Capture fisheries of tilapias

Production

Tilapias contribute to capture fisheries in inland and lacustrine waters (predominantly reservoirs) in Asia and the Pacific, but have not been reported in rivers with the exception of the artisanal fishery in the flood plains of the Sepik River in Papua New Guinea (Coates, 1985). Tropical Asia has a paucity of natural lakes (Fernando, 1991). Almost all lacustrine waters in tropical Asia are reservoirs, with the exception of natural lakes in Indonesia and the Philippines. In this region, tilapia capture fisheries in lacustrine waters are documented from about 20°N latitude to about 15°S longitude. The contribution of tilapias to the total landings in individual water bodies and their contribution to the inland capture fisheries vary widely between water bodies and between countries.

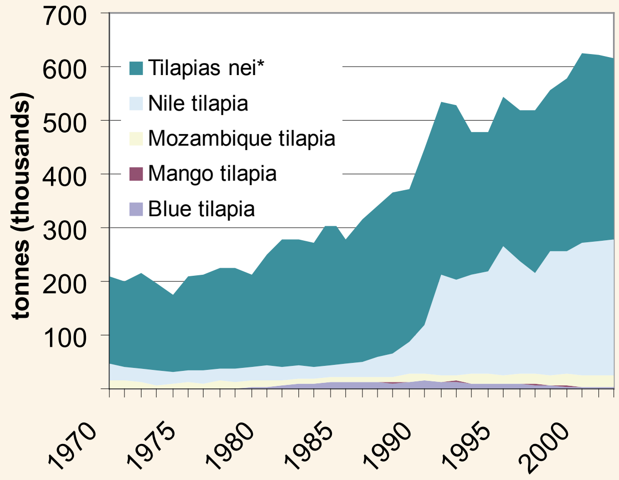
The global tilapia capture fishery production in 2002 was reported as 616 000 tonnes, the bulk of the production coming from Africa (Figure 1). The inland tilapia capture fishery doubled during the last two decades and continues to increase, both in Africa and in Asia and the Pacific (Asia and Oceania under FAO regional classification) regions. The Asia and the Pacific now contributes approximately 20 percent of the global tilapia capture fishery. It is probable that the yield from tilapia fisheries is under-estimated, for two possible reasons.

First, production of tilapias may be grouped with production of other cichlids or with miscellaneous freshwater fishes; and second, some portion of the inland capture fishery yield may be included in aquaculture, (e.g. Lao PDR). It is apparent that tilapia introductions constitute an important component of the inland capture fisheries in India, but species-level production data for tilapias are not included in the national data returns submitted to FAO. It is likely that tilapias are a component of the 377 000 tonnes of miscellaneous freshwater fish reported for India in 2002.

The two main constituent species in the tilapia capture fisheries in the world (Figure 2), and particularly in Asia and the Pacific (Figure 3), are *O. niloticus* and *O. mossambicus*. However, the figure does not convey the complete picture because many countries do not always identify catches up to species level, thus making a group - *Tilapia nei* (“nei”is the FAO term for “not elsewhere included”) – which is a conglomerate of many tilapia species. It is evident from Figure 2 that the contribution of *O. niloticus* to the world tilapia fishery has been increasing steadily; *O. mossambicus* contribution has remained rather static.

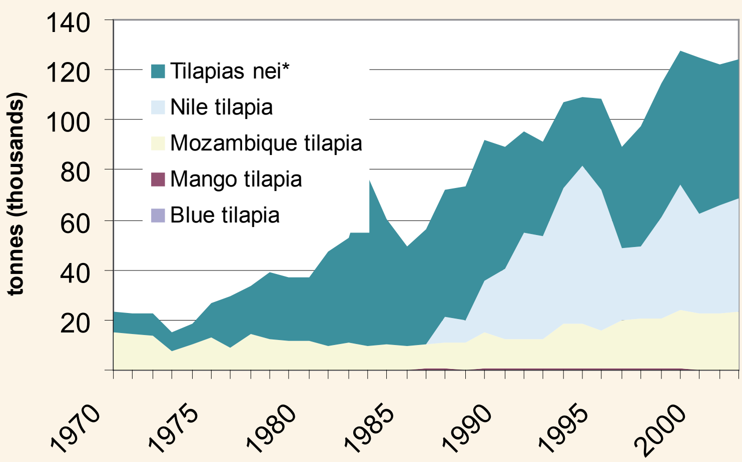
In contrast, the contribution of *O. niloticus* to the fishery in Asia and the Pacific has declined recently, whereas *O. mossambicus* has increased slightly (Figure 3). In Asia and the Pacific, the major contribution to the tilapia inland fishery primarily comes from Indonesia, Papua New Guinea, the Philippines, Sri Lanka and Thailand. Although the overall yield in the region increased over the years (Figure 4), there have been major changes in the contribution from different countries, most notably Thailand. The Thai tilapia fishery commenced with the introduction of *O. niloticus*, reached a peak in the

FIGURE 2
Capture fisheries production of tilapia by species 1970-2002



*Tilapia nei = not elsewhere included

FIGURE 3
Capture fisheries production of tilapia by species in Asia and the Pacific 1970-2002



*Tilapia nei = not elsewhere included

mid-1990s and has since declined significantly. The following sections will attempt to summarize the status of the tilapia inland fisheries in selected countries of the region, starting with Sri Lanka, for which good information is available.

Sri Lanka

Oreochromis mossambicus was the first species to be introduced in to Asia and the Pacific, thus, this species dominated the inland fisheries in countries such as Sri Lanka until very recently. Introduction of *O. mossambicus* (in 1952) triggered the development of an inland fishery in Sri Lanka (Fernando and Indrasena, 1969; Fernando and De Silva, 1984; De Silva, 1988), which came about a few years later (Figure 4). Subsequently, *O. niloticus* was introduced into the region and gradually, this species and *O. mossambicus* x *O. niloticus* hybrids became the predominant species in most of the reservoir fisheries in Sri Lanka (Amarasinghe and De Silva, 1999; De Silva *et al.*, 2001). Sri Lankan inland fisheries declined in 1989 (Figure 4), but are currently showing a resurgence. The main reason for this downward trend is political, due to widthdrawal of the Government of Sri Lanka's support and patronage for national aquaculture development in late 1980s (Amarasinghe and De Silva (1999). However, Sri Lanka's inland fishery has been dominated by tilapias for many years (Amarasinghe and De Silva, 1999; De Silva *et al*., 2001).

