Pathology of tilapias

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Abstract

The pathology of farmed tilapias is reviewed from presently available published data. The effects of intensive production systems on the aspects and importance of pathology are outlined. The main pathogenic organisms are recorded. For the moment, these pathogens seem to represent a potential threat, rather than being primary causes of losses. Conversely, environmental factors together with practical errors resulting from a lack of biological and zootechnical data on tilapias, seem to be responsible for most of the difficulties which are encountered. In the short term, intensive research in genetics, nutrition and zootechny should result in significant health improvements for tilapias.

Keywords : Tilapia, fish farming, parasites, pathology.

Pathologie des tilapias.

Résumé

La pathologie des élevages de tilapias est passée en revue d'après les données bibliographiques disponibles, en essayant de faire ressortir le rôle de l'intensification des techniques dans la physionomie et l'importance des troubles. Les principaux agents pathogènes sont répertoriés mais semblent surtout constituer pour l'heure des menaces potentielles plutôt que des causes primaires de mortalités significarives. Par contre les facteurs d'environnement, l'insuffisance des références zootechniques et la méconnaissance de certains aspects biologiques paraissent responsables de la plus grande part des problèmes actuellement rencontrés. La résolution à court terme de ces problèmes devrait passer par une intensification des recherches génétiques, nutritionnelles et zootechniques.

Mots-clés : Tilapia, élevage intensif, parasites, pathologie.

Many tilapia species are of great interest as far as tropical aquaculture is concerned and have been successfully farmed under various conditions, thanks to their remarkable tolerance to environmental changes and to many diseases. However, such capacities are not unrestricted: there is a risk, when fish farmers rely upon them excessively and forget that many problems occurring in fish culture may result from inappropriate practices and could be easely contained by respecting the basic physiological characteristics of the fish. Extensive production of tilapia in warm water areas has been a success, but there is now a clear tendency towards the development of intensive methods so as to take advantage of brackish or salt water ponds: some unexpected difficulties have sometimes appeared when these new programs were implanted.

In this overview, we try to show that most problems linked to pathology could be solved by adopting technical or zoological improvements. Unlike what has been made in relation to the culture of other fish species, and perhaps because of the excessive confidence in their capacities, the theoretical works devoted to the pathology of tilapia have not been up to their farming development. For many years, as it appears from the reviews by Paperna (1980), Roberts and Sommerville (1982) and Kabata (1985), studies mainly consisted in zoological descriptions of parasites from wildfish populations of Africa in the first place, and then, of fish farms managed in Israel (Paperna and Thurston, 1968; Sarig, 1971). It was not until about 1980, in Israel and South Asia, that the first attempts to intensify production let to an experimental approach. At the same time in Scotland, the Stirling University was setting up an international course on tropical aquaculture and was beginning to contribute to our understanding of the pathology of tilapias.

PATHOLOGY ACCORDING TO THE TYPE OF FISH FARMING

Fish pathology is often explained in the light of sudden changes in the subtle relation existing between fish, their environment and the potential pathogenic organisms present in this environment. The role of the environment is considered of prime importance by many authors. But whereas it is not really difficult to obtain descriptions of the fish populations and of the characteristic pathogenic organisms, it is more difficult to clarify the complex combinations of factors which interact mutually and which are capable of influencing these organisms. Thus, the accurate knowledge and the control of the environmental factors will generally remain theoretical. However, it happens that some disorders which occur in the environment do not result from natural phenomena but from human activity. In such cases, it will be possible to identify the causes of troubles and to take the appropriate measures.

Some factors such as temperature, pH, dissolved oxygen and gases, suspended solids and mineral content, are very important as far as physiology is concerned; these factors should be taken into account in the description of optimal conditions for fish husbandry. This is a condition of success in intensive production units in which the ecosystems are artificially simplified and give the above mentioned parameters, an increased significance. An attempt to illustrate the effects of intensive fish farming on water parameters and their resultant role in the genesis of morbid troubles can be found in *figure* 1. Compared with natural or mildly modified conditions of extensive culture, intensive methods require high densities of fish stocked in limited volumes of water. Such volumes of water should therefore supply more oxygen and nutriment than usual.

It is rather easy to adjust the rate of food to the stocking density of fish, but conversely, the supply in oxygen appears to be a limiting factor in spite of technical devices used to aerate the water. Moreover, food consumption produces metabolic wastes and the excretion of ammoniacal products is directly related to the quantity of food which has been distributed.

