Possible impact of species enhancement in Indian reservoirs through introduction of genetically modified tilapia

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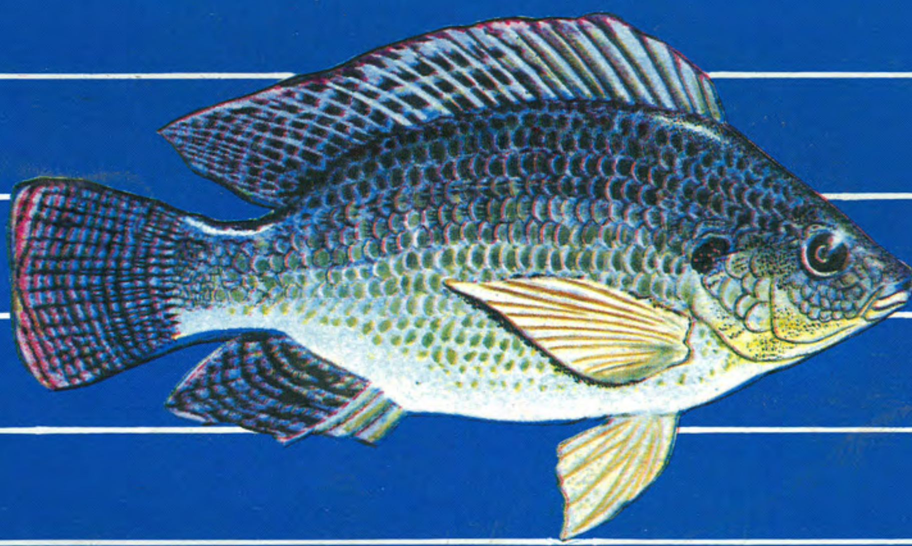

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Preface

The practice of introducing plants and animals out of their range of distribution for agriculture, animal husbandry and recreation dates back to prehistoric times. However, transfer of fish across countries and continents has been of recent origin. Robin Welcome, who traced the history of introduction of fish from the year 1900, reported that the instances of transplanting exotic species had increased steadily during the 1950s and peaked during the 1960s, after which it declined. The main objective of species transfer during the first three decades of the century was recreation and thus trouts and *Cyprinus carpio* virtually dominated the list of species introduced during the period. Tilapias were the most commonly introduced species during the subsequent four decades, when the priority had shifted in favour of aquaculture production.

Oreochromis mossambicus was the first tialpia to be introduced on a large scale for aquaculture operations, which was followed by many others such as *O. niloticus, O. aureus, T. rendalli, etc.* In the island countries like Cuba, Sri Lanka and Papua New Gunea, the tilapia was well accepted as a candidate for aquaculture and enhancement in ponds and reservoirs, as these countries had a poor indigenous fish fauna. On the other hand, in countries like India and Brazil, which had a diverse fish faunistic spectrum, the introduction of new species especially tilapias has always been subject of controversy. The main objection pertains to the propensities of the exotic species to affect the rich biodiversity of these countries. In recent years, many genetically improved varieties of fish are being produced to improve their culturability thereby adding a new dimension to the existing controversies.

Although *O. mossambicus* has been introduced in many countries since the mid-1950s, as a potential candidate for improving yield rates from aquaculture systems, the fish failed to live up to its expectations due to problems like runting, early breeding and over-population. Later, *O. niloticus* was tried more successfully. However, this fish was not officially introduced in India so far. Recently, genetically improved strains of tilapia known by names such as *golden fish, red tialpia, golden tialpia, etc.* are being promoted for high yield rates. Of late, private companies of developed countries have launched vigorous commercial campaigns to produce and culture red tilapia, mainly aiming at the sale of their technical know-how to the developing countries. This technology includes production of mono-sex seed of fast growing varieties of tilapia and their culture in closed systems at a very high density.

The possible impact of such a high density culture involving genetically modified exotic species on the environment and the biodiversity of countries has led to heated national debates in many developing countries including India. Often, scientists and scientific institutions are asked to provide advice on the matter. However, the processes of decision making and the risks involved are so complex, unpredictable and numerous that a scientist or a group of them may not be in a position to generate the necessary advice. Moreover, on account of the social, economic, environmental, aesthetic, ethical and moral issues involved, the decisions are to be made at a political level.

The issues pertaining to introduction of red tilapia in industrial-scale aquaculture have assumed topicality in India. In this backdrop, an attempt has been made here to collect all available facts on the subject and asses the implications of its introduction into the country. The views expressed and ideas espoused in this document are those of the authors which may not be construed as the Institute's opinion on the subject. This is intended to provoke a scientific debate on the matter. The authors shall feel gratified if the readers express their opinion on the subject through appropriate fora/media to continue this debate.

The authors

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1. INTRODUCTION

Tilapia in India has a rather chequered history. When *Oreochromis mossambicus* was introduced in India in the year 1952, the country was in its early phase of inland fisheries development. The fish was thought to be an answer to our search for a species which adapted well, bred profusely, subsisted on a variety of food under diverse ecological situations, and contributed significantly to the country's fish production. Tilapia was first stocked in ponds and then in a number of reservoirs in south India. Although it was originally planned to stock them in selected reservoirs on an experimental basis, by the end of 1960s, most of the reservoirs in Tamil Nadu and those in the Palakkad and Trissur districts of Kerala were regularly stocked with tilapia with the hope of achieving quick hikes in yield rates. Somehow the fish failed to live up to its promise. Its performance in ponds were discouraging from the very beginning due to early maturity, continuous breeding, overpopulation and dwarfing. In the worst cases, it was reported to mature at 6 cm length at an age of 75 days and breed at an interval of one month under tropical conditions. In the reservoir ecosystem of Tamil Nadu, tilapia performed well initially, but the hopes about substantial increase in yield through the fish were soon belied due to the erratic behaviour of its catch in the reservoirs during 1960s and '70s. Later, during the 1970, by the advent of carp seed production and composite fish culture technology, both aquaculturists and the reservoir managers have turned their attention to Indian and exotic carps, almost totally ignoring tilapia as candidate for species enhancement.

2. THE RED TILAPIA

Production of all-male progeny by crossing *T. mossambica* females with *T. hornorum* males by Hickling (1960) aroused the first hope of using inter-specific hybrids as a means of controlling wild spawning. Cross breeding was also found to help in improving catchability, growth rate, temperature tolerance and body coloration. Since this line of work opened up avenues for enhancing the value of tilapia as candidate species for large-scale fish culture, a number of all male or predominantly male hybrids have been produced (Pillay, 1990).

T. nilotica x T. hornorum (Pruginin and Kanyike, 1965)
T. nilotica x T. aurea (Fishelson, 1962)
T. nilotica x T. variabilis (Pruginin, 1967)
T. spilurus niger x T. hornorum (Pruginin, 1967)
T. vulcani x T. hornorum (Pruginin, 1967)
T. vulcani x T. aurea (Pruginin, 1967)
T. nilotica x T. macrochir (Lessent, 1968)

Among them, the one hybrid that has received special attention from fish culturists for some time is the so called red tilapia, the colour of which is a blend of pink, yellow and gold. It is appreciated in the market in preference to the normally silvery grey or black-coloured tilapia. Red tilapia is known to have a faster growth rate and food conversion ratio. It can grow in both fresh- and brackishwater environments. The origin of this hybrid is not yet fully documented. A reddish orange F-2 progeny with superior qualities was obtained in Taiwan by crossing a mutant reddish orange female of *T. mossambica* with a normal-coloured grey male *T. nilotica*. In the Philippines, a similar reddish-orange or golden progeny was obtained by cross breeding a female hybrid of *T. mossambica x T. hornorum* with a strain of *T. nilotica*. Galman and Avatlion (1983) found that the red tilapia is intermediate in several characteristics between *T. mossambica, T. hornorum, T. nilotica* and *T. aurea*, and speculated that all these species are involved in the hybrid.

Lovshin (1982), who has reviewed experience in tilapia hybridization, pointed out that in spite of the knowledge that all-male or predominantly male populations can be produced by hybridization, commercial culture of such hybrids is limited. One reason for this is the difficulty in maintaining pure genetic lines which are necessary to obtain consistent results in hybridization. In commercial production, varying proportions of females occur as a result of contamination of the brood-stock lines. Electrophoretic comparisons of blood proteins and crossing in aquaria of the brood stock until all-male offspring are consistently produced have been suggested as a means of ensuring pure brood stocks. These procedures are feasible in breeding centres, but there are only a few countries where such facilities are available at present for the production and distribution of selected pure lines of aquaculture species. Further investigations by Majumdar and McAndrew (1983) showed that even crosses between pure lines produce varying sex ratios. In 41 trials, only one cross (*T. mossambica* males x *T. macrochir* females) gave 100 percent male progeny.

2.1 Introduction of red tilapia

There is an ongoing natural debate on the introduction of red tilapia into intensive aquaculture systems of India. In this context an attempt is made her to assess the possible impact of the fish on the reservoir ecosystem, in the light of our experience with other tilapia species. Apart from the eco-friendliness and sustainability of the very concept of super-intensive aquaculture practices, the current debate centres around:

a) the wisdom of bringing in an exotic fish despite the availability of a number of indigenous culturable species.

b) the deleterious effects on the biodiversity in case, the alien fish strays into the natural waters.