The inland capture fishery in Sri Lanka, almost entirely based on introduced tilapias, is a unique fishery and is one of the best documented inland fisheries in the tropics. However, capture fishery production even here is not reported by species. Various aspects of this tilapia artisanal fishery in Sri Lanka have been studied and it is considered to be one of the most productive reservoir fisheries in the world, averaging about 260 kg/ha/yr (De Silva, 1988; Pet *et al.*, 1999; De Silva, 2001). Amarasinghe (2002) reported that shallow fishery reservoirs, based almost exclusively on *O. mossambicus* and *O. niloticus,* could yield almost 1000 kg/ha/yr when estimates are based on the actual water level rather than at the full supply level.

Fibreglass canoes used in the artisanal reservoir fishery, Sri Lanka

While yields vary considerably among reservoirs, tilapias continue to account for the great bulk of the landings in all of the individual fisheries, with nearly 25 000 tonnes of a total production of approximately 28 000 tonnes coming from tilapias (FAO FishStat). Variations in the fish yields from reservoirs have been correlated to catchment land-use

FIGURE 4
Capture fisheries production of tilapia by country in Asia and the Pacific 1970–2002

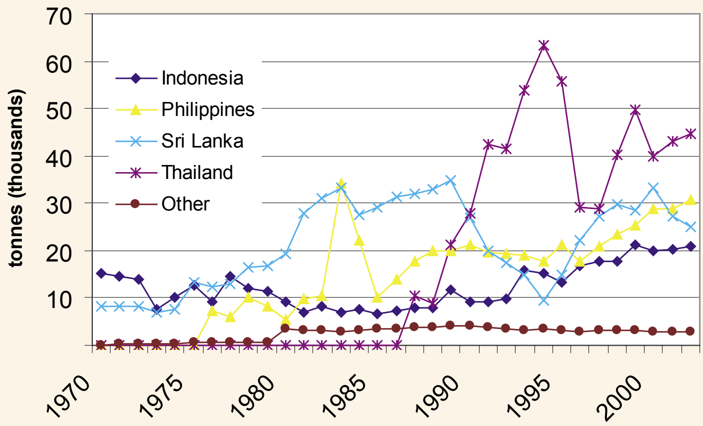


TABLE 2
Reservoirs in which the tilapiine fishes contributed in excess of 20 percent to the total landings in Tamil Nadu, India (based on data from Sugunan, 1995).

Reservoir name	Area at FSL* (ha)	Total production		Tilapiine production	
		t/yr	kg/ha/yr	t/yr	kg/ha/yr
Veeranam	3 885	36	9.3	44	4.1
Poondi	3 263	15	4.6	41	1.9
Wellingtopn	1 554	9	5.8	44	2.5
Krishnagiri	1 248	47	37.7	24	9.0
Perumchani	962	9	9.4	28	2.6
Godar	678	3	4.4	57	2.5
Kadama	657	51	77.6	85	66
Vembakottai	467	18	38.5	22	13.5
Kullur Santhai	316	48	151.9	70	106.3
Barur	256	24	93.8	90	84.4
Pambar	243	26	102.9	35	36
Thumbalahalli	193	11	57	79	45
Chinnar	170	6	35.3	26	9.2
Sathiar	120	6	50	48	24
Thoppaiyar	120	15	125	77	96.3
Nagavathy	118	5	42.4	76	32.2
Kasarikulihalla	105	4	38.1	73	27.8
Varattupallam	89	6	67.4	56	37.8
Sicclagiri Chinnar	54	8	148.1	28	41.5
Periyar	76	17	223.7	53	118.6
Kovilar	74	12	162.2	48	77.8
Maruthanathi	72	8	111	37	41.1
Sicclagiri Chinnar	54	8	148.1	28	41.5

*FSL=Full Storage Level

patterns, i.e. that the greater the forest cover and grassland in the reservoir catchment in relation to reservoir area and/or capacity, the more productive the reservoir (De Silva *et al.,* 2001; Amarasinghe *et al.,* 2002). The contribution of tilapia species to the total fishery often exceeded 70 percent. Over the last two decades *O. mossambicus* has gradually been replaced by *O. niloticus* in individual fisheries (De Silva, 1985a; De Silva, 1988; De Silva *et al*., 2001).

Management of inland fishery in Sri Lanka is mainly through restrictions on the minimum mesh size of gill nets, the only permitted gear in reservoirs and a licensing system that controls the number of crafts (e.g. unmotorized, fibreglass canoes with an out-rigger; generally operated by two fishers) that operate in a given water body (De Silva, 1988). However, it has been suggested recently that the adoption of a co-management strategy for the fishery would be more appropriate for its long-term sustainability (Amarasinghe and De Silva, 1999). An important feature of the fishery, even during the phase when it was dominated by *O. mossambicus*, was that there was no evidence of stunting, a common trait of this species. Although a decrease in the mean size of the catches was observed, this was clearly attributed to overfishing rather than stunting (Amarasinghe *et al.,* 1989; Amarasinghe and De Silva, 1992).

India

India has an estimated reservoir area of about 3 million ha in three size categories of reservoirs; (a) small (< 1000 ha) – an area about 1.5 million ha; (b) medium (1 000 to 5 000 ha) – an area about 500 000 ha; and (c) large (>5 000 ha) – an area about 1 million ha (Sugunan, 1995). By the end of 1960s, *O. mossambicus* had been introduced to many reservoirs in the southern states, contributing significantly to the commercial catches in many reservoirs. The lack of reports makes it difficult to estimate the contribution of tilapia to food security in India. Tilapia production from capture fisheries and aquaculture have not been entered into national and FAO fisheries data bases, even though the gradual dominance of this species in the catches in many reservoirs was documented initially in 1967 (Sreenivasan and Sundararjan, 1967) and reiterated in 1976 (Sreenivasan, 1976).