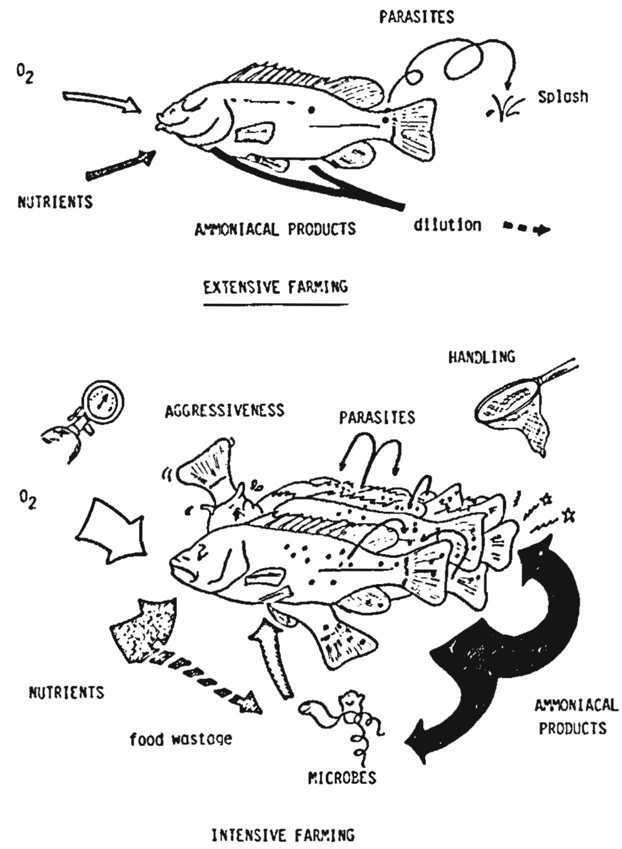

Figure 1. — Interrelations between fish and environmental factors: their importance according to the type of farming.

These products can be partially converted into non-ionized ammonia, which shall become toxic when the water flow is not strong enough to prevent these substances from accumulating.

Fish densities also provide excellent conditions for the multiplication of parasites and bacteria which live naturally in the environment. Parasites, and more particularly those which have a direct reproductive cycle, statistically find the best possibilities to meet their natural host and to ensure their development. Bacteria combine this advantage with the availability of nutritive substances coming from both fish excretion and excessive distribution of diet. Microbial proliferation is always difficult to contain in fish farms. The main species which colonize the habitat are generally the so-called opportunistic organisms, which are usually non-pathogenic, but can have some deleterious effects when sudden changes occur in the environment. In addition to the fact that it has advantageous effects for potential pathogens, the overcrowding of fish can also lead to unexpected changes as regards the behaviour of the fish. Some species of tilapia can show somewhat complicated social relations, and the chronic exposure of territorial animals to stressful conditions is likely to result in aggression and harassment.

To complete this review, it is necessary to mention the direct repercussions of fish manipulation, involving handling, sorting, transportation and treatments, which inevitably induce stress and can even produce more or less severe injuries. In brief, two major kinds of special risks will be associated with the change-over from extensive tilapia ponds to high productivity intensive systems:

— the very effects of technological processes which do not always lean on sufficient experience when applied to recently domesticated species;

— the selection and increased development of pathogenic organisms such as viruses, bacteria and certain parasites, which are capable of spreading directly from one fish to another.

TILAPIAS' MAIN INFECTIONS AND PARASITIC DISEASES

There is no doubt that all potential pathogenic organisms living with tilapia populations will be able to colonize these fish, and surveys of relevant observations have been reviewed in the publications mentioned above. We shall only point out these pathogens of which virulent or harmful properties may represent a real threat for tilapia farming.

Viral diseases

Viruses are not of great significance as far as warm water fish culture is concerned. The only infection known to affect tilapias is lymphocystis, caused by a member of the Iridoviridae group which develops slowly in the fibroblasts of the skin and which produces large numbers of small cutaneous neoplasia. Paperna (1974) has described infected tilapias from African lakes. The disease does not often result in mortalities; yet, the commercial value of infected fish is reduced and the long period of time needed for recovery would seriously compromise the financial balance of intensive farms.

