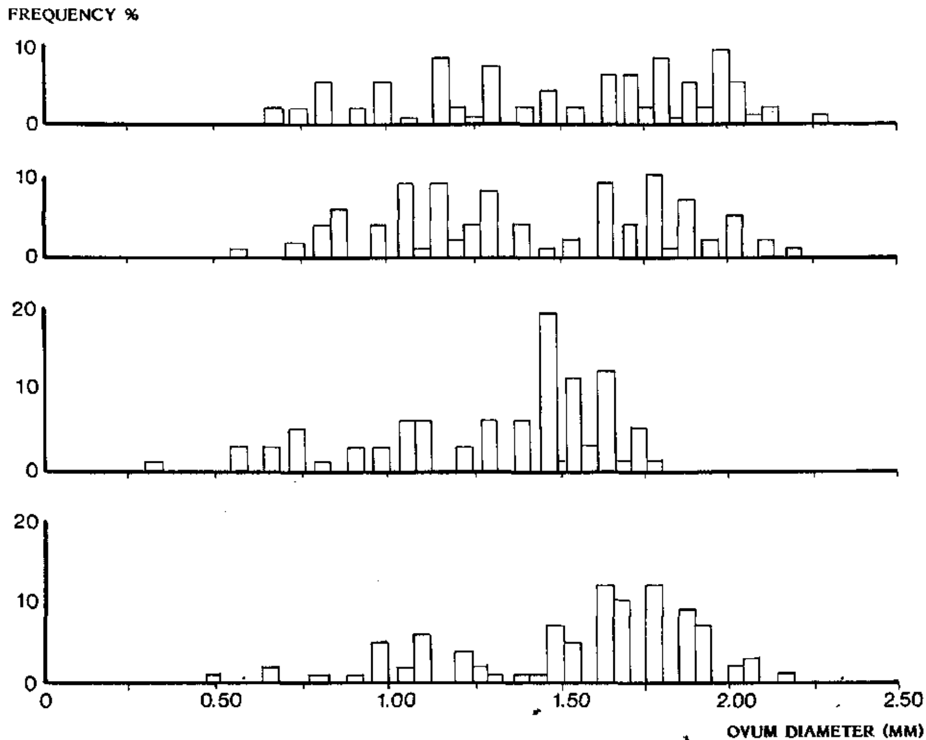

FIGURE 1. OVUM DIAMETER FREQUENCY DISTRIBUTIONS FOR 4 FEMALE MPASA.

If the distributions of ova-diameter frequencies are observed in all females, repeated spawning could occur under natural conditions. Fecundity estimates found in this study (Table 3) were higher than those reported by Tweddle (1983). The most advanced size mode of ova is supposed to represent a single egg deposit. Further morphological characterisation of the other modes would be useful to detect the different ova maturation stages. The presence of several egg groups can serve as a survival mechanism which enables the fish to spawn at several sites and ensures that some eggs will survive. Apparently, this is not the case with Labo mesops (part II of this report) which are decreasing in numbers faster than Mpasa.

Table 3. Fecundity and gonadosomatic indices (GSI) of Mpasa collected in May and June 1983.

Month	Sex of fish	Body wt (kg)	Total length (cm)	No. of eggs	Weight of gonad(g)	GSI %
May	female	1.40	-	-	165.0	11.78
"	"	1.60	55.0	37,792	121.0	7.60
"	"	1.53	54.6	37,313	146.1	10.55
"	"	1.70	-	29,423	105.0	6.17
"	"	1.36	57.2	65,657	148.4	10.97
"	male	1.60	57.0	-	10.0	0.63
"	"	1.55	57.5	-	5.0	0.32
"	"	1.55	54.5	-	3.8	0.25
"	"	1.12	52.5	-	5.0	0.45
June	female	1.20	55.0	37,118	105.0	8.75
"	"	1.45	56.0	63,339	145.5	10.03
"	"	1.35	54.5	35,111	100.0	7.41
"	"	1.35	57.0	34,510	55.0	4.07

Like most other cultured fish, small fry will initially not consume dry feed stuffs and have to be fed zooplankton and Artemia nauplii. Small zooplankton should therefore provide an adequate starter food for Mpasa, however care must be taken to exclude copepods which were observed to prey on unscaled fish; a batch of 50 fry was destroyed in 24 hours.

In indoor experiments, fry survival was low (Table 4), and also the daily gain of 11-19.8 mg per fish compared not too favourably with fast growing species like Clarias lazera (Hogendoorn, 1980). Part of the cause probably was water chemistry since there was no continuous water supply to the aquaria.

Table 4. Growth and survival of Mpasa fry in aquaria.

Feeding regime	Initial no.of fish	Final no.of fish	Final average wt (mg)	Days of growth	Growth (mg.day^{-1})	Survival %	Daily specific growth rate %
Artemia	32	22	1,500	80	19.75	68.8	1.083
Daphnia	30	15	1,140	80	11.25	50.0	0.906
Artemia	33	22	1,400	80	17.5	66.7	1.017
Artemia	32	15	1,420	80	17.5	46.9	1.025

The increase in nitrogenous substances (ammonia from 0.81 to 1.53 mg l^{-1}; nitrite from 0.027 to 0.139 mg l^{-1} and nitrate from 1.92 to 7.4 mg l^{-1}) may have contributed to fish death.

The data obtained on fingerling growth in earthern ponds were far less satisfactory than those for fry. A specific growth rate of 0.27 to 1.08 was obtained, depending on the food supplied; this wasequivalent to a weight increase of about 0.3 g.day^{-1} (Table 5).

Table 5. Growth of Mpasa fingerlings in earthen ponds.

Pond no.	No.of fish	No.of fish ha	Growing days	Food (kg)	Initial average wt (g)	Final average wt (g)	Daily specific growth rate (%)
16	147	7,350	90	26	10.1	26.7	0.469
15	88	4,400	88	forage fish	15.55	26.75	0.271
8	143	1,430	80	chopped fish	8.9	66.16	1.086

The diet of chopped fish was promising, however the different fish densities used may have biased the results although food was supplied in proportion to the biomass. Low dissolved oxygen contents at early morning caused heavy losses (predominantly bigger fish) which stresses the species' need for adequate oxygen supply. Cage culture or flow-through culture systems may be more adequate for Mpasa farming. Since the fecundity of this species is rather high, fry can be collected successfully in natural waters provided it is done before June. After June other migrating species (Barbus johnstonii, Opsaridium microcephalus) will contaminate the catch and identification at the young stages becomes difficult. About 2,000 fry were collected within one day, implying that this source could suffice for an experimental and limited production facility. Normally as the river recedes much fry is stranded in the backwaters and subsequently die.l

Part 2. Nchila

Introduction

The Nchila (Labeo mesops) fishery is reported to have been second to tilapia in commercial importance on Lake Malawi during the 1930s and through the 1950s (Lowe, 1952). Despite efforts to regulate the catches by introducing a 4 inch mesh size, the fishery has declined to near extinction. This decline is typical of fish species which generally ascend rivers to spawn in Malawi (FAO, 1976), probably because, they are vulnerable to fishing by weirs and block nets which are apparently more efficient than gill nets. In areas of low population density supporting a low fishing pressure as on the Tanzanian and Mozambique side of Lake Malawi, Nchila fishery continues to thrive (T.Jones, pers.comm.).

Annual growth of Nchila has been estimated by Lowe (1952) as follows: 12 cm after the first year, 22 cm after the second year and 26-28 cm during the third year. Maturity is attained earlier by males (25 cm) than females (30 cm), in the third and fourth year, respectively.

The feeding habitats of Nchila have not been studied in detail. The mouth form enables them to suck in mud by extending their folded jaw. It seems to particularly prefer mud which contains algae or decayed organic matter; this suggests that it may be deriving nutrients from micro-organisms growing on mud, much like tilapia fish grown in intensely manured ponds (Schroeder, 1978).

Little is known about development of juveniles, but embryological development have been studied in aquaria (Anon, 1965). More information on fecundity, egg and fry survival and survival of adults after spawning is needed to be able to work out a management strategy for Nchila fishery.. The present study was aimed at determining the potential for pond culture i.e. reproduction in confinement, fry rearing and growth in stagnant ponds.

Materials and methods

Several places were scouted for runs of Nchila along shores of Lake Malawi. Nchila runs were reported in Makanjira (eastern arm of Lake Malawi) and Cape Maclear on the western shore of the lake. Shire River, which forms the main outlet to Lake Malawi was reported to support limited runs of the fish. Since live specimens had to be obtained, Shire River was preferred for this study because of its proximity to Domasi. Fishing was conducted around Liwonde using a seine net which was operated both as a beach seine and as a drift net. The strong currents and rough bottom of the river did not, however, allow extensive drifting. Throughout the three fishing surveys only immature fish were caught which were transported to Domasi, in the same way as described for Mpasa.

While at Domasi, some of the fish were fed dry feed in concrete tanks while others were supplied with manure in earthen ponds. Monthly checks on weight gain were conducted throughout 1984. Towards the end of January 1985 some female fish became soft-bellied and somewhat bulged. Males released milt under slight pressure. Mature fish were transferred into hapas and were injected with carp pituitary suspension of varying dosage, 0.64 mg to 3.00 mg per 100 g body weight. After injection, a continuous water supply was maintained in the pond to simulate river conditions. Samples of fertilized eggs were measured with a caliper to the nearest 0.1 millimetre.

Some newly hatched fry were transferred into glass aquaria, for close observation; the rest were kept in the earthen pond or inconcrete tanks. In the tanks small zooplankton and freshly hatched Artemia nauplii were supplied as food. In indoor tanks trout starter feed was supplemented to the live food organisms. Aquaria were aerated as described for Mpasa.

Results and discussion

Hypophysation of Nchila with carp pituitary proved more successful than for Mpasa. Fish as small as 25.6 cm total length weighing about 160 g could be induced to reproduce (Table 6). In fact all the females spawned, except one, were smaller than 30 cm, the latter size being reported by Lowe (1952) as the minimum size for maturity. The pond environment may accelerate maturity or, alternatively, the natural Nchila population may have become progressively stunted since the time of Lowe's study. The latter may have been influenced by the minimum mesh size which was big enough for smaller adults to escape. The body weight and depth changed markedly after spawning in both sexes but more so in females, suggesting that between body depth and length or weight a relationship could be worked out to quantify ripeness of females.

Table 6. Data illustrating the response of Nchila to carp pituitary including preliminary results of the reproduction experiments.

Date	Length (cm) total	Length (cm) fork	Sex	Body weight(g) before	Body weight(g) after	Body depth (cm) before	Body depth (cm) after	Dosage (mg/100 g fish)
Date:25-1-1985*	-	-	female	205	170	-	-	0.78
	-	-	female	505	400	-	-	0.79
	-	-	male	175	170	-	-	0.64
	-	-	male	165	150	-	-	0.68
Date: 5-2-1985	25.0**	22.5	female	200	170	6.0	5.1	2.22
	26.2***	23.7	female	210	180	6.8	5.4	2.02
	30.0	27.0	male	310	300	7.2	6.8	-
	25.6	22.5	male	160	140	5.4	5.0	1.38
Date:15-3-1985****	24.1	21.0	female	140	140	4.9	4.9	3.0
	25.6	22.5	female	240	160	5.9	4.9	3.0
	25.0	21.9	male	230	200	5.4	5.1	1.9
	25.5	22.6	male	-	150	4.9	4.7	-

* additional data: all fish spawned
average egg diameter (mm) and range: 5.05; 4.0-6.5
all eggs died due to poor aeration

** additional data: average egg diameter (mm) and range: 4.84; 3.0-6.0
total no.of fry obtained: 4,678

*** additonal data: average egg diameter (mm) and range: 5.36; 4.0-7.0
total no.of fry obtained: 2,313

**** additional data: average eggs diameter (mm) and range: 4.95; 4.0-7.0
rate of fertilization: 95%
total no.of fry obtained: 1,403.

Unlike Mpasa, Nchila ovulated all eggs at the same time. The eggs 3-7 mm in size after water absorbtion, are semi-pelagic, non-adhesive and transparent. The vitelline membrane is thin and easily damaged.

Since spawning took place at night, it was not possible to observe the spawning act nor to obtain a relationship between weight (or volume) of fish and weight (or volume) of eggs. These data will be obtained in the future from prespawning females. Water temperature during spawning varied from 24 to 29°C. Newly hatched fry measured about 6 mm. Further data are required on their development.

Post spawning mortality in natural populations has been reported by Lowe (1952). Apparently the Nchila in this study were in good condition since all survived after spawning. In nature lack of food during long distance migration in fast flowing rivers may weaken the fish.

The preliminary observations on growth in ponds showed the potential value of manure (Table 7). Since this fish is accustomed to sucking it probably cannot consume food in either pellet or solid form. With this in mind further tests will emphasize the use of manure to take advantage of the natural feeding behaviour.

Table 7. The growth of Nchila juveniles in earthen ponds.

Number of fish stocked		Growing days	Food or manure	Initial average wt (g)	Final average wt (g)	Daily specific growth rate
$pond^{-1}$	ha^{-1}		(kg)			%
20	400	62	307 manure	51.6	68.7	0.20
21	210	331	90.6 pellet	46.0	131.0	0.14
80	800	126	pellet	28.0	46.0	0.12

Recommendations

1. Mpasa fingerlings should next be grown in cages suspended in either the open lake or affluent rivers where dissolved oxygen and nitrogenous substances do not pose a threat to fish survival. Dry formula feed should be tried, but chopped fish also seems to be of potential value.
2. Collection of fry from the backwaters of affluent rivers should be encouraged to fulfill the immediate needs for a limited-size experimental and production facility until a hatchery reared stock becomes available. This will not threaten the fishery since most fry get stranded and die when the rivers recede after the rainy season.
3. The poor growth of fish at Domasi Fisheries Station is undoubtedly related to poor soil (pH = 4.17) and water (pH = 6.5, alkalinity = 21.4 mg/l, hardness = 15.3 mg/l) quality. Therefore, liming and manure studies should be conducted with due attention to the feeding behaviour of Nchila.

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References

Anon, 1965. Annual Report of the Department of Agriculture and Fisheries for the year 1964. Fisheries Research - Part II. Government Printer, Zomba, Malawi.

Alvarez-Lajonchere, L., J.B.Arritola & G.G.Samson, 1981. Some Studies on induced spawning of Mullets (Pisces: mugilidae). In Aquaculture III, International Foundation for Science, Report No.10, Stockholm, Sweden, pp.65-99.

FAO/UN, 1976. Promotion of Integrated Fishery Development, Malawi. An Analysis of the Various Fisheries of Lake Malawi, based on the work of J.Turner. Rome, FI;DP/MLW/71/516, Technical Report 1.

Hogendoorn, H., 1980. Controlled Propagation of the African Catfish, Clarias lazera (C.& V.). II. Feeding and Growth of Fry. Aquaculture, 21: 233-241.

Jackson, P.B.N., T.D.Iles, D.Harding & G.Fryer, 1963. Report on the Survey of Northern Lake Nyasa 1954-55. Government, Printer, Zomba, Malawi. 171 pp.

Lowe, R.H., 1952. Report on the Tilapia and other Fish and Fisheries of Lake Nyasa 1945-1947. H.M.S.O. Colonical Office Fisheries Publications 1 (2), 126 pp.

Schroeder, G.L., 1978. Autotrophic and heterotrophic production of micro-organisms in intensely-manured fish ponds, and related fish yields. Aquaculture, 14: 303-325.

Soma, K., 1979. Preliminary report on seedling production of mpasa, Barilius microlepis. Malawi Fisheries Dept., Report.

Tweddle, D., 1981. The importance of long term data collection on river fisheries with particular reference to the cyprinid Opsaridium microlepis (Gunther 1864) fisheries of the affluent rivers of Lake Malawi. In Seminar on River Basin Management and Development. CIFA/T8, 145-163.

Tweddle, D., 1983. Breeding behaviour of the mpasa, Opsaridium microlepis (Gunther) (Pices: Cyprinidae), in Lake Malawi. J.Limnol.Soc.sth.Afr. 9: 23-28.

Vogele, L.E., 1981. Reproduction of Smallmouth Bass, Micropterus dolomieui, in Bull Shoals Lake, Arkansas. U.S.Dept.of the Interior, Fish and Wildlife Service, technical Paper 106, 15 pp.

Willoughby, N.G., 1979. African Freshwater Fisheries and their Management. Fish.Mgmet., 10: 159-168.

ÉTUDE DE LA QUALITÉ DE L'ALIMENT ET DE LA DENSITÉ SUR LE TAUX DE SURVIE DES ALEVINS DE CHRYSICHTHYS NIGRODIGITATUS

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Résumé

Des études sur l'alimentation artificielle de Chrysichthys nigrodigitatus ont été faites sur des alevins en fin de résorption de vésicule vitelline, dans des bacs circulaires en bois de 2 m de diamètre et 40 cm de haut.

4 types d'aliments ont été testés. Parmi eux, deux ont été fabriqués à partir de sous-produits agro-industriels; le troisième est un mélange de farine de poisson, de cervelle de mouton, de foie de boeuf et de son de blé et le quatrième, un mélange d'oeuf, de lait et de vitamines.

Pour mesurer l'influence de la densité sur le taux de mortalité et la croissance, les alevins ont été répartis en 4 densités différentes.

La durée de séjour par bac a été de 3 semaines.

Les poissons ont eu les mêmes nourritures, et pour chaque expérience, il y a eu trois réplicats.

Les aliments fabriqués à partir de sous-produits agro-industriels ont donné les meilleurs résultats. La meilleure densité est de 2.500 alevins par bac.

Summary

Studies on artificial feeding of Chrysichthys nigrodigitatus were carried out using fry that were completing vitelline vesicle resorption in round wooden tanks 40 cm high and 2 m in diameter.

Four feeds were tested. Two were made from agro-industrial by-products the third was a mixture of fish, sheep brain, cattle liver and wheat bran, the fourth was a mixture of egg, milk and vitamins.

The fry were divided into four batches, each of a different density, in order to measure the effects of population density on the mortality and growth rates.

The fry were maintained in the tank for three weeks.

The fish had the same feed. There were two replications of each experiment.

The feed made from the agro-industrial by-products gave the best results. The best density was 2.500 fry per tank.

Introduction

Chrysichthys nigrodigitatus est une espèce très courante dans les lagunes et les eaux courantes ivoiriennes. C'est un poisson benthique à régime alimentaire omnivore à tendance carnivore. Il a une croissance rapide, puisqu'il atteint 18 cm en un an. Il se reproduit à 33 cm à l'age de 3 ans, entre juin et novembre, dans les eaux douces et les zones généralement dessalées des lagunes. La reproduction en captivité a été obtenue pour la premiere fois en 1981 à partir de géniteurs capturés en lagune à l'état de juveniles de 10 cm puis élevés en étang jusqu'à la maturité sexuelle.

De très fortes mortalités ont été observées durant la phase d'alevinage de ce poisson. Ces mortalités ont été attribuées à un certain nombre de facteurs: qualité de l'aliment fourni, fréquence d'alimentation, et soins apportés aux alevins. L'objectif principal de cette étude est d'améliorer le taux de survie des alevins dans les structures d'élevage en testant différents aliments et en améliorant les soins.

Methodologie

L'alevinage a lieu dans des bacs circulaires en bois de 2 m de diamètre alimentés par l'eau de lagune. La hauteur d'eau dans les bacs est de 20 cm. Les alevins sont nourris dès la résorption de la vésicule vitelline.
Quatre types d'aliments ont été testés:

* Aliment I

. oeuf battu	49%
. lait	49%
. vitamines	2%

* Aliment II

. farine de poisson tamisé (tamisée)	60%
. cervelle de mouton (broyée)	10%
. foie de boeuf (broyé)	10%
. son de blé (tamisé)	15%
. vitamines	2%
. huile de foie de morue	3%

* Aliment III

. farine de poisson (tamisée)	70%
. son de blé (tamisé)	10%
. farine de maïs (tamisée)	10%
. tourteau de coton (farine tamisée)	5%
. vitamines	2%
. huile de foie de morue	3%

* Aliment IV

. farine de poisson (tamisée)	50%
. son de blé (tamisé)	10%
. farine de maïs (tamisée)	10%
. tourteau de coton (farine tamisée)	5%
. tourteau de soja	20%
. vitamines	2%
. huile de foie de morue	3%

L'analyse de ces aliments à l'Université d'Auburn (Fisheries Department) Alabama, U.S.A., a donné les valeurs presentées dans le tableau 1.

Tableau 1. Composition chimique des différents aliments utilisés.

Aliments	Protéines	Lipides	Humidité	Cendres
II	38.9	8.7	28.7	10.3
III	45.6	7.7	12.3	12.3
IV	44.9	5.7	11.8	11.8

L'aliment I n'a pu être analysé. Chaque aliment a été fourni 8 fois par jour (4 fois pendant la journée et 4 fois pendant la nuit), soit toutes les 3 heures et distribué de façon homogène dans les bacs.

Tous les alevins ont été nourris au taux de 10% de leur poids corporel. Ce taux a été ramené à 5% une semaine après le début de la manipulation et maintenu à cette valeur jusqu'a la fin de l'expérimentation.

Les bacs ont été siphonnés après chaque prise de nourriture pour les débarrasser de l'aliment non consommé et de toute matière organique qui pourrait s'accumuler.

Les mortalités ont été relevées à chaque nettoyage.

Les bacs ont eu deux traitements prophylactiques hebdomadaires, l'un au formol et l'autre au permanganate de potassium.

Le débit de l'eau dans chaque bac a été réglé à 10 l/mm.

Pour évaluer l'influence de la densité de stockage sur la croissance et le taux de survie, nous avons stocké les alevins à 1.700, 2.000, 2.500, 3.000, chacune de ces densités étant répliquée 3 fois.

Résultats

Tous les tests n'ont pas pu être menés pendant la même période parce que nous n'avions ni assez d'alevins, ni assez de bacs circulaires; les expériences se sont donc étalées sur près de 3 mois de août à novembre.

Dans l'interprétation de nos résultats, nous n'avons pas pris en compte les fortes mortalités qui nous semblaient venir de la qualité des oeufs.

Influence de la qualité de l'aliment sur le taux de mortalité en fonction de la densité

Le tableau 2 et la figure 1 montrent que le meilleur aliment est le n°IV quelle que soit la densité. Pour les aliments I et III le taux de survie le moins bon a été observé à la densité 2.000. Cela vient probablement du fait que les tests sur cette densité ont été faits fin octobre, début novembre, époque à laquelle de très forts taux de mortalité ont été observés dans tous les bacs quels que soient l'aliment et la densité testés. Hem (1986) a également noté un fort taux de perte en oeufs pendant la même période. Les causes de ces mortalités n'ont pas encore été définies.

A la densité 3.000 alevins par bac, le taux de survie est similaire pour les aliments I, III et IV.

Tableau 2. Taux de survie par aliment en fonction de la densité.

Densité	Taux de survie en %			
	Aliments I	Aliments II	Aliments III	Aliments IV
1.700	0	44	0	78
2.000	21	0	29	53
2.500	37	47	52	77
3.000	46	0	46	47

O : Aucun réplicat n'est pris en compte.

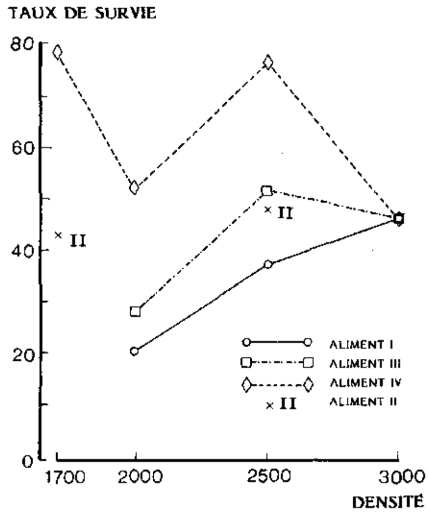

FIGURE 1. INFLUENCE DE LA QUALITÉ DE L'ALIMENT SUR LE TAUX DE SURVIE EN FONCTION DE LA DENSITÉ

Influence de la qualité de l'aliment sur la croissance

Dans le tableau 3, nous avons noté le gain moyen en poids par alevin et le quotient nutritif (Qn). Les valeurs des Qn trouvées ne sont pas des valeurs réelles, parce qu'après chaque distribution de nourriture, il reste une certaine quantité d'aliment (environ 50%). Ce reste non ingéré les poissons n'a pas été pesé, notre but n'étant pas de déterminer un Qn exact, mais de comparer les différents Qn entre eux, étant supposé que dans chaque bac, la quantité de nourriture prise est proportionelle au nombre d'alevins.

Tableau 3. Gain moyen pondéral par alevin et quotient nutritif en fonction de l'aliment.

Densité	Aliments I		II		III		IV	
	Gi	Qn	Gi	Qn	Gi	Qn	Gi	Qn
1.700	-	-	23	5.9	-		34	3,7
2.000	13	1,5	-	-	20	6,7	29	3,4
2.500	17	9,2	18	7,5	20	5,0	30	4.0
3.000	15	6,5	-	-	19	7,1	27	5,9

Gi : Accroissement (en mg) moyen de la biomasse individuelle après 3 semaines

Qn : Quotient nutritif

Le tableau 2 nous montre que c'est avec l'aliment IV qu'ont été obtenus les meilleurs taux de croissance, et les meilleurs Q/n.

Influence de la densité sur la mortalité

Pour évaluer cette influence, nous avons choisi l'aliment IV. Le tableau 4 nous montre que dans les conditions de notre expérience, la meilleurs densité est 2.500 alevins par bac circulaire.

Tableau 4. Taux de survie en fonction de la densité de stockage.

Densité	Taux de survie	Nombre d'alevins après 3 semaines
1.700	78,4	1.332
2.000	53,1	1.062
2.500	77,2	1.930
3.000	46,2	1.419

Notons que le faible taux de survie constaté sur les alevins mis à la densité de 2.000 par bac, vient de ce que l'étude réalisée sur cette densité a été vers fin octobre.

Influence de la densité sur la croissance

Si, après 3 semaines l'on a pu obtenir une meilleure croissance avec l'aliment IV par rapport aux autres, il n'a pas été possible d'évaluer l'effet de la densité sur la croissance, la durée de l'expérience étant très courte (3 semaines).

Discussion

Si nous nous reférons à la composition des Aliments II, III et IV, nous nous constatons que l'aliment II, du fait de sa très forte teneur en humidité, fait développer des moisissures, qui altérent sa qualité.

L'Aliment IV est un dérivé du III, en ce sens qu'il a été obtenu en remplaçant 20% de la farine de poisson par du tourteau de soja. Les deux aliments ne diffèrent que par la plus faible teneur en lipides du IV. La différence de qualité entre les deux aliments peut s'expliquer par le fait que d'une part, la farine de poisson fabriquée à Abidjan n'est pas de bonne qualité, et d'autre part, l'adjonction du soja à cette farine conduirait à un aliment plus équilibré.

L'Aliment I, est peut-être trop riche en protéines. Nous avons constaté que nourris avec cet aliment, les alevins présentaient un ballonnement de la cavité abdominale, suivi parfais de l'éclatement de l'abdomen. Le mélange lait plus oeuf fermente-t-il ou conduit-il à d'autres troubles organiques ?

Conclusion

Cette étude montre que dans les conditions de notre expérience, l'aliment le meilleur est le n°IV avec lequel on obtient un meilleur taux de croissance et un meilleur quotient nutritif. Les alevins nourris avec cet aliment ont un taux de survie de l'ordre de 77% lorsqu'ils sont stockés à la densité de 2.500 alevins par bac.

Dans la mesure où l'objectif de ce travail était de mettre au point un aliment qui permette d'améliorer le taux de survie des alevins, on peut dire que dans une certaine mesure, notre but a été atteint.

Des études doivent être faites pour améliorer cet aliment ou trouver un aliment encore meilleur, permettant d'obtenir une meilleure croissance et un meilleur taux de survie.

References

Dia, A.K., 1982. Étude de la croissance des juveniles de Chrysichthys walkeri (Gunther) en étang en fonction de la densité. Aquaculture, 27(3): 187-195.

Hem, S., Premier résultats sur la reprodoction contrôlée du Crysichthys nigrodigitatus en milieu d'élevage (This volume).

THE AQUACULTURAL POTENTIAL OF THE AFRICAN CATFISH (CLARIAS GARIEPINUS, BURCHELL, 1822)

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Abstract

This paper sets out the results of 10 years of research by the Department of Fish Culture and Fisheries of the Wageningen Agriculture University, on identifying the suitability of C.gariepinus for aquaculture purposes. It focusses on a) reproduction and reproduction techniques, b) nutrition, feeds, feeding and growth, c) fish health control, and d) fish husbandry technology.

Based on the results of this multi-facetted research effort it is argued that C.gariepinus is a highly promising aquaculture candidate for the African region because of the species': (1) excellent adaptation to the climate, (2) high growth rate and very efficient feed conversion, (3) ability to mature and reproduce throughout the year in captivity, (4) acceptance of relatively cheap feeds, (5) ability to support high population densities under cultural conditions, (6) disease-resistance and (7) consumer acceptance.

Since a number of these characteristics are directly or indirectly related to the air-breathing character of the species, the results stress the need for further research of air-breathing fish species for the enhancement of aquaculture development.

Résumé

Cette contribution décrit les résultats de dix années de recherches du Département de la Pisciculture et des Pêches de l'Université d'Agriculture de Wageningen, sur l'évaluation des possibilités d'utilisation de Clarias gariepinus en aquaculture. Elle porte sur les techniques de reproduction; le nourrissage et la croissance; le suivi sanitaire et, les techniques de pisciculture.

Suite aux résultats obtenus par ces recherches multidisciplimaires, il s'avère que C.gariepinus est une espèce offrant de bonnes possibilités en Afrique en raison des charactéristiques suivantes: 1) excellente adaptation au climat, 2) bon taux de croissance et taux de conversion de la nourriture très efficace, 3) capacités de maturation et de reproduction en captivité pendant toute l'année, 4) acceptation d'une nourriture relativement peu coûteuse, 5) tolérance à des densités de population élevées en milieu d'élevage, 6) résistance aux maladies et, 7) bon niveau d'acceptation par le consommateur.

Vu qu'un certain nombre de ces caractéristiques sont directement ou indirectement liées à la respiration aérienne de l'espèce, les résultats indiquent donc que, pour promouvoir le développement de l'aquaculture, il convient d'axer à l'avenir les recherches sur les espèces capables de respiration aérienne.

Introduction

The Department of Fish Culture and Fisheries of the Wageningen Agriculture University has researched the African catfish, Clarias gariepinus*, since 1975 in order to identify and qualify its aquaculture potential. This research has concentrated on the disciplinary fields of reproduction, nutrition, feeding and growth, health control and husbandry techniques. In the course of the years the Department has been and still is engaged in the execution of bi(multi)lateral projects** in the Central African Republic, Israel, and Indonesia devoted to this species (in Indonesia C.batrachus), which provided practical feed-back for the research carried out at the Department.

The aim of this contribution is to review - at least partly - the present state of our knowledge and thereby to illustrate the potential of this species for aquaculture development in Africa.

This work required sustained research effort by the whole staff of the Department, including great assistance from MSc- and PhD-students. Rather than listing all their names here in thankful appreciation, it seemed preferable to refer the reader to the reference list, in which they form the majority.

Reproduction

Reproductive biology and spawning habits of C.gariepinus are scarcely documented in literature, but Richter (1976) and Hogendoorn (1979) made brief literature compilations as background for their reproduction experiments.

More recently De Leeuw (1985) reviewed some aspects of reproductive endocrinology of this species.

Under natural circumstances C.gariepinus exhibits an annual reproductive cycle. In captivity this species may reach maturity at the age of 6-9 months, at which time post-vitellogenic eggs and ripe sperm cells are present, however, final oocyte maturation and ovulation, as well as spermiation do not (or seldomly) occur.

In a number of teleosts final maturation and ovulation is preceded by an increase of the GTH-release by the pituitary. Since Eding et al.(1982) demonstrated that final maturation and ovulation can be induced by exogenous administration of GTH by, for instance, injection with pituitary material or hCG, the absence of final maturation and ovulation in C.gariepinus under hatchery conditions can be explained in two ways, as follows:

- the pituitary does not produce (sufficient) GTH under these conditions, or
- the pituitary produces GTH which is not released (sufficiently).

The latter explanation proves to be valid, because recently De Leeuw (1985) demonstrated that GTH is definitively present in sufficient amounts since the administration of GTH-releasing drugs such as pimozide can be used successfully in inducing final oocyte maturation and ovulation. Obviously the trigger mechanism that evokes increased GTH-release does not (sufficiently) function under hatchery conditions.

* Clarias gariepinus is synonymous to Clarias lazera (Teugels, 1984).

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Using these artificial reproduction methods as described, normally only post-vitellogenic oocytes of over 1.0 mm in diameter will mature (Richter and Van den Hurk, 1982), however, histological examinations of the ovaries of C.gariepinus kept under hatchery conditions revealed a continuous cycle progressing from vitellogenic through post-vitellogenic into atretic follicles (Richter, unpublished).

This observation is in agreement with the fact thet C.gariepinus can be artificially reproduced in the hatchery of the Wageningen University Department throughout the year. In this respect, the observation by Janssen (1985) is worth mentioning. In Africa adult C.gariepinus transferred from outdoor stagnant ponds into the hatchery maintain their annual reproduction cycle for one year, then develop a high pseudogonadosomatic index (between 8 and 20%) which, because it is maintained during subsequent years, makes year-round artificial reproduction possible (Fig.1).

It, therefore, can be stated that many methodologies are now available for successful reproduction of C.gariepinus in captivity.

Using artificial reproduction in stagnant ponds in Cameroon, Hogendoorn (1979) obtained a fingerling production of 17.4 ± 14.4 (S.D.) per m^2 over a 5-10 week period after stocking the pond with parental fish induced with 50 mg/kg body weight of desoxycorticosterone acetate (DOCA, 0,5% in oil suspension).