Sugunan (1995) reported that tropical reservoirs in India provided suitable habitats for *O. mossambicus*, and it has established self-sustaining populations in a number of south Indian reservoirs. Fears of stunted growth have not been realised as the average size has not declined. The most detailed account of the status of tilapia fishery is available for reservoirs in the southern state of Tamil Nadu (Table 2). Tilapia contributed more than 20 percent to the total landings for both medium-sized reservoirs (4 of 10 reservoirs) and small-sized reservoirs (18 of 34 reservoirs). In the latter group, in most instances, tilapia was the dominant species in the landings (Table 2).

The total production in Indian reservoirs is considerably lower than elsewhere (De Silva, 2001a), and so was the tilapia production in Tamil Nadu which ranged from 1.9 to 9.0, and 9.2 to 118.6 kg/ha/yr in medium sized reservoirs over 1 000 ha and below 500 ha, respectively (Table 2). These data indicate that the total fish production as well as the tilapia production was considerably higher in smaller reservoirs. However, there was no apparent statistical relationship between these two parameters. The mean

FIGURE 5
Inland capture fishery production of Mozambique tilapia in Indonesia (tonnes and percent of inland harvest), 1970-2002

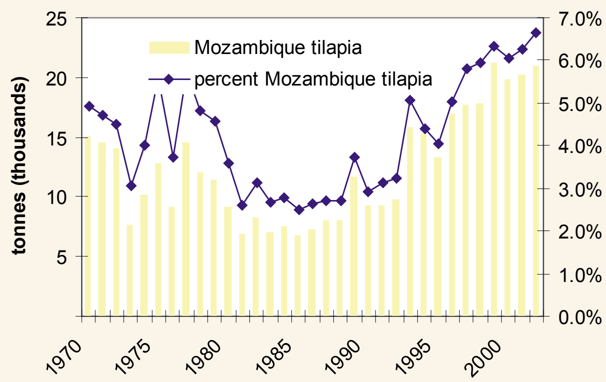


TABLE 3
Role of introduced tilapias in the fisheries of selected natural lakes in Indonesia (based on data from Sukadi and Kartamihardja, 1995 and Sarnita, 1999)

Location/ Lake	Area (ha)	Yield (kg/ha/yr)	Dominant *Tilapia* spp.	Contribution (%)
Sumatra				
Toba	112 000	9	*O. mossambicus*	90
Sulawesi				
Tondano	5 600	340	*O. mossambicus*	20
Liidu	3 500	120	*O. mossambicus**	75–80
Irian Jaya				
Sentani*	9 360	42	*O. mossambicus*	na
Paniai	14 150	na	*O. mossambicus*	10

* = stocked with other *Tilapia* spp.
na = not available

tilapia production in small reservoirs in Tamil Nadu, for example, is estimated to be 53.6±8.2 kg/ha/yr.

Indonesia

Indonesia is one of two countries in Asia and the Pacific in which tilapias have established self-sustaining populations in natural lacustrine water bodies (Fernando, 1991). Indonesia has a long history of tilapia introductions (Lin, 1977; Welcomme, 1984; Pullin, 1988; Eidman, 1989). The dominant species in Indonesian inland capture fishery is *O. mossambicus* (Figure 5), especially in the natural lakes, resulting from early introduction of the species during the 1940s and the subsequent spread to water bodies throughout the country (Sarnita, 1987). The role of introduced tilapias in the fisheries of selected natural lakes in Indonesia is summarized in Table 3. Although tilapias were introduced to most lakes in Indonesia, self-sustaining populations contributing significantly to on-going fisheries did not occur in all lakes. Nevertheless, in some lakes and reservoirs, tilapias account for more than 90 percent of the total landings.

In recently created (man-made) reservoirs in Indonesia, the preferred species for stocking was *O. niloticus*. As a result, the current reservoir fisheries are mostly based on this species. However, according to Baluyut (1999), *O. mossambicus* or *O. niloticus* appear to be the dominat species in Indonesian reservoirs. As *O. niloticus* was first introduced to Indonesia only in 1969, this species became dominant species only in the reservoirs that were built (dammed) in the 1970s (e.g. Jatilnuhur), but in natural lakes *O. mossambicus* continues to be dominant.

Papua New Guinea

Papua New Guinea (PNG) lies East of the Wallace's and Weber's lines and as such represents a zoogeographic zone that is different from the rest of Asia. Consequently, the freshwater fauna of the two regions are markedly different (McDowall, 1981). The Australian region has, according to McDowall (1981), therefore developed a freshwater ichthyo-fauna that evolved from essentially marine families, making it comparatively less diverse than mainland Asia. Coates (1987a) suggested that the success of *O. mossambicus*, introduced in 1954, in the flood plain fishery of the Sepik River, was due to these faunal limitations.

Oreochromis mossambicus supports an important floodplain, artisanal fishery in the Sepik River, and accounts for about 50 percent of the landings, estimated to be about 3 000 – 5 000 tonnes/year (Coates, 1987b). Introduced tilapia has been instrumental in the establishment and sustenance of this artisanal floodplain fishery in the Sepik. Although very little has been documented of this fishery during the last decade, it is evident from Figure 3 that PNG continues to contribute to the tilapia fisheries in Asia, particularly one that is based on *O. mossambicus*. This fishery is rather unique being the only documented floodplain fishery on tilapias in the Pacific.

In order to provide increased food security to inland communities, the Government of PNG, United Nations Development Programme (UNDP) and FAO undertook a stock enhancement project using alien fish species in the Sepik and Ramu Rivers. Previously, alien species of carp, tilapia, and rainbow trout had been introduced for aquaculture development. However, aquaculture was not very successful due to lack of infrastructure and financial constraints. Thus, the establishment of self-sustaining populations of alien fish species was undertaken by the project described here, Fisheries Improvement at High Altitudes for Inland Development (FISHAID). A key feature of the project was the application of the ICES/EIFAC codes of practice on alien species (Coates, 1987a). *Tilapia rendalli* was introduced into the Sepik and Ramu drainages between 1993 and 1997 (David Coates personal communication).