Bacterial diseases

Many bacterial species have been isolated when mortalities have occurred in tilapia farms. *Table* 1 gives some examples of such identified species. As it frequently occurs for fish, the responsability of these bacteria as primary causes of diseases is difficult to assess. Some of them may have acted only as secondary invaders, taking advantage of the transient weakness of the fish which resulted from other causes. In such a case, bacteria proliferate in debilitated subjects which no longer offer natural resistance and are opportunistic. This situation seems to be usual for the bacteria such as *Pseudomonas* sp. (Miyazaki *et al.*, 1984*a*) and Enterobacteriaceae (Wu, 1970). A recent case of vibriosis caused by *Vibrio vulnificus* has been reported in Japan (Sakata and Hattori, 1988) but high doses of bacteria were needed to reproduce the disease experimentally and the virulent properties remain unclear.

Other bacteria display pathogenicity more markedly and more regularly. This may be the case for steptococcal infections of Nile tilapias reported by Wu (1970), by Kitao *et al.* (1981) and by Miyazaki *et al.* (1984*b*). Clinically, streptococci have mainly been noticed in South Asia where they have caused many losses in salt as well as in fresh waters. The parasitic status and pathogenicity of a bacterium are more clearly ascertained when the bacterium can or needs to develop intra-cellularily. This situation is known for two diseases. The first is tuberculosis, more precisely called mycobacteriosis. The responsible agent, *Mycobacterium fortuitum* is frequently present in Cichlidae and a clinical case has been observed in a fish farm in Kenya by Roberts and Sommerville (1982). This chronic granulomatous disease has been observed in various types of fish cultures where the animals were fed with raw fishery trash products. It is always a serious economic threat because the slow course of the disease produces clinical signs on aged fish only. The best way to avoid this problem is to feed the fish with thoroughly controlled diets. The second disease is epitheliocystis, caused by a small Gram-negative agent very close to the Chlamydiaceae family and which infects the epithelial cells of the skin and gills. It produces tumoral lesions resembling lymphocystis ones and can be distinguished through microscopic observation only. It has occasionally been found on wild tilapias (Paperna, 1980).

Yet, the most serious infections reported in tilapias often involve bacteria for which a real status of obligatory pathogen is difficult to establish. They are frequent and have major economic consequences, but their clinical manifestations depend on various factors and the approach of their pathogenicity is not easy. This is the case for columnaris disease due to *Flexibacter columnaris*, a very common gliding bacterium of aquatic habitats, which is frequently associated with the epithelial tissues of the fish and is capable of inducing severe destruction of the skin and gill surfaces. However, this destructive potential is not expressed in all situations and other factors, namely sudden variations in temperatures, are of prime importance. According to Avault *et al.* (1968), the winter period, when the temperature fails below 14°C, is especially dangerous.

Ulcerative and haemorrhagic septicaemia associated with Gram-negative bacteria represent another matter for concern.

Aeromonas hydrophila is a common cause of infection in warm water areas and its deleterious effects in tilapia farms have been pointed out by Balarin and Hatton (1979). Although, the factors associated with the virulence of *A. hydrophila* isolates have been studied by different scientists, these studies have not resulted in general agreement on the question. This is complicated by the fact that *A. hydrophila* is found

Table 1. — Main microbial organisms isolated from tilapia farms.

Infections agents	Tissue location	Clinical signs
VIRUSES		
Iridoviruses		
Lymphocystis virus	Fibroblasts of the skin conjunctive tissue	Non-maligant skin tumors
BACTERIA		
Cytophagaceae		
Flexibacter columnaris	Skin and gills	Destructive local infections
Pseudomonadaceae		
Pseudomonas fluorescens	Systemic infections [o]	Haemorrhagic septicaemia and granulomatosis
Enterobacteriaceae		
Edwardsiella tarda	Systemic infections [z]	Haemorrhagic septicaemia or granulomatosis
Vibrionaceae		
Aeromonas hydrophila	Systemic infections [o]	Haemorrhagic septicaemia
Streptococcaceae		
Streptococcus sp. (β-γ hemolytic)	Systemic infections	Haemorrhagic septicaemia and granulomatosis
Mycobacteriaceae		
Mycobacterium fortuitum	Systemic infections [z]	Chronic granulomatosis
RICKETTSIA (?)		
Epitheliocystis agent	Skin and gills	Epithelial hyperplasia
MYCOSES		
Saprolegniaceae		
Saprolegnia sp.	Skin and gills [o]	Destructive local infections
Aspergillus flavus *A. niger*	Internal mycoses + mycotoxins [z]	Granulomatosis

[o] opportunistic species; [z] possible zoonoses.