Using such methods routinely in hatcheries total average egg production amounts to ± 11% of the female body weight, the individual eggs weighing 1.2-1.4 mg (Fig.2).

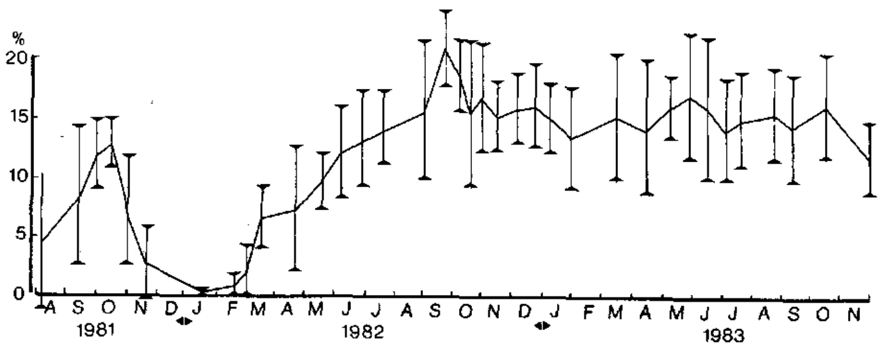

FIGURE 1. EGG PRODUCTION AS A PERCENTAGE OF FEMALE BODY WEIGHT OF C.GARIEPINUS TRANSFERRED FROM OUTDOOR PONDS INTO THE HATCHERY IN JULY 1981 (AFTER JANSSEN, 1985).

Collection of milt is normally doen by sacrificing the male, since normal stripping is impeded by the anatomical features of the genital tract.

After fertilization, incubation, hatching and larval rearing a survival rate of undeformed larvae of up to 70-80% of the eggs incubated can ususally be obtained (Hogendoorn and Vismans, 1980; Richter et al., 1985).

Apart from the fact that C.gariepinus can be reproduced throughout the year, repeated reproduction using the same female can be carried out successfully as was demonstrated by Hogendoorn and Vismans (1980). Although repeated reproduction proved possible with extremely short inter-

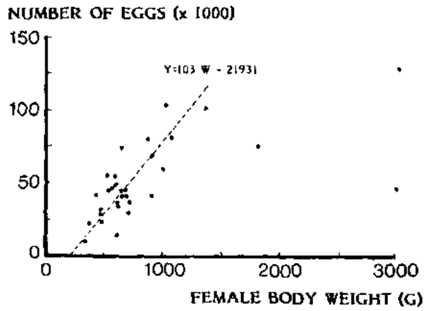

FIGURE 2. NUMBER OF EGGS PRODUCED IN RELATION TO FEMALE BODY WEIGHT. (AFTER HOGENDOORN, 1979).

vals (1, 2, and 3 weeks) the authors do not consider this very practical, since egg production drops to a mere 2.5% of the female body weight. But they argue that repeated reproduction using intervals of 6-8 weeks may be feasible under practical fish farming conditions (Fig.3).

In conclusion safe and dependable methods for reproduction of C.gariepinus in captivity - be it in ponds or in hatcheries - have been developed in such a way that reproduction of the species, and thereby supplying fry and fingerlings, no longer hold back aquaculture development of this African catfish species.

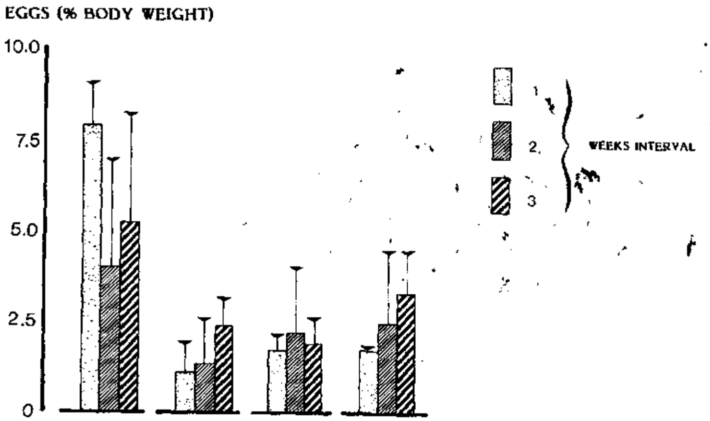

FIGURE 3. EGG PRODUCTION AS A PERCENTAGE OF FEMALE BODY WEIGHT IN RELATION TO THE INTERVAL BETWEEN FOUR SEQUENTIAL HYPOPHYSATIONS (MEAN ± S.D. OF THREE OBSERVATIONS PER TREATMENT). (AFTER HOGENDOORN AND VISMANS, 1980).

Fingerling culture

Recently raising of fry to fingerling size has been reported both in ponds using fertilizers together with additional feeding, and in hatcheries using Artemia nauplii (for first feeding) and complete diets (Hogendoorn, 1979, 1980, 1981; Janssen, 1984).

In pond culture both organic and inorganic fertilizers are applied, with additional feeding mixtures composed of highly effective brewery wastes, rice bran, cotton seed cakes, groundnut cakes and blood-meal. Excellent survival rates (90%) can be obtained in fingerling pond culture, but results may vary to quite an extent - due to predation by tadpoles, insects, etc. - and low survival rates (10%) occur frequently as well.

For this type of culture an average yield of 10-15 individuals (1-5 g) per m^2 over a 5-10 week period can be regarded as feasible under practical conditions.

Similar to other cultivated - marine or freshwater - fish species (Huisman, 1976), C.gariepinus requires, after yolk sac absorption an initial phase of exogenous feeding with natural, preferably live food organisms such as Artemia nauplii or zooplankton. Different factors mentioned in the literature e.g. physical properties of the food, food composition, leaching of food components, lack of digestive capacity, etc. (Appelbaum, 1976, 1979; Huisman, 1979; Jancaric, 1964; Van der Wind, 1979) are thought to contribute to this phenomenon, but no definite solution to this problem has been reached so far.

Experiments carried out by Hogendoorn (1980, 1981) proved that initial feeding with Artemia nauplii, followed by feeding with commercial trout starter granules, leads to excellent results, the fingerlings attaining an

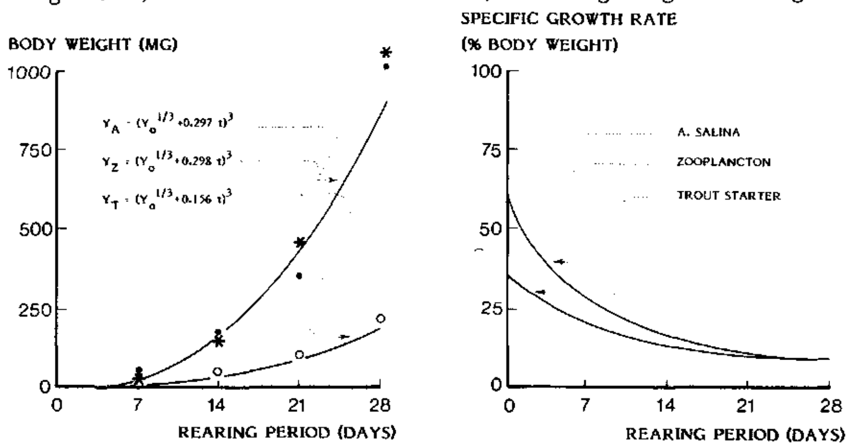

FIGURE 4. INCREASE IN BODY WEIGHT AND DECREASE IN SPECIFIC GROWTH RATE IN RELATION TO THE REARING PERIOD OF C.GARIEPINUS FRY WHEN FED WITH TROUT STARTER ALONE (o), WITH TROUT STARTER SUPPLEMENTED WITH LIVE A.SALINA NAUPLII (.) OR WITH LIVE ZOOPLANKTON (*). AVERAGES OF SAMPLES OF 20 FISH PER WEEK AND PER FEEDING REGIME (AFTER HOGENDOORN, 1980).

individual body weight of 10 g 7-8 weeks after yolk sac absorption at 30°C (Fig.4). In these experiments feed conversion values of between 0.65 and 0.92 were reported, which, compared to values obtained with other fish species, indicate that C.gariepinus is an excellent converter of fish food into fish flesh.

These results obtained under laboratory circumstances at the Wageningen Agriculture University were quite well matched under local circumstances in Africa using a feed mainly based on locally available and fairly priced ingredients as given in Appendix I.

Fattening of C.gariepinus in stagnant ponds

Fattening experiments using C.gariepinus in monoculture as well as in polyculture (with O.niloticus) were carried out in the '70s in Cameroon (Hogendoorn, 1983). More recently this has been extensively studied by the FAO Fish Culture Center at La Landjia, near Bangui in the Central African Republic.

Feeds rather similar to the one given in Appendix I were applied in these studies for additional feeding and mostly organic fertilizers were used. The following facts and figures, obtained in the years are worthwhile mentioning.

• Annual yield of C.gariepinus monoculture, double crop:	20 tons/ha
• Annual yield of C.gariepinus and O.niloticus polyculture, double crop:	10 tons/ha
• Fingerling costs:	
- C.gariepinus	10 FCFA/ind.
- O.niloticus	6 FCFA/ind.
Selling price:	
- C.gariepinus (175 g)	800 FCFA/kg
- O.niloticus (80 g)	700 FCFA/kg

Based on these and other data, Lietar (1980) and more recently Janssen (1985) have demonstrated the economic feasibility of artisanal pond farming using C.gariepinus both in mono- and in polyculture.

Based on these reports some key-figures are given in Appendix II.

Fattening of C.gariepinus in flow-through tanks

Using flow-through husbandry systems in fish culture implies that all feeds have to be supplied from external sources, the natural productivity of the water being of no importance, and, therefore, qualitative and quantitative knowledge on nutritional requirements is essential to obtain (economically) adequate results.

So far most feeding experiments in fattening C.gariepinus were carried out using commercial trout feeds (Hogendoorn, 1983; Hogendoorn et al., 1983), and concerned the effects of body weight, temperature and feeding levels on growth and growth composition. These results indicate that a feed based on the nutritional requirements of rainbow trout (Salmo gairdneri) not only meet - but may even exceed - the nutritional requirements of this African catfish species. Recommended feeding tables for extensive flow-through tank culture were calculated with reference to these experiments (Table 1)

Table 1. Recommended feeding levels (% body weight.day^{-1}) and corresponding estimated growth rates (% body weight.day^{-1}) for **C.lazera** from 1 to 200 g between 20 and 35°C (After Hogendoorn et al., 1983).

Temp. (°C)	Body weight (g) 1	5	25	50	100	200
20	2.9(3.1)	1.9(2.6)	1.2(1.5)	1.0(1.1)	0.9(0.6)	
21	3.6(4.2)	2.5(3.6)	1.7(2.3)	1.4(1.7)	1.2(1.0)	1.0(0.4)
22	4.4(5.3)	3.1(4.6)	2.2(3.0)	1.9(2.3)	1.6(1.4)	1.4(0.6)
23	5.1(6.3)	3.7(5.6)	2.6(3.8)	2.3(2.9)	2.0(1.9)	1.7(0.9)
24	5.8(7.2)	4.2(6.5)	3.1(4.4)	2.7(3.4)	2.3(2.2)	2.0(1.1)
25	6.5(8.0)	4.7(7.3)	3.4(5.0)	3.0(3.8)	2.6(2.6)	2.3(1.2)
26	7.0(8.7)	5.1(7.9)	3.7(5.4)	3.3(4.2)	2.8(2.8)	2.5(1.4)
27	7.4(9.2)	5.4(8.3)	3.9(5.7)	3.4(4.4)	3.0(2.9)	2.6(1.4)
28	7.7(9.6)	5.6(8.5)	4.0(5.8)	3.5(4.4)	3.0(2.9)	2.6(1.4)
29	7.9(9.7)	5.6(8.6)	4.0(5.7)	3.5(4.3)	3.0(2.8)	2.6(1.3)
30	8.0(9.7)	5.6(8.5)	3.9(5.6)	3.4(4.2)	2.9(2.7)	2.5(1.2)
31	8.0(9.6)	5.5(8.5)	3.8(5.2)	3.2(3.9)	2.7(2.4)	2.3(1.1)
32	7.9(9.3)	5.3(7.7)	3.6(4.8)	3.0(3.5)	2.6(2.2)	
33	7.8(8.8)	5.1(7.2)	3.4(4.3)	2.8(3.1)		
34	7.5(8.2)	4.8(6.5)				
35	7.2(7.5)	4.5(5.8)				

C.gariepinus proved to be a very suitable species for high density culture, performing a high growth rate all the while maintaining very efficient feed utilization. It has been demonstrated that in intensive tank culture - providing optimal conditions prevail - C.gariepinus can attain a body weight of 300-500 g in 6-7 months at temperature of 25-30°C, while average feed conversion rates amount to 0.9-1.2.

More recently nutritional studies have focussed on the formulation of a specific diet for C.gariepinus. The effect of dietary protein and energy content on the growth performance of C.gariepinus, taking into account temperature and body composition, have been extensively studied (Machiels & Henken, 1985; Henken et al., 1985; Henken et al., 1986). This research, partly carried out with semi-purified diets is aimed, on the one hand, at dynamic modelling of growth and growth performance, and, on the other, at evaluating feed ingredients for optimal feed formulation.

For the purpose of this review the main results obtained up to now are given in Table 2, (Henken et al., 1986).

Apart from temperature, body composition was demonstrated to have a major effect on feed utilization and growth rate, in the sense that under similar experimental circumstances growth rates in fishes with low body fat content was about twice as high as in fishes with high body fat content (Machiels & Van Dam, unpublished results).

Table 2. Intake levels of crude protein (up to 60% in the dry diet) and metabolizable energy (up to 21 kJ per gram of dry diet), which give the highest values for the following production parameters.

PARAMETER	CRUDE PROTEIN ($g.d^{-1}.kg^{-0.8}$)		METABOLIZABLE ENERGY ($kJ.d^{-1}.kg^{-0.8}$)	
	24°C	29°C	24°C	29°C
GROWTH RATE	4.03	7.33	158.77	210.99
FEED CONVERSION	3.83	5.67	137.60	186.26
PROTEIN GAIN	4.23	↗	139.83	183.16
FAT GAIN	↘	3.26	↗	↗
ENERGY GAIN	3.36	4.92	182.18	↗
PROTEIN EFFICIENCY RATIO	↘	↘	150.97	207.90
APPARENT NET PROTEIN UTILIZATION	↘	2.70	139.83	186.26
EFFICIENCY OF ENERGIC GAIN	3.31	4.83	110.85	172.34

N.B. Parameter value increased (↗) or decreased (↘) with increased intake.

Health control

In general C.gariepinus is a less sensitive fish and - under adequate conditions - will resist, to quite an extent, to pressure from infectious agens. Apart from protozoic and metazoic infestations with common parasites like Costia, Chilodonella, Dactylogyrus, etc., which in case of hazards can easily be controlled with organic phosphate esters (Bromex(R), Dipterex(R), Masoten(R), C.gariepinus is rather sensitive to myxobacterial infections. This infection is mainly associated with "environmental" changes (temperature, water quality, handling of fish, etc.) and can cause trouble, in high density fingerling culture. Antibiotics like chloramphenicol and oxytetracycline are required as curative agents.

Apart from diseases mentioned previously, two syndromesof so far, unknown aetiology occur.

The first one is mostly found in the fingerling stage and concerns a rupture in the caudal part of the intestinal tract, the intestinal fluid flowing into the abdominal cavity. The occurrence of this syndrome, which can result in losses of up to 40% or more, seems to be associated with high intake levels of feeds with low fibre contents.

The second one causes destruction of the arborescent organs and leads to an inflammation of the skull resulting in a lateral skull-break, parallel to the skull plate joints. These symptoms are seldom found in fish smaller than 10 cm.

It must be stressed that apart from curing diseases, the real nature of health control involves emphasis on health as such, which is a multifacetted managerial activity comprising adequate husbandry systems and techniques, water quality control and other aspects.

Husbandry of C.gariepinus

A section on husbandry may deal with a variety of topics, however, the author prefers to restrict this section to some aspects which illustrate the aquaculture potential of C.gariepinus.

Firstly, it must be emphasized that fish can be regarded as a combustion engine, in which the inputs e.g. oxygen and fuel (feed) result in the outputs e.g. waste and performance (growth, activity, etc.). In case feed is not limited, the influx of oxygen into the "engine" controls the extent to which fuel will be combusted and as such controls the performance.

In this respect it must be realised that C.gariepinus is an air-breathing catfish and, therefore, oxygen influx into this "engine" will take place not only via the water but also via the air, the latter containing about 30 times more oxygen per unit of volume than the former. This explains why C.gariepinus can tolerate extremely high densities per unit of water volume and per unit of water exchange.

Second catfish species in general exhibit a rather lethargic behaviour which results in low maintenance requirements. The efficiency of feed conversion has been demonstrated by Hogendoorn (1983), who showed that C.gariepinus utilizes up to 80% of the dietary metabolizable energy for growth, which compares favourably with values for non-air-breathing fishes like trout and carp (Cyprinus carpio) fed with the same diet (Huisman, 1976).

These two facts together lead to the stunning production capacity of air-breathing catfishes. In Thailand air-breathing C.batrachus have yielded over 80 tons per ha annually in stagnant ponds (Panayotou et al., 1982).

In Central African Republic small scale farmers achieved production levels of somewhat over 26 tons per ha annually (Janssen, 1983).

Key figures routinely obtained in the Wageningen Agriculture University Department are given in Table 3 and may illustrate the potential of this species for intensive flow-through tank culture.

Table 3. Key figures routinely obtained in intensive flow-through tank culture of C.gariepinus.

Tanks:	volume (l)	900
	surface (m^2)	2.5
Stocking:	biomass (kg)	180.7
	ind.wt (g)	105.1
	weight ratio fish : water	1:4
Duration of experiment (days)		61
Feed consumed (kg)		175.4
Water flow (l/min)		30
Harvest:	biomass (kg)	360
	ind.wt (g)	237.3
	weight ration fish : water	1:1.5
Feed conversion (kg feed/kg gain)		0.98

Based on oxygen consumption data for 200 g growing carp (Huisman, 1974) calculations indicate that water requirements for C.gariepinus culture will only amount to some 4-5% of those of a comparable carp culture, and the same values can de expected to be obtained in comparisons with other non-air-breathing fish species.

Conclusions

Huet (1972) has listed a few main prerequisites for promising aquaculture candidate species, as follows:

- be acceptable to the consumer,
- be adapted to the climate,
- be able to mature and reproduce in captivity,
- accept and thrive on cheap feeds
- have a high growth rate
- support high density under culture conditions, and
- be resistant against diseases.

Considering that C.gariepinus, in quite a number on countries in Africa, ranks high on the consumer preference list: for fresh-water fish species, frequently coming just after Nile perch, Lates niloticus, and considering its native range (Richter, 1976) as well as the data from the previous chapters, there is no doubt that this species may be considered as an excellent candidate for aquaculture development in the Africa region in general and for the commercial development of aquaculture in particular. Careful and strategic planning with respect to utilizable resources (land, water, feed inputs, fertilizer, manpower, etc.) on a national and/or regional level will prove whether such potential can be fulfilled and which aquaculture husbandry and farming systems can be instrumental to such development.

References

Appelbaum, S., 1977. Geeigneter Ersatz für Lebendnahrung von Karpfenbrut? Archiv. Fisch.Wiss., 28(1) : 31-48.

Appelbaum, S., 1979. The suitability of alkan-yeast (hydro-carbon grown yeast) as a first nutrient for **Coregonus albula** (L.) fry. In: J.E.Halver and K.Tiews (Editors), Finfish Nutrition and Fishfeed Technology I. Heenemann & Co, Berlin, pp.479-489.

Eding, E.H., Janssen, J.A.L., Kleine Staarman, G.H.J. and Richter, C.J.J., 1982. Effects of human chorionic gonadotropin (hCG) on maturation and ovulation of oocytes in the ovary of the African catfish, **Clarias lazera** (C.& V.). In: C.J.J.Richter and H.J.Th.Goos (Editors), Proceedings of the International Symposium on Reproductive Physiology of Fish, Pudoc, Wageningen, pp.195.

Henken, A.M., Kleingeld, D.W. and Tijssen, P.A.T., 1985. The effect of feeding level on apparent digestibility of dietary dry matter, crude protein and gross energy in the African catfish, **Clarias gariepinus** (Burchell, 1822). Aquaculture (accepted).

Henken, A.M., Machiels, M.A.M., Dekker, W. and Hogendoorn, H., (1986). The effect of dietary protein and energy content on growth rate and feed utilization of the African catfish, **Clarias gariepinus** (Burchell, 1822). Aquaculture (submitted).

Hogendoorn, H., 1979. Controlled propagation of the African catfish, **Clarias lazera** (C.& V.) I. Reproductive biology and field experiments. Aquaculture, 17: 323-333.

Hogendoorn, H., 1980. Controlled propagation of the African catfish, **Clarias lazera** (C.& V.) III. Feeding and growth of fry. Aquaculture, 21: 233-241.

Hogendoorn, H., 1981. Controlled propagation of the African catfish, **Clarias lazera** (C.& V.) IV. Effect of feeding regime in fingerling culture. Aquaculture, 24: 123-131.

Hogendoorn, H., 1983. Growth and production of the African catfish, **Clarias lazera** (C.& V.) I. Effects of stocking density, pond size and mixed culture with tilapia (**Sarotherodon niloticus** L.) under extensive field conditions. Aquaculture, 34: 253-263.

Hogendoorn, H., 1983. Growth and production of the African catfish, **Clarias lazera** (C.& V.) III. Bio-energetic relations of bodyweight and feeding level. Aquaculture, 35: 1-17.

Hogendoorn, H. and Vismans, M.M., 1980. Controlled propagation of the African catfish, **Clarias lazera** (C.& V.) II. Artificial reproduction. Aquaculture, 21: 39-53.

Hogendoorn, H., Janssen, J.A.J., Koops, W.J., Machiels, M.A.M., Van Ewijk, P.H. and Van Hees, J.P., 1983. Growth and production of the African catfish, **Clarias lazera** (C.& V.) II. Effects of body weight, temperature and feeding level in intensive tank culture. Aquaculture, 34: 265-285.

Huisman, E.A., 1974. (A study on optimal rearing conditions for carp (**Cyprinus carpio** L.)). (In Dutch with English summary). PhD-thesis, Wageningen Agriculture University, 95 pp.

Huisman, E.A., 1976. Hatchery and nursery operations in fish culture management. In: E.A.Huisman (Editor), Aspects of fish culture and fish breeding. Misc.Pap. 13. Wageningen Agriculture University, pp. 29-54.

Huisman, E.A., 1976. Food conversion efficiencies at maintenance and production levels for carp (**Cyprinus carpio** L.) and rainbow trout (**Salmo gairdneri**, Rich.) Aquaculture, 9: 259-273.

Huisman, E.A., 1979. The role of fry and fingerling supply in fish culture (Chairman's introduction). In: E.A.Huisman and H.Hogendoorn (Editors), EIFAC Workshop on mass rearing of fry and fingerlings of fresh water fishes/Papers. EIFAC/FAO Techn.Pap.35 Suppl.10, pp.3-7.

Huet, M., 1972. Textbook of Fish Culture. Fishing News (Books) Ltd. 436 pp.
Jancaric, A., 1964. Die Verdauung der Haubtnährstoffe beim Karpfen. Zeitschr. Fischerei 12, (8/9/10):601-655.
Janssen, J.A.L., 1983. Premier rapport semestre 1983 du Projet GCP/CAF/007/ NET, FAO, 13 pp.
Janssen, J.A.L., 1984. Premier rapport semestriel 1984 du Projet GCP/CAF/007/ NET, FAO, 21 pp.
Janssen, J.A.L., 1985. L'élévage du poisson-chat Africain, **Clarias gariepinus**, en République Centrafricaine. FAO. (In preparation).
Leeuw, R.de, 1985. Regulation of gonadotropin secretion in theAfrican catfish, **Clarias gariepinus** (Burchell). Thesis State University of Utrecht (in press).
Lietar, C., 1980. Rentabilité d'une ferme piscicole commerciale en République Centrafricaine. Document Technique No.18. Haut Commissariat chargé des Eaux, Forêts, Chasses, Pêches et du Tourisme, Projet CAF/80/002. pp.45.
Machiels, M.A.M. and Henken, A.M., 1985. Growth rate, feed utilization and energy metabolism of the African catfish, **Clarias gariepinus** (Burchell, 1822), as affected by dietary protein and energy content. Aquaculture, 44: 271-284.
Panayotou, T., Wattanutchariya, S., Isvilanonda, S. and Tokrisna, R., 1982. The economics of catfish farming in Central Thailand. International Center for Living Aquatic Resources Management (ICLARM), Manilla, 60 pp.
Richter, C.J.J., 1976. The African catfish, **Clarias lazera** (C.& V.), a new possibility for fish culture in the tropical regions? In: E.A.Huisman (Editor). Aspects of fish culture and fish breeding. Misc.Pap. 13. Wageningen Agriculture University. pp. 51-71.
Richter, C.J.J. and van den Hurk, R., 1982. Effects of 11-desoxycorticosterone-acetate and carp pituitary suspension on follicle maturation in the ovaries of the African catfish, **Clarias lazera** (C.& V.). Aquaculture, 29: 53-66.
Richter, C.J.J., Eding, E.H. and Roem, A.J., 1985. 17 Hydroxy-progesterone-induced breeding of theAfrican catfish, **Clarias gariepinus** (Burchell), without priming with gonadotropin. Aquaculture, 44: 285-293.
Wind, J.J.van der, 1979. Feeds and feeding in fry and fingerling culture.. In: E.A. Huisman and H.Hogendoorn (Editors), EIFAC Workshop on mass rearing of fry and fingerlings of fresh water fishes/Papers. EIFAC/FAO Techn.Pap.35 Suppl.1: 59-72.

Appendix I.

Composition and analysis of a dry diet for **C.gariepinus** (1-200 g) formulated mainly with ingredients locally available in central Africa (Janssen, 1984). 1984).

Composition		Analysis	
Ingredient	%	Contents	%
Dry brewery waste	10	Crude protein	40
Rice bran	15	Crude fat	10
Ground maize	6.25	Nitrogen free-extract	30
Cotton seed cake	25	Ash	9
Groundnut cake	25	Moisture	11
Sesam cake	10		
Blood meal	5		
Dicalciumphosphate	1		
Bone meal	1		
Palm oil	1		
Salt	0.5		
Vitamin-Mineral mix	0.25		

Appendix II.

Economics of **C.gariepinus** culture (price level 1985; Central African Republic).

A. Estimated investment and depreciation of a 5 are pond (interest 12% per annum).

Item	Depreciation period (yr)	Capital recovery factor	Investment (FCFA)	Depreciation (FCFA)
Pond	25	0.128	180,000	23,050
Equipment	5	0.277	35,000	9,700
		Totals	215,000	32,750

B. Estimated annual running costs and returns for mono- and polyculture (FCFA).

	Monoculture	Polyculture
Costs: depreciation	32,750	32,750
maintenance (1.5% of investment)	3,250	3,250
chemicals, fertilizers, feeds	350,000	111,000
fingerlings	100,000	32,000
labor	63,000	42,000
Subtotal	549,000	221,000
Contingencies (10%)	55,000	22,000
Total	604,000	243,000
Returns:	800,000	350,000

PREMIERS RÉSULTATS SUR LA REPRODUCTION CONTROLÉE DE CHRYSICHTHYS NIGRODIGITATUS EN MILIEU D'ÉLEVAGE

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Résumé

L'intérêt économique potentiel que représente l'élevage de Chrysichthys nigrodigitatus nous a amené à consacrer un effort de rescherche particulier en ce qui concerne la maîtrise de la reprodcution de cette espèce dont dépend toute possibilité de production à grande échelle d'alevins et d'individus adultes.

La méthodologie d'approche a été inspirée de celle utilisée lors de nos études antérieures sur la reproduction de Chrysichthys walkeri en utilisant le principe de "confinement" des géniteurs matures dans des tubes obscurs en PVC. Notre action consiste à aider la maturation des gonades à s'achever en milieu controlé. 102 pontes ont été ainsi obtenues. Un premier modèle de prévision de ponte, à partir de la moyenne des diamètres des ovocytes (prélevés in vivo par biopsie ovarienne), a été établie. Une première relation entre la fécondité effective (quantité d'oeufs récoltés à partir d'une ponte) et le poids de la femelle correspondante a été également établie. Une quantité effective de 14 oeufs par gramme de poids de la femelle a été estimée. Enfin la saison de reproduction pour cette espèce ainsi que les conditions physico-chimiques relatives ont été enregistrées.

Summary

The potential economic value of farmed C.nigrodigitatus inspired special research on controlled reproduction, the key factor in large-scale production of both fry and adults.

The methodology was derived from earlier studies on the reproduction of C.walkeri using the principle of confining male spawners in PVC dark basins. The research focussed gonad maturation under controlled conditions. 102 spawns were produced during the study. A spawn forecasting model was made based on the average of oocyte diameters (removed in vivo through a biopsy of the ovary). A preliminary relationship between fecundity (number of eggs collected at each spawn) and the weight of the female was established to be 14 eggs per gram of female. Information on the spawning season and the related physico-chemical conditions were recorded.

Introduction

Il est difficile d'imaginer que l'on puisse à bien l'élevage économique d'une espèce animale quelle qu'elle soit, si l'on ne peut obtenir facilement, par un moyen quelconque, les jeunes individus pour renouveler le stock. Ce problème, qui est général en élevage terrestre, est particulièrement déterminant en aquaculture où le besoin en quantités suffisantes d'alevins est souvent très important.

Il existe deux solutions à ce problème.

- L'approvisionnement pourrait se faire par prélévement d'alevins dans le milieu naturel. Ce procédé est valable pour certaines espèces (Chanos chanos, Mugil spp., Tilapia spp, Oreochromis spp., Chrysichthys walkeri..) et difficile ou même impossible pour d'autre. L'exemple de Chrysichthys nigrodigitatus est typique de cette impossibilité, les zones et la biologie de reproduction en milieu naturel étant mal connues.

- La deuxième solution est la maîtrise, partielle ou totale, de la reproduction. Elle consiste à amener les géniteurs à se reproduire en milieu contrôlé et à pouvoir élever les alevins jusqu'à la taille commerciale.

Chrysichthys nigrodigitatus (Bagridae, Siluriformes) est une espèce très appréciée dans le nombreux pays d'Afrique. Depuis quelques années, elle a fait l'objet d'études et de nombreuses observations (Daget & Iltis, 1965; Dia, 1975; Kola & Olaniyan, 1975; Micha & Frank, 1976; Sivalingam, 1976).

Au Nigeria cette espèce figure parmi les espèces aquacoles choisies par le Troisième Plan national de Développement (Dada, 1976), dans le cadre duquel la reproduction par voie hormonale a été tentée.

Quelques essais d'élevage en étang et en enclos de C.nigrodigitatus ont été signalés respectivement par Ezenwa au Nigeria (1976) et par Hem en Côte d'Ivoire (1982). Mais cette activité n'a pu être développée du fait de la difficulté de se procurer des alevins.

Depuis 1979, un effort particulier a été consenti à la résolution de ce problème et a abouti en 1984 à l'obtention d'une centaine de pontes à la station de pisciculture expérimentale de Layo (Photo 1).

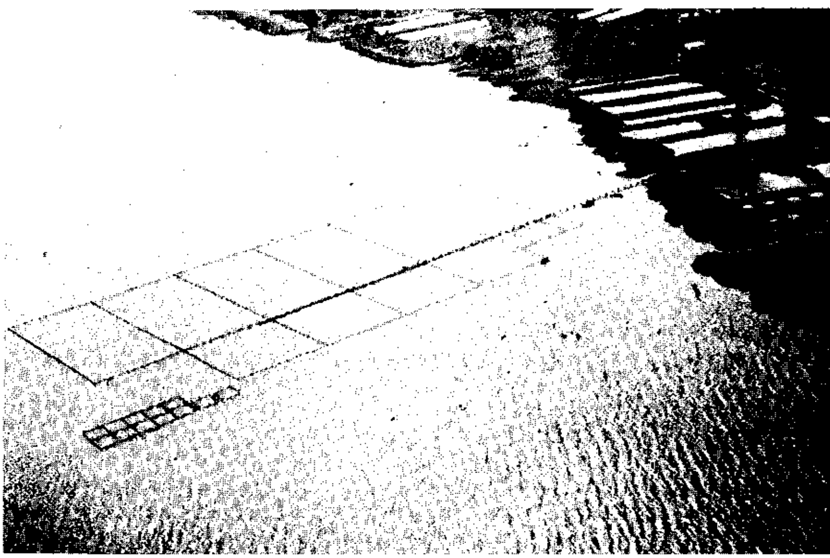

Photo 1. Vue aérienne de la station de recherches piscicoles de Layo.

La présente publication décrit l'ensemble des procédés utilisés permettant le début du contrôle de la reproduction chez Chrysichthys nigrodigitatus: depuis la sélection des géniteurs jusqu'à l'incubation des oeufs. Une première analyse du rôle des facteurs externes dans le processus de maturation des gonades est également effectuée.

Materiels et methodes

Preparation des geniteurs

Les géniteurs utilisés dans cette étude ont été maintenus séparés du stock de grossissement. Ils sont constitués essentiellement d'individus qui sont nés en captivité en 1980 et en 1981 (Photo 2). Le poids moyen individuel, pris à la date de sélection (28-2-1984), était de 1.020 g. Deux cent couples ont été ainsi sélectionnés et stockés (màles et femelles ensemble) dans des enclos à géniteurs, à faible densité de stockage (un poisson tous les 9 à 10 m^2). Ces individus sélectionnés sont nourris cinq jours par semaine avec des granulés "màchoiron" (environ 35% de protéine totale) suivant une eation journalière de 4% de la biomasse, ration inspirée de celle des géniteurs de Ictalurus punctatus (Bardach et al., 1972). Et une fois par semaine, ils sont nourris avec de boeuf frais selon une ration de 1% de la biomasse.