An FAO field mission conducted in 2002 confirmed that Red Makau (*Tilapia rendalli*) has established well and has become a part of daily subsistence of the communities living in the riverine areas. *Oreochromis mossabicus* which introduced in the 1960's for aquaculture has also established viable populations in lowland and highland areas. Community interviews indicated that, although some problems do exist with consumption of introduced spoecies, *Tilapia rendalli* is well-liked and consumed daily by the people. Although many people did not have a habit of eating fish in the highlands, increased fish consumption and the daily sale of alien fish in roadside markets have developed as a result of the introductions. *Tilapia rendalli* and *O. mossambicus* generated significant income for fishers and fish sellers who are mostly women (FAO unpublished information and Ursula Kolkolo personal communication).

Philippines

The role of tilapias in inland fisheries in Philippines has been more controversial than elsewhere in the region, although most of the negative influences on indigenous fisheries have been unfounded in the light of recent evidence. Tilapias play a major role in the inland capture fisheries (Figures 3) of the Philippines. The Philippines is reputed to have about 230 000 ha of lakes and reservoirs, and tilapias are found in almost all of them (Baluyut, 1999). *Oreochromis* spp. are the main species group of inland fisheries in the Philippines and currently accounts for about 31 000 tonnes (FAO FishStat). Baluyut (1999) reported that tilapias accounted for about 25 percent of the total finfish production from inland waters in late 1990s. According to FAO statistics, the share in 2002 was about 23 percent It has also been reported that in the major hydroelectric power generating reservoirs operated by the National Power Corporation, tilapias constitute 56 to 94 percent of the annual landings Baluyut (1999).

Intensive tilapia farming in the Philippines

Thailand

In Thailand, the contribution of individual reservoirs to the national reservoir fishery varies greatly. There are also large annual variations in the water levels of these

TABLE 4
Total and tilapia fish yield in selected reservoirs in Thailand (data supplied by Dr Tuatong Jutagate, Electricity Generating Authority of Thailand)

Reservoir	Area (ha)	Z (m)*	Total (kg/ha/yr)	Tilapia (kg/ha/yr)	Percentage
Ubolaratana	41 000	15.8	30.1	1.13	3.8
Sri Nagarin	40 000	44.6	5.96	0.29	4.8
Khoa Lam	32 320	24	14.47	0.22	1.5
Bhumibol	30 000	44.7	6.75	0.99	14.7
Sirinthorn	29 200	5.1	11.20	0.30	2.7
Sirikit	28 400	36.8	14.81	0.63	4.3
Nam Oun	8 600	6.4	5.20	0.69	13.2
PaK Mun	5 950	9	14.36	0.08	0.56
Kang Krachan	4 970	14.3	28.8	2.60	9.0
Kra Siew	4 800	5	19.77	2.62	13.3
Bang Lang	4 500	20.71	30.20	0.08	0.4
Lam Trakong	4 430	10	6.20	0.85	13.7
Lam Nangrong	2 479	8.7	11.23	4.81	42.8
Nam Pong	2 100	8.6	59.70	9.40	15.8
Mae Kunag	1 488	27.3	24.20	3.54	14.6
Chulaborn	1 200	15.7	30.12	10.09	33.5

*Z(m) = mean depth in meters

reservoirs too. As in the case of Indian reservoirs, fish production in Thai reservoirs is not very high.

The Thai reservoirs under consideration are generally much larger and deeper compared to those in other countries such as India. The available data suggest that the tilapia, in this instance almost exclusively *O. niloticus,* production per area , bears a negative exponential relationship to the size of the water body; the relationship is shown in the formula given below:

$Y = -1.794 \mathrm{Ln}(X) + 18.53$ ($R = 0.70$; $P < 0.05$), where

Y = tilapiine fish yield in kg/ha/yr,

X = reservoir area in ha.

Bernacsek (1997) provided details on reservoir morphometry and fish landing data for 28 in Thailand. Unfortunately, complete time series data on fish production were not available for any of the reservoirs, and in most cases breakdown of the landings to species level was available only for a year or two. Nevertheless, the data suggested that only in four Thai reservoirs (Mae Chang, Chulaphon, Kwan Phayao and Lam Takhong) the contribution of *O. niloticus* exceeded 20 percent of the total fish landings (Table 4), of which, the highest was recorded in Ma Chang reservoir (1 230 ha; total yield of 16.3 kg/ha/yr).

It is important to highlight that tilapias have not come to dominate the fishery in any of the Thai reservoirs, in contrast to the situation in countries such as Sri Lanka, Indonesia and the Philippines. Tilapias, however, continue to contribute to varying extents to the catches. The reasons for this are not obvious, and as such a comparative study on tilapia production in reservoirs may be essential.

Other countries

Tilapias are present in most inland water bodies in other countries such as Malaysia, Hong Kong Special Administration Regions, etc., although inland fisheries are not significantly developed in these countries. On the other hand in Viet Nam, *O. niloticus* occur in many reservoirs in the southern part if the country and contributes considerably to fisheries production. According to Phan and De Silva (2000), this species provides a very good example of a case where fishery based on a self-recruiting species complements that of stocked cyprinids.


Intensive tilapia farming, Malaysia

Among the smaller islands in the South-Pacific (in Solomon Islands) Oreihaka (2001) reported that *O. mossambicus* (introduced in the 1950s) supported a fishery in Lake Tegano, the largest brackishwater lake in Solomon Islands with a surface area of 15 500 ha. This fishery provides the main animal protein source for about 600 people in four villages who have otherwise no easy access to fish resources. The fishery uses dive-fishing and gill net; the daily catch is almost entirely used for consumption. The mean landing size of tilapia is 22.5 cm and there is a belief that the landing size has been decreasing over the years, primarily thought to be a result of overfishing. Consequently, the Government of Solomon Islands is considering the introduction of *O. niloticus* to enhance yields (Oreihaka, 2001).