This throws open almost all the issues involved in the accepted guidelines for selecting a species for transfer (Turner, 1988) i. e., the species should:

a. fill a need created by the absence of a similar desirable species in the locality of transplantation,

b. not compete with valuable native species to the extent of contributing to their decline,

c. not cross with native species and produce undesirable hybrids,

d. not be accompanied by pests and diseases, and

e. live and reproduce in equilibrium with its new environment.

a. Need for a new species

One of the arguments in favour of introducing tilapia into the country is the lack of species in India which is amenable for industrial-scale production. Tilapiine cichlids are known for its culturable qualities and they are rated superior to Indian major carps as a candidate for intensive aquaculture. Production rates obtained through tilapia culture in the countries like Taiwan, Thailand, Brazil, Philippines and Israel are much higher than that of carp culture in India. A major advantage is the relative ease in seed production compared to carps.

O. mossambicus was the first tilapia to gain international reputation. Later, *O. niloticus* was found to be a better candidate due to its faster growth, yield and appearance. As early as in 1984, this fish was considered as superior species for culture in comparison with *O. mossambicus* in Philippines (Smith and Pullin, 1984). Hybrids of *O. niloticus*, when crossed with *O. mossambicus* or *O. aureus*, gave still higher performances. The latter cross also gave all male offspring. *O. niloticus* crossed with albino *O. mossambicus* gave rise to a fast growing variety which came to commercial production in late 1970s. The red tilapia is on record yielding much higher yield rates compared to other tilapias (Galman *et al.*, 1988). Maclean (1984) put the relative performance of the three fish as follows:

1950s	**1970s**	**1980**
O. mossmbicus	*O. mossambicus* x *O. niloticus*	Red tilapia
Yield 2.5 t/ha/yr Growth 140 g/yr	Yield 60 t/ha/yr Growth 700 g/yr	Yield 600 t/ha/yr Growth 1 kg/yr.

Since the emergence of red tilapia, the emphasis has once again shifted in favour of this hybrid fish. Red tilapia hybrids, first produced in Taiwan, are the third generation tilapias combining flavour, colour and other desirable features as quick growth, few bones, tasty flesh, good market acceptance, ease of reproduction and adaptability to a very wide range of environmental conditions (Anon., 1984). Today, the red tilapia and O. *niloticus* seem to be gaining more popularity compared to O. *mossambicus* in many countries. Other species are employed for special situations, for example, blue tilapia (*O. aureus*) for cold water and *O. spilurus* for saline waters.

Red tilapia produced through a three way hybridization involving *O. mossambicus* x *O. niloticus-aureus* (Lester, 1983) account for about 5% of the total Taiwanese culture tilapia production which exceeds 50,000 t/yr. Production systems involving *O. niloticus* is very common in the Palotino Province of Brazil.

b. Competition with valuable native species

Since red tilapia does not keep a pure line and maintain its phenotypic identity in the subsequent generations, the biological traits of parent species need to be considered in evaluating its possible role as competitor vis-a-vis indigenous species. Therefore, biological traits of all the seven species believed to be involved in the development of red tilapia are briefly oulined here. The growth rate, food preferences and the breeding habits are particularly relevant (Tables 1 & 2).

Biological traits of various tilapia species

O. niloticus: grows to 160, 240 and 300 mm in the I, II an III Year respectively on a diet of phytoplankton. The fry is, however, omnivorous. The fish breeds at a temperature of 19 ^{0}C or above, although the breeding season varies considerably depending on the latitude. In Israel, the fish is on record breeding during April to May while in the Nile delta the season extends from April to August. Since the gonado-somatic index shows two peaks, the fish is believed to breed either twice or has a prolonged breeding season.

O. aureus: feed on phyto- and zooplankton attaining sizes of 160, 270 and 310 mm during the I, II and III Years respectively. Breeding season is March to May, but in Nile delta the season extends up to November at a minimum temperature of 20 - 22 ^{0}C. Reproduction occurs mostly in the second year in the size range of 220 - 250 mm, although the smallest size at maturity recorded is 58 mm (SL). In Alabama, females of 100 - 180 mm spawned at intervals of 33 - 59 days producing an average rate of 462 eggs.

Table 1. Food preference and growth rate of various tilapia species

Species	Food	Growth
O. niloticus	Mainly phytoplankton. Feeding on *Microcystis* reported. Fry omnivorous taking periphyton, copepodes and insects. Shift to phytoplankton as they grow up.	I Year 160 mm II Year 240 mm III Year 300 mm
O. hornorum	Unicellular algae and detritus	Female: 310 mm Male: 355mm
O. variabilis	Young feed on planktonic algae specially *Melosira* and Copepoda. Adults (in wild) on bottom algae	I Year 170 mm II Year 240 mm (130-190 mm in ponds in 6 months)
O. macrochir	The dentition suggests adaptation to grazing epiphytic growth but the fish is opportunistic and eat on detritus and phytoplankton.	I Year 101 mm II Year 150 mm III Year 200 mm
	In the wild: The young up to 50 mm feed on epiphytic filamentous algae, fingerlings (5 to 20 cm) live on detritus, adults feed on bottom deposits or plankton. **In ponds:** The adults feed on algae, mostly diatoms. Smaller individuals feed on protozoa, Individuals of 20 - 30 mm size take Cladocera, Copepoda and Ostracoda. However, larger (75 mm) ones do not take zooplankton .	Max. size 430 mm (1.78 kg) (in Zambezi) 2.53 kg (in Dams)
O. spirulus niger	Not a plankton feeder., but grazes on algal films and diatoms. Larger individuals known to feed on insect larvae.	Maximum growth in the wild is not recorded.In ponds 320 mm (454 g)
O. aureus	Phyto-and zooplankton	I Year 160 mm II Year 270 mm III Year 310 mm
O. niloticus vulcani	Diatoms, Protozoa, invertebrates	640 mm (4 - 7 kg) (Max. recorded in Lakes Turkana and Kyogo)

From and as quoted by Trewavas, 1983

Table 2. Size at maturity and fecundity of various tilapia species

Species	Size at maturity	Fecundity	Remarks
O. niloticus	Female 120 mm Male 140 mm	340 eggs *(at 170 mm)* 3,706 eggs *(at 570 mm)*	-
O. hornorum	73 mm	490 eggs	-
O. variabilis	200 - 250 mm	323 - 547 eggs *(200 to 260 mm)*	Breed only after 4 years in the wild. But in ponds known to breed in 6 months. Minimum 3 spawnings in a year.
O. macrochir	180 mm	516 - 1,500 eggs	-
O. spirulus niger	*(In ponds, depending on density)* Female 125 mm Males 105 mm	*In aquarium* 44 eggs *(75 mm size)* 692 eggs *(170 mm size)*	-
O. aureus	220- 250 mm	350 eggs *(at SL 105 mm)* 1,600 eggs *(at SL 153 mm)*	-
O. niloticus vulcani	200 mm	-	-

O. hornorum: Largest female specimens reported are 232 mm from Lower Rufigi and 310 mm from Kilombero. It feeds on unicellular algae and detritus. Largest males reported from the same regions measured 252 and 355 mm respectively. Size at first maturity recorded by various workers ranges from 73 to 97 mm. There are several (at least 3) breeding cycles in a year.

O. variabilis: Food comprises algae and zooplankton and the fish grows to 170 and 340 mm during the first two years. However, in the ponds it can grow up to 130 - 190 mm in six months. Growth is very slow after maturity. A tagged specimen of 233 mm when recaptured after 805 days was of the same length. Fecundity varies from 323 - 547 (200 - 260 mm size) and the fish breeds at least three times in a year.

O. macrochir: The fish basically is a grazer going by the dentition, but its feeding habits are very flexible. Depending on the life stages and the environment food varies among macrophytes, algae, detritus and zooplankton. Normally grows to 100, 150 and 200 mm during the first three Years of life. But largest specimen caught from Zambezi is 430 mm (1.78 kg). Shallow waters a that found in floodplains are ideal for spawning, but with a lower temperature limit of 21 - 23 °C. In hot climate, it breeds throughout the year often with 8 spawning in a year at interval of 6- 7 weeks. Annual breeding migration was recorded from the northern end of Lake Mweru to lower Luapula where swamp vegetation is abundant.

O. spilurus niger: Though not a plankton feeder, the fish is known to graze on algal films and diatoms. Larger individuals feed on insect larvae. Under experimental conditions, spawning was recorded at intervals of four weeks, beginning in the size range of 75 to 88 mm.

Tilapia is known to be a prolific breeder and it exhibits considerable plasticity in feeding behaviour. Moriarty and Moriarty (1973) have demonstrated that *O. niloticus* can assimilate up to 80% of carbon ingested through the algae like *Microcystis, Anabaena* and *Nitzchia. O. mossambicus* has been shown to consume vegetable debris and macrophytes (Bruton and Bolt, 1975; Man and Hodgkiss, 1977). They have also observed that *O. mossambicus* and *O. niloticus* have got a wider omnivore food spectrum compared to many other tilapia species. Philippart and Ruwet (1982) presumed that in feeding habits, the general qualitative characteristics of the tilapia depended on:

(i) The type of the organisms present which depends on the limnological and physico-chemical characteristics of the water body;

(ii) The accessibility to food organisms according to their local distribution; and

(iii) The presence of competing species which forces each species to restrict its food spectrum and to exploit its specializations.

In sewage-fed wetlands of Calcutta, adult *O. niloticus* was observed to feed chiefly on phytoplankton constituting up to 96.4-99.2% of the diet. Bacillariophyceae constituted 17.8 - 65.3 %, Chlorophyceae 11.3-44.4 % and Myxophyceae 23.4-41.0 %, exhibiting wide variations from month to month, more or less oscillating along with the food availability in the environment (Anon., 1991). The fecundity ranged from 290 to 1660 depending on the size (170 mm/80 g to 180 mm/115 g).