Photo 2. Sélection des géniteurs issus des premieres pontes en captivité à la station de Layo en 1980 et 1981.

Contrôle et sélection

Des pêches de contrôle ont été effectuées mensuellement. Ce contrôle a deux objectifs: *évaluer la maturité sexuelle et suivre* l'évolution des paramètres de condition des géniteurs (poids-longueur). Une croissance importante a été observée pendant cette période de 4 mois. Une augmentation moyenne de 30 à 40% par rapport à leur poids initial a été notée.

La sélection des géniteurs prêts pour la reproduction s'effectue premièrement par des examens morphologiques et deuxièment par des biopsies ovariennes avec des examens plus précis en laboratoire (biométrie, diamètre des ovocytes, position de la vésicule germinative, etc.).

Formation des couples

A partir des individus sélectionnés à chaque contrôle mensuel, des couples sont formés.

Un mâle et une femelle ayant une taille similaire, sont en général choisis pour former un couple.

Chaque couple est maintenu enfermé en confinement dans un réceptacle de ponte constitué par un tube en PVC de 30 cm de diamètre et de 80 cm de longueur (Fig.2).

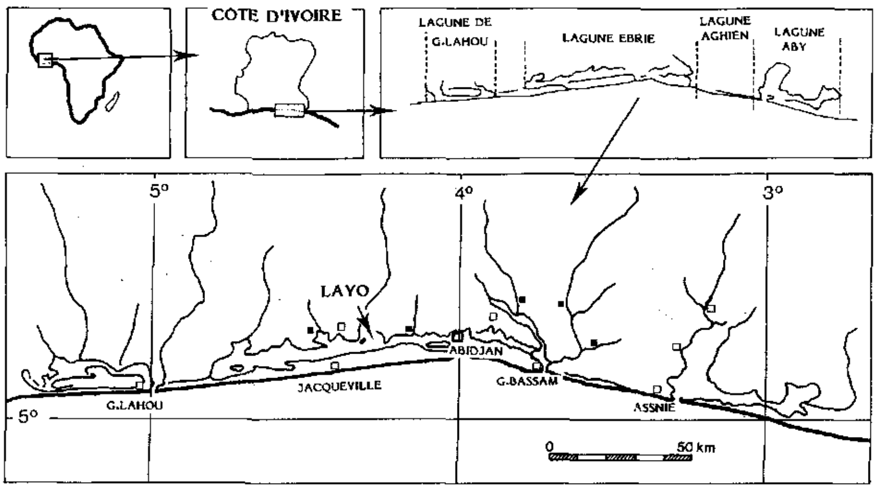

FIGURE 1. SITUATION GÉOGRAPHIQUE DE LA STATION DE LAYO, À PROXIMITÉ DE L'EMBOUCHURE DE LA RIVIÈRE AGNÉBY. (CARTE INSPIRÉE DE LA PUBLICATION DE DURAND ET CHANTRAINE, 1983).

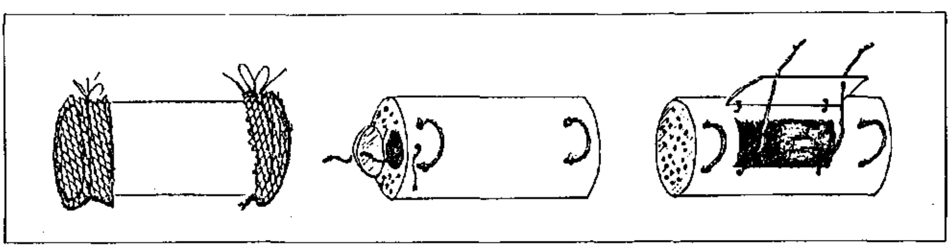

FIGURE 2. RECEPTACLE DE PONTE EN PVC. LES TROIS FORMES DE RECEPTACLE UTILISÉES LORS DE CETTE ÉTUDE.

Photo 3. Prise de vue des réceptacles n° 1 et 2.

Ces couples sont maintenus à jeûn jusqu'à la ponte. Ils sont placés par groupes de 4 ans un bassin en béton de 4 m³ de volume alimenté continuellement par l'eau de lagune (Fig.3). Le débit est d'environ 1 m³/heure.

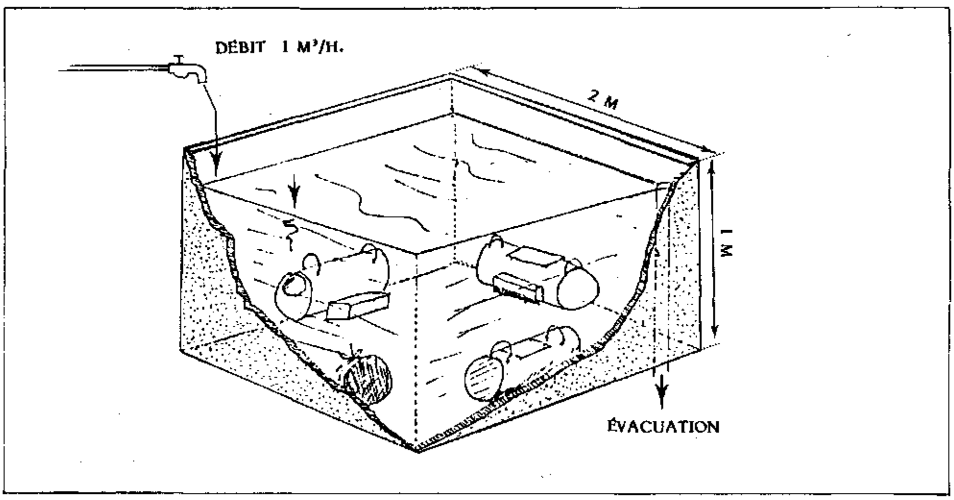

FIGURE 3. DISPOSITION DES RÉCEPTACLES DANS LE BASSIN EN BÉTON.

Contrôle de la maturité sexuelle des géniteurs en confinement: biopsie ovarienne et biométrie.

Le contrôle s'effectue environ tous les 15 jours. Il existe effectivement des caractéristiques telles que coloration du corps, aspect de la papille génitale, embonpoint du ventre, etc., qui pourraient permettre de reconnaître des géniteurs en fin de maturation. Ces caractéristiques présentent cependant un inconvénient: ce sont des critères subjectifs difficilement quantifiables.

Dans le cadre du contrôle de la maturité chez Chrysichthys nigrodigitatus, nous avons tenté de mettre au point quelques paramètres biométriques à caractère plus objectif.

- Chez le mâle, 4 paramètres ont été utilisés: poids frais (P), longueur à la fourche (LF), distance entre les fentes operculaires (LOP) et largeur de la tête prise au niveau des jeux, LT (Fig.4).
- Chez la femelle, en plus des paramètres biométriques externes (poids, longueur à la fourche, distance entre les fentes operculaires, largeur du ventre LVT) une biopsie ovarienne, a été effectuée.

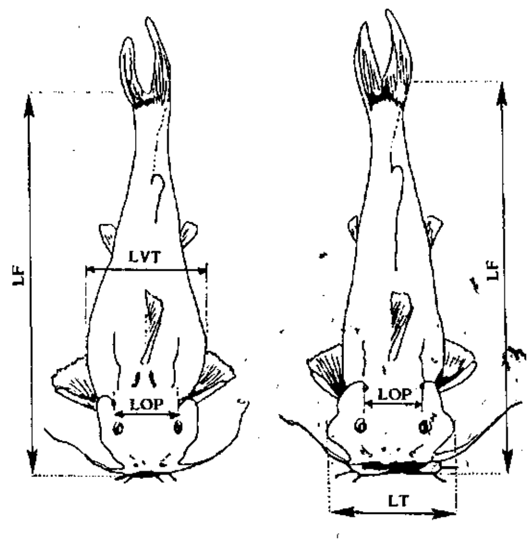

FIGURE 4. PARAMÈTRES BIOMÉTRIQUES UTILISÉS POUR TENTER DE QUANTIFIER LA MATURITÉ DES GÉNITEURS.

Le prélèvement des ovocytes s'effectue par l'intermédiaire d'un cathéter souple (Photo 4), procédé djâ utilisé chez le genre Ictalurus (Markmann & Doroshov, 1983). Un échantillon d'environ 15 à 20 ovocytes est prélevé à chaque biopsie. Le liquide de Serra a été choisi comme liquide éclaircisseur pour examiner la vésicule germinative. L'échelle de la position de la vésicule germanitive est inspirée de celle utilisée par Jalabert et al. (1977). Chaque ovocyte est mesuré sous une loupe binoculaire à l'aide d'un micromètre oculaire. Les mesures ont été effectuées suivant deux diamètres: d, petit diamètre et D, grand diamètre. La moyenne géométrique de ces deux valeurs donne le diamètre théorique de l'ovocyte considéré.

Photo 4. Biopsie ovarienne.

Le degré de maturité d'une femelle prise à l'instant t est ainsi quantifié par la moyenne arithmétique des diamètres théoriques de ces ovocytes échantillonnés.

Lors de chaque biopsie ovarienne, quelques autres renseignements supplémentaires sont également notés tels que: facilité de pénétration du cathéter, résistance à la succion, présence ou non des oeufs opaques, présence ou non de substance interovulaire.

Tous ces renseignements sont saisis dans une fiche appelée "fiche de biopsie" qui permet de visualiser l'évolution d'un couple depuis la date de mise en tube jusqu'à la ponte.

Récolte des données à l'issue de chaque ponte

Après chaque ponte, quelques éléments importants ont été enregistrés tels que la date de ponte, la masse d'oeufs récoltés, le pourcentage de fécondation et la biométrie des géniteurs après la ponte. Les oeufs fécondés sont séparés des geniteurs et placés dans des incubateurs à panier mobile. Les géniteurs sont marqués individuellement au bleu Alcian par l'intermédiaire d'un dermojet. Ce marquage individuel a permis de suivre la reprise de la maturation des géniteurs et leur croissance dans l'enclos. Un calcul rétrospectif du nombre de jours avant la ponte (relatif au diamètre observé lors de chaque biopsie) est effectué après chaque ponte.

Récolte des paramètres physico-chimiques

Trois paramètres physico-chimique ont été considerés durant toute l'année à savoir la salinité, la température et le pH.

La salinité et le pH sont mesurés respectivement par un salinamètre optique et par un pHmètre à papier gradué de 1 à 14.

Pour la température deux types de valeur ont été prises en considération:

- Valeurs à partir de thermomètres maximum-minimum, gradués à un degré près, disposés d'une part dans la lagune et d'autre part dans un des bassins en béton où se trouvent des géniteurs en confinement et
- Valeurs instantanées à partir d'un thermomètre à meroure gradué au 1/10°C.

La température d l'air a été également prise parallèlement par un même type de thermomètre maxi-mini.

Ces trois paramètres sont collectés systématiquement tous les jours et servent à l'ensemble des programmes de recherche de la station.

Résultats et observations

Maturation des gonades et saison de ponte

Les biopsies ovariennes effectuées mensuellement ont permis de localiser la période de début de maturation (Fig.5). Elle coïncide avec le début de la baisse de température de l'eau de lagune causée par les premières pluies de l'année observées en mai. Le diamétre des ovocytes continue à augmenter. Ils passant de 1 mm en début mai à 2,3 mm en début juillet. Cette valeur semble se stabiliser avec la température minimale (autour de 25°5C) observée entre mi-juillet et mi-août. Une augmentation rapide de la diamètre des ovocytes, semble avoir une relation avec la période de réchauffement en août qui correspond à la petite saison sèche. C'est le début de la saison de reproduction qui est marqué par l'apparition des premières pontes de l'année. Le maximum de ponte est observé en septembre. Le nombre de pontes diminue ensuite graduellement jusqu'en décembre.

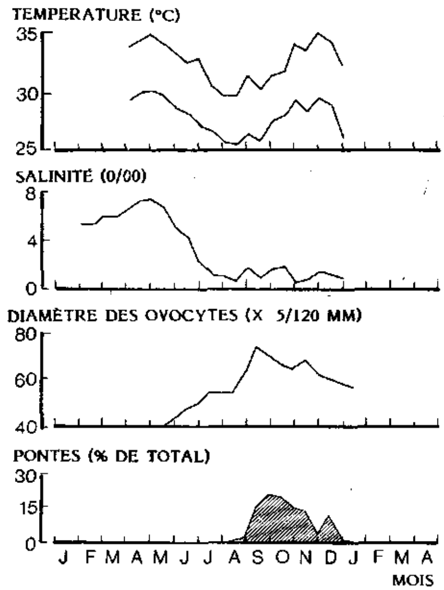

FIGURE 5. EVOLUTION PARALÈLLE DES FACTEURS PHYSICO-CHIMIQUE (ICI TEMPÉRATURE ET SALINITÉ) ET DES PARAMÈTRES BIOLOGIQUES DE LA REPRODUCTION (DIAMÈTRE DES OVOCYTES ET DES FRÉQUENCES MENSUELLES DE PONTES).

L'évolution de la salinité est liée aux deux grandes saisons de l'année. La salinité se situe entre 5 et 6% pendant la grande saison sèche (janvier à mai) et se stabilise autour de 1% de août à décembre. Le mois de juin et juillet constituent la période de transition de ces deux extrèmes.

Contrairement à ces deux paramètres, le pH varie peu. La valeur de 6,5 est constamment trouvée durant toute l'année.

Les 102 pontes obtenues en 1984 sont inégalement réparties sur cinq mois (Fig.5). Les premières pontes ont débuté vers la deuxième quinzaine d'août (2%). Elles présentent un pic très net en septembre (35%). Elles commencent à décroître en octobre (34%). Cette baisse continue jusqu'en novembre (17%), puis elles se terminent en décembre (12%). En janvier, février, mars 1985, aucune ponte n'a été enrégistrée.

Notons que parmi les 110 couples mis en confinement, huit seulement n'ont pas pondu. A partir du mois de janvier (1985), le début de résorption des ovocytes est observé chez ces huit femelles, tandis que les mâles ne présentent plus d'apparence de mâles natures: la tête et la bouche deviennent moins larges, le corps devient très maigre et prend une coloration noire.

Modèle de prévision de la ponte à partir du diamètre des ovocytes

Un calcul rétrospectif de Nj (le nombre de jours avant la ponte relatif au diamètre observé Di lors de chaque biopsie), est effectué après chaque pont (Fig.6).

* Ji = Nombre de jours cumulés depuis la mise en confinement à l'instant i.

* Jp = Nombre total de jours pour parvenir à la ponte.

* Nj = Nombre de jours avant la ponte, avec Nj = Jp - Ji.

* Di = Diamètre instantané.

208 couples de valeurs de Nj et de Di ont été saisis. Portés en coordonnées rectangulaires avec Di en abcisse et Nj en ordonnée, iles forment un "nuage de points" qui visualise la corrélation entre Nj et Di selon l'équation exponentielle suivante:

$$Y = 5609 \exp^{-0.084(X)}$$

avec r2 = 0.68
(r2 est le coefficient de détermination)

Y = Nj, le nombre de jours avant la ponte, exprimé en jours,
X = Di, le diamètre des ovocytes exprimé en unité de graduation micrométrique qui correspond en millimètre :

1 graduation $= \frac{5}{120}$ millimètre

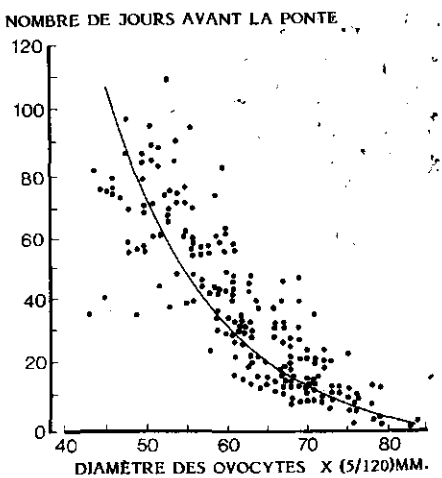

FIGURE 6. COURBE ILLUSTRANT LA RELATION ENTRE LE DIAMÈTRE DES OVOCYTES ET LE NOMBRE DE JOURS À PARVENIR À LA PONTE.

Il existe donc une relation entre le diamètre des ovocytes et le temps de ponte. Comme application des résultats de ces observations on pourrait utiliser le diamètre moyen des ovocytes comme critère de sélection et même comme critère de prévision de la date de ponte pendant la période de reproduction c'est-à-dire entre août et novembre.

Fécondité effective

A l'issue de chaque ponte, les oeufs récoltés (à l'exception de ceux découverts au moment de l'éclosion) ont été pesés et échantillonnés pour estimer leur nombre.

60 couples de valeurs constitués d'une part du nombre d'oeufs récoltés et d'autre part du poids de la femelle correspondante ont été saisis. En coordonnées rectangulaires le nombre d'oeufs étant porté en ordonnée et le poids de la femelle en abcisse. Ces données font apparaître la corrélation de la forme suivante :

$$Y = a\,x^b$$

avec $a = 29{,}45$
$b = 0{,}92$
$r2 = 0{,}54$

(r2, coefficient de détermination)

L'exposant $b = 0{,}92$ montre bien que la corrélation est presque linéaire.

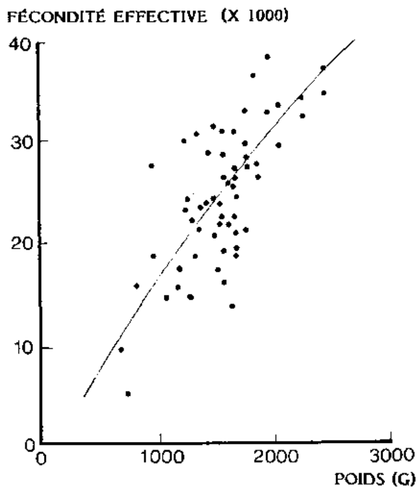

FIGURE 7. COURBE ILLUSTRANT LA RELATION ENTRE LA FÉCONDITÉ EFFECTIVE ET LE POIDS DE LA FEMELLE.

Incubation et résorption vitelline

Les oeufs collectés sont mis en incubation dans des incubateurs à panier mobile. Nous n'avons pas pu effectuer d'étude pour présenter des chiffres précis sur le taux d'éclosion. Mais le résultat général est très satisfaisant et nous pouvons estimer grossièrement la perte moyenne à moins de 20%.

Il faut signaler qu'un fort taux de perte en oeufs a été noté à la fin de la saison de reproduction (fin novembre et début décembre). Il semble être dû à des mauvaises fécondations (vieillissement de gamètes en fin de saison ?) plutôt qu'aux conditions d'incubation.

L'incubation, se déroulant dans de bonnes conditions, dure cinq jours. La gamme de température optimale est entre 27°C et 29°C.

Le transfert des larves vers la structure d'alevinage se fait pendant la période de résorption vitelline, soit 5ème ou 6ème jour après l'éclosion. La résorption complète de la réserve vitelline aura lieu vers le 10ème jour, date à partir de laquelle les larves doivent être nourries et élevées selon la technique utilisée pour Chrysichthys walkeri.

Critères de sélection des géniteurs

Choix des màles

Bien qu'ils soient subjectifs, les critères morphologiques restent considerés pour le moment, comme étant les éléments les plus utilisés dans le choix des màles. Les màles matures peuvent être reconnus de la façon suivante:

1° - La coloration du corps devient noire et légèrement bleutée,
2° - La peau présente un aspect terne et devient gluante,
3° - La tête ainsi que la bouche deviennent plus larges dépaissant très souvent la largeur du corps,
4° - La lèvre inférieur devient épaisse, flasque et présente une coloration blanc-pâle (Photo 5),
5° - La papille génitale devient rose et proéminante,
6° - Les aiguillons des nageoires pectorales ne présentent plus d'apparence de piquant, ils deviennent arrondis et sont recouverts d'une couche de "muqueuse" épaisse,
7° - La nageoire caudale devient "adipeuse" et présente des extrémités arrondies.

Notons que parmi ces éléments, l'élargissement de la tête est le premier signe utilisé dans la reconnaissance d'un màle mûr.

Nous avons essayé de quantifier ce caractère en considérant deux paramètres biométrique (Fig.4): LOP, distance entre les deux fentes operculaires (élément indépendant de toute évolution sexuelle) et LT, largeur de la tête (élément variable et étroitement lié à la reproduction). Le rapport LT/LOP pourrait nous aider à comparer la maturité des màles: la valeur 1,20 correspond généralement à des màles en début de maturation et par contre les valeurs 1,70 à 1,80 correspondent à des màles en fin de maturation. Dans ce dernier cas le màle est prêt à se reproduire.

Planche 5. Changement d'une façon frappante de la morphologie du male en période de reproduction: élargissement de la tête, épaississement de la lèvre inférieure.

Choix des femelles

Comme dans le choix des màles, les critères utilisés à priori sont des critères morphologiques. Bien qu'ils soient subjectifs, ces critères aident incontestablement une première sélection qui doit être ensuite affinée par la biométrie et la biopsie ovarienne. Ces critères morphologiques sont sensiblement les mêmes que ceux utilisés chez les màles:

1° - la coloration du corps,
2° - l'épaississement de la base de la caudale,
3° - l'embonpoint de l'abdomen,
4° - le développement et la coloration de la papille génitale,
5° - le changement de l'aspect piquant de la nageoire pectorale, etc.

L'embonpoint de l'abdomen peut être quantifié par le rapport LVT/LOP (Fig.4). Les valeurs comprises entre 1,25 et 1,40 correspondent à des femelles en repos sexuel ou immatures. Quand la maturation des ovaires progresse, la valeur de ce rapport augmente. Elle atteint 1,80 ou même 1,90 chez les femelles en fin de maturation.

La biopsie ovarienne est le moyen le plus sûr pour déterminer la maturité sexuelle (Harvey & Hoar, 1980; Woynarovich & Horvath, 1981). Elle permet de déterminer le diamètre des ovocytes et de visualiser la position de la vésicule germinative.

La corrélation entre la diamètre des ovocytes et le temps avant la ponte montre bien l'importance de ce paramètre (Fig.6).

La position de la vésicule germinative (ou VG) ne peu être considerée comme un indicateur précis que vers la fin de la maturation. En effet la migration de la VG vers la partie périphérique de l'ovocyte semble avoir lieu dans les 48 heures avant la ponte. Avant cette période la vésicule germinative gravite autour de la position médiane entre le centre de l'ovocyte et sa périphérie.

Notons que quatre cas d'éclatement de la VG - correspondant à l'ovulation des ovocytes - ont pu être observés. Ils ont toujours eu lieu à la vieille de la ponte. A ce stade les oeufs s'entourent d'une couche de substances adhésive et peuvent être expulsés de l'ovaire par simple pression sur l'abdomen. Ce sont des oeufs mûrs prêts à la fécondation.

Observations sur le comportement des géniteurs

Le comportement des géniteurs de Chrysichthys nigrodigitatus rapelle bien celui observé chez C.walkeri (Hem, à paraître): position "tête bêche" des géniteurs dans le réceptacle, nettoyage du substrat par la femelle avant la ponte, etc.

Les oeufs sont adhésifs et ce collent les uns aux autres en grappe massive (Photo 6). Après chaque ponte, on observe une perte importante en poids chez des femelles. On enrégistre une perte d'environ 25% par rapport à leur poids initial. Tandis que chez les màles cette variation est insignifiante.

Planche 6. La masse d'oeufs issue d'une ponte. Fécondité effective moyenne est de l'ordre de 14 à 16.000 oeufs par kilogramme de poids de la femelle.

Cycle de reproduction

Grâce au marquage individuel au Bleu Alcian, des suivis de chaque géniteur ont pu être effectués.

Les màles ayant reproduit en début de saison (août-septembre) peuvent se reproduire une deuxième fois en fin de saison après 40 à 60 jours de récupération dans les enclos à géniteurs (quatre cas ont été observés). Par contre les femelles, ayant perdu environ 25% de leur poids après chaque ponte, auraient besoin d'un temps de récupération plus long avant de pouvoir s'engager dans un nouveau processus de maturation sexuelle. Cela explique l'absence des femelles pouvant pondre une deuxième fois dans la même saison, c'est-à-dire entre août er décembre.

Il est important de signaler un cas très intéressant de reprise de maturation (par apparition de nouvelles couvées d'ovocytes de diamètres plus petits qui remplace l'ancienne couvée d'ovocytes qui sont en cours de résorption) chez une femelle maintenue en confinement avec un mâle caractéristiquement mûr.

Discussion - Conclusion

Bien que la maîtrise de la reproduction chez Chrysichthys nigrodigitatus ait connu un progrès considérable, quelques point restent cependant à éclaircir et feront l'objet de nos programmes de recherche futurs.

Maturation des gonades et saison de ponte

La figure 5 qui presente parallelement l'évolution des paramètres physico-chimiques et la fréquence des pontes, est spécifiquement liée à la station de Layo. L'étude chez Chrysichthys walkeri (Hem et al., à paraitre) a montré que la saison et la période d'étalement des pontes, qui dépendent vraisemblablement de la variabilité de la qualité physico-chimique de l'eau, diffèrent d'un point à l'autre de la lagune Ebrié.Il serait intéressant d'envisager une étude similaire chez Chrysichthys nigrodigitatus. Cette étude doit ensuite être complétée par des expériences en milieux controlés afin de permettre de déterminer des paramètres directement responsables du mécanisme de la reproduction de cette espèce.

Ponte par confinement

L'obtention des pontes en aquarium de 23 à 240 litres ont été déjà mentionnés chez Ictalurus punctatus (Bardach et al., 1972). Mais dans ce cas les pontes sont intégralement induites par des injections hormonales.

Les pontes par confinement dans des tubes en PVC selon notre procédé sont obtenues sans aucune intervention hormonale. Le temps de séjour dans le tube est en moyenne de 3 à 4 semaines. L'ensemble de ces conditions réunies (température, salinité, absence de lumière, contact prolongé entre les geniteurs, etc.) est sans doute favorable à la reproduction. Mais l'importance relative de chacun de ces facteurs qui déterminent la maturation et la ponte, reste pour le moment non identifiée. Leur mise en évidence fera l'objet de nos recherches futures.

Modèle de prévision

L'état des ovocytes est un des indicateurs permettant d'estimer la date de ponte. Il existe certes une corrélation entre le diamètre des ovocytes et le temps de ponte. Ce modèle de prévision pourrait être précisé en considérant d'autres facteurs tels que les paramètres physico-chimique et notamment l'état de maturité des mâles.

Fécondité effective : perte d'oeufs après ponte

La fécondité effective est le rendement en nombre d'oeufs par ponte et par femelle. Elle est égale à la différence entre la fécondité relative (nombre d'oeufs contenus dans les ovaires en fin de maturation avant la ponte) et la perte globale des oeufs après la pointe.

Les pertes peuvent être de diverses origines: par mouvement d'agitation des géniteurs et/ou par prédation des oeufs par le couple.

Ces pertes peuvent être évitées simplement en séparant les oeufs aussitôt fécondés des parents (d'où l'intérêt du modèle de prévision de la date de ponte) et en les faisant incuber dans un incubateur artificiel.

Critères de sélection des màles

La biopsie ovarienne a permis d'évaluer la maturité sexuelle chez les femelles. Par contre les critères de sèlection chez les màles, mis à part le rapport LT/LOP (cf.§ 2.5.1), restent cependant très subjectifs. Des critères objectifs doivent être recherchés.

Le contrôle de la reproduction chez les poissons, selon Donaldson (1975), comporte trois étapes.

- La première étape du contrôle est marquée par l'obtention des pontes pendant la saison naturelle de reproduction. C'est une reproduction semi-contrôlée qui consiste à ramener la maturation naturelle à s'achever en écloserie pour mieux contrôler les pontes et obtenir un meilleur rendement en larves par rapport à des pontes naturelles.
- La seconde étape est le contrôle de la maturation. Elle vise à accélérer ou à retarder la maturation et la ponte, afin de permettre d'étaler la période de reproduction sur plusieurs mois de l'année.
- La troisième et l'ultime étape du contrôle est d'être en mesure d'obtenir des pontes a tout moment de l'année.

Dans le cadre de nos recherches sur la reproduction de Chrysichthys nigrodigitatus, nous sommes arrivés actuellement à la première étape de la maîtrise. Nos recherches futures consisteront donc à parvenir aux étapes ultimes par un contrôle intégral du cycle, se traduisant par l'obtention des pontes tout le long de l'année.

102 pontes, produisant plus de 700.000 larves, ont été enregistrés entre août et décembre 1984. Ce succès a marqué désormais un tournant décisif pour l'aquaculture lagunaire en Côte d'Ivoire: l'élevage de Chrysichthys nigrodigitatus est maintenant possible.

Le procédé de reproduction par confinement des géniteurs dans le tube en PVC, décrit ci-dessus, est un procédé très favorable pour le genre Chrysichthys. Il serait très intéressant d'essayer d'appliquer ce même procédé aux autres espèces qui ont un comportement biologique et une position taxonomique proches du genre Chrysichthys tels que Ictalurus punctatus d'Amérique, Silurus glanis d'Europe ou le Macrones nemurus d'Asie.

Remerciements

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Références

Bardach, J.E., J.H.Ryther, W.O.McLarney, 1972. Aquaculture: The farming and husbandry of freshwater and marine organisms. New York, Wiley InterScience, 868 p.

Dada, B.F., 1976. Present Status and prospects for aquaculture in Nigeria. In: Symposium on Aquaculture in Africa, Ghana, 30 September-2 October 1975. CIFA Tech.Pap., (4) Suppl., 1: 79-84.

Daget, J., A.Iltis, 1965. Poissons de Côte d'Ivoire (Eaux douces et saumâtres). Mémoires IFAN, n°74, 385 p.

Dia, A.K., 1975. Détermination de l'âge des machoirons (Chrysichthys nigrodigitatus). Première estimation de la croissance. Doc.Sci.Cent.Rech. Océanogr.Abidjan, 6 (2): 139-151.

Donaldson, E.M., 1975. Physiological and physico-chimical factors associated with maturation and spawning. FAO/EIFAC/T25: 53-71.

Durand, J.R., J.W.Chantraine, 1982. L'environnement climatique des lagunes ivoiriennes. Rev.Hydrobiol.Trop., 15 (2), 85-113.

Ezenva, B., 1975. Fish seed production in Nigeria.. In: Symposium on Aquaculture in Africa, Accra, Ghana, 30 September-2 October 1975. CIFA Tech.Pap., (4) Suppl. 1: 441-449.

Harvey, B.J., W.S.Hoar, 1980. Reproduction provoquée chez les poissons: théorie et pratique. Ottawa, Ont. IDCR, 48 p.ill.

Hem, S., 1982. L'aquaculture en enclos: Adaptation au milieu lagunaire ivoirien. Aquaculture, 27 (3), 261-272.

Jalabert, B., B.Breton, E.Brjuska, A.Fostier, J.Wieniawski, 1977. A new tool for induced spawning: the use of 17 -hydroxy-20 -dihydroprogesterone to spawn carp at low temperature. Aquaculture, 10, 353-364.

Kola, I., C.I.O.Olaniyan, 1975. The food and feeding habitats of the catfishes, Chrysichthys filamentosus (Boulenger) and Chrysichthys nigrodigitatus (Lacepede) in the Lakki Lagoon, Nigeria. J.Fish.Biol., 10, 105-112.

Markmann, C., S.I.Ooroshov, 1983. Ovarian catheterization of the channel catfish, Ictalurus punctatus. Aquaculture, 35: 163-169.

Micha, J.C., V.Franck, 1976. Biologie des principales espèces utilisées en pisciculture africaine. In: Symposium on Aquaculture in Africa, Accra, Ghana, 30 September-2 October 1975. CIFA Tech.Pap., (4) Suppl., 1: 292-331.

Sivalingam, S., 1976. The biology of cultivable brackishwater and marine finfish in Africa. In: Symposium on Aquaculture in Africa, Accra, Ghana, 30 September-2 October 1975. CIFA Tech.Pap., (4) Suppl. 1: 283-291.

Woynarovich, E., L.Horvath, 1981. La reproduction artificielle des poissons en eau chaude: Manuel de vulgarisation. FAO Doc.Tech.Pêches, (210): 191 p.

RESEARCH ON INTENSIVE CULTURE OF TILAPIA IN TANKS

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Summary

This study is an analysis of 4.5 years of experimental trials with tilapia in a 30 t/yr pilot intensive tank culture system. Initial attempts at reproduction control of tilapia established that at densities in excess of 100 ind/m^3, territorial behaviour disappeared, the sovial hierarchy collapsed and breeding abandoned. This led to the design of an intensive tank system requiring constant water flow for aeration and cleaning.

Tilapia performance in this system suggested a close correlation with respect to tank biomass. At a stock weight in excess of 20 kg/m^3 there is a decline in the rate of increase in productivity (kg/m^3/day) due to an adverse influence on specific growth rate. Increasing numerical density as well as biomass leads to jostling and competition for food such that above 250 ind/m^3 there is a dramatic increase in feed conversion rate beyond an optimum of 1:2.0 - 2.3. Starting size of between 40-60 g is important for optimal tank production performance, and maintenance of uniformity of stock is essential.

From the results a profitability model is recommended for commercial tilapia production.

Resumé

Cette étude analyse quatre années et demi d'essais expérimentaux sur le tilapia dans un système pilote de culture intensive an bacs ayant une capacité de production de 30 tonnes par an. Des tentatives faites préalablement pour contrôler la reproduction du tilapia avaient montré qu'à des densités supérieures à 100 individus pas m^3, le comportement territorial disparaissait, la hiérarchie sociale s'effondrait et la reproduction était abandonnée. Ces constatations avaient entrainé la construction d'un ensemble de bacs d'élevage intensif nécessitant un débit d'eau constant pour assurer l'aération et le nettoyage.