to be a secondary invader in almost all cases of fish diseases and by the fact that most saprophytic strains living in water are likely to act as opportunistic pathogens. The situation is slightly different with *Edwardsiella tarda*, an enteric bacterium, the pathogenicity of which has been well documented for warm water fish (Wakabayashi and Egusa, 1973; Meyer and Bullock, 1973). Tilapias are also susceptible to edwardsiellosis (Roberts and Sommerville, 1982). There again, environmental factors can facilitate the appearance of clinical signs and it even occurs that mixed infections appear in association with *A. hydrophila*. In fact, *E. tarda* is not as frequent in water as *A. hydrophila* and the observation of a granulomatous form of the disease by Kubota *et al.* (1981) may indicate that *E. tarda* can adapt to parasitic development. Whatever its direct effects in fish farms may be, *E. tarda* is also a matter of concern for human health, since it can be responsible for more or less severe enteric fevers affecting man. Van Damme and Vandepitte (1980) have clearly shown that enteric infections among African populations living on fish resources were linked to the consumption of contaminated fish.

Finally, we purposely stress the fact that bacteria are always numerous in the environment of the fish and should always be taken into consideration in fish farming activities. Fortunately, except for chronic systemic infections, their consequences can be weakened by using appropriate therapy. The most efficient treatments consist in using antimicrobial drugs, but should still be conducted cautiously and comply with specific rules, in order to be successful and to avoid or limit undesirable side-effects (Michel, 1988). In fact, the special triggering role of environmental factors in bacterial diseases leads to the idea that maintaining the fish under suitable conditions, with attention paid to the quality of the water, to the cleanliness of the habitat and to the careful handling, should provide the best preventive tools against bacteriosis. Vaccination attempts have been made with *A. hydrophila* (Ruangpan *et al.*, 1986) and *E. tarda* (Lio-Po and Wakabayashi, 1986), but although the results were quite encouraging they have not led to the development of commercial bacterins. Ultimately, when a bacterial infection occurs, it must be kept in mind that the problem can derive from a very different cause; the identification and neutralization of this primitive cause of disorders is generally sufficient to cure the disease for good.

Mycoses (*table* 1)

Saprolegniasis are not different for tilapias reared in fresh waters from what they are for other fish species. They generally affect debilitated or injured animals. The most significant causes of weakness are: low winter temperatures, sexual maturation and the consequences of handling operations (Sarig, 1971). Therefore, fish farmers in Israel avoid handling or disturbing the animals during the winter season. It is possible to fight against mycosis with bath treatments of malachite green.

A single type of systemic mycosis has been reported in Kenyan tilapia farms (Olufemi *et al.*, 1983). Two species of *Aspergillus*, *A. flavus* and *A. niger* were involved. These two species are more commonly responsible for neoplastic manifestations due to the ingestion of contaminated food in which secreted aflatoxins can accumulate. Yet, Olufemi and Roberts (1986) have been albe to reproduce the disease experimentally and have obtained granulomatous lesions after oral administration of isolated strains. This was the first time that *Aspergillus* infections were described in fish and they probably originated from contaminated food stored under poor conditions.

Moreover, some parasites which are innocuous for tilapias are transmissible to man.

Among the protozoan parasites of tilapias, there are several myxozoan species; their frequency has been pointed out by Baker (1963). *Henneguya*, *Myxobolus* and *Myxosoma* genus have been recorded; these genera are known to cause severe damage in other cultured fish species. Their development should always be anticipated when mud sediments provide for the survival of spores. Some coccidia, which seem to be specific to Cichlidae, have been described in recent publications on studies carried out in Israel and South Africa. It seems that, at least one of them, *Eimeria vanassi*, which develops in the digestive tract, causes growth malfunction and even alevin mortalities under farming conditions (Landsberg and Paperna, 1987).

Table 2. — Main parasites species isolated in tilapia farms.

	Groups and species	Location
PROTOZOA		
Flagellates	*Ichtyobodo (Costia)* (*)	Skin and gills
Ciliates	*Trichodina* (*)	Skin and gills
	Tripartiella (*)	
	Chilodonella	Skin and gills
	Ichtyophtirius (*)	Skin
Sporozoa	*Eimeria vanasi*	Intestinal mucosa
MYXOZOA	*Myxobolus*	
	Myxosoma	Internal cysts
	Henneguya	
MONOGENEA	*Dactylogyrus* (*)	
	Cichlidogyrus (*)	Skin and gills
	Gyrodactylus (*)	
TREMATODES		
Heterophyidae	*Heterophyes* (z)	
	Haplorchis (z)	
Clinostomatidae	*Clinostomum*	Internal cysts
	Euclinostomum	
Diplostomatidae	*Diplostomum*	
NEMATODES		
Anisakidae	*Contracaecum* (z)	Internal tissues
CRUSTACEA		
Branchiura	*Argulus*	
Copepoda	*Lernaea* (*)	Skin and gills
	Ergasilus (*)	
Isopoda	*Nerocila*	

(z) possible zoonoses; (*) significant losses reported.