The Indian reservoirs generally harbour a high density of Myxophyceae, Bacillariophyceae, and Chlorophyceae in that order. If we exclude the large reservoirs, the depth of inland waters bodies are also within 10 m. (*i.e.*, 6-10 m in case of small reservoirs and 2-5 m in case of wetlands, tanks and ponds). The temperature variation is limited mostly to 20-30 °C. Such an environment, by all biological standards, is ideally suited to tilapia. So is also the case with most of the commercially important native carps. Obviously, there is bound to be a competition between carp and tilapia species. Therefore, a possible competition for domination between the tilapia and the major carps is ultimately decided by the recruitment success. Tilapia, being able to breed in confined waters, has an obvious advantage over the major carps.

c. *Crossing with other native species producing undesirable hybrids*

The red tilapia is developed through hybridization with the primary objective of stocking the intensive aquaculture systems, where monosex populations are preferred for obvious reasons. Therefore, their chances of colonising a natural water body are apparently low. Moreover, even if both the sexes get access to a water body and breed, they do not keep their identity as a phenotype for long. *However, it is to be kept in mind that at the present level of technology, neither hormone treatment nor hybridization ensures a cent per cent unisex progeny.* Moreover, the fish will continue to bear the genomes of other species.

All species of tilapiine cichlids known by the name Tilapia, *Oreochromis*, and *Saratherodon* are known to hybridize loosely among themselves. The probable chances of tilapia hybridizing with indigenous species are difficult to predict. The Indian cichlids *Etroplus suratensis* and *E. maculatus* are particularly vulnerable. Inter-specific and inter generic hybridization is common in reservoir ecosystem due to the acute shortage of breeding space (Natarajan, *et al.*, 1976).

d. diseases

Although the tilapias are more resistant to diseases than many other species both in wild and cultured habitats, a wide range of disease problems can occur. Till 1983, no viral problems other than lymphocystis have been recorded. The bacterial pathogens include aeromonads, myxobacteria (commonest *Flexibactor columnaris*) and psedomonads (*Edwardsiella tarda*). A wide range of parasitic problems occur including trichodinids, *Ichthyophthirius* and various intermediate stages of digenean flukes. Nutritional problems are a major difficulty in intensive culture, with aflatoxicosis, a major cause of losses associated with poor quality storage of food ingredients.

Establishment of rigourous quarantine procedures through national legislation is necessary to prevent the accidental introduction of pathogenic organisms. Apart from brood stock and juveniles of fish, inputs like feed and farm implements can carry viral pathogens.

e. Equilibrium with the new environment

Unlike the high yielding varieties of plants and animals developed through genetic engineering for the agricultural and animal husbandry sectors, the process of evolving genetically superior strains in fisheries sector is not well developed. In any case, the tilapia hybrids cannot be compared with the transgenic GMOs (genetically modified organisms) developed for the agriculture and animal husbandry sectors. The red tilapia, for instance, has been developed through selective hybridization of mutant and normal strains that are found in nature and in many cases, they do not breed true. This, coupled with the fact that the tilapia species tend to hybridize among themselves create hurdles in developing strains with firm characteristics.

There are not many recorded instances of red tilapia establishing a breeding population in a water body. Ang et al., (1989) considered that the red tilapia were not less prolific than *O. mossambicus*. He reported that the red tilapia, not treated with hormone for monosexuality, escaped into mining pools in Malaysia, where it proliferated into stunted populations. He further reported the escape of these stunted red tilapia into streams and rivers of the country.

Depending on the parentage, red tilapia hybrids bear the genomes of other tilapia species, which might eventually produce their respective biological traits in open water ecosystems. Therefore, our past experience with other tilapia is important.

3. PERFORMANCE OF TILAPIA IN INDIAN WATERS

The warm waters of the tropical reservoirs in India have provided a conducive habitat for the tilapia and the fish has carved out a niche for itself in a number of south Indian reservoirs. The fears of its stunted growth have been allayed as the average size of tilapia did not decline as much as it did in ponds. Sreenivasan (1967) stated that the fluctuating water levels affected the breeding pits of the fishes and the predators took a heavy toll of their young ones. These two factors are believed to keep check on the excessive proliferation of tilapia in reservoirs.

Size of tilapia in the commercial catches of reservoirs has been very good, as opposed to the unmarketable size reported from the ponds. The average size of tilapia from Tamil Nadu reservoirs has been 1.5 kg during the 1960s, with the minimum size of 500 g. Similarly, tilapia weighing 2.5 kg was very common in Malampuzha reservoir, Kerala during the 1960s, with an average size of 1.5 to 1.75 kg. The present sizes of 0.5 to 0.7 kg in Malampuzha and 0.68 kg in Tamil Nadu reservoirs are well within the limits of market preference, their continuous slide in size over the years is a cause of concern as it is feared that if the fall in size continues, it may become unmarketable.

Tilapia has dominated and virtually eliminated all other fishes including the stocked Gangetic carps in a number of reservoirs in Tamil Nadu. Vaigai, Krishnagiri, Amaravathy, Uppar and Pambar reservoirs in Tamil Nadu are harbouring sizeable populations of tilapia since 1960s, contributing substantially to commercial catches. While its contribution has declined since 1979-80 in Vaigai, it continues to form a major fishery in rest. In Krishnagiri, the fish has a changing fortune on account of competition with the mullet, *Rhinomugil corsula*. From the predominant position in the 1960s the percentage of tilapia came down to 4.3% in 1983-86, only to increase in the year 1989-90 to 69% (Jhingran, 1991). At present, tilapia forms 24% of the catch.

Performance of *O. mossambicus* in different water bodies including the culture-based fisheries has been assessed by several authors. Menon and Chacko (1957), Menon and Krishnamoorthy (1956), and Menon *et al.* (1959) have tried to ascertain the performance of fish in respect of its feeding habits, growth and possibility of raising them as forage for the murrels under culture systems. Sreenivasan (1967) has summed up the utility of tilapia in Indian waters based on his elaborate analysis of its performance in Tamil Nadu waters. This seems to be the only serious and critical evaluation of the species in India till the 80s taking into consideration both its bio-ecology and production trends. Most other literature on the species is restricted to its yield prospects, studies on sex reversal and the physiological responses to environmental stresses. The second comprehensive review on tilapia in Indian waters was by Jhingran (1983) who analysed in detail the pros and cons of tilapia's performance and expounding its role in the capture fishery systems of India.

The Committee for Introduction of Exotic Aquatic Species in India set up by the Government of India has also gone into the details of the species and the possible impact of its wide-scale adoption in Indian waters for enhancing the production. Some commercial houses have entered the field in the past by employing biotechnological approaches in tilapia farming, the most prominent among them was the venture of Vorion Chemicals, Madras which cultured the hybrid variety the *golden tilapia* (Rangaswami, 1988). M/s Vorion Chemicals is reported to have achieved a production rate of 65 t per hectare per year in its farm. The following paragraphs intend to give an up-to-date information on the performance of *O. mossambicus* in selected Indian waters.

3.1 Tilapia in fish ponds

In India, tilapia culture trials were conducted in ponds as early as the 50s. The experiments at the Cuttack centre of CIFRI revealed that the species adversely affected the survival and growth of carp seed in the nurseries. *Further, the tilapia up to 50 mm length have been observed to feed directly on carp fry.* Extreme competition for food was demonstrated by the very low survival and poor growth of major carp fry in nurseries. The weight of carps stocked in culture ponds along with tilapia also was much less than the weight of fish grown in exclusive carp ponds (Anon., 1959). The monoculture of male tilapia yielded comparatively better results. But in some cases, the few female tilapia finding entry to ponds could jeopardise the stock density and defeat the purpose of its monoculture.

Panickar and Tampi (1954) found tilapia in aquaria growing to 15, 28, 35, 39 and 55 mm at the end of first, second, third, fourth and fifth months respectively. A growth of 160 mm in 8 months in irrigation well has been reported from Madras. Devadas and Chacko (1953) recorded a growth of 60 mm in 8 months.

According to the Cuttack Research Centre of CIFRI, a daily growth of 1.5 to 2 mm was observed in *O. mossambicus in* culture ponds. In another experiment, when stocked @ 2,500/ha, the fish grew to 187.5 mm/103.75 g from an initial size/wt of 128.5 mm/31 g in two months. Under monosex culture at 3,000/ha stocking density, the specimens of av. 142 mm/53.12 g grew to 300 mm/454 g in twelve months and to 500 g in 14 months. In the third experiment, when stocked along with Indian major carps and Chinese carps @ 3,750/ha (tilapia, 625/ha), tilapia males weighing 104 g grew to 340 g in $6^1/2$ months. Initial results of tilapia farming in sewage-fed farms were extremely encouraging with yield around 8,000 kg per hectare. But the uncontrolled breeding and the stunting phenomenon later brought down the yield to around 3,000-4,000 kg in a year.

3.2 Tilapia in tanks

Tilapia *O. mossambicus* is reported from the ponds and tanks of peninsular India and a few tanks in the Raipur city of Madhya Pradesh. The yield from a few tanks in Tamil Nadu and M. P. is given in Tables 3 & 4.

Table 3. Contribution to the total catch by various fish species from major tanks in Tamil Nadu during 1989-90.

Species/groups	Large tanks: Production (kg)	Large tanks: % to the total catch	Seasonal tanks & other ponds: Production (kg)	Seasonal tanks & other ponds: % to the total catch
L. rohita	2736	18.9	3390	12.5
C. catla	774	4.2	2540	9.4
C. mrigala	-	-	845	3.1
Major carps Total	3510	24.3	6775	21.9
Common carp	10566	73.0	17220	63.7
O. mossambicus	396	2.7	2780	10.3
Catfishes & murrels	-	-	240	0.9

Data source: Department of fisheries, Tamil Nadu.