Les performances du tilapia dans ce système permettent de supposer qu'il existe une étroite corrélation entre celles-ci et la biomasse dans les bacs. Pour une mise en charge supérieure à 20 kg par m^3, on observe une baisse du taux d'augmentation de la productivité (kg par m^3 et par jour)liée aux effets néfastes de ces mises en charge sur le taux de croissance spécifique. L'élévation de la densité numérique et de la biomasse entraîne des perturbations et une plus grande concurrence pour la nourriture: à un taux supérieur à 250 poissons par m^3, le taux de conversion augmente radicalement et dépasse le taux optimal de 1 sur 2 à 2,3. Un poids de départ de 40 à 60 g est essentiel pour assurer une performance optimale de production en bacs et il importe de veiller au densité de charge constante.

À partir des résultats obtenus, on a pu construire un modèle de rentabilité que l'on recommande d'adopter dans toute entreprise d'exploitation commerciale de tilapias.

Introduction

By the year 2000 Africa's population of nearly 900 million will require 5.5 million tonnes of fish to sustain present levels of consumption. Twice this amount is necessary to achieve a balanced nutrition. The maximum sustainable yield of fishery resources however is estimated at 4.0 million. 6 Million tonnes will therefore have to come from alternative developments, in particular aquaculture. Of over 140 species tested to date in fish farms in Africa, tilapia are the most popular. Over 31 species have been used in various system types ranging from extensive drain in fish ponds, howash, and acadja units to intensive tanks, raceways and cages, but the most popular is subsistence pond culture. Current production is however low, a total of between 7,000 - 145,000 t/yr (Balarin, 1985). To increase output to meet demand each nation would have to develop annually an estimated 2000 ha of ponds (Balarin, 1984a). Although the technology to achieve this is well documented (Balarin and Hatton, 1979) there is a need to improve the efficiency of production in the short term. A fully integrated approach is necessary (Balarin, 1984b). Perhaps more important however is the need to intensify or adopt more intensive methods such as tank culture systems.

Intensive tank culture of fish is not new, but the application of concepts of production as applied to other fish e.g. salmonids, has only recently been introduced for tilapia production. The first recorded use of tanks or raceways for rearing of tilapia was in Hawaii in 1959 (Uchida and King, 1962). By 1982, as few as 15 countries had reported experimental or commercial activities. These were reviewed by Balarin and Haller (1982). Notable developments outside Africa include research on recycling units using heated power station waste water at Thihange in Belgium (Melard and Philippart, 1981), large scale production units employed in Taiwan (Spotts, 1983) reported to produce over 40,000 tonnes of tilapia annually, a 100 t/yr commercial farm recently established in Cyprus (Anon, 1985), as well as various developments in South America, U.S.A., China and S.E. Asia. In Africa, Balarin (1985) lists tank culture interest in 20 countries of which commercial units are currently only in production in Kenya, Zambia and Zimbabwe.

The work in Kenya carried out by Baobab Farm Ltd. is considered a pioneer in this field (Balarin, 1981 and 1982a) and is recognised internationally as the "Baobab Tank Culture System" for tilapia. Operating as a test unit since 1974, early research results were summarised by Balarin (1979) and Balarin and Haller (1981). This study is a report of the production figures of a 30 t/yr pilot farm which was first commissioned in 1981. A preliminary analysis of results was given by Balarin (1982b) and the current analysis summarises 54 months of test operations.

Materials and methods

Site Description

Baobab Farm located 10 km north of Mombasa on the Kenyan coastline of East Africa, in 1971 introduced fish farming as part of an integrated process of land reclamation. The site, a worked out coral limestone quarry, is excavated to within 0.5 m of the ground water table which is at sea level. Water is abundant, varying in salinity from 1.0 - 15.0 ppt. and is at a near constant temperature of 26°C (+ 1°C) all year round. Initial trials with tilapia were in ponds excavated into the ground water table but resulted in poor growth due to the characteristic prolific breeding of this species (Haller, 1974). A research facility was constructed in 1972 to examine techniques of improving production. Currently this unit has over 150 test tanks of 20 - 20,000 l, and most of the pioneer research took place here. At densities above 100 fish per m^3 disruption of the social hierarchy was shown to cause aggression to subside so that territorial behaviour was lost, and consequently breeding was abandoned (Balarin and Haller, 1981). This discovery led to the design of an intensive tilapia tank culture system.

Constructed in 1980, this pilot unit consisted of 24 fry ongrowing raceways of 10 x 1.5 x 0.5 m (= 5 m^3 water) and 12 circular fattening tanks of 6 x 1 m (= 20 m^3 water); a total of 360 m^3. Water is pumped from the ground at 250 - 300 m^3/hr and flows by gravity through two raised tiers of raceways before a third re-use in the fattening tanks (Balarin 1979 and 1982a). Waste water enters a series of stabilisation ponds. Here an aquatic weed, Pistia is used as a bio-filter for nitrogenous waste in a semi-recirculating system.

Fish Species

Upto 12 species of tilapia and various strains are maintained on site. Predominantly Oreochromis spilurus (52.6 ± 5.3%) and Oreochromis niloticus comprise the majority of farm raised fish. Reared in "Baobab Breeding Arenas" (Haller and Parker, 1981), fry at 5 g size enter the raceways for on-growing to 40 - 50 g. The stock programme for the trial is the same as that described in Balarin and Haller (1983). Fish undergo a rigorous grading programme whereby 30 - 50% of incoming stocks were graded out at below 30 g size. By this process there is a positive selection for 60 - 80% male fish (mean 65.6% ± 5.9). Slow growing stocks, generally female fish, which would never achieve a market size in an economic time period are therefore removed at an early stage.

Husbandry

Tilapia at 40 - 50 g were stocked in the fattening tanks at densities varying from 25 to 375/m^3. A constant water flow was maintained at between 0.5 - 1.0 l/min/kg for aeration and waste removal. The circular tank design permitted the most efficient distribution of water and removal of wastes. As feed a commercially available pelleted feed of 25 - 30% protein was used. The daily feeding rate varied from 5% at start to as low as 1.5% near finishing using the following formula:

$$\text{Log } Y = 1.309 - 0.457 \text{ Log } X \quad (b = 0.457 + 0.039)$$

Where Y = % food per body weight (g) per day
X = mean body weight (g)

Feeding was as frequent as possible, between 6 - 8 times per day to ensure an even distribution of rations, with a non-feeding day at least once per week. Every two weeks fish were sampled and weighed using a 3 m throw net and 300 to 500 fish (i.e. 5 - 10%) were weighed. Feeding and flow rates were then adjusted accordingly. At harvest, fish were graded for sales and total weight recorded.

Experimental Procedure

From the onset of production in 1981 to mid 1985, 135 production cycles were monitored. This represents a sample of 85.9 tonnes out of a recorded 103 tonnes total output (i.e. 83.4%): nearly 700,000 fish. Accurate records were maintained of all tank histories from stock weight and number to details of harvest, total feed and losses. Annual summaries are given in Table 1, and individual tank productivity has been estimated as kg/m^3/day. Growth of individual fish was recorded as specific growth rate (S.G.R.).

The results represent 4.5 years of tank performance records from which a model has been derived for intensive tilapia production in tanks. All culture conditions were therefore maintained as standardized as possible. Occasional variation in feed formulation may have occurred according to availability of ingredients. Husbandry methodology remained consistent, and by use of such a large sample seasonal variations are likely to be minimal. Analysis in 1982 of the first 18 months of results showed no significant difference in growth patterns with season (Balarin, 1982b). Preliminary analysis of these early data was used to derive a correlation coefficient to determine the best goodness of fit of the regression equation for subsequent analysis (Table 2).

Results

The results of the present study are summarised in Table 1 and Fig. 1. For comparative purposes results of two earlier studies (Balarin, 1979 and 1982b) are presented in Table 2.

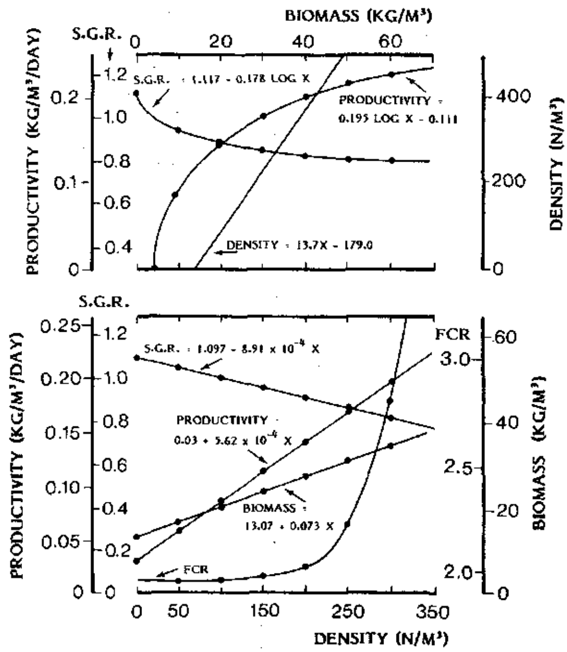

FIGURE 1. SUMMARY OF TILAPIA PERFORMANCE IN 20 M³ CIRCULAR TANKS.

This Study

The summary of performance (Table 1) indicates that the 135 production cycles were stocked at an average of 5182 (± 230) fish per tank (= 259 ind/m³) at a starting size of 56.8 g (± 4.0 g) or 14.7 kg/m³. After 104.6 (± 8.6) days, tanks were harvested at 636.3 kg (± 35.2 kg) or 31.8 kg/m³ at a mean weight of 129.1 g (± 6.7 g). Trade loss due to mortality and other causes (e.g. escapees, predatory birds, etc.) is estimated at 2.02%. The results give a S.G.R. of 0.85 (± 0.04)%/ind/day and a production rate of 0.176 (± 0.011)kg/m³/day with an overall feed conversion rate (FCR) of 2.37 (± 0.09).

Extrapolation of data implies an annual tank production of 64.2 (± 4.0)kg/m³. This however is the mean of an experimental range of between 4.7 - 143.8

kg/m^3/yr and is therefore lower than the average to be expected in production tanks due to suboptimal experimental stocking rates especially in the year 1981. Assuming a total outgrow volume of 360 m^3 it is possible to arrive at an overall production mean for 1982 - 1985 of 77.6 ($\pm$ 4.0)kg/m^3/yr. From total annual output in Table 1 it is possible to calculate annual productivity of the farm as:

1981 = 13.4 kg/m^3/yr.
1982 = 79.0 kg/m^3/yr.
1983 = 81.8 kg/m^3/yr.
1984 = 73.8 kg/m^3/yr.
1985 = 76.0 kg/m^3/yr. (data for first 6 months).

There is a linear increase in productivity (kg/m^3/yr) with density (n/m^3): Fig. 1, expressed by Equation 1c (Table 2). The corresponding increase in production (kg/m^3) is given in Equation 2c. It would appear from Fig. 1 that increasing tank biomass (kg/m^3) does have a significant influence on productivity (kg/m^3/day). The curvi-linear relationship (Equation 3c - Table 2) suggests that at densities above 10 - 20 kg/m^3 there is a marked reduction in productivity. As the tank biomass increases there is a negative influence on growth (Equation 4c, Table 2). A more significant correlation between S.G.R. and numerical density (Fig. 1, Equation 5c) suggests an interaction between individuals, a feature which is not supported by an increase in mortality rates at higher densities (Equation 6c, Table 2).

The starting size of the tank stock has a decided effect on subsequent S.G.R. (Fig. 1 - Equation 7c). Harvest size however does not appear to be correlated to S.G.R. (Equation 8). Time spent in the system does appear to be of some significance (Equation 9); prolonged production time reduces productivity and S.G.R. (Fig. 1).

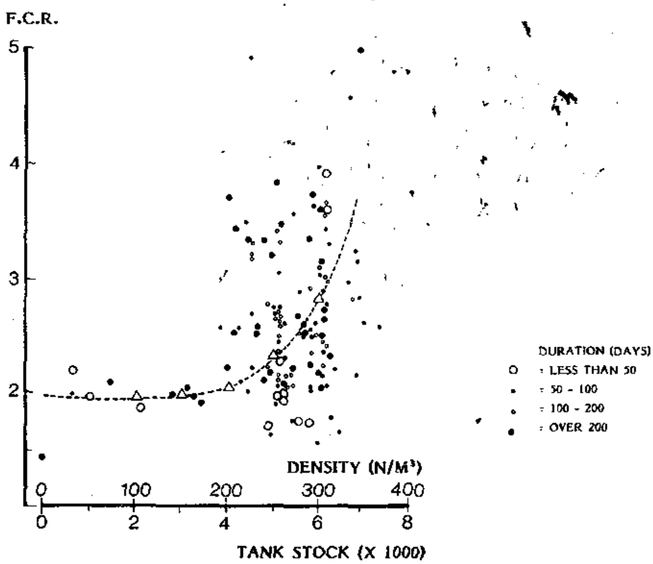

FIGURE 2. RELATIONSHIP BETWEEN STOCK DENSITY AND F.C.R. OF TILAPIA IN 20 M^3 CIRCULAR TANKS.

No regression coefficient could be obtained to express the interaction between stocking density and F.C.R., but from data presented in Fig. 2, there is an apparent inverse relationship. F.C.R. deteriorates dramatically at densities above 200 - 250 ind/m^3. A similar trend is evident with respect to tank biomass but is not as significantly correlated.

Comparison of Results

The regression equations for performance during the present study are compared in Table 2 with earlier data at $P < 0.05$. Whereas the expression for numerical density vs. productivity (Equation 1) and biomass vs. productivity (Equation 3) are not significantly different, there is however a difference between the other equations listed in Table 2. This suggests a variation between test periods. In order to overcome any such variable a large sample size representing 4 - 5 years has been used in the final analysis. Equation series 'c' therefore is more likely to approach the normal expected long term performance of a tank system.

Conclusions

To a commercial fish farmer it is important that production time be minimised to permit a rapid economic turn-over of the system. This study shows that for tilapia as the tank biomass increases so does productivity but the rate of increase declines in a logarithmic relationship. A point is eventually reached at which there can be no further increase in production rate. Tank stocks beyond 20 kg/m^3 show a rapid deterioration in productivity until at 102.65 kg/m^3 the tank doubling time is 12 months, 50% of that at 20 kg/m^3. The annual maximum expected production of a 20 m^3 tank would be 2,053 kg and therefore the production potential of the 12 tank pilot farm would be 24,636 kg.

The relationship between biomass and productivity is a consequence of a decline in S.G.R. at higher densities. It would appear that numerical density is more significantly correlated with influencing S.G.R. (Table 2). This is supported by an earlier study (Balarin, in prep.). At a high stock number interaction between individuals leads to an increase in jostling. Larger fish therefore succeed in getting more food and better water quality conditions. Smaller or less aggressive fish are often damaged through such encounters, injury ranging from skin abrasions, bruising to rupture of an eye. The increase in competition for food could account for the drastic increase in F.C.R. at densities above 250 ind/m^3 (Fig. 2). Productivity therefore decreases where competition due to the weight of numbers becomes excessive. It is important therefore to ensure a uniform size stocking as well as to maintain an intensive and frequent feeding regime. The importance of size Equation 7 and 8 implies that stocking at the start with larger fish tends to enhance the severity of the encounters in particular within the size range of 40 - 60 g. The strong correlation of starting size influencing growth rather than size at harvest suggests that the interaction between fish occurs very early in a production cycle and lasts until harvest. However it can not be ignored that this decline in S.G.R. with size may be a feature of attaining a mature state which consequently is reflected in retarded growth rates. The results nevertheless suggest that stocking at a smaller size is advisable.

It is now possible to postulate an operational model for commercial activity (Fig. 3). On the assumption that a starting size of 50 g is optimal and that harvest biomass determines production (Equation 3) the expected yield will therefore decline as biomass increases and is directly correlated with numerical density. Annual yield therefore does not increase significantly beyond a harvest biomass of 30 - 40 kg/m^3. From Figure 3 it is evident, that harvesting below

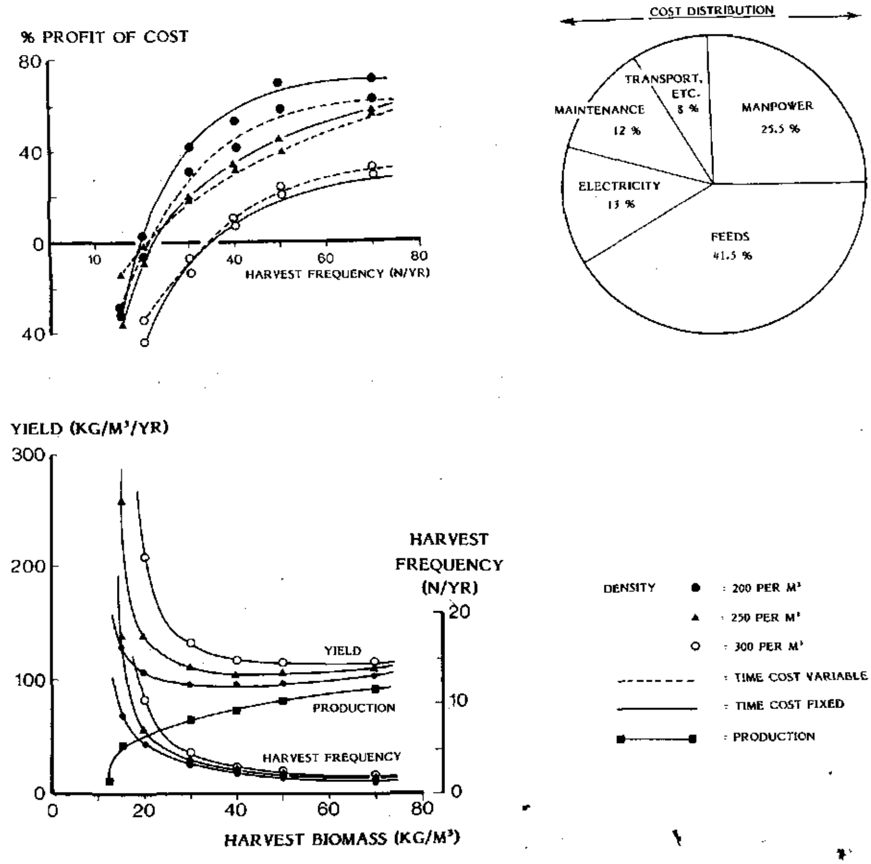

FIGURE 3. COST DISTRIBUTION, % PROFIT, PRODUCTION MODEL AND EXPECTED YIELD FOR TILAPIA TANK CULTURE AT THREE DENSITIES (200 (o), 250 ( ) AND 300 (o) PER M³).

this biomass would result in a more rapid turn-over of the stock, in excess of 3 - 5 cycles per year. However such a shorter time period would result in reduced productivity. Therefore, the apparent increase in yield is more a feature of the initial stock biomass rather than the result of the growth increment obtained in the production system. Thus to increase production by a more rapid turn-over of stocks it is necessary to have a larger support unit (i.e. more raceway for on-growing fry).

From 4.5 years of economic records it is evident that feeds play a significant role in production costs, nearly 42% (Fig. 3). Adopting 1985 operation costs and assuming both a fixed and variable operation time cost it has been possible to calculate an expected economic return for the hypothetical production model (Fig. 3). The break-even point can be summarised as:

at $200/m^3 = 19 - 22\ kg/m^3$
$250/m^3 = 21 - 23\ kg/m^3$
$300/m^3 = 34\ kg/m^3$.

There does not appear to be any significant increase in the profit margin when the harvest biomass exceeds 50 - 60 kg/m^3. In conclusion therefore it can be recommended that the most profitable operation of a "Baobab Tilapia Tank Culture System" would be to stock at 200 ind/m^3 at 50 g size. Harvesting in 150 - 180 days at between 40 - 50 kg/m^3 a mean size of 200 - 250 g can be expected. This would permit 2 - 2.5 cycles per year yielding 95 - 100 kg/m^3/yr with a profit margin of 40 - 70% of the operational cost.

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References

Anon, 1985. Tilapia lead the way to seabass and bream. Fish Farm Int., 12 (5): 9 p.

Balarin, J.D. 1979. Intensive Tilapia Culture in Circular Tanks - A report on Baobab Farm, Kenya, Kenya, Baobab Farm Publ. 123 p (mimeo)

Balarin, J.D. 1981. Kenya Cement Factory Develops Intensive Tilapia Farming System. Aquaculture Mag. (Sep./Oct.), 7(6): 46-47.

Balarin, J.D., 1982a. Kenya Pioneers Intensive Tank Culture of Tilapia. ICLARM Newsletter (Jan), 5(1): 17-18.

Balarin, J.D., 1982b. Preliminary analysis of the performance of a Pilot Baobab Tilapia Farm. Kenya, Baobab Farm Publ. 34 p (mimeo).

Balarin, J.D., 1984a. Intensive Tilapia Culture: A Scope for Future Food Production in Developing Countries. Outlook on Agriculture, 13(1): 10-19.

Balarin, J.D., 1984b. Towards an integrated approach to tilapia farming in Africa. The Courier, 85: 82-84.

Balarin, J.D. 1985. Aquaculture Practices in Africa: Systems in use and species cultivated. A Status Report. Proc. Conslt. Workshop on Village Level Aquaculture Dev. in Africa, Freetown 14-20 February, 1985: 28 p.

Balarin, J.D. (in prep.). A study of Factors influencing tilapia production during intensive tank culture. Ph.D. Thesis, Stirling University, Scotland.

Balarin, J.D. and Haller, R.D., 1981. Intensive tilapia culture: A Scope for the future. Proc. K.M.F.R.I. symp. on aquatic resources in Kenya: A need for research - July 1981: 368-405.

Balarin, J.D. and Haller, R.D., 1982. The intensive culture of tilapia in tanks, raceways and cages. Chapter 5, Recent Advances in Aquaculture by J.F. Muir and R.J. Roberts (eds.) Croom Belm Ltd. Lond.: 265-356.

Balarin, J.D. and Haller, R.D., 1983. Commercial tank culture op tilapia. In: Fishelson, L. and Yaron, Z. (eds) Proc.Int.symp. on Tilapia in Aquaculture: 473-483.

Balarin, J.D. and Hatton, J.D., 1979. Tilapia. A Guide to their biology and culture in Africa. Stirling University Publ. Scotland: 17 p.

Haller, R.D., 1974. Rehabilitation of a limestone quarry, Mombassa, Kenya. Bamburi Portland Cement Co. Publ. 32 p.

Haller, R.D. and Parker, I.S.C., 1981. New Tilapia Breeding System Tested in Kenya Farm. Fish Farming Int., 8(11): 14-18.

Melard, C. and Philippart, I.C., 1981. La production de Tilapia de consommation dans les rejects industriel D'eguchaude en Belgique. Cahiers d'Ethologie Applique I, (Supl.2): 122 p.

Spotts, D., 1983. High Density Tilapia Culture, Taiwan. Aquaculture Magazine 9(6): 21-23.

Uchida, R.N. and King, J.E., 1962. Tank Culture of Tilapia. US Fish Wildl. Serv., Fish Bull. 62: 21-52.

Table 1. Summary of tank performance 1981-1985.

Parameter		Annual Average (Range i)					Overall mean (± SEM)
		1981	1982	1983	1984	Mid 1985	
Production Cycle	Total Annual Yield (kg)	4329	28 455	29 464	26 575	13 686	103 00[illegible]
	No. sampled	25	24	41	37	8	135
	Duration (days)	164.2 (33 - 278)	98.6 (25 - 176)	75.3 (36 - 112)	99.3 (76 - 122)	119.7 (112 - 145)	104.6 (± [illegible])
Density (No/Tank)	Start	3549 (536 - 6049)	5640 (4002 - 7457)	5633 (4138 - 7316)	5263 (3797 - 6883)	5327 (5030 - 6073)	5222 (± 230)
	Finish	3345 (507 - 5618)	5603 (3961 - 7405)	5622 (4147 - 7299)	5133 (3801 - 7022)	5794 (4707 - 6377)	5075 (± 235)
	% Loss	5.40 (0.4 - 11.0)	0.68 (0.1 - 3.9)	0.47 (0.1 - 15.9)	2.63 (0.7 - 17.5)	0.59 (0.1 - 12.4)	[illegible]
Average Fish Weight (g)	Start	57.3 (16.4-167.4)	57.6 (39.0-93.8)	49.9 (39.6-137.0)	63.3 (38.0-101.6)	57.7 (48.0-85.3)	56.8 (± [illegible])
	Finish	176.0 (91.2-227.5)	141.2 (88.9-239.1)	101.4 (73.4-220.0)	120.8 (76.5-190.5)	139.4 (115.2-163.2)	129.1 (± 6.72)
	Specific growth rate in %(S.G.R.)	0.87 (0.4 - 1.50)	0.91 (0.70-1.48)	0.98 (0.62-1.50)	0.68 (0.35-1.04)	0.75 (0.58 -0.98)	0.85 (± 0.04)
Food	Feed conversion rate (F.C.R.)	2.56 (1.85-5.45)	2.27 (1.33-3.47)	2.36 (1.54-4.56)	2.19 (2.31-4.98)	2.84 (2.14-3.64)	2.37 (± 0.09)
Production Rate	Tank Total (kg) Harvest	615.7 (70.5-1143.2)	762.1 (488 -996)	569.6 (332 - 733)	604.8 (447 - 760)	810.5 (613 - 978)	630.[illegible] (± [illegible])
	$kg/m^3/day$	0.125 (0.013-0.21)	0.231 (0.120-0.394)	0.198 (0.122-0.318)	0.143 (0.089-0.212)	0.197 (0.146-0.24)	0.176 (± 0.011)
Production Cost ii	US$/kg	10.47	0.87	0.96	1.07	1.25	1.04 (± 0.19) iii
	% Feeds	25.4	38.9	36.1	42.5	52.8	[illegible].5 (± [illegible])

i) The range of values for each year appears in parentheses.
ii) Current exchange rate US$ 1.00-17.00 Km. 00 = 17.00 Km
iii) Excludes year 1981 as full production had not yet been acieved.

Table 2. Comparison of various analysis of Tilapia performance in tanks.

Equation No. (Fig. No. 1)	Parameters	Source (i)	Regression Equation	Statistic n	r	(± SE b) (ii)	(iii) (P<0.05)
1	X = density (n/m^3)	a	Y = 0.067 + 4.34 x 10^{-4}X	13	0.555	2.44 x 10^{-4}	a
	Y = Productivity (kg/m^3/day)	b	Y = 0.019 + 6.39 x 10^{-4}X	29	0.865	6.57 x 10^{-5}	a
		c	Y = 0.030 + 5.62 x 10^{-4}X	135	0.601	6.48 x 10^{-5}	a
2	X = density (n/m^3)	a	Y = 21.53 + 0.071X	13	0.302	N.S.D. (P = 0.05)	-
	Y = Biomass (kg/m^3)	b	Y = 0.191 - 2.356	28	0.957	0.0124	a
		c	Y = 15.77 + 0.073X	135	0.491	0.0112	b
3	X = Biomass (kg/m^3)	a	Y = 0.159 Log X - 0.100	13	0.617	0.061	a
	Y = Productivity (kg/m^3/day)	b	Y = 0.0165 Log X - 0.057	33	0.903	6.73 x 10^{-3}	a
		c	Y = 0.195 Log X - 0.111	135	0.649	0.02	a
4	X = Biomass (kg/m^3)	a	Y = 1.57 - 0.354 Log X	13	0.172	N.S.D. (P = 0.05)	-
	Y = S.G.R. (%/ind/day)	b	Y = 1.795 - 0.51 Log X	29	0.715	0.114	a
		c	Y = 1.117 - 0.178 Log X	135	0.160	0.095	b
5	X = density (n/m^3)	a	Y = 0.645 + 2.7 x 10^{-3}X	13	0.424	N.S.D. (P = 0.05)	-
	Y = S.G.R. (%/ind/day)	b	Y = 1.443 - 2.55 x 10^{-3}X	29	0.739	4.5 x 10^{-4}	a
		c	Y = 1.097 - 8.91 x 10^{-4}X	135	0.220	3.66 x 10^{-4}	b
6	X = density (n/m^3)	a	Y = 10.01 - 0.0272	13	0.350	N.S.D. (P = 0.05)	
	Y = mortality (% loss)	b	Y = 0.021 - 0.211	29	0.92[illegible]	4.75 x 10^{-3}	a
		c	Y = 2.71 ± 1.350 x 10^{-3}X	135	0.01[illegible]	N.S.D. (P = 0.05)	-
7	X = Size (start) (g)	a	Y = 1.27[illegible] - 1.525 x 10^{-3}X	13	0.76[illegible]	2.22 x 10^{-4}	a
	Y = S.G.R. (%/ind/day)	b	Y = 1.033 - 2.872 x 10^{-3}X	33	0.446	5.0 x 10^{-4}	a
		c	Y = 1.124 - 4.534 x 10^{-3}X	135	0.489	7.49 x 10^{-4}	b
8	X = Size (harvest) (g)	a	Y = 1.427 - 1.526 x 10^{-3}X	13	0.53[illegible]	N.S.D. (P = 0.05)	-
	Y = S.G.R. (%/ind/day)	b	Y = 0.9[illegible] - 7.6[illegible] x 10^{-3}X	33	[illegible]	N.S.D. (P = 0.05)	-
		c	Y = [illegible] - [illegible] x 10^{-3}X	[illegible]	[illegible]	N.S.D. (P = 0.05)	-
9	X = Time (days)	a	Y = [illegible] - [illegible] x 10^{-3}X	13	[illegible]	N.S.D. (P = 0.05)	-
	Y = S.G.R. (%/ind/day)	b	Y = [illegible] - [illegible] x 10^{-3}X	33	[illegible]	N.S.D. (P = 0.05)	-
		c	Y = [illegible] - [illegible] x 10^{-3}X	[illegible]	[illegible]	[illegible] x 10^{-4}	a

i) a. Experimental trials 1975-1979 (Balarin, 1979)
b. 30 t/yr Pilot Farm Trials 1981-1982 mid (18 months) (Balarin, 1982)
c. 30 t/yr Pilot Farm Trials 1981-1982 mid (54 months) (This study)

ii) "Standard error of 'b' is presented for data of correlation coefficient ofprobability $P < 0.05$

iii) Corresponding alphabetic symbol indicates a non significant difference (N.S.O.) between regression at $P < 0.05$)

LA PRODUCTION DE NAISSAN DANS LA STRATÉGIE DE DÉVELOPPEMENT DE LA CONCHYLICULTURE

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Résumé

Les mollusques bivalves représentent la part la plus importante et la plus rentable des cultures animales en mer. Le dévelopement de cette culture nécessite que la production de "graine" ou "naissain" soit maitrisée. Le naissain peut être soit d'origine naturelle (ramassage ou captage), soit d'origine industrielle (écloseries et/ou nurseries). Le naissain naturel est limité à certaines espèces et à une époque de l'année, les quantités obtenues peuvent varier considérablement d'une année à l'autre de façon incontrolable, mais le coût de production est peu élevé. C'est le contraire pour le naissain d'écloserie. Cependant, pour ce dernier, la production de larves oeillées (environ 0,2 mm) ou de postlarves (environ 2 mm) que l'on grossit jusqu'à 2 cm en nurserie, est un moyen d'abaisser les coûts de production. Il est préférable d'investir dans la production de naissain naturel lorsque celle-ci est possible, abondante et pas trop irrégulière. Par contré, il faut avoir recours au naissain d'écloserie, lorsque les espèces ne sont pas captables, lorsque le stock de reproducteurs est trop faible (par exemple: après surpêche ou pollution), lorsque l'espèce est en dehors de sa zone de reproduction naturelle, lorsqu'on veut améliorer le cheptel par sélection génétique ou hybridation contrôlée. De récents développements de cultures nouvelles de Bivalves sont basés sur le naissain de captage (par exemple: Fatinopecten yessoensis, au Japon) ou sur le naissain d'écloserie (par exemple: Tapes philippinarum, en France). Certaines des stratégies mises au point en zones tempérées pourraient être adaptées en zone intertropicale où, jusqu'ici, la conchyliculture est très peu développée.

Summary

Bivalve mollusks make up the largest and most profitable part of sea animal farming. This culture can only be developed if the production of seed and spats is well controlled. Spats can be produced naturally (collection and capture) or industrially (hatcheries and/or nurseries). Natural spats are limited to certain species and to certain periods of the year. Quantities can vary considerably and uncontrollably from one year to the next but in this system, production costs are not very high. For hatcheries the situation is the opposite, but in the hatcheries the production of eyed larvae (about 0,2 mm) or postlarvae (about 2 mm) grown to reach up to 2 cm in the nursery can reduce production costs. Investing in the production of natural spats is preferable whenever this is possible and production is abundant and not too irregular. On the other hand, hatcheries should be used when the species cannot be caught or when the reproduction stock is too small (e.g.after overfishing or because of pollution), when the species are outside their natural range, or when the aim is to improve the species through controlled genetic breeding. Recently new bivalve cultures have been developed using captured spats such as Patinopecten yessoensis in Japan or hatchery spats such as Tapes philippinarum in France. Certain strategies developed in the temperate zones could be adapted to the tropics where, up to now, mollusk farming is still in a very preliminary stage.

Introduction

La conchyliculture ou aquaculture des mollusques représentait en 1985, selon Huisman et Machiels (1985), 55,9% de la production aquacole animale dans le monde, contre 42,3% pour les poissons. La production de mollusques étant essentiellement marine et celle des poissons principalement dulçaquicole, on peut voir dans ces données une légère prépondérance de l'aquaculture marine. Cette prépondérance n'est due qu'aux résultats de l'Asie-Océanie, qui représentent 79,3% de la production aquacole mondiale. Dans les autres parties du monde, la production de poissons est supérieure è celles des mollusques. En particulier, l'Afrique n'a qu'une production insignifiante de mollusques, ce qui montre que la mise ne valeur de sa frange côtière par la culture est à peine ébauchée, alors que les possibilités y sont considérables.