Internal parasites (*table* 2)

Internal parasites are frequent under natural conditions; however, the low density of fish does not favour their transmission. Unless an ecological disorder occurs, these parasite populations scarcely increase so as to lead to clinical signs. Under intensive farming conditions the situation is different, although some parasite species require complex cycles of development, some accidents can happen when fish are farmed in natural habitats. Tilapias are actually farmed under such conditions and the risks, even though they are small in terms of probability, are serious because there is still no treatment which would be efficient enough to stop a parasite outburst.

Trematodes are also frequent. Their developmental cycle requires diverse successive hosts: a molluscan, a fish and a piscivorous vertebrate. Therefore, they are a threat only when young fish are captured in the wild and when predators have access to the ponds. In fact this latter eventuality occurs frequently. Two heterophyiid flukes, *Heterophyes heterophyes* and *Haplorchis pumilio* are very frequent in the Mediterranean area, in Africa and in Asia (Paperna, 1960; Roberts and Sommerville, 1982). The active penetration of their larvae through the skin of the fish can lead to mortalities when massive infestations affect young animals. But it is mainly as zoonoses that these diseases have severe consequences. These two species infest a wide range of host species and, when ingested by man, they disseminate through the arterial system and can lead to thrombus, with serious vascular consequences.

Adult Clinostomatidae (*Clinostomum* and *Euclinostomum*) develop in the pharynx and œsophagus of birds, namely herons, whereas their larval metacercariae encyst in the internal tissues or organs of the fish. Serious cases of massive infestations have been reported in Hawaï and in Africa for *O. mossambicus* (Paperna, 1980). Diplostomastidae, which are transmitted by birds are extremely frequent in natural environments, but rarely lead to massive infestations. For some species, *Neascus* larvae encyst in the skin tissues and cause typical reactions associated with melanization (black spot disease); this results in an alteration of the commercial value of the product. Paperna and Thurston (1968) have described such lesions for tilapias. For other species, metacercariae known as *Diplostomulum* larvae, specifically encyst in the lens and eye tissues. The resulting blindness is highly detrimental for the fish which have difficulties in finding their food and which thus become easy preys for predatory birds. Such cases of diplostomiasis have been reported by Paperna (1980), for Cichlids of South Africa.

Cestode parasitism is not very important, although some cases of infestation have been reported for wild fish (Fryer and Iles, 1972). Conversely, *Contracaecum*, a nematode worm which belongs to the Anisakidae family, may prove to be dangerous for man. This worm was discovered on *Sarotherodon alcalinus* by Scott (1977) and on *O. niloticus* by Paperna (1964). The parasite is ingested by the fish along with the crustacean (which is its first host) and then develops in the viscera of the fish; man is not an usual host, but the accidental ingestion of contaminated fish can result in severe granulomatous reactions.

Ectoparasites

Many different organisms are common parasites of the body surface of fish. They can proliferate under certain breeding conditions *e.g.* when ponds are overcrowded, because their reproduction and development cycles are generally direct and do not require to find different hosts. Moreover, the detrimental effects of these parasites are exacerbated by all the necessary farming manipulations which temporarily weaken the fish. Protozoans are always present in the environment of the fish. Mastigophora, such as *Ichtyobodo* have been considered as responsible for losses recorded several times in tilapia farms (Sarig, 1971; Roberts and Sommerville, 1982). Ciliata have also been frequently recorded. The most significant genera are *Trichodina* and *Tripartiella* which can proliferate to dangerous level in fish farms, *Chilodonella*, which seems to affect more particularly debilitated fish, and especially *Ichtyophtirius*, the "white spot disease" agent, which lives beneath the epidermis of the fish, rendering the infestation difficult to cure. Paperna (1970) was the first scientist who discovered this parasite on farmed tilapias. Actually, it seems that this latter parasite was introduced in Uganda as well as in Hawaï, along with fish species which had been imported for farming.