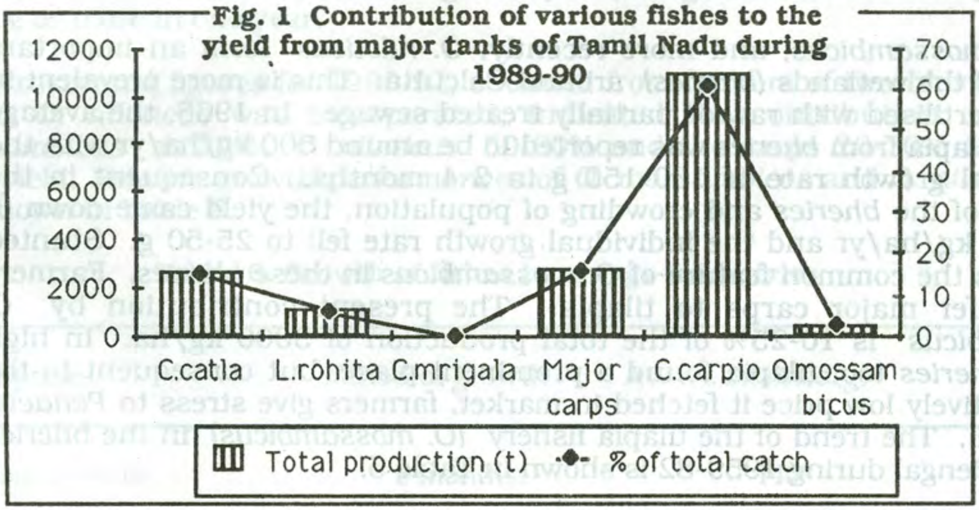
Table 4. Yield of *O. mossambicus* from tanks of Raipur district, M. P.

Tank	Area/depth (ha/m)	Contribution by tilapia (kg /ha)	(%)	Total yield from the tank (kg /ha)	(t)
Budha Talao	22/3	590	55	1074	36.5
Maharaj bundh	5/3	Fairly good		Data not available	
Naya Talao	5/3	1980	66	3000	15
Teligandha	N.A.	Fairly good		N.A.	

Data source: Personal communication with farmers.

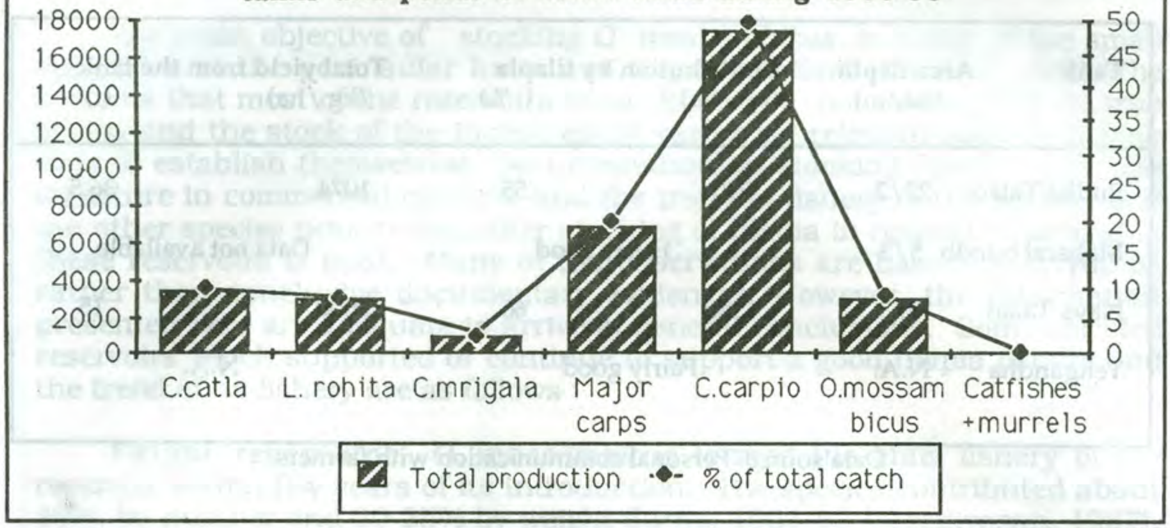
Figs. 1 & 2 provide the general information on the relative contribution of major carps, *C. carpio* and *O. mossambicus* in Tamil Nadu tanks. *C. carpio* being heavily stocked in tanks have been able to keep down the population of *O. mossambicus* to 2.7% in large tanks and 10.3% in seasonal tanks & ponds, on an average level.

Fig. 1 Contribution of various fishes to the yield from major tanks of Tamil Nadu during 1989-90



Source : Department of Fisheries, Tamil Nadu

Fig. 2 Contribution of various fishes to the yield from small tanks and ponds of Tamil Nadu during 1989-90



Source : Department of Fisheries, Tamil Nadu

3.3 Tilapia in wetlands *(bheries)*

O. mossambicus, and more recently, *O. niloticus* form an important fishery of the wetlands *(bheries)* around Calcutta. This is more prevalent in *bheries* fertilised with raw or partially treated sewage. In 1968, the average yield of tilapia from *bheries* was reported to be around 500 kg/ha/yr with the individual growth rate of 100-150 g in 3-4 months. Consequent to the siltation of the *bheries* and crowding of population, the yield came down to 150-200 kg/ha/yr and the individual growth rate fell to 25-50 g. Stunted growth is the common feature of *O. mossambicus* in these *bheries*. Farmers now prefer major carps to tilapia. The present contribution by *O. mossambicus* is 10-25% of the total production of 3000 kg/ha. In high saline *bheries* too, tilapia found a prominent place, but consequent to the comparatively low price it fetched in market, farmers give stress to *Penaeus monodon* . The trend of the tilapia fishery *(O. mossambicus)* in the bheries of West Bengal during 1959-82 is shown in Table 5.

Effect on carps : Table 3 clearly indicates the impact of tilapia fishery in the bheries and the overall impact on the yield. The carp fishery which contributed up to 93% in 1959 was reduced to nil by 1971, associated with an overall reduction in the yield to the extent of 87.7%. With a subsequent emphasis on carps and selective fishing of tilapia, the yield of carps recovered by 1982, reducing the tilapia contribution to 10%.

Table 5. Trend in yield composition from wetlands (bheries) in West Bengal during 1959-82

Year	Total production from bheries (t)	Catch composition (%)	
		Carps	*O. mossambicus*
1959	8940	93	-
1969	9670	95	-
1971	1200		100
1973	3500	20	80
1975	5500	25	70
1977	7400	20	80
1979	4000	50	50
1980	4500	85	15
1981	7500	90	10
1982	8500	90	10

With the reduction in size and overpopulation, *O. mossambicus* is no more a preferred species in the *bheries* and there is a shift towards *O. niloticus. O. niloticus* in bheries is reported to grow up to 700 g in 4 months, and even 1000 g or more in one year.

Provisional figures for 1990-91, obtained from farmers of two *bheries* in which *O. niloticus* was incorporated, indicated the contribution of *O. mossambicus* as 20%, *O. niloticus* 50-60% and the carps 20-30% to the total yield. Relative growth performances of *O. mossambicus* and *O. niloticus* are shown in Table 6.

Table 6. Growth of fishes in sewage-fed bheries

Species	Period of growth	Av. wt. attained(g)
O. mossambicus	8 months	140*
O. niloticus	8 months	250
Indian major carps	8 months	560

* Ten years before, *O. mossambicus* was reported to grow to 100-150 g in 4 months.

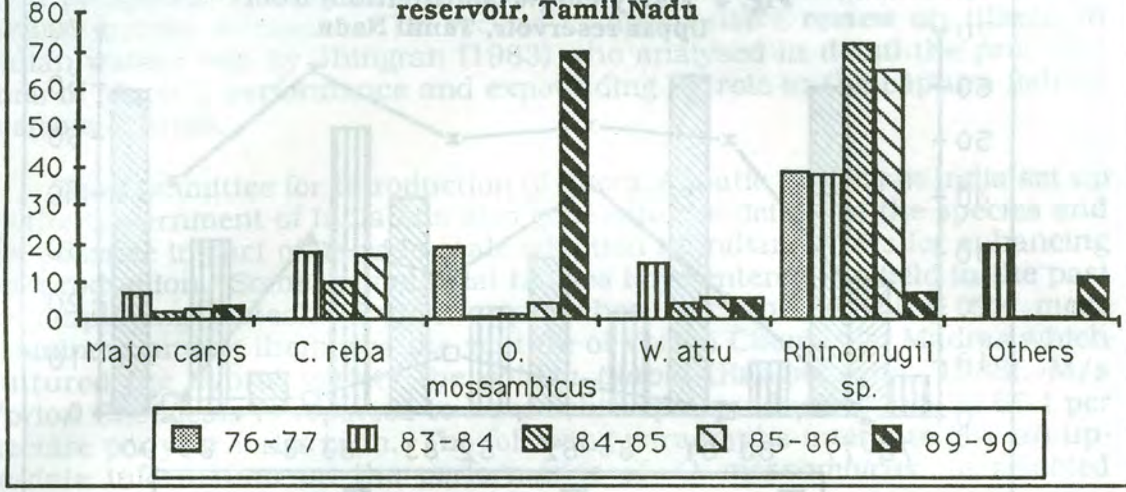
3.4 *O. mossambicus* in Indian reservoirs.