Ainsi, les cultures marine, tout particulièrement celle des Bivalves, qui représentent l'essentiel des mollusques cultivés, pourraient être développées sur les côtes africaines. Cependant, pour alimenter cette activité et surtout pour la diversifier, la maîtrise de la production des "graines" appelées "naissain" chez les Bivalves, apparaît comme une nécessité inéluctable. C'est pourquoi, après avoir établi les caractéristiques des diverses sortes de naissain, nous verrons leurs avantages respectifs et nous analyserons leur rôle dans les stratégies de développement de la conchyliculture.

Diverses sortes de naissain

Les tailles de naissain

Rappel sur l'ontogenèse chez les Bivalves

Au cours de son ontogenèse, un Bivalve subit de profondes transformations de structure et en conséquence de physiologie, ce qui conduit à distinguer 6 stades fondamentaux: périzygotique, embryonnaire, larvaire, postlarvaire, juvénile et adulte. Ces stades peuvent être regroupés soit selon le mode de vie (ou l'écologie): les 3 premiers sont pélagiques, les 3 suivants benthiques, soit selon la morphologie; les stades juvéniles et adultes représentent l'imago, tandis que les stades antérieurs ont un aspect pré-imaginal dans la mesure où ils n'ont pas acquis leur morphologie définitive (Fig.1).

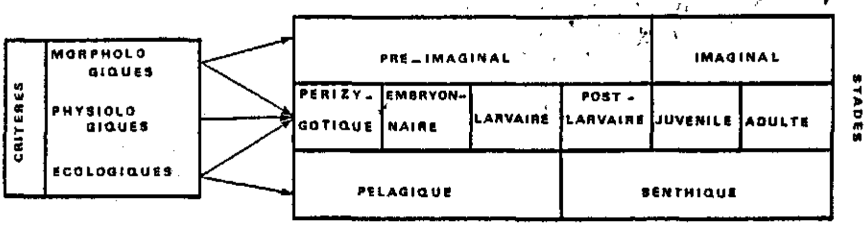

Fig.1 - Les stades d'ontogenèse des Bivalves et leurs regroupements en fonction des critères retenus.

Traditionnellement le terme de naissain correspond au stade juvénile, mais récemment il a aussi été appliqué aux postlarves et aux larves prètes à la métamorphose (pédivéligères).

Les juvéniles

Les juvéniles de Bivalves ressemblent aux adultes, mais ils ont une taille plus petite et ne sont pas sexués. Grâce à une coquille bien calcifiée, ils peuvent être semés sur parc et subir les techniques de grossissement (sur sol, en élévation ou en suspension) appliquées aux adultes, avec parfois une protection particulière contre les prédateurs, pour les plus jeunes. Ce naissain, a une taille variant d'environ 0,5 à 2 cm, selon son âge et l'espèce à laquelle il appartient. Il peut être commercialisé soit fixé sur son support (par exemple de vieilles coquilles) soit libre. Son émersion peu durer de 1 â 10 jours selon les espèces. Il est à la base de toute conchyliculture.

Les postlarves

Le stade de postlarvaire dure environ 2 semaines et la taille du naissain pendant cette période varie rapidement de 0,5 mm à 5 mm environ. La coquille peu calcifiée, est encore fragile et les manipulations sont délicates: elles ne peuvent être réalisées qu'avec prudence par des personnes spécialisées. C'est un produit d'écloserie traité en nurserie, qui supporte des émersions de 1 à 3 jours.

Les pédivéligères

Ce sont des larves prêtes à se métamorphoser. Chez certaines espèces (notamment les huîtres) elles acquièrent une tâche pigmentaire appelée oeil, aussi les nomme-t-on souvent "larves oeillées". Elles sont encore pélagiques mais peuvent ramper avec leur pied très mobile sur les surfaces qu'elles explorent. C'est un produit exclusif de certaines écloseries, qui résiste à l'émersion pendant 1 à 2 jours lorsequ'il est placé en milieu humide et qu'il est protégé contre les températures élevées.

Origines du naissain

Le naissain d'origine naturelle
Modes de collecte

Le mode le plus simple correspond au ramassage du naissain, soit à la main, soit à l'aide de tamis.

Exemple: le ramassage des jeunes palourdes (Tapes philippinarum) dans les aires d'accumulation, par exemple l'embouchure de l'Edo en baie de Tokyo. De là cette semence est répartie sur des parcs découvrants, protégés et travaillés (Cahn, 1951). Cette technique, ancienne au Japon, a été introduite en 1948 en Malaisie pour l'arche Anadara granosa (Rhyter, 1968).

Cependant, le mode le plus répandu et le plus efficace consiste à utiliser des collecteurs notamment pour les espèces épigées. Celles-ci, au moment de la métamorphose se fixent sur tout support non occupé, ce qui est rare dans la nature. Ainsi le collecteur, placé au bon endroit et au bon moment agit comme un piège à postlarves lorsque par sa forme et sa nature il est adéquat. Ainsi, pour les moules les collecteurs sont le plus souvent des cordes, pour les huîtres des surfaces courbes (coquilles, tuiles, plastiques) pour les pectinidés des filets ensachés.

Exemple: Le captage des huîtres est le plus ancien et le plus varié. En France, dans les années 70, il a atteint une intensité et une diversité maximales. Les collecteurs les plus utilisés étaient alors les chapelets de vieilles coquilles d'huîtres, les tuiles chaulées et les collecteurs en plastique également chaulés. Le chaulage permet un décollage plus aisé du naissain lorsqu'il a atteint une taille suffisante (1 à 2 cm) pour être semé sur les parcs (Lucas, 1976).

Taux de collecte

Les taux de collecte importent relativement peu pour le ramassage, mais sont déterminants pour le captage où l'investissements dans la fabrication et la mise en place des collecteurs doit être rentabilisé.

Il existe donc un seuil inférieur de densité de captage (nombre de naissain par collecteur) au-dessous duquel la technique n'est pas rentable économiquement.

Exemple. Le captage de la coquille St.Jaques européenne (Pecten maximus) entrepris en Bretagne selon les procédés japonais n'a pas permis d'atteindre le seuil de rentabilité, puisque les meilleurs scores moyens obtenus n'ont pas dépassé 35 naissains par collecteur, alors qu'au Japon la densité de captage était de quelques milliers par collecteur (Buestel et al., 1974).

Variations interannuelles

Les taux de captage subissent les aléas du milieu naturel et, en conséquence, la production de naissain, à investissement égal, varie d'une année à l'autre, sans contrôle possible.

Deux causes principales peuvent provoquer des effondrements de production: certaines conditions climatiques et certaines pollutions.

Exemple: Pendant 5 années consécutives, de 1977 à 1981, la production de naissain de Crassostrea gigas dans le bassin d'Arcachon (France), qui s'élevait normalement à 5 milliards d'individus, a été nulle malgré des pontes normales. La mortalité des larves a été expliquée par l'action indirecte des peintures antisalissure à base d'organostanniques employés pour les bateaux de plaisance. L'interdiction utiliser ce type de peinture a permis de rétablir la production de naissain à partir de 1982 (Robert, 1983).

Le naissain d'écloserie et de nurserie

Les écloseries commerciales de Bivalves ont commencé à se développer dans les années 60 après les travaux de Loosanoff et Davis (1963) à Milford USA et ceux de Walne (1966) à Conwy, Pays de Galles.

Caractéristiques des écloseries

Les éloseries sont des établissements où l'on obtient du naissain à partir de géniteurs chez lesquels on a induit la ponte (de l'ordre de 10 millions d'oeufs par femelle). Les géniteurs subissent généralement un "conditionnement" par action sur la température et la nourriture, de façon à obtenir des gamètes en toute saison. Le traitement de l'eau de mer utilisée, l'élevage de larves, les cultures d'algues monocellulaires servant à leur nourriture, les modalités de la métamorphose représentent autant de technologies qui ont été mises au point dans les écloseries des USA et d'Europe.

Les écloseries de production sont très diverses selon leur status (public ou privé), leur relations avec les entreprises conchylicoles (écloseries indépendantes ou intégrées à une firme), leur rythme d'activité (périannuel ou saisonnier), la nature des produits fournis (pédivéligères, postlarves libres d'huîtres, de palourdes, de pectinidés etc.), leur dimensions (de 1 personne employée à plus de 10). En bref, les écloseries peuvent avoir un caractère artisanal ou industriel, mais dans un cas comme dans l'autre, leur rentabilité est très souvent aléatoire et les échecs techniques et économiques de ces entreprises sont encore très fréquents.

Caractéristiques des nurseries

Les nurseries sont des installations où les postlarves de 1 à quelques millimètres sont élevées jusqu'à des tailles de 1-2 cm. On utilise directement l'eau de mer sans traitement autre qu'une décantation éventuelle et une filtration grossière pour éliminer les prédateurs. Généralement les nurseries sont situées à terre où l'eau de mer circule par pompage, parfois elles sont installées en mer sur radeau.

Les espèces

Selon les espèces, les productions de naissain sont très variables comme le montre le tableau 1. Les données de ce tableau ne sont ni exhaustives, ni actualisées en raison des difficulté d'information. Cependant elles fournissent un panorama de la diversité de production en naissain de Bivalves.

Tableau 1. Quelques exemples de production de naissain chez les Bivalves. Origine: A: collecte en milieu naturel, B: écloseries.
Niveau de production: Production annuelle en nombre de naissains (de taille supérieure à 5 mm) de l'ordre de 10^6 pour le niveau 1, 10^7 pour 2, 10^8 pour 3, 10^9 pour 4 et plus pour 5.
Références: (1) Cahn, 1951, (2) Ryther, 1968, (3) Furukawa, 1971, (4) Aquacop & De Gallande, 1979, (5) Curtin, 1979, (6) Lucas & Lucas, 1980, (7) Lavoie, 1985, (8) Lucas, 1985, (9) Dao, Comm.pers., 1985, (10) Deustua, Comm.pers., 1985, (11) Flassch, Comm.pers., 1985.

Espèces	Lieu de production	Année de référence	Origine		Niveau de production	Références
			A	B		
Anadara granosa	Malaisie	1957	+		3	(2)
Mytilus edulis	Europe	1977	+		4	(6)
Mytilus edulis	Corée du Sud	1977	+		5	(6)
Mytilus viridis	Tahiti	1978		+	1	(4)
Ostrea edulis	Europe	1977	+		3	(6)
Ostrea edulis	Europe	1980		+	1	(8)
Ostrea edulis	Canada	1984		+	1	(7)
Crassostrea gigas	Monde	1977	+		5	(6)
Crassostrea gigas	Europe,USA	1980		+	2	(8)
Crassostrea virginica	Amérique N.	1977	+		5	(6)
Crassostrea virginica	U S A	1980		+	2	(8)
Crassostrea glomerata	N. Zélande	1978		+	1	(5)
Pinctada martensii	Japon	1968	+		4	(3)
Pinctada sp.	Japon	1984		+	1	(8)
Patinopecten yessoensis	Japon	1977	+		4	(6)
Pecten maximus	France	1984		+	1	(8)
Chlamys varia	France	1984	+		2	(9)
Argopecten purpuratus	Pérou	1984	+		3	(10)
Tapes philippinarum	Japon	1941	+		4	(1)
Tapes philippinarum	France	1984		+	2	(11)
Mercenaria mercenaria	Amérique N.	1980		+	2	(8)

Intérêt respectif des diverses sortes de naissain

Les avantages du un-à-un

L'obtention de naissain libre de tout support, peut être obtenu sans difficulté en écloserie y comris pour les espèces normalement cimentées comme les huîtres.

Ce un-à-un présente de nombreux avantages: d'une part il présente un poids et un volume minimum ce qui permet des expéditions lointaines à faible coût; d'autre part il a une morphologie régulière ce qui permet d'obtenir des animaux adultes bien calibrés, qualité recherchée dans les pays où l'animal est commercialisé vivant (comme cela se fait en Europe, Afrique du Nord, Canada). Par contre, si seule la chair extraite des coquilles est commercialisée (comme c'est le cas en Corée, Japon, USA, Mexique), la forme de la coquille importe peu et les cultures d'huîtres se font sur les collecteurs d'origines, ce qui est plus simple et moins coûteux que la culture du un-à-un. On voit donc que le choix d'un type de naissain se décide en fonction du mode de culture et de commercialisation du produit.

Le coût de production

Il est très difficile de comparer entre eux les coûts de production du naissain, qui varie en fonction de l'origine (naturelle ou industrielle), de la taille, de l'espèce considerée, du pays producteur... sans compter que d'une année sur l'autre le prix du naissain naturel varie en fonction inverse de l'intensité de captage.

Pour simplifier le problème on peut se référer à une seule espèce, la plus cultivée et la plus internationale: Crassostrea gigas.

Pour du naissain de cette espèce, d'une taille de 1 cm environ, les prix unitaires pratiqués en France en 1985 ont varié dans les limites suivantes: de 4,5 centimes à 6,5 centimes pour du naissain naturel détaché des collecteurs, et de 8,5 à 10 centimes pour du naissain un-à-un provenant d'écloserie.

Ainsi les prix d'écloserie, quoique plus élevés, se rapprochent désormais des prix du captage. Cependant il ne faudrait pas en conclure que les prix indiqués permettent à toutes les écloseries d'equilibrer leur budget. Seules les plus performantes y arrivent, les autres ne se maintiennent que grâce à des subventions publiques ou privées. En outre, l'investissement pour une écloserie est toujours plus important que pour une opération de captage. C'est pourquoi il est préférable de promouvoir les techniques de captage pour lancer une culture nouvelle de Bivalves. Cependant, dans certains cas, la solution écloserie est la seule possible.

Le rôle des écloseries

Le recours au écloseries est nécessaire dans des cas bien précis, qui sont les suivants.

Espèces se trouvant hors zone de reproduction naturelle

Exemple: L'huître plate européenne Ostrea edulis a été introduite sur la côte atlantique du Canada depuis 1969, où elle a une croissance satisfaisante mais où la reproduction n'est pas assurée dans le milieu naturel. Deux petites écloseries situées dans la Province de Nova Scotia produisent environ 3 millions de naissain de 3-4 mm annuellement, ce qui a permis la commercialisation de 3,3 tonnes d'huîtres en 1984 (Lavoie, 1985).

Espèces ayant un stock de géniteurs insuffisant dans la zone de culture

Exemple: C'est le cas de Pecten maximus en rade de Brest (France) où depuis 1963 le stock de pêche s'est effondré. Après des tentatives de captage infructueuses en milieu naturel à partir de 1973, (Buestel et al., 1973) une production en écloserie a été entreprise à partir de 1977 (Buestel et al., 1982) pour atteindre une production de plus d'1 million de naissain en 1985 (Cochard, comm.pers.) assurant ainsi un programme de repeuplement.

Espèces non captables en milieu naturel

C'est le cas de la plupart des espèces hypogées qui sont insensibles à l'effet piège des collecteurs, car les postlarves tombent sur le fond et s'enfoncent dans le sédiment sur de vastes étendues.

Parmi ces espèces hypogées non captables on peut citer la Palourde du Pacifique (Tapes philippinarum) la Palourde européenne (Tapes decussatus) produites dans les écloseries françaises et britanniques, le Clam Mercenaria mercenaria (USA et Europe), la mye Mya arenaria (USA) et prévoir, dans les prochaines années d'autres productions d'espèces comestibles telles que les cardiidés, les véneridés, les mactres, les arches, les donax.

Espèces en expérimentation

On rappellera seulement l'intérêt des écloseries pour l'expérimentation en génétique notamment pour l'obtention d'individus hybrides ou polyploïdes.

Le naissain dans les stratégies de développement de la conchyliculture

Développements liés à la production de naissain

Dans les années récentes, des cultures nouvelles de Bivalves se sont développées grâce à la maîtrise de la production de naissain. On en donnera deux exemples, l'un concernant le naissain de captage, l'autre le naissain d'écloserie.

Exemple 1. La culture de la Coquille St.Jacques, Patinopecten yessoensis au Japon (Pectiniculture).

Cette culture a débuté en 1961 sur les bases d'un captage de naissain naturel, dans la baie de Mutsu puis dans diverses baies de Hokkaïdo (Muller-Feuga & Querellou, 1973). Les résultats du captage n'ont cessé de progresser par la suite, entrainant l'essor de la culture de cette espèce, qui se pratique soit sur sol, soit en suspension. Ainsi la production commercialisée en poids total frais, est passée de 6000 tonnes en 1970 à 83000 tonnes en 1977 (Lucas & Lucas, 1980).

Exemple 2. La culture de la Palourde du Pacifique Tapes philippinarum en France.

Cette espèce à été introduite au début des années 70 en France. Sa culture est entièrement basée sur la production de 2 ou 3 écloseries, qui ont fourni en 1984 environ 50 millions de naissains. La même année, grâce au naissain de 1982, la commercialisation des adultes a atteint 235 tonnes. Un plan de développement prévoit pour cette espèce une progression régulière des cultures, notamment sur la côte atlantique. (Flassch, comm.pers.).

Les problèmes posés par l'absence de naissain

Dans certaines zones de culture, le naissain ne peut être produit sur place. Ce manque d'autarcie a pour conséquence une dépendance vis-à-vis des fournisseurs de naissain, dépendance d'autant plus contraignante que le fournisseur est lointain ou étranger. En général, ces cultures n'ont pas de possibilité d'extension.

Exemple 1. La culture de Crassostrea gigas au Maroc.

Depuis 1956, l'huître creuse est régulièrement cultivée dans la lagune de Oualidia, sur l'Atlantique, où la production d'adultes a longtemps oscillé autour de 100 tonnes par an, pour atteindre 200 tonnes en 1984. Cependant, il n'a jamais été possible de produire du naissain au Maroc, aussi toutes les cultures de C.gigas ont-elles été réalisées à partir de naissain importé de pays étrangers: France ou Japon (Beaubrun, 1976; Shafee, comm.pers.). La situation est la même en Tunisie pour la culture d'Ostrea edulis dans le lac de Bizerte (Tritar, comm.pers.).

Exemple 2. La culture d'Ostrea edulis en Galice (Espagne).

Il existe quelques bancs naturels d'O.edulis en Galice, mais trop réduits pour y pratiquer un captage régulier et abondant. Aussi toutes les cultures pratiquées en suspension ou en surélévation, sont alimentées par du naissain importé de France. Cette situation a eu pour conséquence l'introduction en Galice vers 1980, des maladies connues en France sur cette espèce (Marteilia refringens et Bonamia ostreariae), ce qui a provoqué l'effondrement de la production (Polanco, comm.pers.).

Les problèmes posés par le naissain excédentaire

On pourrait croire qu' "abondance de bien ne nuit pas" et qu'un excès de naissain ne saurait contrarier les résultats d'une culture. Or de nombreux exemples montrent que la recherche d'un équilibre entre quantité de naissain et capacité de production est nécessaire et que la surabondance de naissain conduit à des catastrophes.

Exemple 1. Dans la baie de Mutsu au Japon, le captage de Pecten yessoensis a été si efficace, que dans un premier temps, les pectiniculteurs japonais ont eu tendance à surcharger leurs cultures en suspension. Il s'en est suivi des malformations de la coquille et des mortalités inhabituelles. la situation n'a été rétablie qu'en détruisant une partie du naissain capté.

Exemple 2. Sur les côtes du Pérou, dans les années 1970, la pêche par plongée de la Coquille St.Jacques Argopecten purpuratus s'est considérablement développée (vente du muscle adducteur congelé aux Etats-Unis). Parallèlement il s'est développé une culture sur parcs à partir d'exemplaires de 30-40 mm récoltés en plongée et commercialisés à 80 mm environ. Ainsi s'amorçait une nouvelle pectiniculture basée sur le ramassage.

Cependant à partir du printemps 1982, la température de l'eau de mer s'est élevée pour atteindre 29°C en janvier 1983, soit environ 7°C de plus que les années normales (phénomène El nino). Cette variation climatique a fait disparaître diverses espèces benthiques mais a eu pour effet sur la Coquille St.Jacques d'accroîtree la densité des populations, ainsi que leur taux de croissance; en conséquence les récoltes par pêche ont considérablement augmenté, provoquant la chute des prix et compromettant la culture naissante de cette espèce (Wolff, 1984).

Les exploitations limitées au naissain

Dans certains cas particuliers, des cultures limitées au naissain peuvent avoir un certain succès.

Exportation de naissain

Certain pays se sont spécialisés dans l'exportation de naissain. Une telle activité peut demeurer marginale, c'est le cas en particulier du naissain naturel. Ainsi, le Japon a exporté à diverses reprises son naissain excédentaire de captage d'huître (Crassostrea gigas) soit aux USA (côtes du Pacifique); soit en France (lors du remplacement de l'huître creuse Crassostrea angulata décimée par une épizootie par Crassostrea gigas) soit dans divers pays (Maroc par exemple). Cette activité a aussi été acquise en Irlande et en Ecosse pour du naissain de captage de Coquille St.Jacques (Pecten maximus), importé en France dans un but de repeuplement, au début des années 80.

Par contre, pour le naissain d'écloserie, les exportations à l'étranger ont tendance à devenir plus régulières.

Transit du naissain

Les écloseries industrielles produisent du naissain tout au long de l'année. Ce naissain prégrossi en nurserie, est vendu pour le grossissement quand il atteint 1-2 cm. Cependant, le naissain né en automne ne s'accroît que très faiblement pendant l'hiver en pays tempéré. On la demande des conchyliculteurs est très forte de mars à mai, époque idéale pour les semis. Ils s'ensuit que pour faire face à cette demande, une écloserie francaise, la SATMAR, fait transiter depuis 1979 son petit naissain en pays tropicaux où la pousse est active de décembre à mai. Après avoir fait des essais en Guyane, en Martinique et au Sénégal, c'est dans ce dernier pays que s'opère la pousse hivernale en nurserie. Ainsi en 1984-85, 15 millions de palourdes et 40 millions d'huîtres ont été prégrossies au Sénégal (comm. pers., Diss-Mengus).

Conclusion

Cette étude a montré le rôle décisif de la production de naissain en conchyliculture et a analysé les avantages et inconvénients respectifs du naissain naturel et du naissain industriel. Dans les pays industrialisés ces 2 sources de naissain sont utilisées, de façon à mieux réguler la production, tout en évitant des coûts de production excessifs. Cette régulation, qui garantit l'essor des cultures, est encore inégale et dépend des espèces cultivées et des pays concernés. Cependant, il apparaît que les modèles de développement de la conchyliculture, mis au point dans les pays tempérés, pourraient être transférés ou adaptés dans les pays intertropicaux où la conchyliculture demeure jusqu'à présent très peu développée. L'introduction dans les pays tropicaux de la conchyliculture, qui est bien moins délicate que la culture des crustacés ou des poissons marins, pourrait être soit une source de protéines pour le pays lui-même (à condition d'adapter le produit aux traditions locales comme par exemple le séchage ou le fumage) soit une source d'exportation de haute valeur commerciale (congélation ou conserve). Certains exemples de conchyliculture nouvelle en Amérique latine ou en Asie démontrent que cette stratégie de développement peut être effective.

Références

AQUACOP & De GALLANDE D., 1979 - Production de naissain et élevage de la Moule verte *Mytilus viridis* en Polynésie française. Lette d'information sur les pêches CSP n°19. In Aquacop : Aquaculture en milieu tropical : 224-250. Ed. IFREMER, Brest, 1 vol. 477 p.

BEAUBRUN P.C., 1976 - Les huîtres au Maroc et l'ostréiculture dans la lagune de Oualidia. *Bull. Inst. Pêches mar. Maroc, 22* : 13-143.

BUESTEL D., DAO J.C. & MULLER-FEUGA A., 1974 - Résultats préliminaires de l'expérience de collecte de naissain de coquille Saint-Jacques en rade de Brest et baie de Saint-Brieuc. *Actes de Colloques CNEXO, 1* : 47-60.

BUESTEL D., ARZEL P., CORNILLET P. & DAO J.C., 1977 - La production de juvéniles de coquille Saint-Jacques (*Pecten maximus* L) *Actes de colloques CNEXO, 4* : 307-315.

BUESTEL D., COCHARD J.C., DAO J.C. & GERARD A., 1982 - Production artificielle de naissain de coquilles Saint-Jacques *Pecten maximus* L. Premiers résultats en rade de Brest. *Vie marine, 4* : 24-28.

CAHN A.R., 1951 - Clam culture in Japan, general headquarters supreme commanders for the allied powers. *Nat. Res. Sectien. Report n°146 :* 1-103.

CURTIN L., 1979 - Oyster hatchery pilot scheme setting up, operation and future role of hatcheries. *Tech. Rep. Minist. Agric. Fish (N.Z.) n° 155 MAF ed.* 16 p.

FURUKAWA A., 1971 - Outline of the japanese marine aquiculture. *Jap. Fish. Res. Convers. Assoc. Tokyo,* 1-39.

HUISMAN E.A. & MACHIELS M.A.M., 1985 - Fish production for food in the tropics. *XIII Intern. Congr. Nutrition, Brighton V.K. 18-23 Aug.85* (in press).

LAVOIE R.E., 1985 - The culture of molluscs in Canada. An overview. International Seminar on Shellfish culture development and management. La Rochelle, France, March 4-9, 1985 (sous-presse).

LOOSANOFF V.L. & DAVIS H.C., 1963 - Rearing of bivalve larvae. Advances in *mar. biol., 1 :* 1-136.

LUCAS A., 1976 - La culture des mollusques ou conchyliculture p.229-258 in Bougis et coll. Océanographie biologique appliquée. L'exploitation de la vie marine. Masson ed. Paris, 1 vol. 320 p.

LUCAS A., 1984 - Développement contrôlé des Bivalves marins. *Haliotis, 14* : 339-346.

LUCAS A., 1985 - Stratégie de développement des écloseries de Bivalves. International seminar on shellfish culture, development and management. La Rochelle, France, March 4-9, 1985 (sous-presse).

LUCAS A. & LUCAS N., 1980 - L'aquaculture dans les mers tempérées. *Norois 106* : 237-250.

MULLER-FEUGA A. & QUERELLOU J., 1973 - L'exploitation de la coquille Saint-Jacques au Japon. *Rapp. Scient. et Techn. CNEXO, 14* : 1-57.

ROBERT R., 1983 - Etude sur les causes de la perturbation et du développement larvaire de *Crassostrea gigas* dans le bassin d'Arcachon. Thèse de 3ème cycle, Université de Brest, 169 p.

RYTHER J.H., 1968 - Invertebrates and algae culture in the status and potential of aquaculture. Report n°2 : 1-260.

WALNE P.R., 1966 - Experiments in large scale culture of the larvae of *Ostrea edulis* (L.).*Fish. Invest. Ser. 2* : 1-53.

WOLFF M., 1984 - Early setback for scallop culture in Peru. *ICLARM letter July 84* : 19-20.

BIOLOGICAL ADAPTATION OF PACIFIC OYSTER (CRASSOSTREA GIGAS, THUNBERG) IN A MOROCCAN LAGOON AT OUALIDA

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Summary

Growth, mortality and reproduction of the Pacific oyster, Crassostrea gigas, Thunberg, in a Moroccan lagoon (Oualidia) were studied during the period 1981-1984 in order to understand how these oysters imported from France were adapted to a new ecosystem.

Cultch free oyster spats kept in trays at intertidal level grew from 6 g (mean live weight) to 43 g in one year, while spats attached to cultch material (shells or scallops) suspended from rafts at intertidal level showed lower growth rate; spats weighing 1 g attained only 15 g after nine or ten months. After this time period, when these spats were separated from cultches and reared in trays at subtidal level, they showed remarkable growth rates and attained marketable sizes within six months.

The high spat mortality rates recorded in summer decreased in autumn and winter and also as size increased. Annual mortality rates were calculated to be 70% for spats with cultches and 77% for cultch free spats, and these rates for large oysters varied from 13 to 54% depending the size.

The reproductive cycle of oysters in Oualidia was studied using histological sections of the gonad and by monitoring seasonal changes in dry body weight of a standard animal. Gametogenetic activities started in January-February with gonadal proliferation occurring in March-April; the gonads were ripe in May. Between June and September, spawning and gametes reconstitution can take place several times. The gonads reach a resting stage in October. In addition to the complete spawning in September-October, important partial spawning in July was also noticed.

Growth and reproduction of the oysters imported into Oualidia lagoon do not seem to be affected by their new environment. Higher mortality rates of spats, observed during this study, may be reduced by improving the culture techniques and choosing a suitable period for introducing the spats in the culture grounds.

Résumé

La croissance, la mortalité et la reproduction des huîtres japonaises, Crassostrea gigas, Thunberg, dans la lagune de Oualidia (Maroc) ont été étudiées au cours de la période 1981-1984 pour évaluer jusqu'à quel niveau ces huitres importées de France on pu s'adapter dans un nouvel écosystème.

Les naissains libres pesant 6 g (poids vif) gardés dans des cages en bois au niveau intertidal, atteignent 43 g au bout d'un an. Au contraire, les naissains fixés sur des collecteurs (coquille de Pecten maximus) montrent un taux de croissance plus faible; les naissains de 1 g atteignent au bout de neuf ou dix mois 15 g seulement. Après cet intervalle de temps, quand ils sont separés de leur collecteurs et élevés en casiers au niveau subtidal, ils montrent un taux de croissance remarquable et arrivent à des tailles commercialisables six mois plus tard.

Les taux de mortalité très élevés observés durant l'été diminuent en

automne et en hiver. La mortalité diminue au fur à mesure de l'accroissement. Les taux de mortalité calculés sont de 70% pour les naissains fixés dans les collecteurs et de 77% pour les nassains libres. Pour les huîtres adultes ils varient de 13 à 54% selon la taille.

Le cycle de reproduction des huîtres à Oualidia a été étudié d'une part à l'aide de coupes histologiques de gonade et d'autre part à l'aide d'un suivi du poids sec d'un animal standard. La gamétogénèse commence en janvier-fevrier avec un developpement rapide des gonades durant mars-avril. Les gonades sont mûrs au mois de mai. Entre juin et septembre, les pontes successives et la reconstitution des gamètes peuvent se derouler plusieurs fois et les gonades arrivent en phase de repos en octobre. En plus de la ponte complète en septembre-octobre, une ponte partielle très importante en juillet a été aussi remarquée.

La croissance et la reproduction des huîtres introduites dans la lagune de Oualidia ne semblent pas être affectées par le nouvel environnement. Le taux de mortalité le plus élevé dans cette étude peut être réduit considérablement en améliorant les techniques de culture, et en choisissant unne meilleure période pour les naissains dans les parcs ostréicoles.

Introduction

Though natural oyster beds of Ostrea edulis, Crassostrea angulata and Ostrea stentina have been reported to occur in Atlantic coastal waters and lagoons of Morocco (Dollfus, 1934; Collignon, 1960; Beaubrun, 1976) they have not yet been exploited commercially. These oysters were either inaccessible for fishing or found at a very low density level (beaubrun, 1976). However, oyster consumption in Morocco has been noteworthy since 1920 since adult oysters have been imported from foreign countries such as Portugal and France for immediate sale after keeping them for some days in coastal waters. Since 1952, oyster spats have been imported from Spain and Portugal (C.angulata); from Senegal (C.rhizophorae) and Japan (C.gigas), and reared in coastal lagoons up to marketable sizes. As C.gigas gave better yields then the other species, the oyster farmers preferred to cultivate these pacific oysters.

Although aquaculture in coastal lagoons benefits from the fact that C.gigas has a fast growth rate in the Moroccan climate (oysters attain a marketable size in less than a year (Beaubrun, 1976)) it is still at a very early stage. Since Moroccan fishery, in general, has been reported to regress, the Moroccan government is very interested in initiating aquaculture programmes to fulfil unmet national protein requirements. At present Morocco produces nearly 150 tons of oysters per year, whic is insufficient to meet the national demand let alone any potential export market.

This paper is part of a programme to evaluate the possibility of large-scale oyster production in Morocco. The growth and mortality of C.gigas in Oualidia Lagoon have already been studied (Shafee & Sabatié, in press). Experiments on the reproduction of oysters were carried out from 1982 to 1984. This report attempts to review obvious efforts to assess the adaptability of French oysters to the Moroccan environment.

Description of the study area

Oualidia Lagoon, situated on the Moroccan Atlantic Coast (Fig.1), has a warm temperate climate with mean temperatures of 24°C in the summer and 12°C in the winter. The period of rainfall extends from September to April, with peak values during winter months (120 mm). The downstream region of the lagoon is oval in shape with two mouth openings that communicate with the Atlantic Ocean (Fig.1). This enlarged zone, which has a sandy bottom, narrows to a long up-stream region of 6 km length and 0,4 km average width. The extreme end of this zone ends with the installation of salt pans.