Monogenean species have been found frequently on Cichlids (Paperna and Thurston, 1968). *Dactylogyrus* has been found occasionally on the gills of the fish and some representatives of *Gyrodactylus* have been recorded in Africa. But *Cichlidogyrus* which is specific to that group of fish, is the most important and diversified genus: Paperna (1960) has listed at least 16 species in Uganda; according to Kabata (1985) and to many different authors quoted by Roberts and Sommerville, *C. sclerosus* is the most common genus in Africa and Asia.

Crustacean parasites can cause severe damage to intensive fish farms. Their clinical effect depends, to a great extend, on their abundance and on the age of the fish. Still, they are a real threat for farming because they are constantly present in the environment and are difficult to control. Furthermore, the microlesions they inflict on the skin or gills of the fish can facilitate the penetration of fungal and bacterial organisms.

It has been found that a certain number of typical organisms which have been described for other species, also parasitize tilapias. Among the copepods, *Lernaea* species have frequently been recorded and have sometimes been associated with clinical manifestations in Africa and Israel (Fryer, 1968; Paperna, 1969). In Israel, Sarig (1971) has studied some cases of *Ergasilus* invasions in ponds where different species of fish were farmed together. It seems that tilapias did not suffer as much as mullets from that infestation.

According to Kabata (1985), argulosis due to organisms belonging to the Branchiura are also frequent and the impact of *Argulus indicus* is particularly important in Asian areas. Finally, some cases involving isopods have also been recorded in farms of the Ivory Coast (Morand, 1985), and Paperna (1980) pointed out the predatory action of *Nerocila orbignyi* on Nile tilapias.

The complete eradication of ectoparasites from a natural habitat is impossible. Positive effects can be obtained indirectly by respecting hygiene rules and through correct zootechnical practices which optimize the conditions in which fish are held and enable them to offer a better resistance to aggressors. Conversely, a preventive use of anti-parasite therapies, such as those used in salmonid production, does not appear to be of great assistance and could only apply under exceptional circumstances, such as in small ponds for instance. Moreover, minimal recommendations on the efficiency and toxicity of common drugs, such as formalin, copper sulfate, potassium permanganate and organophosphate have not been as thoroughly defined for tilapia as for other species. It must be recalled here that high temperatures, salinity and other water parameters can have an influence on the effects of the treatment; any treatment should therefore be carefully planned and we would advise testing the drug on a small sample of fish first. In the present state of our knowledge, formalin when used against protozoans and monogeneans, as well as trichlorphon (Neguvon) when used against crustaceans, appear to be the only drugs for which sufficient experience can guarantee a general reliability.

DISEASES CAUSED BY ENVIRONMENTAL FACTORS

Physical and chemical characteristics are major factors determining the quality and suitability of the water for fish farming. Optimal or tolerable values are usually defined for each species of fish although the limits thus edicted can sometimes be transgressed, according to the specifity or to the genetic of the fish population, and according to their ability to adapt under exceptional circumstances. In this respect, tilapias are particularly suitable for farming, but this ability is not a sufficient criterion for an accurate evaluation of the qualities of the species. Another factor which should be taken into consideration is the ability of the fish to withstand occasional modifications of the environment since such modifications can alter the resistance of the fish. Consequently, susceptibility to diseases or the direct effects of environmental factors depend not only on the absolute value of these rate factors but also on the amplitude of their variations. This is important in the case of intensive farming when microbial populations are always present and when handling results in stress. The design of farming facilities, the distribution of artificial food, the handling and drug treatments result in changing environmental conditions and that technology is one of the most important factors as regards the health of the fish. This will be illustrated in the following examples.

Gas-bubble disease

Supersaturation of water with gas can lead to very typical diseases: fish exhibit important emphysematous lesions. These accidents are generally associated with the fact that ponds are supplied with spring or well water rising to the surface through narrow pipes. These supersaturations seem of little consequence in tilapia farms, although Roberts and Sommerville (1982) have mentioned them.

Salinity

On the contrary, salinity is a major factor for tilapia production. Some species are known to live naturally in salt water and the main objective in developing such methods is to obtain higher growth rates and also, perhaps, to manage water resources which have been somewhat neglected up until now. Experiments have been carried out in Taiwan and it soon appeared that tolerance to salinity was not only a matter of species, but also depended upon the genetical or geographical origin of the strains (Liao and Chang, 1983). Some problems appeared for "red tilapias" – the *O. niloticus* × *O. mossambicus* hybrid –, when it was transferred to salt waters: higher heterogeneity, increased sensitivity to handling operations, partial recovery of pigmentation and eye lesions.