The main objective of stocking *O. mossambicus* in many of the small reservoirs in the peninsular India was a quick enhancement of yield (The fact was that most of the reservoirs those days were not managed in its true sense, and the stock of the Indian major carp seed released into them took time to establish themselves). Documentation on stocking figure, yield, size structure in commercial catches, and the trend in fishery of the species and the other species prior to and after stocking of tilapia in respect of several of these reservoirs is poor. Many of the observations are based on enquiries rather than conclusive documentary evidences. However, the information presented here are adequate to arrive at general conclusions. Some selected reservoirs which supported or continue to support a good tilapia fishery and the trend of its fishery are as follows :

Vaigai reservoir **:** *O. mossambicus* formed the chief fishery of the reservoir within few years of its introduction. The species contributed about 40% by number and 20-25% by weight during 1961-63 (Sreenivasan, 1967). By the year 1976-77, the landings from the reservoir were almost entirely of tilapia, contributing up to 94.2% of the yield, and major carp was reduced to about 4%. Surprisingly, there was a drastic change in the species spectrum in the following years, tilapia declining to 0.43% by 79-80, 0.14% in 80-81 and no contribution during the subsequent years. The exact cause could not be ascertained.

Krishnagiri reservoir (Area, 1263 ha): Tilapia was reported to contribute substantially to the catch in the 1960s with specimens measuring 500 g and over being common in the catches. Earlier records show that *O. mossambicus* contributed 19% in 1976-77 in a fishery dominated by *Rhinomugil* sp. (38%). Tilapia was reduced to 4.3% during 1983-86 with a corresponding increase in mullets (59%). The reservoir then gave an overall yield of 37.6 kg/ha/yr. The yield went up further to 50.5 kg by 1989-90, tilapia contributing 68.9% to the catch, and the mullet, a mere 6%. The major carps remained more or less steady (3.7-6.6%) all through the years, although a high rate of stocking (683 nos./ha) during 1985-89 did not reflect any impact of it in the catches. Population of *C. reba* was comparatively high (11.5-16.8%) during the lean period for tilapia, but the species failed to contribute to the fishery by 89-90, when tilapia had the peak contribution (Fig. 3).

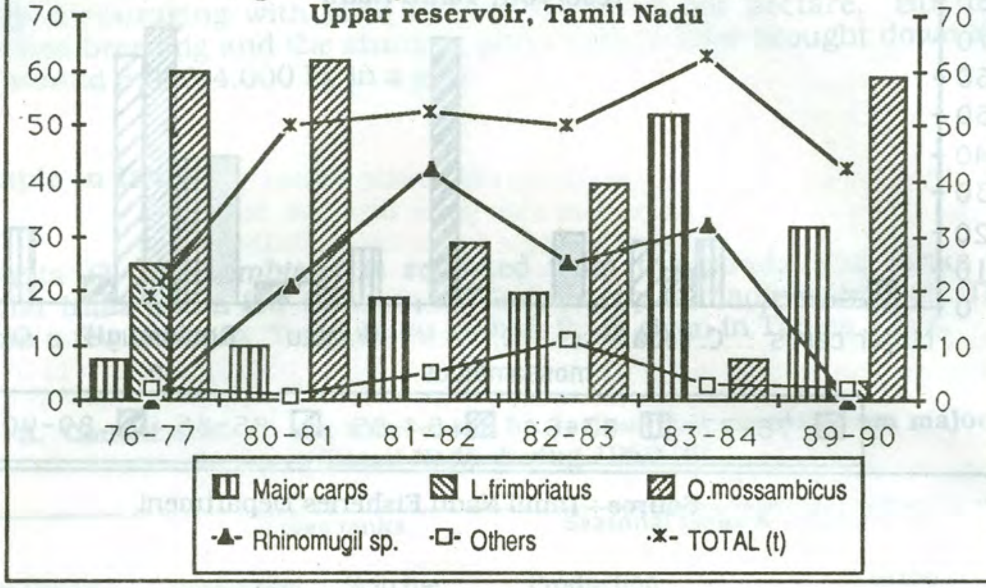
Fig. 3 Fish yield (% contribution) from Krishnagiri reservoir, Tamil Nadu



Source : Tamil Nadu Fisheries Department

Uppar reservoir (Area, 440 ha) : The trend in fishery of the reservoir is given in Fig. 4. There was a contrasting trend between major carp and *O. mossambicus* fishery in the reservoir for quite a few years. The major carp contribution was only 7.1% to the total yield of 42 kg/ha/yr from the reservoir in 1976-77, in contrast to 62.5% of the tilapia. The major carps improved their performance to 16.5% during 1980-83 raising the yield to 119 kg/ha/yr for the reservoir, but was adequately supported by the mugil contributing 32.3%. Tilapia's contribution was then reduced to 44%. By 1989, major carps' share was 33% and that of tilapia 58%. *Mugil* became non-significant, equally displaced by both tilapia and carps. It was the balanced population of tilapia, carps and mullet that gave the best result (129 kg/ha) in this reservoir.

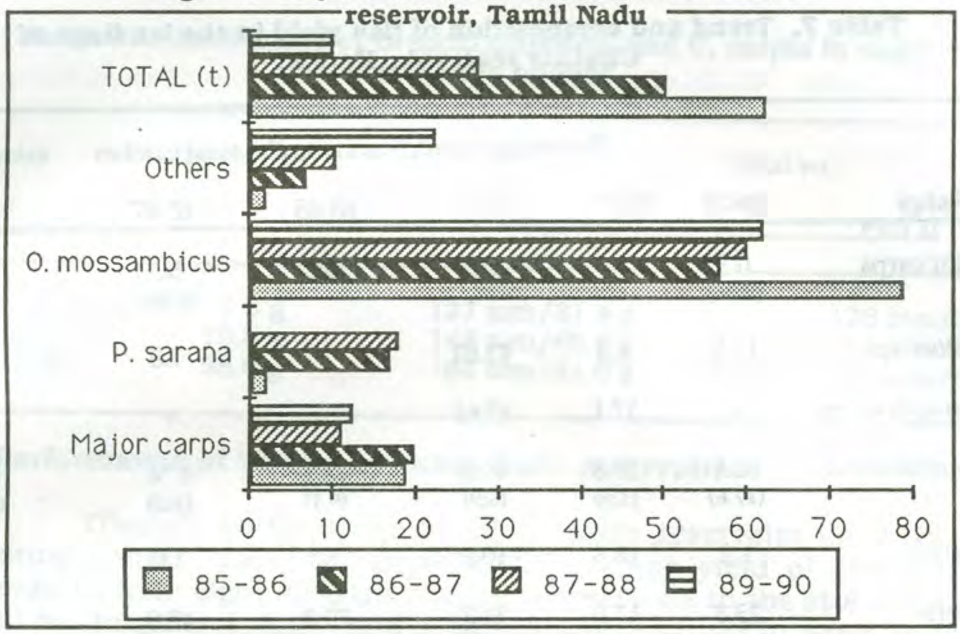
Fig. 4 Fish yield (% contribution) from Uppar reservoir, Tamil Nadu



Source : Tamil Nadu Fisheries Department

Pambar reservoir (Area, 100 ha): Percentages of major carps (11.6-19.4%) and tilapia (56.6-77.2) fluctuated relatively less in the total yield (106-633 kg/ha/yr). Maximum total fish yield was obtained when tilapia population was the highest (Fig. 5). The high stocking rate of 1,995 nos/ha of the major carp seed during 1985-89 is not at all reflected in its yield.

Fig. 5 Fish yield (% contribution) from Pambar reservoir, Tamil Nadu



Source : Tamil Nadu Fisheries Department

Chulliar reservoir (Area, 165 ha) : Table 7 shows the fish yield pattern during 1969-1989 and the relative contribution by various species to the fishery from Chulliar reservoir of Kerala. Tilapia's contribution did not bear any direct relationship with any other group of fish, possibly with the exception of *Glossogobius* sp. Major carps remained insignificant till 1985 despite a stocking rate of 100 nos/ha/yr during 1968-78. Common carp contribution was poor (1.2%) during 1969-73 despite heavy stocking @ 1030 nos./ha/yr during this period. It rose to 18.6% during 73-74 (stocking rate 671 nos/ha/yr). The decline in tilapia during this period cannot be related to common carp population since it continued to decline even after the common carp became negligible in the catch. Similarly, tilapia recorded 60.1% when major carp contribution was both paltry (0.3%; 1969-73), as well as significant (18-8%; 1989-90). Tilapia population, it seems, got influenced in the reservoir by the *Glossogobius* sp. entering into the reservoir in 1973, through the link canal from the nearby Meenkara reservoir. During the next eight years, its fishery was significant in the reservoir with an average contribution of 28.9% to the total catch and tilapia plunging to 45%. *Puntius* sp. also experienced a major rise in population during this period. The species composition in the reservoir experienced a significant change after a severe drought in 1981-82 when the reservoir dried up completely. Miscellaneous varieties (species details not available) took a stronghold in the reservoir during the next four years until tilapia once again began to dominate in the catches.

Table 7. Trend and composition of fish yield in the landings of Chulliar reservoir, Kerala.