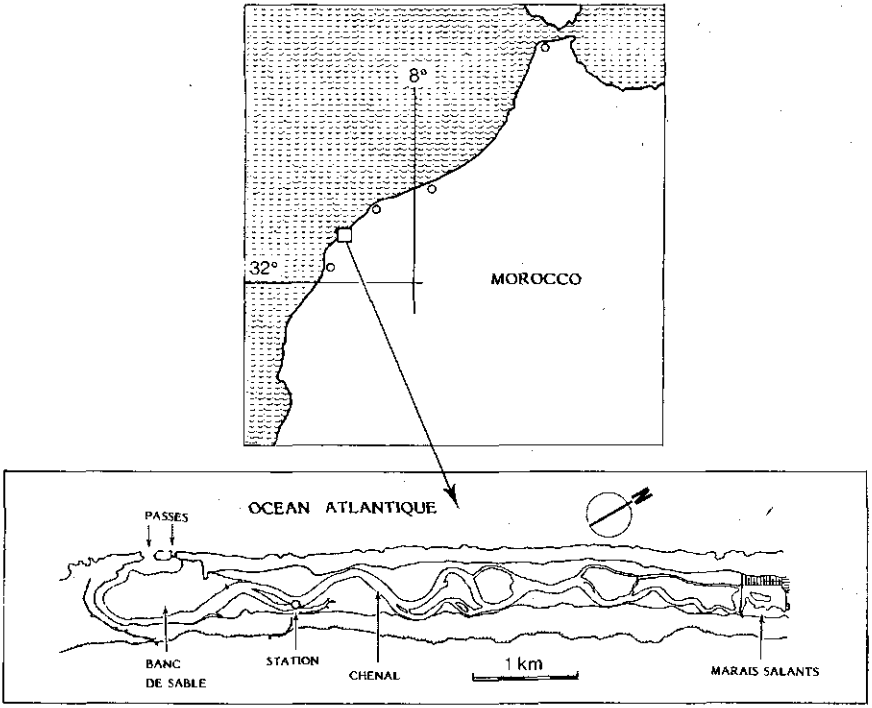

FIGURE 1. LOCATION OF THE EXPERIMENTAL STATION IN OUALIDIA LAGOON (MOROCCO) (AFTER SHAFEE AND SABATIÉ, IN PRESS).

The ecosystem of Oualidia Lagoon is strongly influenced by tidal cycles. During high tide the lagoon gets filled with water from the Ocean and during low tide the lagoon water runs off into the Ocean. Natural springs exist all along the lagoon, but many are concentrated at the up-stream end thereby causing a progressive decrease in salinity from the mouth openings to the up-stream end.

The lagoon becomes shallower at the up-stream end. During the lowest spring tide, the depth varies between 1.8 and 0.2 m depending on the location. As a result, during low tides, the temperature of the water is influenced by the temperature of the atmosphere, and during high tides it is influenced by that of the ocean. In addition to tidal effects, the ecosystem is also subject to seasonal variations characteristic of temperate regions.

The experimental station (Fig.1) selected has been inhabited since 1956 by an oyster farmer who has been very co-operative during the present research experiments. The experimental station has a depth of 0.75 m during the lowest spring tides, and the maximal tidal amplitude was 2.20 m. The tidal current was 0.5 m/s during high and low neap tides and 1 m/s and 0.70 m/s during high and low spring tides.

Seasonal and tidal effects on the salinity, temperature, concentration of Chlorophyll A pigments and particulate organic matter in the experimental station of Oualidia Lagoon have been described by Shafee and Sabatié (in press) for the period 1981-1983. The results of their findings are summarised hereinafter.

The amplitude of variation in salinity between tidal cycles was higher during spring tides (6‰ and lower during neap tides (2‰). Salinity also showed slight seasonal variation (Fig.2A) with higher values in summer (mean = 35 to 38‰) and lower values in winter (mean = 30 to 33‰); this was related to evaporation and precipitation respectively.

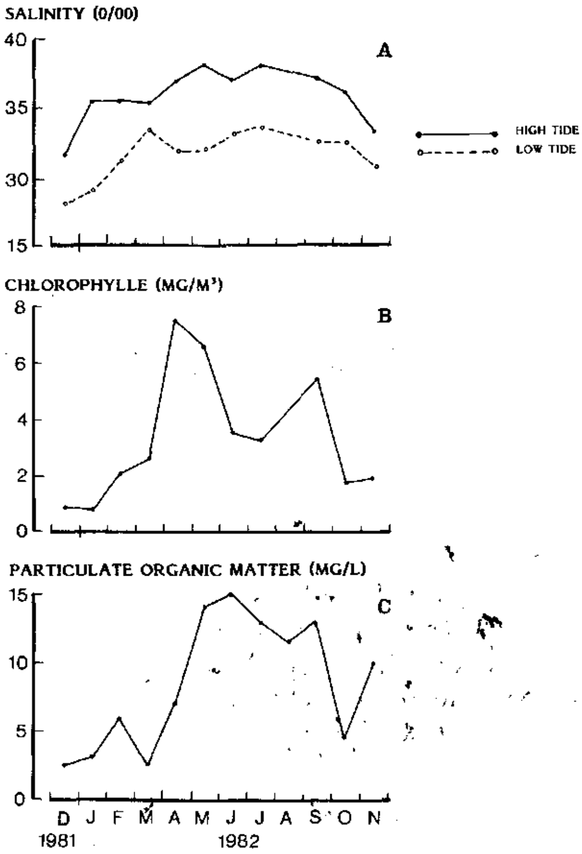

FIGURE 2. SEASONAL VARIATION IN SALINITY (A), CHLOROPHYLL a (B) AND PARTICULATE ORGANIC MATTER (C) OF THE LAGOON WATER AT THE EXPERIMENTAL STATION IN OUALIDIA (SHAFEE AND SABATIÉ, IN PRESS).

Temperature underwent diurnal, tidal and seasonal changes (Fig.3). The amplitude of diurnal variation was greater in summer (11°C) then in winter (3°C). The highest temperature in summer was 26°C and in winter 14°C. Temperature readings showed higher values during high tide in winter than in summer.

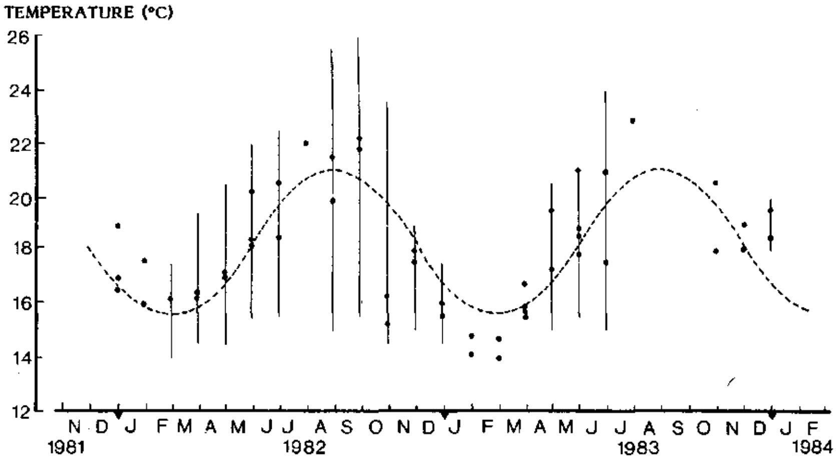

FIGURE 3. SEASONAL VARIATION IN TEMPERATURE OF THE LAGOON WATER AT THE EXPERIMENTAL STATION IN OUALIDIA (SHAFEE AND SABATIÉ, IN PRESS).

Variations in Chlorophyll A concentrations were typical of seasonal cycles of temperate regions, with peak values occurring in spring and autumn, slightly lower values in summer and lowest values in winter. The highest value for Chlorophyll A was observed in April (8 mg/m^3) and the lowest values were observed in January (1.28 mg/m^3). The concentration of particulate organic matter remained more or less high (10 to 15 mg/l) throughout the year 1982, except during the winter (2.5 to 6 mg/l).

Material and methods

Culture technique

Oyster farmers use a standard technique to rearing oysters in Oulidia Lagoon.

Every year in February or March oyster spats from the culturing grounds of Gironde (France), are imported for fattening in Oualidia Lagoon. Scallop shells (Pecten maximus) are used as cultch material.

The scallop shells on which a number of young oysters have been spatted, are strung on a metal wire through holes drilled at the centre of the shell. Usually 10 to 15 shells are strong on a wire of 1 to 1.5 m long and folded to form two parallel lines. Vinyl tubes are placed between cultches for spacing. These strings of cultches, hung vertically from a rack, are attached to the lagoon floor at intertidal level. This rack culture can last up to nine or ten months. Spatted in October, by December, the oysters have already reached a size of 60 mm length, are separated from cultches and placed individually in trays of 2 m x 1 m x 0,15 m dimension. The frame is made of iron and the mesh of plastic net. Each tray can contain 200 to 300 oysters, and is placed at the intertidal level on supports. The oysters are washed and cleaned every fortnight. After six months they can be sold at the local market.

Reproduction

Beginning on 14th December, 1982, samples of oysters were collected from the experimental station at monthly intervals. During every sampling period 40 to 50 oysters ranging from 30 to 100 g live-weight, were taken from different trays, at random, brought to the laboratory, scrubbed with a brush to remove fouling organisms and washed in sea water. Whole live-weight of each individual was noted.

The individuals were opened and descriptions of apparent (macroscopic) gonad condition were recorded, based upon colour, appearance of follicles in the matle, texture of mantle, and extent of infiltration of the mantle by genital tissue. Usually 10 open oysters were chosen at random and a portion of their visceral mass was removed for histological study. All samples came from the same anatomical portion of the oysters, namely, near the digestive tract. Tissues were embedded in wax (M.P.= 55°C) and 6.6 sections were prepared and stained in Trichrome de Masson (Martoja & Marolja, 1967).

The soft body of each remaining oyster was removed separately from its shell and dried in an oven at 60°C until the weight was constant.

The gonadal condition of Crassostrea gigas was determined during each sampling period by using the different stages explained by Kennedy (1977) for mussels. A gonad index was calculated for each sample.

The different gametogenetic stages were ranked as follows:

Stage O	: Resting stage	= 1
Stage 1 & 2	: Development	= 2
Stage 3A	: Ripening	= 3
Stage 3B & 3C	: Spawning and redevelopment	= 2
Stage 3D	: Recently spent	= 1

For each sample the number of oysters at each stage was multiplied by the numerical score of that stage. These products were summed and the result divided by the total number of oysters in the sample. Thus if all individuals were spent, resting or of indetermined sex, the gonad index was 1.0 (the minimum) and if all were fully mature, the index was 3.0 (the maximum). In general a period of gametogenetic development is indicated by an increase in the index while a decrease indicates that spawning (including redevelopment and further spawning) was occurring.

The relation between whole weight (W) and dry body weight (W_d) were expressed in grams by the following linear regression equation:

$$\ln W_d = \ln a + \ln W \cdot b \quad (1)$$

where 'a' and 'b' were coefficients of the Functional Regression explained by Ricker (1973).

Results

Visual observations of opened oysters revealed that C.gigas displayed follicular development in the visceral mass during gametogenetic activity. Gonadal tissues could occupy more than half of the body. When the gonads were ripe, a whitish layer covered the visceral organs. During this period gametes could be released easily by pressing the gonadal tissue lightly. During spawning the volume of the gonad decreased, and the visceral mass became yellow in colour. When the gonads were completely spent, the body became thin and sometimes "watery". It was not possible to indentify the sex by visual observations of gonads. Moreover, spent stages might be confused with early developmental stages.

Different gametogenetic stages observed during microscopic examination are shown in appendix I. Results are presented both as percentage distribution of these stages (Table 1) and as gonad index (Fig.4). When sampling began on 14th December, 1982, most of the oysters were in the resting stage. Gonad development started slowly in January, and all gonads were ripe in May. During June, July and August partial spawning and redevelopment of gametes took place simultaneously, and the complete spawning occurred in September. The gonads of most of the oysters returned to the resting stage in October.

Table 1. Distribution of stages of gonad development in samples of Crassostrea gigas from Oualidia Lagoon, Morocco.

Date	Stage (%)						
	0	1	2	3A	3B	3C	3D
1982:							
1 Dec.	78	22	-	-	-	-	-
1983:							
15 Jan.	57	29	14	-	-	-	-
11 Feb.	56	33	11	-	-	-	-
13 March	29	57	14	-	-	-	-
26 April	25	25	50	-	-	-	-
7 May	11	-	22	-	-	-	-
9 June	-	-	20	20	40	20	-
18 July	-	-	8	15	39	23	15
6 Aug.	-	-	-	27	18	36	18
25 Sept.	18	-	-	18	18	-	46
19 Oct.	70	-	-	-	-	-	30
13 Nov.	56	33	-	-	-	-	11
15 Dec.	70	30	-	-	-	-	-

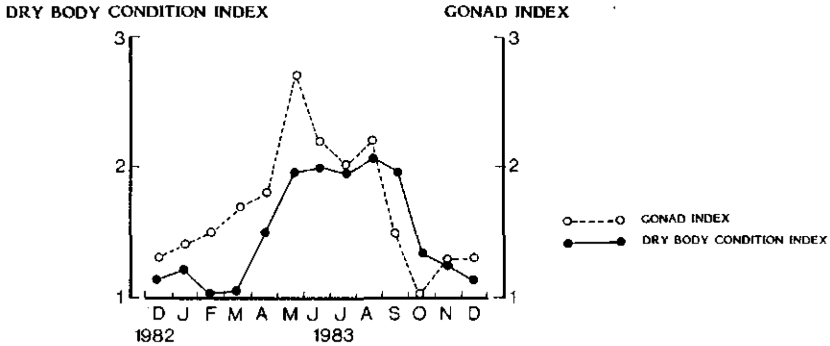

FIGURE 4. SEASONAL VARIATION IN GONAD AND DRY BODY CONDITION INDEXES OF CRASSOSTREA GIGAS IN OUALIDIA LAGOON.

Coefficients of regression relating whole weight (W) and dry body weight (W_d) of oysters were calculated for oysters collected during every sampling period. The results are shown in Table 2, which also shows a 95% confidence interval for slopes (b) and elevations (s), the number of pairs of observations for each regression (n) and the coefficient of determination (r^2). Using these regressions, the dry body weight of a standard animal (75 g whole live-weight) has been calculated and plotted in Fig.4, as dry body condition index. Seasonal variation of this index follows closely that of the gonad index showing that the increase in tissue weight and gametogenetic activity occurred simultaneously.

Table 2. Monthly regression equations (Y on X) relating whole live-weight (X) and dry body weight (Y) for Crassostrea gigas from Oualidia Lagoon, Morocco.

Date	a ± 95% C.I.	b ± 95% C.I.	N	r^2
1982:				
1 Dec.	- 3.97 ± 0.57	0.95 ± 0.09	36	0.83
1983:				
15 Jan.	- 4.46 ± 0.27	1.08 ± 0.08	40	0.88
11 Feb.	- 4.10 ± 0.24	0.95 ± 0.07	38	0.87
13 March	- 4.84 ± 0.30	1.13 ± 0.09	41	0.87
26 April	- 4.17 ± 0.22	1.06 ± 0.06	24	0.97
7 May	- 3.60 ± 0.32	0.99 ± 0.08	33	0.87
9 June	- 5.22 ± 0.41	1.37 ± 0.10	24	0.93
18 July	- 6.15 ± 0.84	1.58 ± 0.22	13	0.89
6 Aug.	- 3.93 ± 0.33	1.08 ± 0.08	19	0.93
15 Sept.	- 4.55 ± 0.80	1.21 ± 0.19	24	0.67
19 Oct.	- 4.55 ± 0.40	1.12 ± 0.11	25	0.87
13 Nov.	- 4.36 ± 0.58	1.06 ± 0.25	15	0.86
15 Dec.	- 3.54 ± 0.35	0.85 ± 0.09	17	0.89

Discussion

There is a current feeling among oyster farmers in Morocco that the present annual yield from oyster cultivation is far less than that obtained during earlier days when C.gigas was imported directly from Japan. Beaubrun (1976) pointed out that the mortality rate of japanese spats in Oualidia was insignificant, and their growth rate was very high. The spats could grow to marketable size in less than one year. He even suggested ways to reduce the growth rate so that marketing could match seasonal demand.

The present study on Pacific oysters imported from France shows that their reproductive biology has not been affected by the new ecosystem in Oualidia. The periods of formation and of gametes are more or less the same as those observed by His (1976) and by Le Dantec and Marteil (1976) in temperate waters. The gametogenetic activities start in late winter, and the gonads are ripe in late spring. Spawning and redevelopment of gametes occur during the summer. The gonads return to resting stages in early autumn.

As far as the growth of these oysters is concerned, except for spats with cultches, cultch free oysters show remarkable growth rates, comparable to those reared in other temperate regions as observed by Deslous-Paoli, 1982; Sumner, 1980; Sumner, 1981 and Walne and Spencer, 1971. The growth rates of spats as observed by Shafee and Sabatié (in press) are shown in Fig.5. A weight gain of only 15 g by spats attached to cultches is found to be very low, in comparison with the 30 g weight gain observed by other authors (Berthomé & Fernandez, 1979; Deslous-Paoli, 1982). This slow growth was assumed to be caused by overcrowding of spats and also delayed separation of spats from cultches (Shafee & Sabatié, in press). Once these spats were separated from cultches and reared in trays, their growth rates rose (Fig.6). The seasonal growth rates of both spats and large oysters follow the same trend observed in other temperate regions and links closely with reproductive cycle.

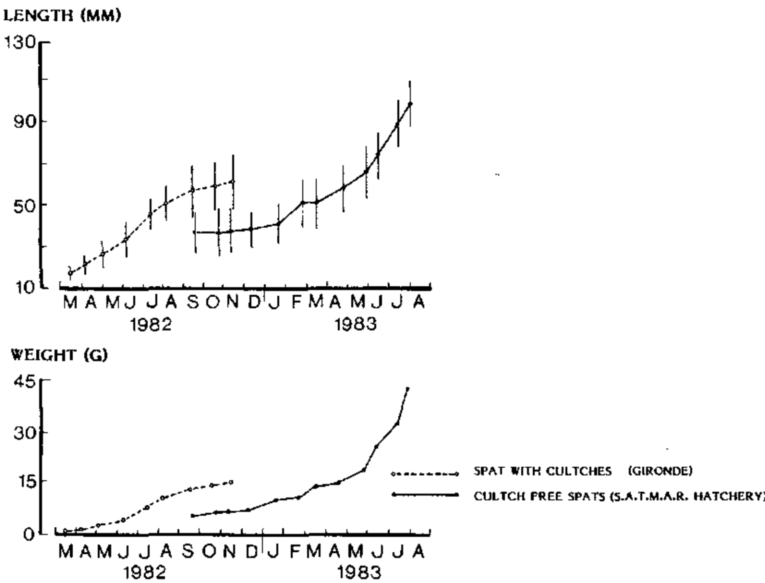

FIGURE 5. SEASONAL GROWTH OF OYSTER SPATS WITH CULTCHES (DISCONTINUOUS LINE) AND CULTCH FREE SPATS (CONTINUOUS LINE) REARED IN THE EXPERIMENTAL STATION AT OUALIDIA (SHAFEE AND SABATIÉ, IN PRESS).

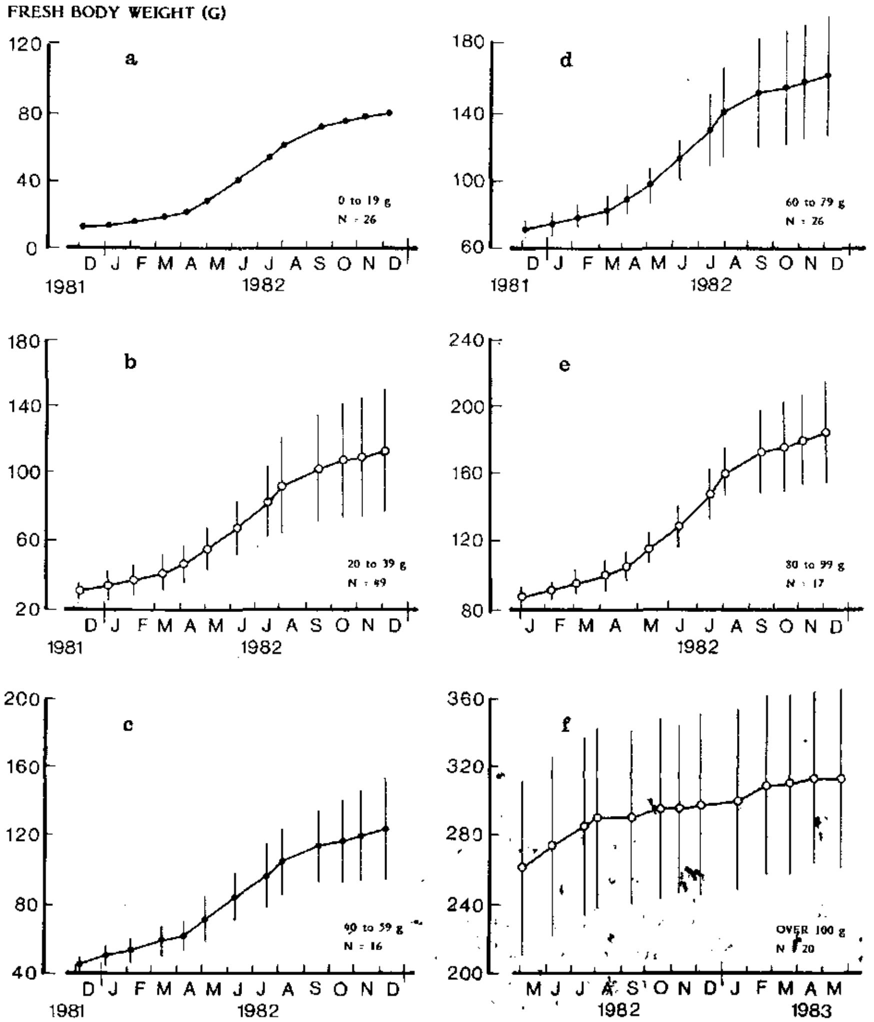

FIGURE 6. SEASONAL GROWTH OF CULTCH FREE OYSTERS OF DIFFERENT SIZE CLASSES REARED IN THE EXPERIMENTAL STATION AT QUALIDIA (SHAFEE AND SABATIÉ, IN PRESS).

Mortality seems to be the major obstacle for oyster culture work in Oualidia Lagoon. Annual mortality rates of cultch-free spats and spats with cultches were 77% and 70% respectively (Shafee & Sabatié, in press), and these values are higher than those reported from other culturing grounds (Walne & Spencer, 1971; Spencer & Gouga, 1978; Spencer et al., 1978). However, as the oysters grew, these rates declined, and large oysters reared in trays had a 15 to 54% mortality. Temperature appears to be the major cause of mortality (Fig.7 and 8).

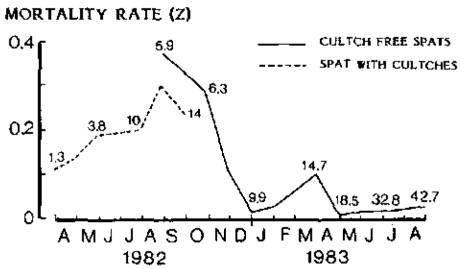

FIGURE 7. SEASONAL MORTALITY RATES OF CULTCH FREE SPATS (CONTINOUS LINE) AND SPATS ATTACHED TO CULTCHES (DISCONTINOUS LINE) REARED IN THE EXPERIMENTAL STATION AT OUALIDIA (SHAFEE AND SABATIÉ, IN PRESS).

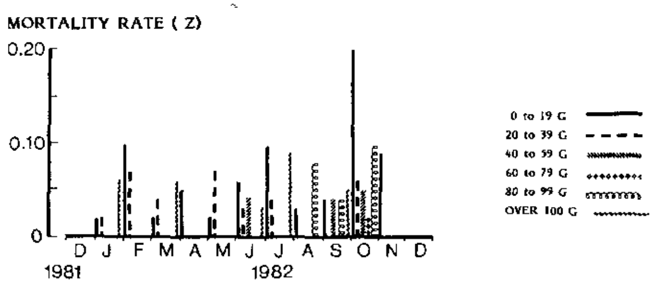

FIGURE 8. SEASONAL MORTALITY RATES OF CULTCH FREE OYSTERS AT THE EXPERIMENTAL STATION IN OUALIDIA (SHAFEE AND SABATIÉ, IN PRESS).

It is to be observed that during summer and early autumn when the lagoon has high temperature and great diurnal variation, most of the oysters experience thermal stress, and survival depends essentially upon the size of the animal; the larger the animal the better chance it has to survive.

Besides thermal stress bacterial and parasitic contamination during importation, may explain the high mortality rates but this aspect has not been examined here. Attempts to collect natural spat falls in Oualidia Lagoon were unsuccessful, and the small number of spats that have been fixed in seed collectors died before growing to a large size.

Except for the high mortality rates, C.gigas successfully adapted to the new ecosystem in Oualidia. Mortality rates may be reduced to a considerable extent by importing the spats during early winter instead of in March. If they are large enough they may withstand thermal stress during summer and autumn.

References

Beaubrun, P.C., 1976. Les huîtres au Maroc et l'ostreiculture dans la lagune de Oualidia. Bull.Inst.Pêches Mari.du maroc, N°22, pp.13-143.

Berthome, J.P. & N.Fernandez-Castro, 1980. Etude de la croissance et de la qualité de trois lots d'huîtres creuse Crassostrea gigas dans le bassin de Marennes - Oléron en 1979. Manuscript presented at the International Council for the Exploration of the Sea 1980, 14 p.

Collignon, J., 1960. Les huîtres et l'ostréiculture au Maroc. Bull.Inst.Pêches Marit. du Maroc. N°4, pp.9-17.

Deslous-Paoli, J.M., 1982. Croissance et qualité de l'huître Crassostrea gigas, Thunberg en élevage dans le bassin de Marennes - Oléron. Tethys, 10(4): 365-371.

Dollfus, R.P., 1934. Les huîtres comestibles sur la côte atlantique du Maroc: bancs naturels, perspectives ostréicoles. Compte - rendu de la 58e session de Assoc.Franc P.Avanc.des Sciences, Rabat, 1934, pp.246-248.

His, E., 1976. Contribution à l'étude biologique de l'huître dans le bassin d'Arcachon. Activité valvaire de Crassostrea angulata et de Crassostrea gigas; application à l'étude de la reproduction de l'huître japonaise. Thèse présentée à l'Université de Bordeaux I pour l'obtention du titre de Docteur en Science Biologiques, 63 p.

Kennedy, V.S., 1977. Reproduction in Mytilus edulis aoteanus and Aulacomya maoriana (Mollusca: Bivalvia) from Taylors Mistake, New Zealand. N.Z. Journal Mar.Freshwater Res., 11(2): 255-267.

Le Dantec, J. & L.Martell, 1976. La conchyliculture française. Deuxième partie. Biologie de l'huître et de la moule. Rev.Trav.Inst.Pêches Marit., 40 (2°), pp. 125-320.

Ricker, W.W., 1973. Linear regression in fishery research. J.Fish.Res.Bd. Canada, 30, pp. 409-434.

Shafee, M.S. & M.R.Sabatié, 1986. Croissance et mortalité des huîtres dans la lagune de Oualidia. Aquaculture: in press.

Spencer, B.E. & C.J.Gouga, 1978. The growth and survival of experimental batches of hatchery reared spat of Ostrea edulis and Crassostrea gigas, using different methods of tray cultivation. Aquaculture, Vol.13, pp. 293-312.

Spencer, B., D.Key, P.F. Millican & M.J.Thomas, 1978. The effect of intertidal exposure on the growth and survival of hatchery-reared Pacific oysters (Crassostrea gigas Thunberg) kept in trays during their first ongrowing season. Aquaculture, 13, pp. 191-203.

Sumner, C.E., 1980. Growth of Pacific oyster, Crassostrea gigas Thunberg, cultivated in Tasmania. I. Intertidal stick culture. Aust.J.Mar.Freshwater Res., 31, pp. 129-135.

Sumner, C.E., 1981. Growth of Pacific oysters, Crassostrea gigas Thunberg, cultivated in Tasmania. II. Subtidal culture. Austr.J.Mar.Freshwater Res., 32, pp. 411-416.

Walne, P.R. & B.E.Spencer, 1971. The introduction of the Pacific oyster (Crassostrea gigas) into the United Kingdom. Shell fish Inf.Leafl., Fish. Lab., Burnham on Crouch. Essex, 21, 8 p.

Appendix I.

Various stages of gametogenetic cycle in the gonadal tissues of Crassostrea gigas *Thunberg reared in the experimental station at Oualidia.*

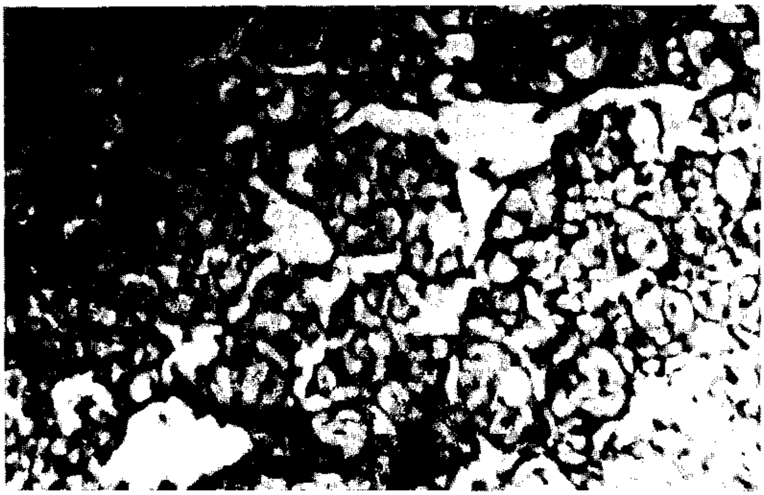

Fig. A. Stage 0

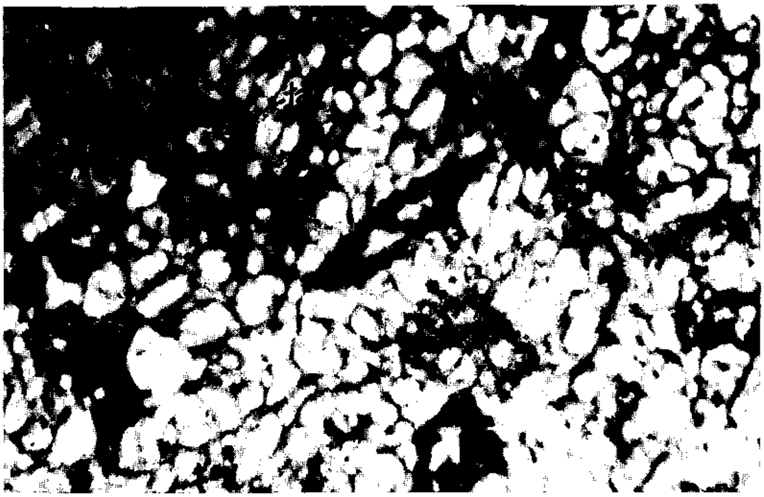

Fig. B. Stage 1, Female
e.f. = early follicle

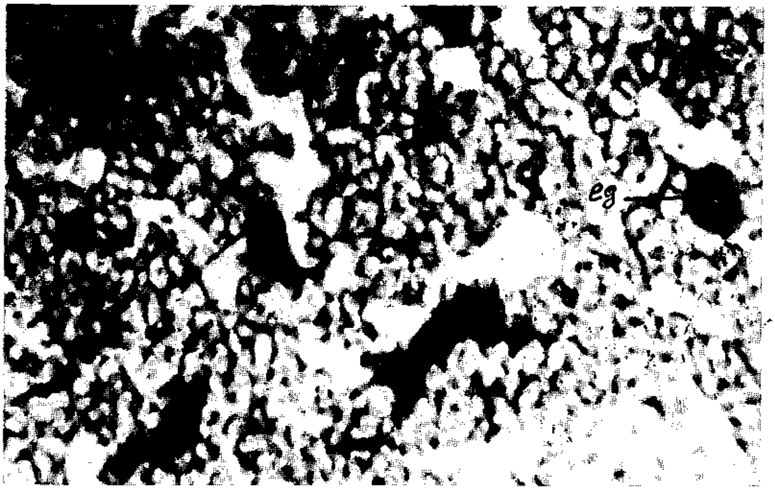

Fig. C. Stage 1, Male
e.g. = early gametogenetic stage

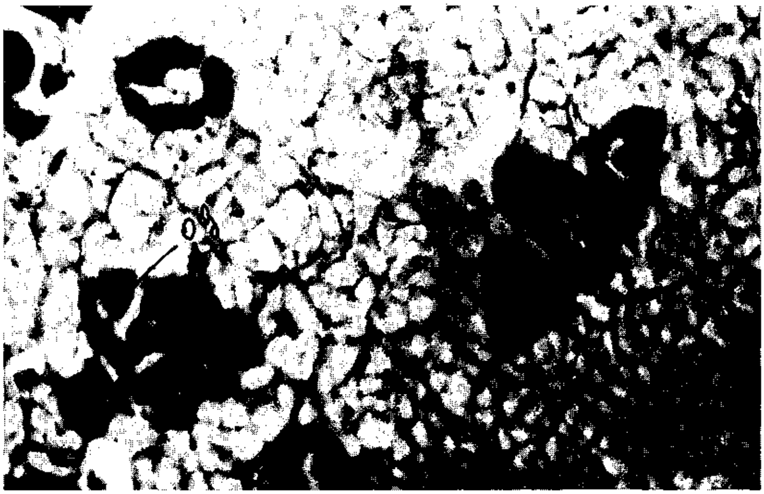

Fig. D. Stage 2, Female
og = oögonium

Fig. E. Stage 2, Male
e.g. = early gametogenetic stage
s.p.z. = spermatozoids

Fig. F. Stage 3A, Female
og = oögonium

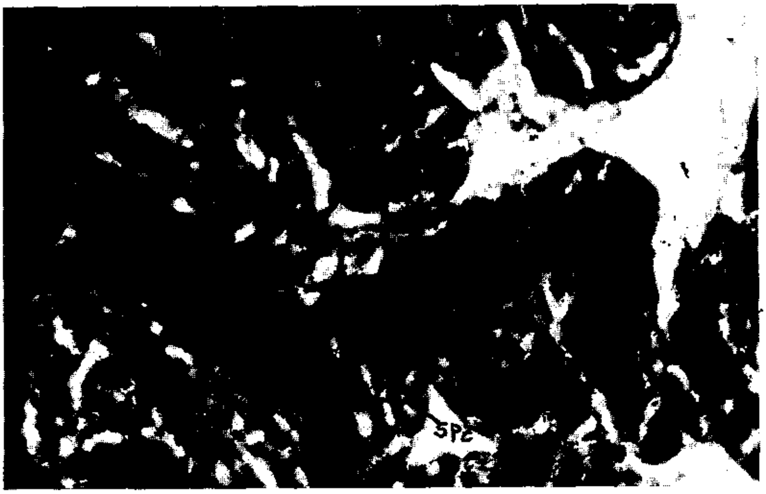

Fig. G. Stage 3A, Male
s.p.z. = spermatozoid

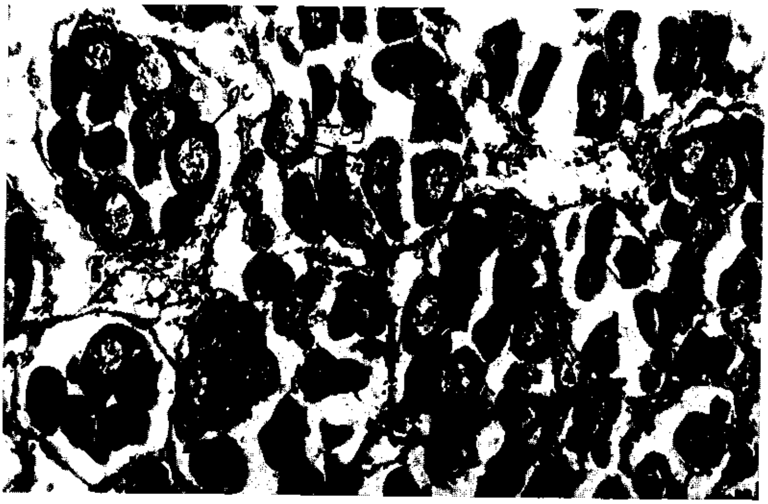

Fig. H. Stage 3B, Female
o.c. = oocyte
c.y. = cytoplasma
N = nucleus
n = nucleolus