Watanabe *et al.* (1985) have studied the effects of the transfer of Nile tilapias to sea water at different stages of their development. They have been able to show that early transfer improved the resistance of fish to variations in salinity. Al Amoudi (1987) tried to add NaCl to the diet of his fish before transferring them, so as to increase their resistance and concluded that a progressive adaptation is necessary. It seems therefore that the choice of the suitable fish and their gradual adaptation to salinity are important factors in the successful rearing of fish in salt waters. These conclusions are further substantiated by the failure of tests which have been carried out in the Ivory Coast. It seems that the *O. niloticus* strain which had first been chosen was very sensitive to salinity variations. This information was not available when the farming site was chosen and the locality proved to be subject to major salinity variations. The animals have been replaced by other strains (*O. aureus* and the *O. aureus* × *O. niloticus* hybrid) and the preliminary results are much more encouraging (Doudet, 1986). It seems therefore, that the best way to get over the problem of the exploitation of these salt waters is to select perfectly adaptable strains or hybrids and to acclimatize them progressively.

Blooms of plants and algae

The proliferation of the vegetal or algal biomass is a rare but still unexpected phenomenon which has very severe consequences. Algal blooms were observed by Swingle (1967), who recognized different genera: *Microcystis*, *Anabaena*, *Oscillatoria* and *Spirulina*. In the Ivory Coast, severe floods have often been followed by the drifting of tremendous quantities of floating plants which completely destroyed the farms located down-stream (Doudet, 1986). Microscopic algae can release poisonous substances into the water, but a constant detrimental effect results from the accumulation of organic materials. Massive asphyxia is the most common sign observed when such blooms occur. There is no remedy and it is only by careful prospective study of the potential fish farm sites that hazardous locations can be avoided. Yet, even with such precautions, meteorological factors still remain uncontrolled!

PROBLEMS LINKED TO THE DENSITY OF FISH

Oxygen

Under intensive farming conditions, the density of fish is limiting factor; both the number of fish stocked in the pond and the feeding rate must be calculated according to the amount of dissolved oxygen in the water. As we have seen before, unusual circumstances (major variations in the temperature, low water supply during the dry season, vegetal blooms, etc.) can have critical consequences.

Ammonia

This is also a classical aspect of fish management; soluble un-ionized ammonia is a serious matter of concern only when the pH value is high, or when the waterflow is too low to renew adequately the water (*fig.* 1). In fact, tilapias seem to be able to adapt to critical values of un-ionized ammonia, provided the variations are not too sudden (Redner and Stickney, 1979).

Behavioural stress

Henderson-Arzapalo and Stickney (1980) have carried out research on unexplained problems observed in intensive farms, where *O. mossambicus* and *O. niloticus* displayed chronic mortalities associated with poor growth. They were able to detect a compound with a high molecular weight, further identified as a betaglobulin, both in the fish cutaneous mucus and in the surrounding water. When injected subcutaneously to tilapias, this protein produced local and systemic signs (fin congestions, dyschromia and opercular hyperventilation) similar to those which had been observed in cases of cutaneous anaphylaxis. Similar clinical signs could be reproduced with injections of histamine. According to the authors, some mechanisms involved in the control of fish populations could exist, as demonstrated for other species (goldfish and danio). In the present case, this control might be mediated by the release of biological substances which are believed to induce auto-immune response. These substances are not strictly specific and can act at least in species belonging to the same genus. The confirmation of such experiments would result in practical restraints since optimal density of fish should be strictly defined. In any case, the behaviour of tilapias appears to be complex enough to be taken into consideration and it is clear that difficulties linked to social stress can be expected under intensive farming conditions.

PROBLEMS RELATED TO NUTRITION

Any attempt to farm a new species of fish is hampered by the lack of theoretical knowledge of its dietary requirements. This is the case for tilapia, for which nutritional disorders have already been described on several occasions.

Cataract

Clinical observations of the opacification of the eye lens have been made, but it is still difficult to link them to specific causes. Of course, origins other than nutrional ones can account for eye pathology: water salinity and bacterial infections can also result in occular diseases. Nevertheless, food deficiency (in zinc for instance) is known to cause severe problems in other species, and it seems obvious that better adjustments of the diets to tilapia requirements would improve the situation.