A village fish stall, Sri Lanka

Small-scale, subsistence fisheries based on *O. mossambicus* have also been developed in Lake Vailhai in the Kingdom of Tonga. *Oreochromis mossambicus* is also fished off the coasts off Vaváu and Nomuka in the Kingdom, and the Cook Islands (Nelson and Eldredge, 1991). However, there is very little information available on the extent of these fisheries and their socio-economic impacts on the respective communities.

TABLE 5
Price ranges and profit margins for principal inland fish varieties (fresh fish) in the Anamaduwa District, North West Province, Sri Lanka (modified after Murray *et al.*, 2001)

Species	Size range (g)	Price (Rs.) (SL Rs. 97=1 US$)			Retail margin (Rs.)[4]
		Landing[1]	Wholesale/ primary retail[2]	Retail[3]	
Tilapia					
Large	>180	30–40	40–50	60–80	50–60
Medium	80–180	30–35	35–45	45–60	29–33
Small	<80	20–30	25–35	30–40	14–20
Snakehead	All sizes	50–60	60–70	70–100	17–43
Eels	All sizes	40–50	50–60	70–80	40–33
SIS[5]	50–250	15–30	30–40	40–50	33–25

[1] Price paid by primary intermediaries (2-wheeler vendors, etc.) to fishers.
[2] Wholesale price paid by secondary intermediaries (2-wheeler vendors and junction sellers) and price paid by consumers, at sites .3–4 km and <3–4 km from the site of landing, respectively.
[3] Retail price paid by consumers to secondary intermediaries (2-wheeler vendors and junction sellers) in villages and rural towns not immediately adjacent to the landing sites.
[4] Retail margin earned by primary and secondary intermediaries.
[5]Small indigenous species and includes: *Mystus keletius, M. gulio, M. vttatus, Heteropneustes fossilis, Puntius sarana, P. filamnentosus, Glossogobius giuris, Channa punctata, Anabas testudineus, Masaracembalus auratus, etc.*

Oreochromis mossambicus was introduced to Nauru in the early 1960s to benefit from its high production potential. Rather than becoming a food fish, it became a pest for reasons of its unattractive appearance compared to milkfish, small size and mainly because of its effect on milkfish farming. Farmers noticed that milkfish have difficulties in competing with tilapia hence most people gave up milkfish farming in frustration. In 1998 *O. niloticus* was introduced as a food fish. It was hoped that *O. niloticus* would cross breed with *O. mossambicus* to produce larger off-spring. Taste analysis through the importation of freshly chilled *O. niloticus* from Fiji proved that it is well liked as a food fish.

Australia

Special consideration of tilapias in Australia is presented because here tilapias have been categorized as a noxious species. Tilapia introductions into natural and quasi-natural waters in Australia have been accidental and are thought to have occurred through imports from the aquarium industry. Currently, self-propagating populations are found in tropical and sub-tropical Queensland and in Western Australia (Arthington *et al.*, 1984; Arthington and Blühdorn, 1994). It is thought that feral populations of tilapias consist of two species, *O. mossambicus* and *Tilapia mariae* and a third morph that is a potential interspecies hybrid between *O. mossambicus* and one or more species such as *O. hornorum*, *O. niloticus* and *O. aureus* (Mather and Arthington, 1991). The available evidence suggests that the *O. mossambicus* population in the Gascoyne-Lyons system (24°S; 166°E) is highly stunted, reaching maturity at a mean standard length of 9 cm as opposed to populations from other locations which reach maturity around 18 cm (Blühdorn and Arthington, 1990).

Tilapia imports to Australia have been prohibited since 1963 (Michaelis, 1989). In most states, policies for prohibiting and/or discouraging importation, possession and transfer of tilapias are in place. Although there are penalties, ranging from fines to two-years' imprisonment, more emphasis is laid on public education programs aimed at preventing the spreading of tilapias. It is unlikely that tilapias could become a food fish resource in Australia. Their use in scientific studies to better understand stunting and other related aspects has been suggested by Arthington and Blühdorn (1994).

Sun-dried cage cultured tilapia, Saguling reservoir, Indonesia

Marketing

Tilapia inland capture fisheries, in the region, tend to be almost exclusively artisanal, often based on crafts such as traditional dug-out canoes or equivalents. Gill nets are the most commonly used gear. The landings from individual crafts, at the best of times, rarely exceed 100 kg/day (Moreau and De Silva, 1991). Daily fluctuations in catches are a norm for these fisheries (Amarasinghe *et al*., 1989).

Within the context of marketing, landings tend to be much more localized and are not organized to deal with large quantities of produce. Marketing of the inland tilapia catches received limited attention because quantities marketed on a daily basis, in a given locality, are often in small quantities.

Murray *et al.* (2001) described the marketing networks, system of vendors operating on push bicycles and/or small two-wheeler motorcycles, commonly used in Sri Lankan reservoir fisheries. These tend to be highly organized with close links between individual fishers and primary vendors/wholesalers. The system ensures rapid distribution of the produce even to the remotest locality.

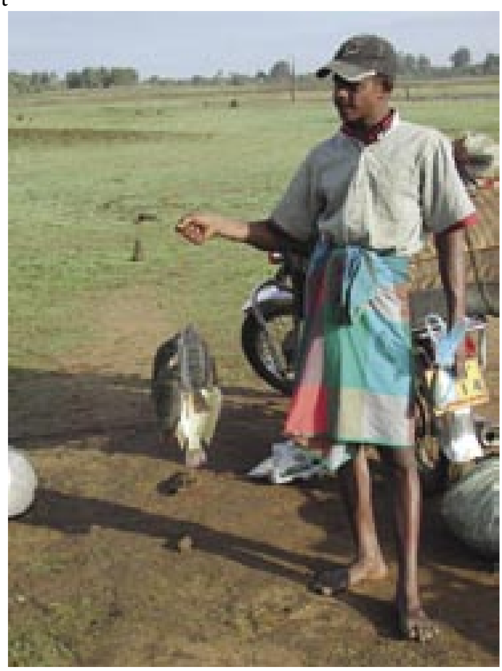
The price of tilapia is considerably lower than most popular marine varieties (e.g. fresh tuna, which commands a price 100 percent more than tilapias) but comparable to that of lowest priced marine varieties (e.g. sardines) (ARTI 1998–99). Tilapia prices also compare favourably with other freshwater varieties (Table 5). Tilapias provide an easily accessible and affordable animal protein source to the relatively poor, rural sectors of the communities, and in certain instances these are the only fish resource available to these communities.