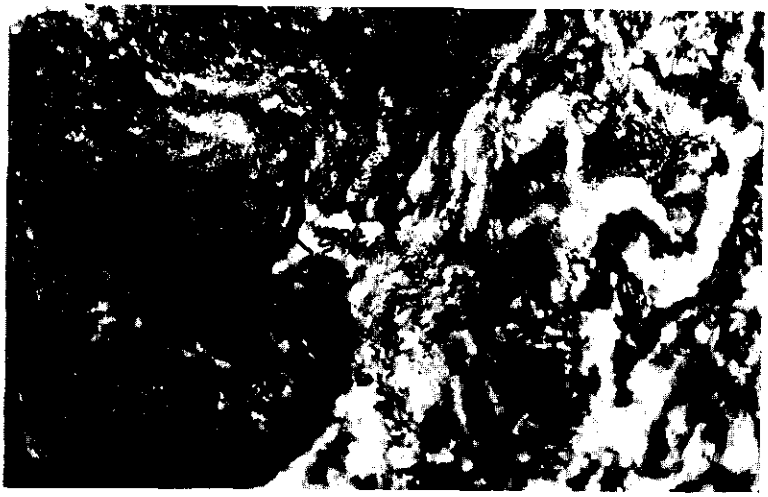

Fig. I, Stage 3B, Male
s.p.z. = spermatozoid

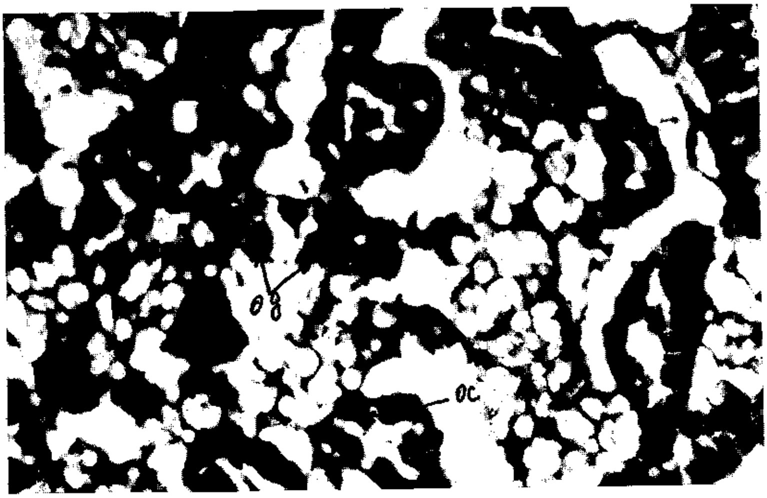

Fig. J. Stage 3C, Female
o.c. = oocyte
o.g. = oogonium

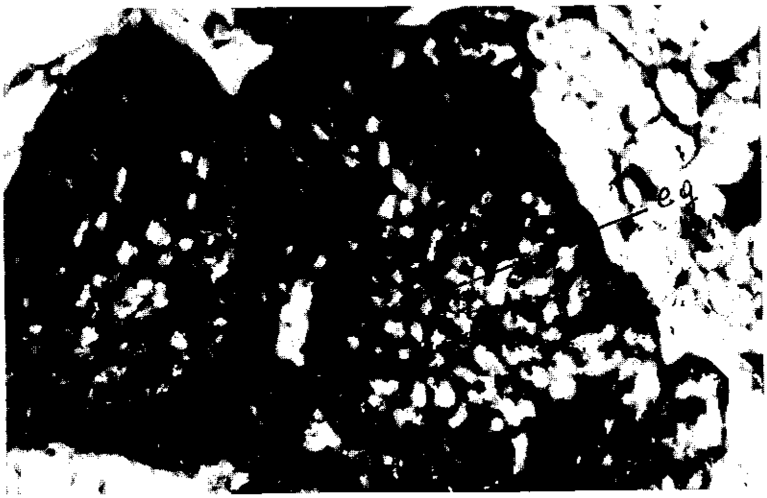

Fig. K. Stage 3C, Male
e.g. = early gametogenetic stage

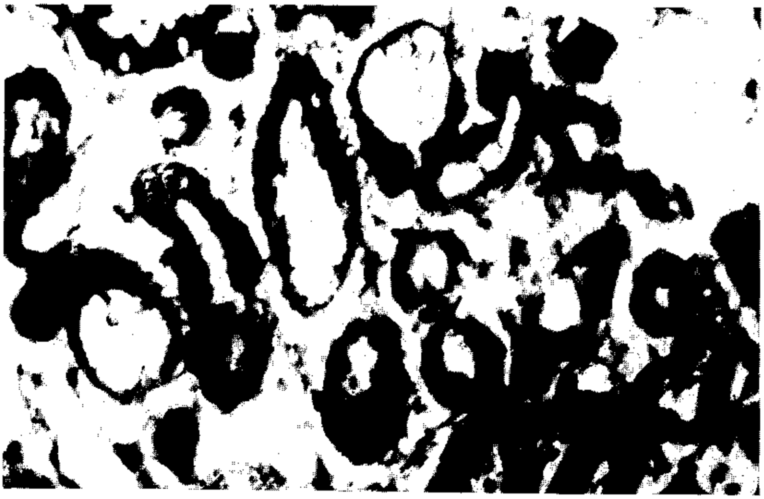

Fig. L.   Stage 3D, Female

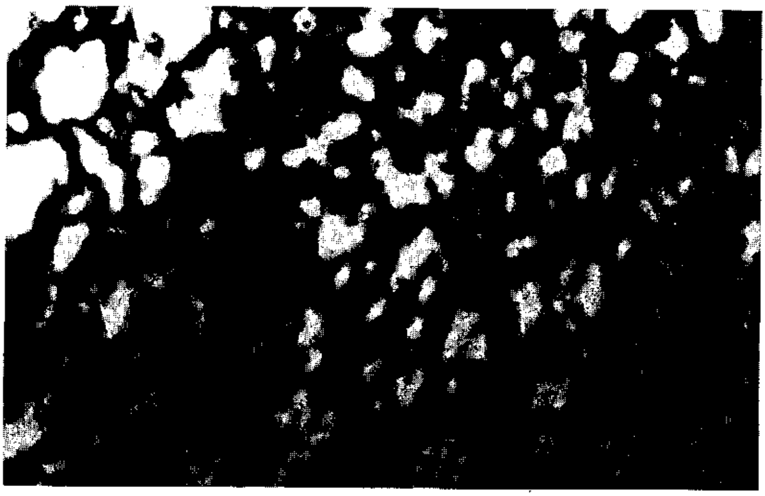

Fig. M.   Stage 3D, Male

THE FUTURE OF FLOATING CAGE CULTURE IN TANZANIA

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Summary

This paper reviews cage culture and, more particularly,in Tanzania, viz. Siganus canalicullatus in floating cages. It is seen that this rabbitfish, which is essentially herbivorous feeding mainly on algae, can be fed on a pelleted diet made of a mixture of algae and fishmeal. Due to high costs involved in making suitable feed, it has been recommended that this rabbitfish be reared in pen culture rather than cage culture.

Poblems reviewed and discussed include feed availability, supply of fingerlings, buoyancy, fouling, pollution, theft, vandalism and socio-economic factors.

It has been concluded that, although cage culture in Tanzania looks promising, especially using fishes that are planktivores, culturing rabbitfishes in floating cages would be economically unviable.

Résumé

L'auteur décrit brièvement la pisciculture en cages flottantes et, de façon plus détaillée, celle de Siganus canalicullatus en Tanzanie. Il montre que cette espèce, essentiellement herbivore et se nourrissant surtout d'algues, peut accepter un régime exclusivement administré sous forme de granulés composés d'un mélange d'algues et de farine de poisson. Compte tenu des coûts élevés de la préparation d'aliments adaptés à Siganus canalicullatus, on recommande de le cultiver en enclos plutôt qu'en cage.

Au nombre des problèmes exposés figurent tous ceux qui relèvent des disponibilités alimentaires, sources d'approvisionnement en alevins, capacité de flottaison, obturations pouvant survenir, pollution, vols, vandalisme et de divers facteurs socio-économiques.

L'auteur conclut en signalant que même si l'avenir de la pisciculture en Tanzanie offre de bonnes perspectives de réussite, notamment dans le cas de poissons planctophages, aucune entreprise visant à élever Siganus canalicullatus en cage flottante n'est économiquement viable en l'état actuel des connaissances.

Introduction

Cage culture is an enclosure culture which holds the organisms captive within an enclosed space while maintaining a free exchange of water. A cage is usually totally enclosed on all, or all but the top, sides by screen or netting. Cage culture seems to be of a recent origin (Ling, 1977, Beveridge, 1984). Documentary evidence suggests that cage culture originated in Asia, e.g., cages are reported have been used in rearing Leptobarbus hooveni in Indonesia since 1922. The culture of carp in submerged bamboo or "bulian" is reported to have developed independently since the early 1940s (Vaas & Sachlan, 1975).

In Tanzania the origin of floating cage culture can be traced back to 1978 when the author embarked on the culture of rabbitfish, Siganus sp., in floating cages. Before this, cages were merely used to keep captured organisms. For example in 1973, Bwathondi reported that lobster-fishermen used to keep lobsters in submerged cages in Kilwa awaiting transportation to Dar es Salaam. Or in freshwaters, cages, usually box traps, also known as "Madema", were used to keep captured fish while fishermen continued their fishing.

Cage construction

The cage culture method has spread throughout the world; by 1978 it was being used in over 70 countries (Coche, 1978). In most areas, new materials such as nylon, plastic, polyethylene and steel are now being used; they last longer than wood or natural fibres and allow for better water exchange. Most designs currently in use have a bouyancy mechanism which is usually included in the collar of the cage. The bouyant collar is made of light wood such as bamboo, or of steel or plastic. The synthetic net is suspended from the floating construction.

The cages used in this report were described by Bwathondi (1982a). They were made of a square wooden frame (3.05 x 3.05 m) joined at the edges by brass screws; brass is preferred because it is rustproof.

A hole is made at each corner of the frame, into which a galvanised pipe of 2 cm diameter and 183 cm length is inserted so that it can be suspended in the water when the net cage is fixed on the frame supported by the pipe. Two plastic floats are enclosed on a small wooden prism (Fig.1).

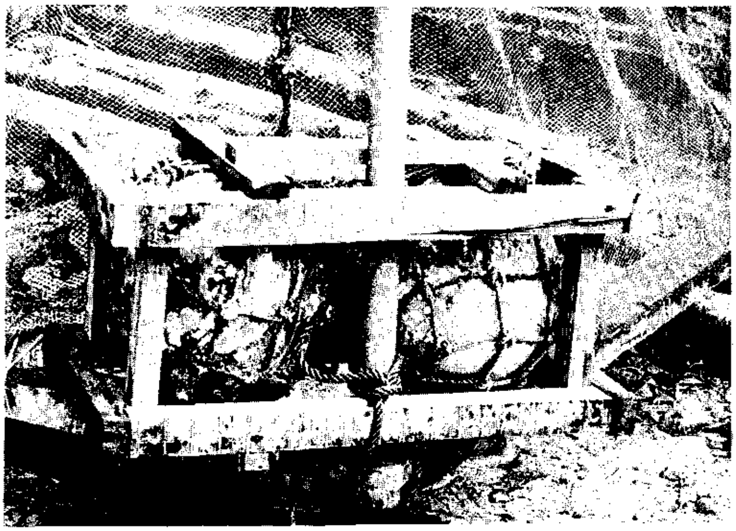

Figure 1. Two floats enclosed in a prism at thecollar of the cage.

A single prism with the floats inside is fixed at the corners of the cage. After assembling, the cage (Fig.2) is transported to the culture site where it is tied to a wooden raft (Fig.3 and 4). The raft is also provided with floats and anchored to the bottom of the sea by heavy concrete blocks.

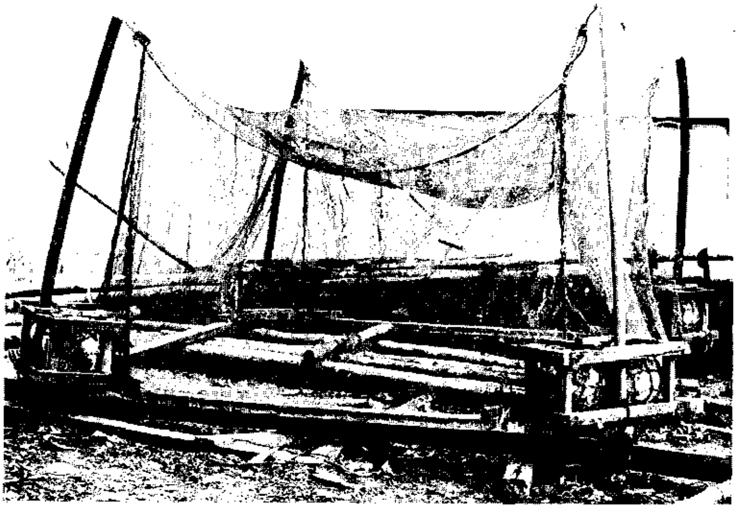

Figure 2. Cage before setting.

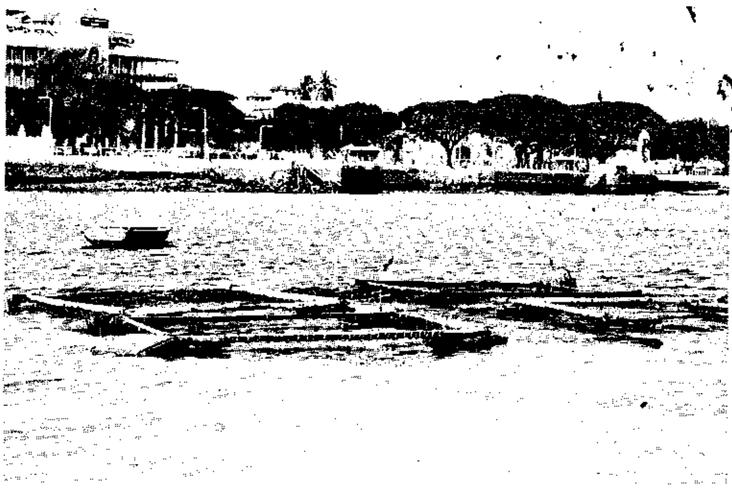

Figure 3. Cages at the culture site.

Figure 4. Cages attached to a floating raft.

The cost of the bouyant collar is usually high, sometimes as much as 40% of the total cost of the cage; this depends on the type of float used. Attempts were first made to use fixed cages but later abandoned because they were not able to withstand adverse weather conditions.

Results

The growth rate of S.canaliculatus reared in floating cages was recorded by Bwathondi (1982b). It was found that fish reach marketable size (total length: 21 cm) in about seven months, provided fish measuring 3.5 cm total length (about 1,5 months old) were used for stocking.

Fish reared in cages were fed a mixture of algae and minced sardines. It was observed that on a straight algae diet fish fed continuously, with their ingestion being almost equal to their egestion rate, whereas feeding with the algae-fish mixture (made into pellets) greatly reduced defecation and stimulated growth. Fish grew from 16 g to 150 g in less than six months. The condition factor (K) of the reared fish averaged 1.32 thus confirming good growing conditions (Bwathondi, 1982a).

Both economic and technical factors greatly influence the development of cage fish culture throughout the world. The use of intensive cage culture is only feasible if the fish being cultured can be sold at a sufficiently high price to generate a profit at harvest (Beveridge, 1984). According to a report of the ADCP (1983) feed costs represent up to 40-60% of the total operating costs in intensive aquaculture. ADCP (1983), however, recommends holding feed costs down to no more than 20% of the farm-gate value of the fish. In the present programme with rabbitfish, the estimated value of feed was calculated, although most of it was obtained free of charge. When a daily feeding level of 5% of the fresh body weight was computed, the feed costs of one ton of fish of market size varied between US $ 800 and 1500. Considering local market prices for fish these feed costs are too high for the fish farmers and, therefore, this feed can only be used in experiments.

The experiments showed that the feed quality deteriorated with time, although feed prepared during sunny days was found to maintain its quality longer than feed prepared on rainy days. In view of the above dangers of aflatoxine in poor quality feed needs to be stressed (Otufemi et al., 1983; Roberts, 1983).

One of the most important items in any fish culture project is the availability of fry and fingerlings. The culture of rabbitfishes, Siganus canaliculatus, in Tanzania depends upon the seasonal collection of fry from the grassbeds, especially 1,5 months after the breeding season when the fry measures about 3.5 cm total length. Beach seiners, usually in groups of five persons, use seine nets of 1.2 cm mesh size. A good haul may bring in up to 400 fry. The fry then have to be sorted out to avoid transferring undesired fish species, such as predators on rabbitfish fry to the rearing cages. Proper reproduction techniques could eliminate this risk as well as the risk of over exploiting of the wild stock and would ensure a constant supply of seed fish. Unfortunately this has not been attempted in Tanzania, despite the fact that the technology is known available.

Floating cages should be bouyant enough to remain raised from the bottom of the sea where bottom dwelling organisms could enter the cages.
Bwathondi and Ngoile (1982), recorded a number of cage foulers around Zanzibar. The intensity of fouling may be so high that the total weight of the cage increases to five times its original weight. Because timber and oil drums are expensive, efforts should be made to find inexpensive available materials which can remain bouyant for at least one six to seven month rearing season. Foulers not only cause flotation problems, they also reduce water circulation in the cages. Bwathondi (1982c) points out that oysters now considered as foulers, could be made profitable by an integrated polyculture programme involving both fish and oysters.

Cages located in river areas may suffer greatly from siltation which is favoured by reduced water circulation. In such cases growth rates drop or, in time, the fish may die.

Many aquaculture projects carried out in industrial areas have to be foresaken because of pollution problems. Most developing countries are fortunate because their waters are relatively unpolluted. But occasionally pollutants or pesticides do reach the culture sites. In 1980, for example, there was a spill of toxaphene in the vicinity of Zanzibar harbour. This insecticide killed all the fish in the area, including the cultured fish. Similar risks may occur in eutrophic lakes where massive fish-deaths may occur as a result of water deoxygenation following the collapse of algal bloom and the rapid mixing of stratified water layers. Bwathondi et al. (1984) observed such massive fish-kills in Lake Victoria. If cages had been placed in the affected parts of the lake at that time, the fishes would all have died.

Twice (in 1980 and 1981) the project experienced storms and vandalism. The storms destroyed two cages after they were detached from the main anchorage on the raft. Theft and vandalism were perpetuated mainly by children who occasionally swim in the vicinity of culture sites.

Socio-economic problems seriously hamper aquaculture development in Tanzania. Ordinary fishermen generally consider marine fish culture to be "foreign" or simply an academic exercise. Efforts are underway to introduce fish culture especially as an inland fisheries activity. The response is encouraging (Bwathondi, 1985).

Discussion

Intensive cage culture of fishes is largely restricted to temperate countries where fishes like trout and salmon, which fetch high prices, are grown on expensive, high protein feeds. In the tropics, however, fishes, though popular, are sold very cheaply so that feeding high protein feeds would be uneconomical.

Furthermore, tropical fish have a variety of natural foods such as macrophytes, plankton and detritus. Supplementary feeds derived from low cost agricultural by-products could, therefore be used to improve the productivity of tropical fish culture.

Our studies, show that rabbitfish live on algae (more than 90%) and plankton. The algae consumed are fairly large and need firm anchorage, which means they cannot be left to grow in cages. The best culture practice for this macrophyte feeder, therefore, would be pens instead of floating cages. But for other species like tilapia and grass carp which feed on a wide range of food, cage culture is to be preferred.

At present problems of fingerling supply, pollution, adverse weather conditions, theft and, vandalism curtail the development of cage culture in Tanzanian coastal waters.

In conclusion it is stressed that in Tanzania floating cage culture may be profitable when used to rear planktivorous fishes. Such cultures would be ideal in Tanzanian inland waters especially in the ponds and large dams where supplementary feeds could be added to improve production of cage reared fish.

References

ADCP, 1983. Fish feeds and feeding in developing countries - an interim report on the ADCP Feed Development Programme. Rome, UNDP/FAO, Aquaculture Development and Coordination Programme (ADCP)/Rep/83/18, 97 pp.

Beveridge, M.C.M., 1984. Cage and pen fish farming. Carrying capacity models and environmental impact. FAO Fish.Tech.Pap. (255): 131 pp.

Bwathondi, P.O.J., 1973. The Biology and Fishery Potential of Palinurid lobsters in Tanzania. M.Sc.Thesis. University of Dar es Salaam.

Bwathondi, P.O.J., 1982a. The culture of rabbitfish, Siganus spp. in Tanzania. IFS, Stockholm, Sweden. 35 p.

Bwathondi, P.O.J., 1982b. The Aquaculture of rabbitfish Siganus canaliculatus, Park 1797, and problems of cage culture in Tanzania. Univ.Dar. Science J. Vol.8 (1 & 2): 43-53.

Bwathondi, P.O.J., 1982c. The potential of Marine polyculture in developing countries: Case study in Tanzania. Atlantica Volume 5.

Bwathondi, P.O.J., 1985. Fish culture as a means of alleviating fish protein deficiency in Tanzania. Paper presented at a seminar on utilization of food: Morogoro, Tanzania, 27-31 May, 1985.

Bwathondi, P.O.J., & M.A.K.Ngoile, 1982. Bivalves fouling floating cages used in aquaculture. Indian J.Mar.Sc.11 (3): 283-285.

Bwathondi, P.O.J., F.M.M.Chale & E.B.Katunzi, 1984. Mass mortality of fishes in Kagera side of Lake Victoria 29/4/84-1/5/84. Report, TAFIRI.

Coche, A.G., 1978. Revue des pratiques d'élevage des poissons en cages dans les eaux continentales. Aquacul:ture, 13: 157-189.

Ling, S.W., 1977. Aquaculture in Southeast Asia. Seattle, Washington, University of Washington Press. 108 p.

Otufemi, B.E. C.Angins & R.J.Roberts, 1983. Aspergillomycosis in intensively cultured tilapias from Kenya. Vet.Rec. 112: 203-204.

Roberts, R.J., 1983. Tilapia: farm fish for the tropics. Span 26(2): 78-79.

Vaas, K.R. & M.Sachlan, 1957. Cultivation of common carp in running water in West Java. Proc. IPFC 6 (1-2): 187-196.

AMÉLIORATION DE LA PRODUCTION D'ALEVINS DE CARPES

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Résumé

La communication décrit les essais de reproduction artificielle réalisés sur la carp dans des stations de recherche piscicoles à Madagascar. Les travaux ont porté sur l'élevage des géniteurs, l'induction de la reproduction, la reproduction artificielle et l'incubation des oeufs. L'accent a été mis aussi sur la technologie requise pour une production à grande échelle d'alevins d'un mois, utilisés par les paysans malgaches pour empoissonner leurs rizières et leurs étangs. Cela justifie l'inclusion, dans cette étude, d'un chapitre sur l'utilisation éventuelle de différents types d'engrais organiques et leurs effets sur le développement du plancton, principale source de nourriture des larves, notamment pendant les premières semaines la résorption de la réserve vitelline.

Les espèces ayant fait l'objet de cette étude sont la carpe commune (Cyprinus carpio L.) et la carpe argentée (Hypophtalmychtys molitrix).

Summary

This paper describes experiments on artificial reproduction in carp at the fish culture research stations in Madagascar. Work focussed on spawner husbandry, induced spawning, artificial reproduction and incubation of eggs. Emphasis was also placed on the technology required for large-scale production of one month old fingerlings which Malagasy farmers stock in rice-fields and ponds. This explains why the study included the possible use of various types of organic fertilizers, and the effects of these fertilizers on the development of planktonic organisms, the main food for larvae, especially during the first few weeks after resorption of the yolk sac material.

The species covered in the study are the common carp (Cyprinus carpio L.) and the silver carp (Hypophtalmychtys molitrix).

Introduction

Le développement de l'aquaculture a été pendant longtemps freiné par l'insuffisance d'alevins. En 1979, par la méthode de reproduction naturelle, les 3 Stations piscicoles principales arrivaient à peine à produire 100.000 alevins. Cette méthode ne s'effectue pas toujours avec succès pour différentes raisons: actions dévastatrices des prédateurs, des micro-prédateurs et des insectes carnivores, parasitage des larves, insuffisance de nourriture des larves et des alevins, limitant le nombre d'alevins produits.

Tel n'est pas le cas en reproduction artificielle dont la mise au point va pouvoir apporter un outil d'un niveau technique élevé aux stations piscicoles et va permettre de produire massivement des alevins.

Préparation des géniteurs

Les espèces ayant fait l'objet de l'étude sont la carpe commune (Cyprinus carpio L.) et la carpe argentée (Hypophtalmychtys molitrix).

Les travaux étaient menés dans les Stations de recherches Piscicoles de Kianjasca (Moyen Ouest) et d'Analamazaotra (Côte-Est), situées respectivement à 180 km et à 130 km de la capitale.

Trois mois avant la saison de reproduction qui se situe entre mi-septembre et mi-novembre, les géniteurs stockés à 3 individus/are ont reçu une nourriture riche en protéines, à raison de 5% de la biomasse. Ce qui a eu en général pour effet l'accroissement pondéral des produits sexuels et la vigueur des larves confirmant l'existence de corrélation directe entre le développement des oeufs dans les ovaires et la nourriture (Tableau 1).

Tableau 1. Comparaison du poids des oeufs (Cyprinus carpio).

Stations de Recherches		Poids des géniteurs (kg) 1981	1982	1983	Poids des oeufs correspondants(g) 1981	1982	1983
Kianjasoa							
N°	21	3.9	4.1	4.3	200	875	875
	72	5,7	6,4	6,4	305	500	600
	59	3,7	4,9	5,1	55	375	-
	13	3,6	5,3	5,4	-	675	460
Analamazaotra							
N°	235	3,2	4,2	4,5	190	405	550
	82	4,3	4,4	4,2	650	750	750
	204	3,9	4,0	4,2	330	-	310
	133	5,4	4,6		350	540	-

- : ponte négative.

À la Station de Kianjasoa où la température de l'eau se situe entre 22°C et 28°C, il a été démontré pour la première fois et confirmé la possibilité d'avoir une double reproduction au cours de l'année à condition que les géniteurs soient abondamment nourris.

Tableau 2. Essai de 2ème reproduction (Cyprinus carpio).

Géniteurs O N°	Poids (kg)	Poids d'oeufs (g) Octobre 1982	Février 1983
10	4,5		315
13	5,4	675	355
21	4,3	875	185
58	5,1	-	475
72	6,4	675	475

Néanmoins, de tableau montre que les oeufs produits en février sont moins nombreux que ceux d'octobre.

Induction de la reproduction

Les hypophyses utilisées étaient importées d'Italie et d'Israël. On a aussi expérimenté avec succès des hypophyses extraites sur place sur des tilapias. Elles étaient traitées à l'acétone avant emploi.

La dose de 3 mg/kg suffit pour provoquer la pleine ovulation des femelles. A la Station de Kianjasoa, une seule injection peut déclencher la maturation des oeufs. A Analamazaotra, les femelles étaient induites deux fois à 12 heures d'intervalle.
Sans tous les cas, la tranquillité des femelles injectées est un facteur important dans le succès de l'ovulation.

Ponte artificielle

La ponte est déterminée par la tagesgrade d'ovulation (1) qui est de ± 10 jour à Analamazaotra et ± 9 jours à Kianjasoa.
Une femelle est prête à pondre dès qu'elle se livre aux premières manifestation actives de la ponte naturelle ou quand elle est constamment chaussée par un mâle.
On mélange à sec oeufs et laitance (1 kg/5-10 ml) pendant une heure en y versant petit à petit une solution fertilisante d'eau, d'urée et de NaCl qui a pour propriétés de préserver la mobilité des spermatozoïdes et d'empêcher les oeufs de s'agglutiner.

Incubation

L'incubation se fait en carafe de Zoug de 7 L. Le débit d'eau est réglé à 0,8 l par minute pendant le premier jour, à 2,1 à partir du deuxième jour.
Ses traitements préventifs au vert de malachite contre le Saprolegnia sont appliqués deux fois par jour à partir du 2ème jour.
La durée d'incubation varie en fonction de la température. Elle est de 46 heures à Kianjasoa où les températures minima et maxima enrégistrées en octobre sont de 24° et 28°; 76 heures à Analamazaotra (température minima: 19°, température maxima: 25°).
Les larves fraîchement écloses sont siphonnées dans des carafes de plus grande capacité où elles sont gardées jusqu'à la résorption du sac vitellin. La veille de leur transfert, les larves sont nourris au jaune d'oeuf réduit en fines miettes ou à la farine de soja.

Préparation des étangs de grossissement des alevins

Le succès du grossissement des larves dépend de la préparation des étangs d'alevinage puisque la nourriture naturelle reste leur nourriture de base surtout durant la première quinzaine de leur vie.
15 jours avant la mise en eau, on utilise de la chaux vive comme désinfectant (1,5 kg/are) et de la fumure organique (100 kg/are) en vue d'améliorer la productivité.
Après la mise en eau qui a lieu 8 jours avant le déversement des larves on fertilise les étangs au superphosphate-triple (100 g/are) et au sulfate d'ammonniaque (200 g/are) dissous avec 10 kg/are de fientes sèches, de bouse, ou de crottin frais, répandu à la surface de l'eau.
Les organismes planctoniques commencent à se développe à partir du cinqième jour. On a pu dénombrer à Kianjasoa 1.500 individus de zooplancton par litre d'eau composés de 70% de Rotifères, 30% de Cladocères et de Copepodes.

(1):Tagesgrades d'ovulation $= \frac{\text{température moyenne quotienne}}{\text{nombre de jours}}$ X(multipliée par

À la vieille du transfert des larves en étang, les prédateurs d'alevins et concurrents alimentaires tels têtards, grenouilles, nèpes, Cyclops, étaient éliminés par sennage avec des filets à très fines mailles.

On a constaté qu'à partir du 5ème jour qui suit le déversement des larves, la population de Rotifères disparaît complètement. Il y a nécéssité de refertiliser les étangs tout en apportant aux alevins de la nourriture artificielle contenant 20-25% de protéines.

À la densité de mise en charge de 9.000 larves à l'are, on a récolté après 4 semaines de grossissement des alevins de 40-45 mm de longueur, le taux de survie variait entre 67 et 85%. Ces grosseurs sont supérieures aux taille habituelles de cession.

Étude sur la plantonologie

Cette étude qui est en cours a pour objectif de voir les effets des différents types d'engrais organiques sur le développement du planeton et sur la croissance des larves: engrais verts, fientes de poule, crottin de porc, bouse de vache.

Elle va donc permettre de statuer sur les possibilités d'utiliser divers types d'engrais en fonction des disponibilités, d'augmenter les doses d'engrais organiques de façon à ne distribuer que le minimum de nourriture artificielle, devenue de plus en plus chère.

Carpe Argentée (Hypophtalmychtys molitrix)

La technologie de reproduction induite de la carpe argentée est identique à celle de la carpe commune. La seule différence porte sur la reproduction artificielle proprement dite qui est très simplifiée chez la carpe argentée en ce sens qu'on n'utilise pas de solution fertilisante car les oeufs n'ont pas de pellicule collante.

Discussion

Les résultats d'essais menés ont montré que:

- à Kianjasoa, la période de reproduction se situe, entre mi-septembre et fin octobre, tandis qu'à Analamazaotra où les températures sont moins élevées, elle va de début octobre à mi-novembre.
- il est possible la saison de reproduction induite jusqu'en février-mars.
- le développement des oeufs les ovaires serait en corrélation directe avec la nourriture d'où la nécessité impérieuse de nourrir convenablement les géniteurs.
- 90% des femelles injectées ont répondu favorablement aux hypophysations en expulsant tous les oeufs contenus dans la ovaires.
- on a obtenu 70-80% d'éclosion, voire 95% avec des soins très particuliers.
- on pourrait aller au-delà de 9.000 larves à l'are en mise en charge alors que jusqu'en 1982, on pensait qu'on ne pouvait pas excéder le chiffre de 3.000.-
- le succès de l'alevinage est fonction de la bonne gestion des étangs et du stock.