Skeletal deformities

In this case too, it is possible to refer to problems which have been experienced with other species in order to explain some abnormalities observed in tilapias. Two types of deformities have been described (Roberts and Sommerville, 1982). The first is characterized by the atrophy of the fins, especially the dorsal and caudal ones, which can be completely absent.

The second is characterized by an antero-posterior shortening of the body. This last type of malformation is also known for other species and may occur during the development process; such perturbations along with the abnormalities that Rothbard *et al.* (1980) have recorded in young alevins can also derive from the fecundation or incubation conditions.

The nutrition factor cannot be excluded in some cases; recent acquired knowledge in marine aquaculture (sea bass and sea bream for instance) should draw every fish farmers' attention to the importance of supplying the fish with adequatly composed diets.

Diet imbalance and microbial or parasitic diseases

Nutritional imbalance can produce more insiduous effects, affecting the natural defences and rendering the fish more vulnerable to infections and infestations. This leads to the necessity of treating the fish more frequently; since overtreatments have also side effects, the risk is to weaken the fish even more. The identification of the primary causes of disorders would be the only way to solve the problem for good. An accurate knowledge of the fish nutritional requirements would help to overcome many difficulties that pathologists are presently unable to manage properly.

Aflatoxins

The accumulation of fungal aflatoxins in fish diets is linked to inappropriate storage conditions. These toxins induce a typical chronic development of hepatic tumors. Only granulomatous aspergillomycosis has been observed in tilapias but the frequency of *Aspergillus* sp. in their culture areas endows the problem with a worrying significance.

The handling of fish

A fish farmer cannot escape necessity of regularly treating, sorting and trapping his fish. The only way to avoid or minimize the stress or wounds is to carry out handling operations at favourable periods, using a soft and adapted material. In some geographical area, the cold season is a difficult period during which husbandry manipulations should be prohibited. A critical point is the adaptation of materials and techniques which is not only a matter of improving designs and devices but also of practical experience.

CONCLUSION : priority for the development of research works

In many cases, appropriate development of therapy, preventative treatments and in the long term, vaccinations, could provide reliable control methods. Unfortunatly, there are serious impediments to such application, particularly in African countries.

— There is little definite knowledge of the effect of drugs in warm or salt water environments and their efficiency and toxicity threshold values therefore remain doubtful.

— Bath treatments in farms using facilities such as cages or fences set down in natural waters, does not appear realistic.

— The costs of oral medecines are prohibitive in areas of limited economic welfare.

Nevertheless, the situation is not hopeless! For many reasons which are linked to data obtained for other species, to the history of fish pathology, and to the increased susceptibility of debilitated animals, the actual importance of true pathogens has certainly been overestimated. Viral diseases have scarcely been recorded in tilapia farms. Microbial infections are generally caused by opportunistic species, and even when obligate pathogens are involved, clinical signs often result from environmental factors. Parasites are a major problem, but their effects can be fairly well controlled when they affect post-juvenile fish reared under good conditions. It is noteworthy that no major plague has ever been described for Tilapias, as is the case for fish cultures conducted in cold or temperate waters.

Consequently, it should be possible to limit efficiently the effects of pathogens through sanitation, by insisting on the control of the animals which are introduced to the farms or on the necessity of respecting quarantine periods, and through a general program for the hygiene of sites, by choosing fish strains which are adapted to the local environment and by ensuring good rearing and feeding conditions.

Sanitation is primarily a matter of individual and political will, however, good practices should be supported by well established data and there lies the true difficulty for tilapia health control. Scientists could improve our knowledge and provide professionals with additional and valuable informations.

In conclusion, we would like to point out the two paths of investigation which we think are the most promising.

— Research and selection of fish strains according to their growth performances and to their capacity to withstand stressful conditions and salinity variations; this should ensure more successful tilapia production. The improvement of current practices will be beneficial only if applied to suitable fish. The recent problems which have occurred in farms of the Ivory Coast provide us with a good illustration of such a necessity.

— The study of tilapias' basic requirements also appears as a priority and could help to solve various problems at the same time. In addition to the rational conduct of feeding, it would be wise to take care of food storage and preservation conditions, which appear to be a critical concern in African countries.

Thus, we can see that solutions linked to zootechnical problems would result in significant improvements in the health of tilapias and could help many farms to reach commercial profitability. Then, the action of pathogenic organisms could be evaluated and specific methods of control could be sought.

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