	Percentage contribution to the total catches					
Fishes	69-73	73-77	77-81	83-85	85-87	88-90
Major carps	0.3 **(0.06)**	-	0.5	0.2	5.5 **(0.06)**	11.46 **(18.7)**
Puntius sp.	12.5	6.5	42.61	-	1.0	-
Glossogobius sp.	-	17.1	42.61	-	-	-
O. mossambicus	60.1 **(17.6)**	39.8 **(1.9)**	49.8 **(6.9)**	28.2 **(9.1)**	4.74 **(5.2)**	60.1 **(27.9)**
C. carpio	1.2	18.6	10.2	1.0	1.0	0.2
Others	23.3	17.0	23.7	70.0	45.0	-
Total yield(kg)/ **(kg/ha/yr)**	19285 **(29.2)**	3173 **(4.8)**	9152 **(13.9)**	10643 **(32.3**	3635 **(11.0)**	15344 **(46.5)**
Seed stocked (Nos./ha/yr)						
Major carps	19	182	-	-	-	1070
C. carpio	1030	672	-	-	-	303

Meenkara reservoir (Area, 259 ha): The reservoir did not show violent fluctuations in the percentage composition of tilapia in the total catch. At the same time, major carps showed an increase from 0.5 to 35.7% during 1973-90 supported by regular stocking (Table 8). The period 1988-90 showed a substantial improvement in the population by both major carps and tilapia raising the total yield to 38.43 kg/ha/yr. *Puntius curmuka* showed a definite decline during the period.

Peechi reservoir (Area, 1263 ha): Peechi reservoir has shown a rise in major carp population closely following the intensity of stocking (Table 9). The yield of tilapia per unit area also showed an increasing trend along with major carps during 1975-87. However its population experienced a rapid decline during 1987-90 in relative (57.4 to 10.6%) as well as in absolute terms (4.8 to 0.76 kg/ha/yr). *Puntius* sp. and *L. fimbriatus* had a steady percentage contribution to the total yield.

Table 8. Trend and composition of fish yield in the landings of Meenkara reservoir, Kerala.

	Percentage contribution to the total catches						
Fishes	66-72	73-75	75-77	77-79	81-83	86-88	88-90
L. rohita	2.01	0.1	0.4	1.1	0.27	0.12	0.19
C. catla	1.49	1.0	0.15	-	-	9.83	30.84
C. mrigala	3.77	-	-	-	0.75	14.00	4.72
Major carps (Total)	**7.27**	**1.1**	**0.55**	**1.1**	**1.02**	**23.50**	**35.70**
C. carpio	6.17	0.75	4.99	9.97	3.4	9.83	1.49
P. curmuka	12.95	23.38	16.91	6.67	23.12	5.82	1.55
O. mossambicus	**57.34**	**53.56**	**48.90**	**40.06**	**36.72**	**52.0**	**46.62**
Total yield(kg)/	42935	11741	10920	5606	4390	19415	47374
(kg/ha/yr)	(9.96)	(9.53)	(8.86)	(4.55)	(4.32)	(15.76)	(38.43)
Major carps (kg/ha/yr)	1.01	0.15	0.05	0.05	-	3.77	13.72
Seed stocked (No. ha/yr)	176	-	-	166	-	94	258
Tilapia (kg/ha/yr)	7.99	5.10	4.33	1.82	1.31	18.19	16.38

Malampuzha reservoir (Area 2,213 ha): *O. mossambicus* in Malampuzha reservoir is known for its faster growth, larger size and better taste. Enquiries at the landing site revealed that specimens of tilapia weighing up to 2.5 kg was quite common in the reservoir till 1969 and the average weight was reported to be 1.5-1.75 kg. The present average weight is around 500-700 g and specimens weighing 1.5 kg are rare in the catches. However, there is no documentation of the size structure of the catches over the years to quantify the decline in growth in absolute terms. Figures for the period 1982-86 suggested a decline in its fishery. But the fear was set at rest by the catch record of 1986-89, when the yield per ha again shot up to 1.63 kg during the period. Table 10 gives the trend in the fishery of the species along with other major groups of fishes in the reservoir. The increase in major carp fishery is sustained by the moderate rate of stocking (244 nos; 1986-89). *Puntius curmuka* does not seem to be influenced by the tilapia population.

Table 9. Trend and composition of fish yield in the landings of Peechi reservoir, Kerala.

	Percentage contribution to the total catches					
Fishes	66-67	70-75	75-80	85-87	87-89	89-90
L. rohita	10	-	-	1.9	2.6	4.8
C. catla	0.5	-	-	9.8	26.3	57.3
C. mrigala	1.5	6.4	-	11.2	12.9	95.0
Major carps (Total)	2.0	6.4	-	22.9	41.8	71.6
L. fimbriatus	11.6	3.4	2.5	1.0	1.9	3.2
Puntius sp.	-	5.7	7.5	9.4	13.2	7.8
O. mossambicus	44.7	66.2	69.9	57.4	35.0	10.6
Others	41.8	18.3	19.84	9.2	8.0	6.8
Total production (kg)	2038.5	3756	5520	21017	21262	17943
(kg/ha/yr)	(1.61)	(0.6)	(0.9)	(8.3)	(8.41)	(7.10)
Major carps (kg/ha/yr)	Negligible	0.04	-	1.9	3.5	5.08
Stocking seed (No./ha/yr)	-	-	-	184	1016	58
O. mossambicus (kg/ha/yr)	0.7	0.4	0.6	4.8	2.95	0.76

Table 10. Trend and composition of fish yield in the landings of Malampuzha reservoir, Kerala.

Fishes	Percentage contribution to the total catches					
	71-76	77-81	82-86	86-89	Seed stocking (86-89)	
L. rohita	0.1	0.1	0.7	4.3	24	
C. catla	1.0	0.2	4.1	7.3	76	
C. mrigala	0.4	0.1	4.4	8.3	144	
Major carps (total)	1.5	0.4	9.2	19.9	244	
P. curmuka	30.1	29.3	61.9	30.2	-	
P. curmuka + Misc. carps	35.0	41.8	78.0	39.2	(*C. carpio*) (*H. molitrix*)	851 32
O. mossambicus	**43.8**	**33.7**	**5.1**	**30.9**	**1300 ha/yr**	
Other fishes	19.7	24.0	7.2	11.0		
Total yield (kg) (kg/ha/yr)	43590 (3.94)	33754 (3.81)	40454 (4.57)	35137 (5.29)		
Major carps yield (kg/ha/yr)	0.06	0.02	0.42	1.0		
O. mossambicus	**1.73**	**1.29**	**0.24**	**1.63**		
P. curmuka (kg/ha/yr)	1.18	1.12	2.83	1.60		

Sondur reservoir (2400 ha) **:** This reservoir, situated in the Raipur district of Madhya Pradesh, was created in 1987 on the Sondur river and has been utilized for fisheries development since 1989. *O. mossambicus,* finding its entry into the reservoir in the same year, accidently from the Dandakaranya culture waters of Orissa formed a major fishery in 1989 itself. The details of the fish yield from the reservoir during 1989-91 is given in Table 11.

Table 11. Yield from Sondur reservoir (Madhya Pradesh) indicating contribution by different groups of fishes.

Fish groups	% contribution		Yield (kg/ha)	
	1989-90	1990-91	1989-90	1990-91
Major carps > 1 kg	1.4	2.8	0.23	0.30
Major carps < 1 kg + Large catfishes	4.0	2.4	0.67	0.25
Small catfishes	8.7	9.6	1.50	1.00
Carp Minnows	65.9	45.6	11.00	4.90
Carps Total	69.5	49.6	11.60	5.20
O. mossambicus	20.0	39.6	3.30	4.28
Total Production (kg)	**24,954.0**	**15,856.0**		
Total yield (kg/ha)			***16.70***	***10.67***

Data source : Dy. Director of Fisheries, Govt. M.P., Raipur

The relative contribution by tilapia increased substantially both in terms of kg/ha and percentage contribution to the total catch with a corresponding decrease in carp minnows and catfishes. The overall yield of carps was reduced to half. However, the major carps had a steady yield during both the years.

3.5 Cage/pen culture experiments

Cage culture of *O. mossambicus* was undertaken in India about 23 years ago on an experimental basis. A density of 150 fingerlings per m^2 gave the highest production of 31 kg/m^2 (16.38 t/ha/month). The growth rate was 41 g (6 g to 47 g) in 99 days culture period with a survival rate of 88.8%. Under the experiments conducted during 1990-91, (Anon., 91) pens were erected with split bamboo in *bheries* of West Bengal, leaving an effective area of 10.2 sq. m (3 x 3.4 m). Each pen was stocked with *O. niloticus, O. mossambicus* and *C. carpio* in the ratio of 1:2:1 at a combined density of 40,000 nos/ha. The growth after 5 months of rearing is given in Table 12.

Table 12. Production of *Oreochromis* spp. and C. carpio in cages installed in bheries

Species	Initial wt.	Final wt.	
		Pen I	*Pen II*
O. mossambicus	8.4 g	127 mm/31.4 g	128 mm/32.5 g
O. niloticus	19.5 g	148 mm/65.6 g	147 mm/64.5 g
C. carpio	38.8 g	164 mm/81.0 g	169 mm/89.2 g

3.6 Performance of Tilapia in Tamil Nadu reservoirs

Tilapia's performance in Tamil Nadu reservoirs portrays some interesting trends. Table 13 depicts the average yield of *Oreochromis mossambicus* from eight different classes of reservoirs in the size range of 50 to 1000 ha. In general, high yield of tilapia was observed in small reservoirs of the area 50-200 ha. The largest reservoir giving a significant yield (34.8 kg/ha) of tilapia was Krishnagiri with an area of 1,280 ha, followed by the 3,263 ha Poondi reservoir with a tilapia yield of 15.9 kg/ha. Except for these two reservoirs, all the other major reservoirs (above 1000 ha) have either negligible population of tilapia or no tilapia at all. Highest yield from any tilapia dominated reservoir was from Pambar, a 100 ha reservoir, yielding 633 kg/ha (1983-84) with a species composition of tilapia 77%, major carps 18.4% and *P. sarana* 2.4%. In Table 14, the reservoirs are arranged according to the percentage contribution of *O. mossambicus* . The yield rate was substantially higher in reservoirs which had more than 75% of tilapia in the harvest. From the above observations, it was difficult to arrive at any definite conclusions regarding the effect of tilapia on the major carps or *vice versa*. The yield by the major carps did not show any definite trend in these reservoirs, though their highest yield rate was obtained from reservoirs having less than 25% tilapia in the catches. It is significant that all these reservoirs were adequately stocked with major carp seed and yet, the major carp yield was restricted to less than 12.25 kg/ha/yr. Even the four reservoirs having no tilapia also had low yield of major carps (0.6-4.0 kg/ha) in spite of heavy stocking (343-890 nos/ha).