Employment and other social impacts

The social impacts of tilapia fisheries are difficult to quantify. However, a number of important facts emerge from the foregoing sections:

- Almost without exception, tilapia capture fisheries tend to be a rural and an artisanal fishery activity, providing an opportunity for employment in areas where employment avenues are often limited.
- In some countries, particularly Sri Lanka, all evidence suggests that the introduced tilapias are responsible for the establishment and the subsequent sustenance of an inland fishery. Similarly, tilapia fisheries play a major role in reservoirs and lakes in Indonesia and the Philippines and have begun to dominate the fisheries of most lacustrine waters.
- Tilapias continue to contribute to an important and an affordable animal protein source to the poorer sectors of the community. In certain countries and regions, tilapias may be the most important fish source available to rural communities. This was further confirmed by workers at the Asian Institute of Technology who conducted a series of workshops to assess the economic value of alien species in IndoChina (Yakupitiyage and Bhujel 2004). For example, in Thailand alien species accounted for 12 kg fish/person/year (41.6%) of the total fish consumption. The highest consumed exotic species is Nile tilapia which account for 8.52 kg fish/person/year for seven Thai provinces. Although the contribution of tilapias from inland fisheries to the overall fish consumption in most nations has not being quantified, it is evident that in Sri Lanka, for example, tilapias contributed significantly to increased fish consumption.

It is estimated that there are about 15 000 fishers in perennial reservoirs, full time and part time, operating about 5 000 non-mechanized boats in Sri Lanka (Anon 1995). As the island's inland fishery is based on tilapias, it is reasonable to conclude that this fishery is responsible for direct employment and if the vendors who make a living on the fisheries are also taken in to account, the employment opportunities created would be much higher.



The day's animal protein supply, Sri Lanka

In countries such as Indonesia and Philippines, where inland fisheries are also mostly based on tilapias, the situation appers to be similar to that Sri Lanka in terms of providing employment opportunities, increasing the fish supplies at an affordable rate to the poor rural sectors of the community and other socio-economic impacts. In the Philippines, tilapia is the preferred species among all freshwater fish (de la Cruz, 1998). Thus, the government provided support to improve its marketability and quality. The Philippine Government's policy with regard to inland fishery development is currently based on tilapias, and it is also the preferred group for fishery enhancement in inland waters (de la Cruz, 1998).

According to Coates (1985), the *O. mossambicus* floodplain fishery in Papua New Guinea, despite its relatively low yield of 3 000 to 5 000 tonnes/year, is an important fishery in terms of direct benefit to the community, and provided employment for nearly 11 500 people. Furthermore, from a nutritional viewpoint, this fishery contributed significantly to the major animal protein source requirement of the community. *Tilapia rendalli*, which was introduced much later is now contributing to rural economies and the catches are sold in village markets (David Coates personal communication).

General considerations

It is evident from the foregoing sections that tilapias play a crucial role in the sustenance of inland capture fisheries in Asia and the Pacific. Furthermore, apart from the direct contribution to the fish supplies in Asia and the Pacific, tilapias often provide an affordable source of animal protein to poor, rural communities. Inland fisheries in which tilapias contribute to are based on natural recruitment. The individual fisheries have developed through either deliberate seeding and/or invasion from other connecting waters, and rarely if ever, is continuous seeding required to sustain these fisheries. Table 1 gave the number of tilapia fish species introduced to Asia and the Pacific. Although only *O. mossambicus* and *O. niloticus* have been successful in contributing significantly to inland capture fisheries in the Asian region, tilapias do not dominate fisheries throughout all the reservoirs and lakes in Asia. For example, tilapias do not dominate the fisheries in any of the lacustrine water bodies in Thailand, in contrast to those in Indonesia, the Philippines and Sri Lanka. Indeed, the impact of tilapias on a fishery could differ among water bodies and even within the same watershed. It is also important to point out that although tilapias have been present in Asia and the Pacific for over five decades, with the exception of the Sepik River flood plains, there has been no documentation of the establishment of viable populations in any other river systems in the region.

Historically, only the success stories of introduced tilapias in inland fisheries have been well examined (Fernando and Holcik, 1982; De Silva and Senaratne, 1988). Since the public awareness on

Tilapia in a fish market in Sri Lanka

TABLE 6

Some potential adverse impacts of alien aquatic species (after Bartley and Casal 1998)

Effect	Mechanism - Biological	Mechanism - Social
Reduction or elimination of aquatic species	Competition, hybridization, predation/herbivore, disease transmission	Change in fishing pressure and access to resources; treatment measures to enhance introduced species
Change in terrestrial fauna	Change in abundance of preferred prey	Fish farms providing more food for birds and animals or killing predatory birds
Change in fishery management	Change in stock composition	Successful introductions lead to other introductions
Alteration in habitat	Burrowing, sediment mobilization, removal of vegetation	Change in land use, e.g. creation of fish farms
Socioeconomic impacts	Change in species abundance or distribution leading to changes in fishing or consumption practices	Change in access rights, land tenure; financial liability for damages through national and international legislation

environmental risks of alien species introductions has increased significantly over the past decade and measures are being taken to understand such impacts with the view to mitigate them, an objective assessment of the benefits and impacts of introduced tilapias in inland capture fisheries in Asia and the Pacific is essential.