Conclusion

À Madagascar, le problème de base en pisciculture est la production et la distribution d'alevins d'espèces économiquement intéressantes en quantités suffisantes pour assurer l'empoissonnement annuel des rizières et des étangs familiaux. À raison de 3.000 à l'Ha, 50.000 hectares de rizières demandent 150 millions d'alevins. Or, la production d'alevins cessibles des stations piscicoles en reproduction naturelle n'est que de l'ordre de 300.000 unités/an.

La seule solution au problème posé consiste à créer en zone rizicole et auprès des grands lacs des écloseries de moyenne importance, d'une capacité de 10-15 millions d'alevins, du type de celle qui existe à Analamazaotra, où l'on pratique la reproduction artificielle et qui seront gérées par du personnel compétent.

En se basant sur une production minimale de 10 millions d'alevins âgés de 4 semaines par écloserie et un taux de survie en rizière de 50%, atteignant un poids moyen individuel de 150 g après 4 mois, la production serait de l'ordre de 750 tonnes.

Ainsi, une bonne maîtrise des techniques de reproduction de la carpe, en améliorant la capacité de production d'alevins, aurait un impact non négligeable sur la production de poissons.

COMPARATIVE STUDIES OF THE CATFISH CRYSCHTHYS NIGRODIGITATUS (LACEPEDE) IN THREE ISOLATED GEOGRAPHICAL AREAS IN NIGERIA FOR BREEDING PURPOSES

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Summary

For a successful breeding programme in Nigeria, using the most popular cultured catfish, C.nigrodigitatus (Lacepede) a study was conducted to identify strains with a better genetic potential for fry survival. Three isolated geographical areas were selected as a follow up to an earlier seven areas study. Factors compared were fecundity, egg size, hepatosomatic index, gonad index, and condition.

Size of eggs as well as fecundity vary considerably between individual fishes and between locations. They are correlated with the size and age of females. In Warri River specimens of C.nigrodigitatus produced larger eggs and gave higher number of eggs per female. For successful breeding programmes, fish culturists are advised to collect their broodfish from this area, since large egg sizes apparently enhance fry survival.

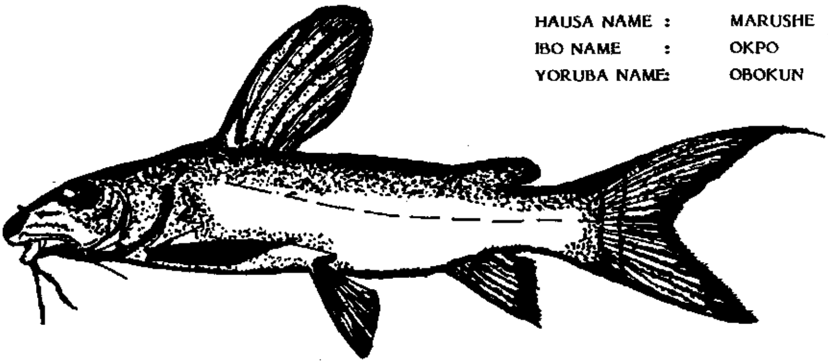
Résumé

Une étude détaillée a été réalisée sur le poisson-chat d'élevage le plus apprécié au Nigéria, Chrysichthys nigrodigitatus (Lacepede) en vue d'identifier la souche dotée du potentiel génétique le plus favorable à la survie des alevins. On a élargi l'étude qui concernait au préalable sept régions à trois autres régions choisies en raison de leur isolement géographique. Divers paramèters ont été comparés: fécondité, taille des ovocytes, rapport hépatosomatique, indice des gonades et coefficients de condition.

La taille des oeufs comme la fécondité varient considérablement d'un poisson à l'autre et d'un emplacement à l'autre. Ils sont en corrélation avec la taille et l'âge des femelles. Dans le fleuve Warri, les C.nigrodigitatus ont produit par femelle les oeufs les plus gros et les plus nombreux. Pour réussir leur programme de reproduction, on recommande aux pisciculteurs de choisir leurs reproducteurs dans cette zone car on a aussi constaté que des oeufs plus gros favorieraient la survie des alevins.

Introduction

The catfish, C.nigrodigitatus (Fig.1) is very common in fresh and brackish waters of Nigeria. Research results have confirmed that the species grows very rapidly in ponds and readily accepts supplemental diets (Maclaren, 1949; Sivalingam, 1972; Ezenwa, 1978). Because of the high market demand for this species and its abundance in major rivers, estuaries and lagoon systems in most parts of West Africa, a thorough examination of the quality of the existing strains is very important for a successful breeding programme. Ezenwa (1978) used meristic and morphometric characteristics in separating various stocks of the species in seven stations in Nigeria. Other factors commonly used in such studies include serum tests and parasitic incidence. Several authors have added fecundity and ova size as additional tools in differentiating strains of fish species (Nagasaki, 1958; Pitt, 1964). Rounsefell (1957) concluded from his fecundity data that location-related differences existed between populations of the same species of salmon.



HAUSA NAME : MARUSHE
IBO NAME : OKPO
YORUBA NAME: OBOKUN

FIGURE 1. CHRYSICHTHYS NIGRODIGITATUS .(LACEPEDE).

Leone (1967) established fecundity and egg size as additional criteria for the separation of three surf smelt populations, Hypomesus pretiosus (G). This study using fecundity and egg size parameters identified the stock with a genetic potential for larger egg size, which is an important determinant of larval and fry survival in pond breeding programmes. No such studies have been made in Nigeria.

Matertials and methods

From the 5th to the 25th September, 1978, 150 live gravid females of 45 cm total length were collected from three different localities, e.g. Badagry lagoon, Warri creeks, Imo river (Figure 2)

In 1980 this collection was repeated on exactly the same dates. Fish were weighed to the nearest 0.1 g and total lengths recorded to the nearest cm. The number of eggs per female was established by using a gravimetric method. Since it was proven that there were no statistical differences between egg sizes from the anterior, the mid and the posterior parts of the ovary, egg sizes were determined by measuring 100 randomly selected eggs per female.

One way analysis of variance was used to prove statistical differences.

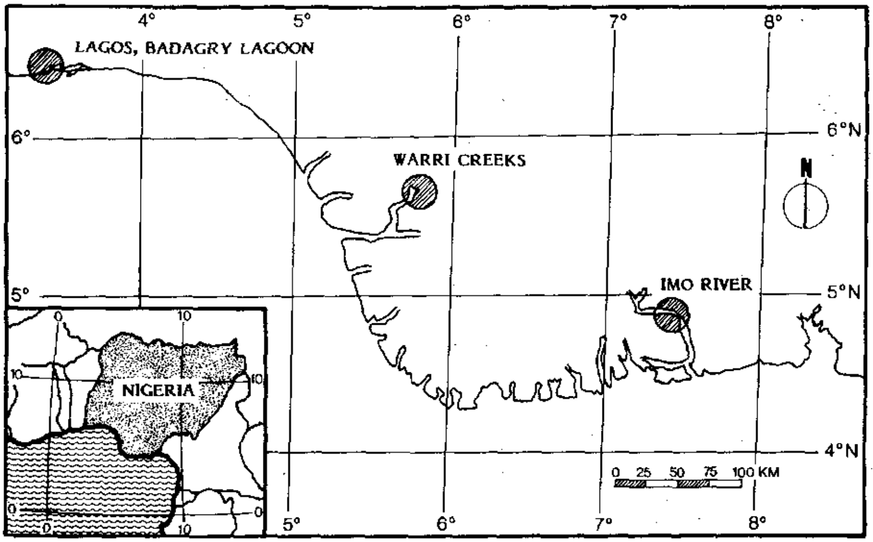


FIGURE 2. THE NIGERIAN COAST SHOWING POSITIONS OF THE STUDY SITES.

Results

There were marked variations in the number and size of the eggs produced by the female fish of the same length and the same location (Tables 1 and 2).

One way analysis of variance proved that the differences in egg number and size between the three populations were statistically significant ($P < 0.05$).

In addition to these data *Table 2* shows the results of the other morphometric measurements carried out.

Table 1. Number of eggs per female and egg diameter in C.nigrodigitatus from three different locations.

Location	Total length (cm)	Total weight (kg)	No.of eggs per female range	mean (±S.D)	Egg diameter (mm) range	mean (±S.D.)
Badagry Lagoon	45 45	890.5	9,000-18,750	12,602(±2,488)	2.50-2.75	2.63(±0,08)
Warri Creeks	45 45	950.7	14,000-19,815	16,300(±1,187)	2.70-2.00	2.80(±0.08)
Imo River	45 45	810.4	8,665-18,566	11,316(±1,992)	2.25-2,60	2.45(±0.08)

Table 2. Mean parameter values measured in C.nigrodigitatus from three different locations.

Location	Gonadal index	Hepatosomatic index	Condition factor
Badagry Lagoon	8.899	1.0807	0.9673
Warri Creeks	11.6247	1.1217	0.9159
Imo River	8.7338	1.1567	0.7859

Discussion

The data on fecundity and egg size provide clear evidence of heterogeneity among the three populations of C.nigrodigitatus. The mean egg size of specimens from Warii Creeks (2.8 mm) is larger than those from Badagry Lagoon (2.6 mm) and Imo River (2.4 mm). Further, variations were found in fecundity, gonadal index, hepatosomatic index and the condition factor.

Similar work on egg size of Chrysichthys spp. have been reported by other authors. Ajayi (1972) reported 2.160 mm as maximum egg diameter for C.auratus in Kainji Lake. Ikusemiju (1976) reported a mean egg diameter for C.walkeri in Lekki Lagoon of between 2.35 and 2.40 mm, as well as an absence of variation between the mean egg diameter in different parts of the ovary.

Bagenal (1971) illustrated intra-population as well as geographical variation in egg size in carp by referring to data collected in Russia, Germany and Ireland. Hulata et al.(1974) reported that large egg size was an important determinant of larval and fry variability and pointed out that, therefore, under certain circumstances breeding for large eggs could be of economic value. Taube (1976) reported that egg size in the 'river' brown trout differed appreciably between individual fishes of the same size or age. Ezenwa (1981) showed that the length of the female was linearly correlated both with egg size ($r = 0.861$; $P < 0.05$) and with fecundity ($r = 0.960$; $P < 0.05$). McFadden et al.(1965) made similar observations in brown trout.

Based on the data presented, both fecundity and egg diameter could be used as criteria to identify different strains of C.nigrodigitatus.

Furthermore for fish farming programmes in Nigeria brood stock from Warri Creeks seem to be preferable to those from the other locations studied.

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References

Ajayi, C., 1972. Biological studies on the family Bagridae in Lake Kainji, Nigeria. M.Phil.Thesis. University of Ife, Nigeria.

Bagenal, T.B., 1978. The interrelation of the size of fish eggs, the date of spawning and the production cycle. J.Fish.Biol. 3, 207-219.

Ezenwa, B., 1978. Studies on the distribution, age and growth of the Catfish, C.nigrodigitatus. M.Sc.Thesis, University of Lagos, Nigeria. 193 pp.

Ezenwa, B., 1981. A study of the reproductive biology of the catfish, Chrysichthys nigrodigitatus (Lacepede) in Nigeria. Ph.D.Thesis, University of Lagos, Nigeria. 178 pp.

Hulata, R., R.Moav & G.Wohlfarth, 1974. The relationship of gonad and egg size to weight and age in the common carp, Cyprinus carpio L. J. Fish.Biol. 6, 745-758.

Ikusemiju, K., 1976. Distribution, reproduction and growth of the catfish, C.walkeri (B), in Lekki Lagoon. J.Fish.Biol. 8, 453-458.

Leone, C.C., 1967. Fecundity of surf smelt in the state of Washington. M.Sc.Thesis. University of Washington, Seattle. 99 pp.

McLaren, B.I.R., 1949. Brackish water fish cultivation experiments in Lagos. Fed.Fish.Occ.Paper No.I.

McFadden, J. et al., 1965. Some effects of environment on egg production in brown trout, Salmo trutta. Limnol.10 (1): 88-95 pp.

Nagasaki, F., 1958. The fecundity of Pacific herring, Clupea pallasi, in British Columbia Coastal Waters. J.Fish.Res.Bd.Canada. 15(3): 313-330.

Pitt, T.K., 1964. Fecundity of American plaice. H.platesiodes (F) from Grand bank and Newfoundland areas. J.Fish.Res.Bd.Canada. 21(3): 507-612 pp.

Rounsefell, Y.A., 1957. Fecundity of North American Salmonidae. US.Fish & Wildl.Serv.Fish.Bull.: 57(122): 451-486.

Sivalingan, S., 1972. Fish culture possibilities around Lagos Lagoon and results of recent trials. Fed.Fish.Occ.Paper No.13.

Taube, C.M., 1976. Sexual maturity and fecundity in brown trout of the Platte River, Michigan. Trans.Am.Fish.Soc.Vol. 105 No.4: 529-533 pp.

STUDIES ON THE STRUCTURE OF THE PITUITARY GLAND OF THE CATFISH, CHRYSICHTYS NIGRODIGITATUS (L.) AND PRELIMINARY RESULTS FROM SPAWNING IN PONDS AND CONCRETE TANKS

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Summary

Most desired cultured fishes in Nigeria do not spawn in captivity. One of such species that abounds in both fresh and brackish waters is Chrysichthys nigrodigitatus, (Lacepede). The inability to spawn in a confined environment was the main reason for studying the structure of the pituitary gland; the aim was to determine the approximate position of the gland in order, to facilitate rapid location and removal and then possibly prepare solutions for large scale seed production and to ascertain the gross and microscopic morphology of the gland during the annual reproductive cycle. As a follow up the research team also carried out studies on the hormonal status of the fish before spawning through qualitative and quantitative analyses of urinary 17-ketosteroids (17KS), representing androgenic activity, and 17-hydroxycorticosteroids, representing immuno-suppressor groups. The levels of these steroids determined the dosage of CLOMID (citrate de clomifene) used in hormonal induction. This aspect of steroid metabolism has been neglected and will therefore continue to be a major constraint to understanding infertility of cultured fish in confined environments.

Résumé

La plupart des espèces aquacoles appréciées au Nigéria ne fraient pas en captivité. Chrysichthys nigrodigitatus (Lacepede) est l'une des plus répandues de ces espèces et on la trouve aussi bien dans les eaux douces que dans les eaux saumâtres. Son incapacité à pondre en captivité nous a conduit à entreprendre des études sur la structure de l'hypophyse, à la localiser approximativement en vue de pouvoir rapidement procéder à son ablation aus cas où des extraits devraient être préparés pour assurer une production d'alevins à grande échelle. La morphologie de la glande, enfin, a été examiné à l'oeil nu et au microscope, pendant le cycle annuel de reproduction. L'équipe chargée des recherches sur l'hypophyse a également réalisé une étude sur l'état hormonal des poissons avant la ponte et, ceci, en pratiquant des analyses quantitatives et qualitatives de 17 kerosteroides (17KS) d'urine révélant l'activité androgène, et de 17 hydroxycorticosteroïdes, révélant l'existence de groupes immuno-suppresseurs. Les mesures ont permis de déterminer les doses de CLOMID (citrate de clomifène) à utiliser pour l'induction hormonale de la ponte.

Cet aspect du métabolime stéroïde n'a pas été étudié et continuera d'être un obstacle majeur à la compréhension de l'infertilité d'espèces aquacoles élevées en captivité.

Introduction

The brackish water catfish C.nigrodigitatus is regarded as a highly prized food fish on Nigerian markets. Sofar the lack of dependable artificial reproduction methodologies have hempered rational culture of this species. This study focusses on some morphological characteristics of the pituitary in C.nigrodigitatus during it's reproduction cycle as well as on field trials to artificially induce reproduction of the species.

Materials and methods

Between January 1982 and December 1983, five hundred specimens, 40 to 55 cm in total length, 850 g to 1.5 kg in weight, collected live from Lagos/Epe lagoons were used for morphological studies. The brain was dissected by cutting open the areas corresponding to the pharyngeal teeth. The pituitary gland is more easily located through this method than by cutting through the hard boney plates of the head. Sagittal sections of the pituiatry gland were made and examined under a binocular microscope. By using of Azan staines it was possible to identify various types of cells.

Six hundred brooders of the catfish collected from the wild during the pre-spawning period (Table 1) were distributed to two spawning stations. Total length of specimens used for the spawning station with earthen ponds at Lagos varied from 35-58 cm and total weight from 700-1200 g; length and weight varied respectively from 36-60 cm and from 580-1350 g for those transfered to Patani Warri station with concrete tanks and earthen ponds, located five hundred kilometers away from Lagos. Water chemistry parameters were recorded in the two stations.

Table 1. Changes in the ovaries during the various periods of the annual reproductive cycle of the catfish, C.nigrodigitatus (Ezenwa, 1981).

Period of reproductive cycle	Duration	Ovarian characteristics
Resting stage	February-March	The germ cells are small and spherical. OOgonia with mean diameter of 0.02±0.01 mm
Immature	April-June	Gradual increase in thickness of ovarian wall with slight vasculari-zation. The mean diameter of the oocytes is 0.19±0.24 mm
Maturing	July-September	Developing eggs visible through ovarian wall. Oocytes in various stages of vitellogenesis. Yolk formation very prominent. Mean oocyte diameter is 1.64±0.45 mm. Ovarian wall distended.
Pre-spawning	October-November	Fully formed, yolk laden oocytes. Egg diameter 2.73±0.17 mm.
Spawning	November-December	Ovary is full with ripe spherical and yellowish running eggs. Ovary wall thin due to distension of ovary with ripe eggs. Mean diameter of eggs is 3.0 mm
Post-spawning	January-February	Ovaries very flabby and empty, with a very few oocytes which failed to develop or are in the process of degeneration.

Urine samples were collected from each specimen, and the levels of 17-ketosteroids-(17KS), representing androgenic activity, and 17-hydroxy-corticosteroids, representing immuno-suppressor groups, were determined. These levels were used to determine the dosage of CLOMID (CITRATE De CLOMIFENE) to be used only for the females.

One month prior to the natural spawning season three injections were given intraperitioneally at a dosage of 20 mg/kg fresh body weight, spread over 24 to 72 hours. Groundnut pellets (52% protein) were administered to the brooders at 10% body weight per day.
the brooders at 10% body weight per day

Results and Discussion

Figure 1 shows that the pituitary gland in C.nigrodigitatus is located in the brain case in a position corresponding to the pharyngeal teeth. The gland is whitish and oval in shape, located anterior to the saccus. It is located more anteriorly than in other fishes and is embodied in a jelly-like mass which also encloses the paired olfactory lobes.

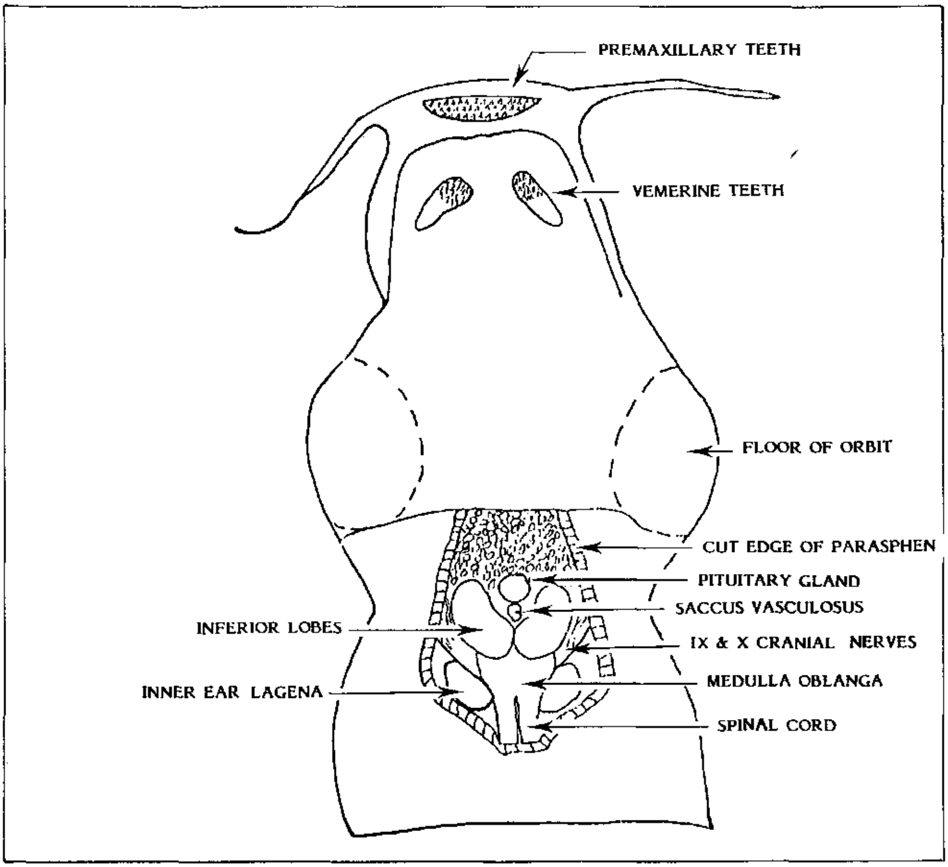

FIGURE 1. ROOF OF MOUTH OF CHRYSICHTHYS NIGRODIGITATUS WITH PARASPHENOID CUT TO SHOW THE VENTRAL PART OF THE BRAIN.

Figure 2, shows that the sagittal section of the pituitary gland is kidney-shaped and attached to the hypothalamus by a very narrow tract of fibres.

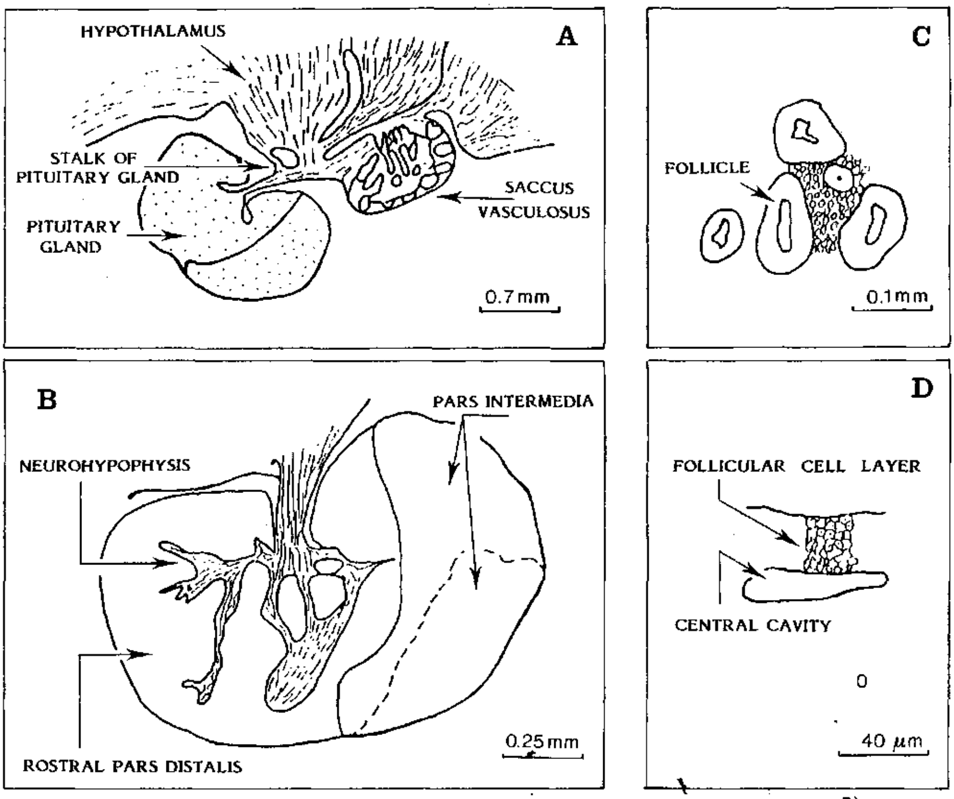

FIGURE 2. A.AND B. SAGITTAL SECTIONS OF PITUITARY GLAND.
C. GROUP OF FOLLICLES FROM ROSTRAL PARS DISTALIS
D. DETAILS OF A PORTION OF A FOLLICLE.

These lead to the dorsal and central neurohypophysis enclosed by the glandular adenophyophysis. Unlike in the majority of teleost fishes, the neurohypophysis interdigitates more extensively with the rostral pars distalis of the adenohypophysis. The pars intermedia of the adenohypophysis is not invaded by the nerve tissue. Azan stain shows that the anterior pars distalis contains follicles, and cell masses between the follicles. Prolactin is normally secreted by the follicle cells. The pars intermedia is basophilic. Various investigators using both light and electron microscopes described two different gonadotropic cell types. Examination of the eel pituitary by electron microscope indicated the presence of a gonadotropic cell type (type I) that contained secretory granules of 1,900 Angstroms in diameter, whereas the second type (type II) contained secretory granules of 1,300 Angstroms in diameter, (Knowles & Vollrath, 1966). Cook and van Overbeeke (1972) found that of these two types of granules, one is very active in the early phase of sexual maturation while the second is very active in the final phase of gonadal development. Nagahama and Yamamoto (1970) stated that the smaller granules disappear after spawning. Clemens and Johnson (1965) also found the pituitary gonadotropin activity to be low after spawning or during gonadal regression but relatively high during most other parts of the year.

Data collected during the period between January 1982 and December 1983 on the hormonal status of the broodfish revealed that both male and female fishes of C.nigrodigitatus have more androgenic and 17-hydroxy-corticosteroid material during the pre-spawning and spawning periods than at other times. This concurs with findings by Clemens and Johnson (1965), Swift and Pickford (1965), and Gerbilskii (1940). It was also found that the concentration of hormones in female fishes weighing one kg was not statiscally different from the concentration in female fishes weighing 500 g.

Ezenwa (1981) showed detailed histological changes in the ovaries and testis during the various periods of the annual reproductive cycle of the catfish C.nigrodigitatus. Using this information (Table 1) efforts have been made to obtain a consistant, successful, spawning result by using pituitary extract and CLOMID.

As mentioned the broodfish were kept in earthen ponds at Lagos and in concrete basins or earthen ponds in Patani Warri.

Water quality parameter values prevailing during the experimental period are given in Table 2.

Table 2. Water quality parameter values.

	Lagos	Patani Warri	
	earthen ponds	earthen ponds	concrete basins
pH	6.75-8.0	6.0-7.5	7.5-8.5
Oxygen (ppm)	6-12	8-10	15-20
T (°C)	28-30	26-28	26-30
Turbidity (cm) (Secchi disk reading)	45-55	35-45	?
Condictivity (µmhos)	800-15,000	10-50	50-200
Salinity (%o)	1.5-8	0-0.5	0-0.8

Subsequent to the CLOMID injections to the females, one month prior to the natural spawning period was only observed in the earthen ponds at Lagos, and a fry survival rate of 20% has been estimated. There was no spawning at all at the Patani Warri station.

Considering water quality determinations, as given in Table 2, salinity could be a major factor in spawning, the more so, since, in the wild, species spawn in rather brackish water with a salinity of between 1 and 3% (Ezenwa, 1981).

Despite the inconsistent results the use of synthetic steroids like CLOMID could, conceivably, be used not only in experimental but also in commercial fish seed multiplication programmes. The drug is simple to use and less expansive than pituitary extracts that involve sacrifying the donor fish.

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References

Clemens, H.P. & W.W.Johnsons, 1965. Specificity of the gonadal hydration factor in the pituitary of some freshwater fishes. Copeia 1965, 389-398.

Cook, K. & A.P.Van Overbeeke, 1972. Ultrstructure of the pituitary gland (pars distalis) in sockeye salmon Oncorhynchus nerka, during gonad maturation. Z.Zellforsch. 130: 338-350.

Ezenwa, B., 1981. A study of the reproductive biology of the catfish (Chrysichthys nigrodigitatus (L.) in Nigeria. PhD. Thesis, University of Lagos, Nigeria. 178 pp.

Gerbilskii, N.L., 1940. Seasonal changes in the gonadotrophic potency of the pituitary gland in fishes. Dekl.Akad.SSSR 28. 571-573.

Knowles, F. & L.Vollrath, 1966. Neurosecretory innervation of the pituitary of the eels, Anguilla and Conger: - and the structure and ultrastructure of the neurointer-mediate lobe under normal and experimental conditions. Phil.Trans Roy, Soc. London 250 B: 311-327.

Nagahama, Y. & K.Yamamoto, 1970. Morphological studies on the pituitary of the chum salmon, Oncorhynchus Kefa (1). Fine structure of the adenohypopysis. Bull.Fac.Fish.Hokkaido Univ.20: 293-302.

Swift, D.R. & G.E.Pickford, 1965. Seasonal variation in the hormone contents of the pituitary gland of the perch, Perca fluviatilis L. Gen.Comp.Endocrinol., 5: 354-365.

TABLE RONDE SUR LE DÉVELOPPEMENT DE L'AQUACULTURE EN AFRIQUE : RÉSUMÉ

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En conclusion a eu lieu un débat sur le développement de l'Aquaculture en Afrique, articulé autour de 4 thèmes
- les objectifs de ce développement,
- les contraintes, et les moyens, et
- enfin les possibilités du futur

Les objectifs à atteindre sont de plusieurs ordres

On a admis la nécessité d'une aquaculture intensive de caractère commercial destinée par exemple à l'exportation ou au moins à limiter l'importation de poisson donc à épargner les devises souvent trop peux disponibles dans les pays tropicaux. Plusieurs personnes ont toutefois mentionné la nécessité d'une intégration de l'aquaculture aux autres activités agricoles traditionnelles; on espère ainsi promouvoir une vie économique rurale et la création d'emplois en milieu paysan.

Cette intégration à l'agriculture permettrait une utilisation optimale des ressources en eau et la valorisation des déchets agricoles tout en améliorant l'état nutritionnel et sanitaire des populations; on peut même parler d'augmenter la "qualité de la vie" en zone rurale. Ces objectifs sont indissociables de la nécessité pour la population de prendre en charge "psychologiquement" les pratiques aquacoles, ce qui ne peut se faire sans que les techniques soient, au préalable, parfaitement au point et les espèces candidates à l'aquaculture judicieusement sélectionnées après études adéquates. A terme, l'aquaculture est destinée enfin à permettre une certaine épargne des productions piscicoles des eaux libres déjà très souvent surexploitées en raison d'un effort de pêche considérablement accru depuis 30 ans.

Les moyens actuels de développement de l'Aquaculture

On a pensé immédiatement à l'éducation du public qui doit prendre ainsi connaissance de la valeur alimentaire du poisson. Ce qui permet la création de marchés potentiels utilisant les circuits commerciaux existants. La vulgarisation s'effectue auprès des producteurs de poissons, et elle est soumise à l'existence de technologies adaptées elles mêmes résultant de recherches de caractère finalisé. Ces dernières sont possibles grâce à la dissémination des connaissances scientifiques sur l'ensemble de continents et aussi aux équipments de recherche disponibles. Ces facilités sont fonction des efforts financiers consentis pour la recherche scientifique. Enfin le développement de l'Aquaculture est conditionné très souvent par l'octroi de prêts à des taux préférentiels pour les premiers investissements.

Les contraintes du développement de l'Aquaculture

Il faut d'abord mentionner que l'Aquaculture est très récente en Afrique (60 ans) alors qu'elle fait partie intégrante de la vie du paysan asiatique depuis des siècles. Son développement est donc freiné par l'absence de "conscience aquacole" de la part du paysan africain. Celui-ci ne parvient pas à comprendre que l'aquaculture est en fait une forme de zootechnie qui a les mêmes exigences que les élevages d'animaux terrestres avec en plus, les difficultés liées au milieu aquatique et à la sensibilité écologique des animaux aquatiques. Un participant a fait remarquer que les élevages en eau douce sont plus difficiles que ceux d'animaux terrestres et que ceci est encore plus net pour les élevages en lagune ou en mer.

Par ailleurs, l'histoire du développement de l'Aquaculture en Afrique, marquée par de nombreux échecs suscite la méfiance du paysan comme celle des pouvoirs publics peu enclins à considérer le développement de l'aquaculture comme une priorité; cela se traduit dans le choix en matière d'investissement et d'approvisionnement en produits importés (engrais, aliments) qui se fait au détriment de l'aquaculture pour laquelle il n'existe pratiquement pas de projets à long terme.

L'aquaculture est handicapée par des contraintes liées à son propre fonctionnement: insuffisance des aliments pour poissons, technologies mal adaptées ou mal assimilées, manque de personnel qualifié, le marché souvent mal organisé ou inorganisé souvent d'ailleurs à cause du contexte sociologique défavorable. Il existe par exemple de nombreuses croyances religieuses et des tabous traditionnels amenant de la méfiance à l'égard des poissons; autant de faits qui empêchent toute stimulations ou incitation de l'aquaculture potentiel. Un dernier point à mentionner est le régime foncier ou de propriété des terrains qui empêche l'installation d'étangs dans des zones qui seraient pourtant, à d'autres points de vue, favorables.

Les possibilités de développement de l'Aquaculture

L'Aquaculture en Afrique ne pourra réellement démarrer que si l'on parvient à metter à exécution les recommendations suivantes:

. Un projet de développement de l'Aquaculture devra avoir un réel impact rural et être conçu à écehlle également commerciale ou si l'on préfère avoir un impact socio-économique approprié.

. Les objectifs futurs ne pourront dans chaque contexte c'est à dire, en gros, dans chaque pays, n'être définis qu'après réflexion approfondie sur les tentatives précédentes et les causes et les modalités de leurs échecs.

. Il faudra s'assurer que le développement de l'Aquaculture ne va pas à l'encontre d'autres intérêts concurrentiels par exemple pour l'occupation des sols, les approvisionnements en aliments artificiels ou en fertilisants, notamment ceux qui sont importés.

. Enfin, il faut prvoir le développement de la recherche finalisée pour l'Aquaculture y compris certaines investigations apparemment de type fondamental et académique dont les applications ne peuvent être envisagées que dans plusieurs années.

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