For none of these reservoirs data have been recorded regularly on the catch structure of either tilapia or other species contributing to the fishery. Hence, it is difficult to arrive at any conclusion on growth reduction related to age or fluctuation in population density of fishes from these waters. Experiences of fishermen and officials are the only clues for any such conclusion. Catla is reported to grow up to 8-10 kg in three

Table 13. Yield of *O. mossambicus* in relation to the area of the reservoirs

Area of reservoirs (ha)	No. of reservoirs	Contribution of tilapia (kg/ha)	Percentage of the total yield (range)
up to 50	3	101.50	32.3-50.6.
50-100	10	82.4	13.2-219.7
100-200	6	43.8	0.50-87.3
200-100	9	19.44	0.06-53.5
500-1000	10	10.3	0.3-53.6
1000-5000	4	9.0	0.3-34.8
5000-10000	2	4.7	0.7-9.8
Above 10000	1	0.14	1.9
Total :	45	7.8	0.14-219.7

Data source : Tamil Nadu Fisheries Department

Table 14. Reservoirs categorised on the basis of the percentage contribution of *O. mossambicus* (1989-90)

Contribution by tilapia (%) to the total catch	No. of reservoirs	Av area (ha)	Av. yield (kg/ha/yr)	Average no. of major carp seed stocked (No. /ha)	Contribution by major carps (kg /ha/yr) (Average)
Above 75	9	160 (74-657)	79.3 (50-291)	463 (133-1615)	7.84
50-75	12	426 (50-1280)	44.5 (4-346)	453 (164-2667)	6.51
25-50	14	672 (31-5760)	28.9 (3-358)	363 (290-2399)	6.77
2-25	7	1,995 (196-7265)	25.3 (5-98)	327 (213-2073)	12.25
0-2	9	2502.1 (388-15540)	8.1 (14-57)	352 (288-888)	2.56

Data source : Tamil Nadu Fisheries Department years in Chulliar reservoir, in which tilapia maintained a population contributing 40-60% to the total catch during most of the years. In Malampuzha, catla of 15 kg are not rare in the catches. *P. curmuka* was reported to grow up to one kg in this reservoir during 1960-70, but the maximum size now reported is about 250 g. *Labeo calbasu* weighing more than 1 kg and *L. rohita* above 4 kg are also common in the catch.

4. GENERAL CONSIDERATIONS

One of the important factors that determines the success of introduction of exotic fishes is their feeding habits. None of the Indian culturable carp feeds on Myxophyceae blooms like *Microcystis aeruginosa* and tilapia will be a welcome addition to blue greens-dominated reservoirs like Rihand. Tilapia is known to digest this abundant resource and has a high assimilation rate too. This has been indicated by Moriarty and Moriarty (1973) to be the primary reason for very high yields of tilapia in shallow tropical lakes. It is known that in certain alkaline lakes, *O. niloticus* grows to exceptionally large size. It is suspected that high sodium to calcium ratio in such lakes breaks down the cell walls of the blue greens allowing its digestion by the fish. On the other hand, the dam stocking with weed-eating tilapia has shown poor results in Tanzanian impoundments. Moyle (1976) has reported on introduction of two species (*O. mossambicus* and *T. zilli*) for weed and insect control in California. Since then, it has become the most abundant and widespread species. The tilapias have affected the relative abundance of different fish and the total number of zooplankton organisms to which native fish were highly adapted. The introduction and proliferation of macrophyte-feeding tilapias, especially of *T. rendalli*, have seriously perturbed the ecology of certain water bodies. It has devastated in three years nearly 3000 ha of *Ceratophyllum* and *Nymphaea* beds and, in consequence, caused almost total disappearance of a valuable indigenous fish, *Paretopus petite* in lake Kyle of Zambia (Lamarque *et al.*, 1975)

Sreenivasan (1967) has studied the influence of tilapia on other dominating species of fishes in Madras waters. He found that in ponds such as West Moats in Tanjore district of Tamil Nadu, tilapia did not influence the carp growth. He, however, observed that in Ayyakulam pond, the growth of *C. catla*, *L. fimbriatus* and *C. mrigala* was adversely affected by tilapia. The growth of *Chanos chanos* was restricted by tilapia to less than 100 g instead of the usual growth of 500 g/yr in many waters of Tamil Nadu. However, Sreenivasan (*op. cit.*) could not establish any characteristics of the water bodies that may be regarded as conducive to tilapia populations.

Many long distance transplantations of tilapias to a different climatic zone or to different altitudes have also proved to be failures like those of *S. macrochir*, *S. andersonii*, *S. spilurus niger*, *T. rendalli* in certain cold regions in South Africa. Studies reveal that tilapias have established themselves and formed stable populations mostly in environments characterised by suitable temperature conditions and a vacant niche.

A number of cases are available in India where establishment of tilapia has generated unfavourable conditions characterised by the following :

Initial growth of population is followed by spontaneous regression with failures resulting from competition with local species or due to environmental conditions. This is evident from the case studies of some south Indian reservoirs like Vaigai, Peechi, etc.

Excessive reproduction leads to overpopulation and dwarfing. Instances are available from some reservoirs in south India where, owing to these traits, tilapia supplanted the native ichthyofauna.

Disappointing results due to continuous reproduction (overpopulation and dwarfing) in tropical environments and to slow growth and winter mortalities in regions with a distinct cold season. This explains the difference in the performance of tilapia in north and south India. A consignment of tilapia transplanted into the Baghla reservoir in Uttar Pradesh failed to survive.

Notwithstanding the negative features of tilapia introductions as mentioned above, the fish portrays many positive characteristics. Studies have indicated that in polyculture systems containing catfish and tilapia, production of tilapia is good and the catfish production is also accelerated without changing the food application. One of the greatest advantages of tilapias is that they feed low on the food web and graze on phytoplankton, filamentous algae, zooplankton and detritus. While they do well on commercial feed, they do equally well in systems having animal manures. All male tilapia hybrids cultured in cages have given yield upwards of 9,072 kg/ha/yr in temperate countries. In philippines, farming of *O.niloticus* with pigs or poultry has produced outstanding results. Perhaps. the most difficult problem associated with tilapia culture is their uncontrolled reproduction. They are sexually precocious and can begin to reproduce when less than 100 g in size.

4.1 Need for introduction and stocking in reservoirs.

Fish stocks in a newly filled reservoir will be invariably inadequate both in terms of species number and biomass; compared to its trophic resources. This entails the adoption of appropriate steps towards species and stock enhancement. Species enhancement refers to addition of species into an ecosystem with a view to colonising unshared and vacant niches and increase production. Introduction is the process by which a species is released outside its range once or repeatedly, accident or willingly, often resulting in establishment of its naturalised population. Even through the current debate is not directly on introduction of red tilapia into open waters, if the fish eventually finds its way into a natural water course and starts breeding there, it would amount to introduction. Thus, it will be pertinent to examine the merits of introduction in reservoirs.

Performance of tilapia in Indian reservoirs has already been discussed. Sri Lanka and Cuba are the countries that have achieved commendable success in increasing yield by introduction of Tilapia. The two island nations have depauperate fish fauna without any culturable indigenous species.

Sri Lanka produces 27,000 to 30,000 tonnes of fish per year from the reservoirs which is equal to 300 kg/ha comprising mainly *O. mossambicus, O. niloticus and T. rendalli.* (Amarasinghe, 1991).

Culture based fisheries of Cuba contributes 19,000 to 20,350 tonnes which is equal to 200 kg/ha supported by *O. mossambicus, O. niloticus* and *O. aureus* (Sugunan, 1996).

Brazil has imposed strict restrictions on introducing species into its river courses. Even trans-basin movements within the country are not allowed normally. But the small reservoirs in the nine states of the northeast are the exceptions where many Chinese and African species have been introduced. Performance of *O. niloticus* has been exceptionally well in the small water bodies of the northeast especially in the states of Ceara and Pernambuco (Gurgel, 1984; Sugunan, 1996). Maximum and average yields of small reservoirs with *O. niloticus* have been reported to be 776.9 kg/ha and 346 kg/ha/year respectively.

Cage culture of tilapia hybrid (*O. mossambicus* female x *O. niloticus* male) was done in the 30.6 ha Longdong reservoir of Guangdong Province, China in 1982. Within 134 days, an average yield of 57.4 kg/m3 was reported with a survivaal of 95.6%

4.2 Role of exotics in reservoir fisheries of India

In reservoir fisheries of India two types of management options are available *viz.,* 1. culture-based fisheries of very small reservoirs and 2. the enhanced fisheries of large reservoirs. In the first category, the fish harvest depend entirely on the stocked fish which is harvested before it breeds. Thus, it involves basically a stock recapture system and the management options are *the size at stocking, size at capture* (mesh size regulation) *stocking density* and *the fishing effort* (fishing mortality). Indian major carps are known to be ideal candidates for culture-based fisheries and higher production rates have been demonstrated in India by using them as stocking material. There is no merit in bringing in new species of tilapia for management of this category of reservoirs.