Most tilapias, apart from being relatively intolerant of cold temperature (Chervinski, 1982), are known to be rather robust and capable of surviving in wide ranges in salinity (Stickney, 1986), low oxygen, and several other water quality parameters (Ross, 2000). It is not surprising, therefore, when Moreau *et al.* (1986) observed that the growth of tilapia populations in some western Asian nations and Sri Lankan reservoirs (De Silva and Senaratne, 1988) compared very well with that of the populations in the natural range of distribution in Africa.

The success of tilapia fisheries in the region has been attributed to a number of factors. Foremost among these is the omnivorous dietary habits of introduced tilapias, enabling a change in food preference according to availability (Maitipe and De Silva, 1985), and capable of obtaining essential nutrients from food sources which often appear to be nutritionally sub-standard (De Silva, 1985). *Oreochromis niloticus* also has the ability to utilize blue-green algae, an abundant resource in tropical reservoirs during certain seasons, as a nutritional source, thereby expanding the available food source spectrum for these species.

The relatively high reproductive capacity of tilapias (i.e. ability to spawn through the year in most trpical freshwaters) (De Silva and Chandrasoma, 1980), low mortality of eggs and fry, availability of suitable nesting sites (De Silva and Sirisena, 1988), short generation time, and other reproductive traits (Turner and Robinson, 2000) are also likely to contribute to their success in natural and quasi-natural waters. The high reproductive capacity could compensate and essentially act as a buffer for the relatively high fishing pressure and in certain instances, the very high bird predatory pressure on juveniles (Winkler, 1983). Fernando and Holcik (1982) attributed the success of tilapias to the availability of a vacant niche as a result of the paucity of truly lacustrine species in the indigenous fish fauna in the Asia- Pacific. This explanation, however, fails to provide answers to the relative lack of success of tilapias in water bodies in Thailand.

Hybridization between species may result in hybrid vigour in the first generation, with an ensuing increase in production. However, this seems no to be largely responsible for the success of tilapias, as colonizers. In Asia, as elsewhere, where tilapias have been introduced, there is a high probability that hybridization occurs among co-habiting tilapia species in natural or quasi-natural waters. This has been demonstrated in tilapia populations in reservoirs in Sri Lanka (De Silva and Ranasinghe, 1989), and in the Philippines (Macaranas *et al*., 1986). Amarasinghe and De Silva (1996) observed that the fecundity of hybrids were significantly lower than that of the parent species (in the case of *O. mossambicus* and *O. niloticus*). These authors hypothesized that in the long-term this could result in a reduction of the reproductive capacity of the populations and consequently be detrimental to the maintenance of the relatively successful reservoir fishery for tilapias in Sri Lanka reservoirs. Tilapia populations in such reservoirs require high reproductive rates (De Silva, 1988) to withstand the high fishing pressure as well as bird predation (Winkler, 1983) .

Controversies

Biodiversity is defined as 'the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and ecosystems' (UNCED, 1992); this is now the official definiaiton of the Convention on Biological Diversity (CBD). According to Maclean and Jones (1995), six major disturbances that may directly alter community dynamics and influence biodiversity are; habitat loss and degradation, over- exploitation, the spread of alien species, secondary extinction, pollution, and climatic changes. These authors recognised that the above disturbances, either singly or in various combinations, accelerate environmental change and in so doing, modify community composition, structure and function by reducing or eliminating the abundance of those species not adapted to the altered environment.

The majority of countries where tilapias have been introduced are signatories to the CBD and therefore have pledged to protect. In many areas where tilapias have been introduced and have been reported as a problem, other factors, e.g. habitat degradation and over-fishing, have been responsible for declines in native biodiversity. If environments are maintained well and ecosystems intact, there is much less of a chance that tilapias would be a future threat to biodiversity.

Impacts of introduced species will fall into two broad categories – i) ecological, which includes biological and genetic effects and ii) socio-economic (Table 6). However, these two categories are not independent and socio-economic changes brought about by alien species can in turn cause more ecological changes and vice versa (Bartley and Casal 1998). Thus, a reduction in native species may be from direct interaction with an exotic species, or it may result from increased fishing pressure or changes in land use brought about by the presence of a newly established species.

With respect to introductions, attention is generally focussed on the immediate environment to which the organism is introduced. However, considerable environmental impact could occur indirectly. One of the best examples in this regard is the destruction of wetlands (45 tonnes of firewood per month) and reclamation of wetlands for developmental activities on the Kenyan coast of Lake Victoria which were triggered off by the development of an export oriented kiln-drying industry for Nile perch (Riedmiller, 1994). Introductions, therefore, may have very high ecological costs and often such costs are not accounted for when evaluations are made.

Such undesirable influences are also known from Asian waters. An example is the almost complete disappearance of the native cyprinid flock (*Barbus* spp.) in Lake Lanao in the Philippines where introduced tilapias were purported to have contributed to the decline (Frey, 1969).

The most specific detrimental effects due to tilapias have been alleged in the case of the near extinction of the small endemic goby (or "sinarapan", *Mistichthys luzonensis)* in Lake Buhi in the Philippines (Baluyut, 1983). Gindelberger (1981) on the other hand, was more cautious in his evaluation of the status of "sinarapan" but Aypa (1993) believed otherwise. The only direct evidence that the decline and/or near extinction of "sinarapan" was due to the introduction of *O. mossambicus* was based on a laboratory study which indicated that the cichlid feeds on "sinarapan" and the increase in landings of the cichlid which happened to coincide with the decline of the former. Apart from the fact that the laboratory study was inconclusive, other factors such as damming of the river flowing from the lake, intensification of the fishing effort, and more importantly, the introduction of gears (e.g. motorized push nets) which destroyed the beds of the aquatic macrophyte, *Vallisneria*, the breeding grounds of sinarapan (Gindelberger, 1981) received little attention from the report of Aypa (1993). The balance of evidence seems to suggest that the decline of "sinarapan" was probably a result of a number of factors, the least influential of these being the presence of the alien cichlid. It is heartening that with better management of the fishery activities in Lake Buhi, "sinarapan" is staging a recovery. More recently, Guerrero (1999) considered the influence of tilapias on the biodiversity of finfish in lakes and reservoirs in the Philippines and concluded that there had not been any adverse affects of the introductions on the endemic fish fauna.

It has also been suggested that in Lake Toba, Indonesia, the decline of the indigenous cyprinid species *Lissochilus*, considered to have cultural importance, was due to the introduction of *O. mossambicus* to the lake (Baluyut, 1999). The latter is estimated to account for 86 percent of the fish landings in the lake. Supporting evidence with regards to this observation is not available.

A comparable situation has been reported from Kaptai Lake, a large reservoir in Bangladesh (Hussain 1996) where the decline of the indigenous carp fishery is attributed to an increase in *O. niloticus* landings. However, *O. niloticus* landings account for less than one percent of the total fish yield in the reservoir. Similarly in this case, a thorough study has not been undertaken, including aspects on increased use of disruptive gear, landing of indigenous carps during their spawning migration, etc. Admittedly, there have been isolated instances where tilapia introductions have been implicated in certain faunal changes. In these instances, the introduced tilapias, although present at the site may, in all probability, are not the primary cause of the changes.

Pethiyagoda (1994) considered that the introduced tilapias are potential threats to the indigenous freshwater fishes of Sri Lanka. In his account, it was conceded that tilapias are absent from rapids and streams and other natural waterways in Sri Lanka. However, it was suggested that with increasing siltation of lowland streams resulting from increasing deforestation, it was likely that tilapias could, with time, invade the central hills. The author also suggested that the main breeding season of *O. mossambicus* coincides with that of most indigenous species, the displacement of the latter could therefore be assumed. The author failed to recognize that *O. mossambicus*, which has been on the island for over 50 years, was unsuccessful in establishing itself except in man-made environments such as reservoirs. Recently, Wijeyaratne and Perera (2001) demonstrated that tilapias and indigenous species co-habit without competition for food resources and tilapia was not observed to feed on the young of any of the indigenous species.

Pethiyagoda (1994) also suggested that the decline in freshwater turtles, *Lissemys punctata* and *Melanochelys trijuga* was the result of high fishing pressure for *O. mossambicus* in the reservoirs. Although this may be true, reservoirs are man-made and thus, not the natural habitat of these turtles. In the same context, there has been a significant increase in the bird fauna that primarily feeds on the young of the tilapias (Winkler, 1983).

Australia has a high degree of endemism in its inland fish fauna (McDowall, 1981). At present, however, detailed studies have indicated that *O. mossambicus* has not had any ecological impact in Australia (Arthington, 1991). For example, there was specific evidence to show that it does not compete for food resources with indigenous eel- tailed catfish, *Tandanus tandanus* and the omnivorous teraponid, *Leiopotherapon unicolor*, when they occure together (Arthington and Blühdorn, 1994). Arthington and Blühdorn (1994) suggested that since feral tilapia populations had been there for only about 20 years (now 30 years) the current lack of an impact is no reason for complacency. The authors believed that a few more decades have to pass before any firm conclusions are drawn with regard to its impacts.

Taking the above evidence in to account, it is reasonable to conclude that deliberate and accidental tilapia introductions to Asia and the Pacific have overall been positive. Tilapias are a value fishery resource in most countries in the region where they generate of employment opportunities and provide an affordable and easily accessible animal protein resource to the poorer sectors of the community. There is neither explicit evidence nor an objective synthesis of currently available information to suggest that tilapias on their own have brought about negative ecological impacts including loss of biodiversity in the region. Constant vigilance and objective assessment of their influence on the environment and on biodiversity are necessary. Monitoring and continuous assessment in an objective way are also needed. The current success in tilapia introductions should not deter countries from undertaking cautious and responsible introductions in the future following international codes of practice such as the ICES/EIFAC Code and guidelines (ICES 1984; Turner, 1988; Bartley *et al.*, 1996).

In contrast to the markedly positive impacts of tilapia introductions to mainland nations of Asia and Papua New Guinea, introductions to South Pacific Island nations remain somewhat controversial. Nelson and Eldredge (1991) reported that of the five tilapia species and one hybrid that are known to have been introduced to the islands, only *O. mossambicus* (introduced to Cook Islands, Samoas, Wallis Island, Fiji, New Caledonia, Solomon Islands, Tonga, Line Islands and Caroline Islands at Yap) and *T. zillii* (introduced to Fena reservoir in Guam) are known to have established themselves in natural and/or quasi-natural freshwater habitats. Establishment of tilapia species in brackishwater habitats occurred in Papua New Guinea (Glucksman *et al.* 1976), Tonga, Caroline Islands, Nauru and Kiribati (Nelson and Eldredge, 1991). The inadvertent introduction of *O. mossambicus* to Fanning Atoll in the Linne Islands in 1959 resulted to a further spread of this species to a number of lagoons in the atoll (Lobel, 1980). No harmful effects on the marine fauna of the lagoons have been documented. Tilapias are not consumed by the population of the atoll, but are thought to provide an important food source to carnivorous marine species that move in and out of the lagoons with the tides (Lobel, 1980).

The lack of quantitative information and objective studies on the effects of tilapias in the small island states of the South Pacific have paved the way for some of the perceived negative influences of tilapias in the region, such as:

- Tuvalu-stunted populations of *O. mossambicus* are thought to hinder the culture of milkfish in lagoons (Uwate *et al*., 1984).
- There was a breakdown of traditional milkfish culture in the inland ponds and lagoons of Kiribati and Nauru (Ranoemihardjo, 1981).

Such negative impacts need to be weighed against the positive ones, most notably in Papua New Guinea's Sepik River flood plain fishery (Coates, 1985; 1987b). This is a good example of a fishery that developed and sustained in various islands. More importantly, after nearly 50 years since tilapia introductions to the ecosystems of South Pacific Islands, there have not been any reports of tilapias being responsible for the disappearance of any indigenous species, even in very isolated water bodies exhibiting a high degree of endemism such as Lake Tegano in the Solomon Islands.

Tilapia nests in a milkfish pond in Kiribati