Large Indian reservoirs are managed on the basis of enhancement. They are annually stocked for broadening the species spectrum and to augment the stock. However, experience shows that the stock and recapture system is not valid for Indian reservoirs. Experience in a number of medium and large reservoirs prompts us to conclude that the stocking programme can be termed as successful, only when the stocked fishes breed in the reservoir and contribute towards autostocking. In many cases, despite persistent stocking, the transplanted species did not show up in the catch, thereby rendering the expenditure incurred in stocking as waste. Only in a few instances the resources mobilised for stocking operation were compensated by generation of income through recapture of the stocked fishes.

Sreenivasan (1984) reviewed the impact of stocking in 10 reservoirs of Tamil Nadu. The stocked catla built up a naturalised population in Mettur reservoir. Just 10 000 fingerlings were stocked during 1922 to 1935, which formed the nucleus of a self-propagating stock and dominated the catch during the 1960s. Catla fisheries, however, suffered periodic set-back due to breeding failures. The current contribution is as low as 10%. Recapture of two other stocked fishes *viz., L. rohita* and *L. calbasu* is reported to be adequate (Sreenivasan, 1984). However, stocking of *L. fimbriatus* (over 2 million), common carp (1 million), *L. kontius* (0.4 million), *P. carnaticus* (0.4 million), *C. reba* (several hundred thousands) and *P. dubius* (several hundred thousands) is believed to be wasteful, since they were never recaptured in any appreciable quantity. Experience of Gandhisagar, Mettur and Sathanur illustrates the success stories where the stocked fishes bred and propagated themselves. Fernando and Holcik (1982) have clearly demonstrated that riverine fish species that colonise the reservoir ecosystem were not capable of establishing a naturalised population in reservoirs and hence their low productivity. The African cichlids are known to have better adaptibility to lacustrine conditions and so are many cichlids and clupeids. Many instances such as success of Tilapias in Sri Lankan reservoirs (Amarasinghe, 1991) the *kapenta, Limnothrissa miodon* in Kariba (Fernando and Holcik, 1982). *Corica siamensis* in Ubolratna, Sirinthon and Sirikit reservoirs of Thailand (Pawaputanon, 1991) have been cited to substantiate the theory. Indian major carps being predominantly riverine fishes fail to establish in the reservoirs and this results in the wasteful stocking exercises. Any substantial increase in large reservoirs can be achieved only when the stocked fish breed and sustain themselves *O. mossambicus* has not done well in the south Indian reservoirs. However, *O. niloticus* can play a more positive role in the management of large reservoirs of India.; Average fish yield in Sri Lanka (300 kg/ha) and Cuba (200 kg/ha) are achieved through African cichlids, whereas in spite of sustained stocking with carps, Indian reservoirs still yield less than 20 kg/ha, one of the world's lowest yields (Sugunan, 1995).

O. niloticus can be tried in some protected Indian reservoirs to assess its usefulness for enhancement. The fish maintains good size and commands a good price in Calcutta market.

5. INTRODUCTION OF FISH (ISSUES INVOLVED IN DECISION MAKING)

Issues involved in the use of exotic species and genetically modified organisms (GMO) are elaborated by Pullin, 1994. Genetically modified organisms are defined as organisms whose genetic characteristics are changed, purposefully or otherwise, by any captive breeding, selection and genetic management. This is a broader definition than most in common use, which tend to be applied only to populations that have been subjected to genetic management. Genetic management includes hybridization, manipulation of ploidy and sex determination, and gene transfers. The broad definition used here reflects recognition that any captive-bred populations of a given species can have impacts on open water populations of the same species, ranging from disease transmission to disruption of migration patterns, introgression, etc. A recent Bellagio conference on Environment and Aquaculture in Developing Countries (Pullin et al., 1993) produced a scheme for decision making that could be applied to all aquaculture and enhanced fisheries development including the use of exotic species and GMOs. Its three-fold evaluation process encompasses social effects, environmental effects and assessment of the current state of knowledge upon which decisions can be based.

Such tools are not yet in common use. Proponents of projects, the donors that support them and their intended clients and beneficiaries are under pressure to demonstrate rapid and highly visible impacts. Introductions of exotic species and trials with GMOs can promise rapid recognition. Consultants and entrepreneurs can 'sell' the imported materials, technology, and political benefits for all concerned. This may discourage thorough prior appraisal of the potentials of native species and traditional practices, combining outside knowledge with indigenous knowledge.

Decision making on the use of exotic species and GMOs is therefore a political process that requires, as a key input, the best possible scientific advice, geared towards realistic and practical assessment of risks. Again, apart from existing international codes of practice, good risk assessment tools are lacking. Moreover, most countries lack adequate arrangements for the quarantine of aquatic organisms. Much of the world's agriculture and forestry is based upon exotic species. About 95% of all livestock products (meal, milk and eggs) derives from five species.

Dr. Robin Welcomme of FAO has led the documentation on this (Welcomme 1988). Beverton 1992 reviewed 1,354 purposeful introductions of exotic fish into inland water: 73% had little or no effect on the receiving ecosystems because they disappeared without trace, were unable to spawn naturally or became established to only a limited extent, 3% went through boom and bust cycles; 17% became established with beneficial or neutral effects; and only 7% had discernible harmful effects.Decision making on introductions involves complex biological, socio-economic and political issues and setting parameters to asses the risk involved is next to impossible. In the face of uncertainties, insufficient knowledge and pressing needs, no decision will be risk free or as Bodansky (1991) has put it "the precautionary principle seem to suggest that the choice is between risk and caution, but often the choice is between one risk and another". Risk assessment is, therefore the key approach.

Very often R&D Organizations, groups or individual experts are approached for advice on introductions. Risks and issues involved in the decision especially on GMOs are so diverse and uncertain that a national consensus is often difficult to arrive. Even a small group of scientists often fail to agree on the possible impacts.

A debate about decision making in natural resources management, the difficulties of achieving scientific consensus and how to cope with uncertainty is also gathering momentum. Its practical effect in aquaculture and fisheries has been limited so far, although aquatic examples are often cited. Most fisheries R & D, that involve exotic species, proceed without systematic procedures for risk assessment, such as those described by Bomford (1991) for exotic vertebrates except fish. The nearest equivalents for fish are international codes of practice (Turner 1988) but these have seen little use to date (Courtenay and Robbins 1989; Coates 1992) perhaps because their implementation is thought to be complex and difficult. Bartley (1994) has summarized the simple steps involved in implementing the codes (Box 1), showing that this is not so.

----------------- Box 1 -----------------

Proposal to Import Including :

Planned use of exotic species
Location of facility
Passport information
Source of exotic species

Independent Review Including Evaluation of :

Disease organisms associated with exotic species
Ecological requirements/interactions
Genetic structure and hybridization potential
Socioeconomic considerations
Local species that may be imported

Advise/Advice

Approval

Protocols If Approved :

Quarantine
Confinement
Monitor

Juliano *et al.* proposed the following simple guidelines for importation of exotics into a country:

1. A thorough study of utilizing indigenous/ exotic species be made for whatever purpose/objectives have been planned before any decision to introduce an exotic species is made.

2. If and when a decision to import an exotic species is made, a thorough study of its biology, results of introduction in other countries, and the effects of such introduction on local species and the environment should be undertaken before actual importation is made.

3. Importation of the exotic species from a very reliable source, preferably from a research organisation where diseases have been controlled and the genetic constitution of the species is guarantied should be ensured.

4. On arrival of the imported species, strict quarantine measures should be undertaken.

5. It is desirable that no organisms are released into natural waters or to private individuals until the F-1 generation or F-2 generation has been produced, and which has been produced, and which has been given a clean bill of health by pathologists.

6. Introduction of exotic species in natural waters should be properly monitored and done gradually in one or two areas before any introductions into major natural waters are made.

Pullin (1994) summarised a balanced policy as follows:

Most countries already have a long history of introductions and a far from clean slate with respect to escapes or releases of exotic aquatic organisms. GMOs are already used in aquaculture and their use will undoubtedly increase. In aquaculture and fisheries development, some loss of biodiversity is unavoidable, as in agriculture and forestry. It should, however, be possible to establish risk assessment procedures that will enable decision makers to weigh potential benefits against potential environmental costs, including losses of biodiversity.

For example, if in a developing country, with little or no aquaculture, a proposal was made to bring in an exotic species for aquaculture or enhanced fisheries, and risk assessment revealed that this species might colonize that country's open waters (and may be also those of neighbouring states) to the detriment of valuable native biota and habitats, then the potential costs may be judged to be too great and a recommendation made to investigate instead the potential of native species, including their scope for genetic improvement.

Conversely, where exotic species or GMOs are already the basis of important aquaculture and enhanced fisheries with no evidence of them having caused significant environmental harm, then it would be reasonable to pursue further development of such aquaculture or fisheries. Indeed, expansion to new areas could be supported, *given prior thorough appraisals of the possible environmental and social consequences.*

Points for discussion

1. The merits of the suggestion to introduce red tilapia for culture in India needs to be assessed in the light of the above mentioned facts and guidelines.

2. As far as the culture systems are concerned, answering the following simple questions can perhaps lead to better assessment of risks and thereby helping decision making on introduction:

   Why not Indian carps?
   If carps are not good enough, why tilapia?
   Which tilapia?
   Why red tilapia?
   Why not niloticus?
   Which are the native species likely to be affected?
   What happens if red tilapia enters the river systems?

3. Are the following claims (made by the parties concerned) acceptable?

   * Red tilapia will not breed into the naturalised stocks
   * Production of monosex populations are fool proof
   * Production systems can be maintained without resorting to frequent import of seed and feed

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