Inland Fisheries Resources and the Current Status of Aquaculture in Sri Lanka

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By
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Preface & Acknowledgements

These working papers are interim components of a UK Department for International Development (DFID) funded natural resources research program R7064, currently operational in Sri Lanka and Southern India. The project is of 3 years duration from 1999-2002 and aims to investigate the potential for integrated aquaculture options within small-scale farmer managed irrigation systems to bring benefits to marginal groups within diverse, risk-prone semi-arid and water-stressed regions of the world. Benefits are expected to be increased opportunities for livelihood diversification and more efficient and sustainable use of dwindling per capita water supplies.

Principle collaborators are the Institute of Aquaculture, Stirling University, UK, and in Sri Lanka the Agribusiness Centre of Peradeniya University and CARE international. The latter have also provided generous in-country financial support.

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All statements of fact or opinion in this document should be taken as interim statements. The work is continuing and matters covered in this report may be revised in the light of future information received. The document has been prepared to provide information exchange within the research team and with counterparts elsewhere. Comments or requests for further information are invited and should be sent to the project leaders in UK or Sri Lanka listed below:

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Project background

Arid and semi-arid regions of Southern India and the lowland Dry-zone of Sri Lanka's are representative of water-stressed areas experiencing erratic seasonal water availability, high rates of land degradation and chronic poverty. It is estimated that almost half the world's poorest people, nearly 500 million, live in such drought prone-areas and depend on irrigated agriculture to provide them with much of their food supply (UNDP 1997). This will rise to 20% of the world's population by 2050 (Engelman and Leroy 1993). Increasing frequency of drought and competition for water with industrial and domestic users will combine to make water a dwindling per capita resource in these areas. It has been predicted that both India and Sri Lanka will face a fresh-water crisis in the near future (Nigam et al, 1998). Much water is currently wasted due to inadequate management and conservation practices. World-wide irrigation efficiency[1] may be as low as 37% (Postel 1996) and there is a need for more integrated approaches to water management which take into account its multiple uses for purposes besides irrigation (Gowing 1998, Redding 1990). Since agriculture is responsible for some 70% of global water use (FAO 1995), the potential for water savings through multiple use, including aquatic production is enormous.

An emerging development priority has emerged following a paradigm shift where irrigation systems are being reassessed as components of the whole water basin. It is now realized that water and land management practices at the wider watershed level can lead to increased options for on-farm water management at the individual level (Pretty 1995). Watershed development is a huge development initiative in Sub-Saharan Africa, India and other semi-arid areas of the world and often involves the construction of large numbers of small community or farmer-managed water bodies for rainfall harvesting, groundwater recharge and the prevention of soil erosion. In Sri Lanka, as in many parts of India, traditional watershed management exists in the form of the ancient community-managed cascade tank systems. Large-scale rehabilitation of tank systems has taken place over recent decades in both countries.

Two thirds of the predicted shortfall in world fish production (20-30 million tonnes by the year 2000) will occur in the semi-arid tropics (FAO 1995), further underlining the need for such research effort. Despite this potential, attempts to integrate fish production into these water bodies have been rare and usually based on conventional commercial semi-intensive pond aquaculture. Whilst the resource-rich have been able to adopt such an approach, it has proved inappropriate for poorer marginalised groups. By investigating aquaculture options for both traditional and modern watershed development structures, the research results are likely to have broad applicability.

Although large-scale irrigation systems supply the greatest area of farmland, the greatest numbers of farmers still cultivate in rain-fed dry lands, where they rely on small-scale systems. Furthermore the scope for further expansion of large-scale systems is limited, whilst great potential exists to increase the availability of smaller systems through the adoption of watershed development programmes, which include water-harvesting components.

The project aims are to identify social and bio-economic constraints to the integration of aquaculture into farmer-managed irrigation systems and to develop and promote effective approaches to aquaculture for farmers in diverse risk prone dry-land regions of India and Sri Lanka. Intended beneficiaries are the rural poor. Within this group, opportunities for landless,

[1] The percentage of irrigation water actually consumed by crops during their growth.

lower caste unemployed youth and women's groups, all of whom have traditionally derived least, benefit from irrigation developments, will be given special consideration. The project has sought to promote a participatory approach to the design and implementation of targeted research. Research outputs include technical guidelines to engineers, policy guidelines to planners and donors, research guidelines to scientists and extension guidelines to field-level implementers. The closely linked DFID KAR[2] engineering programme (R7123) is investigating the potential for integrating aquaculture into larger formally managed irrigation systems of semi-arid areas in contiguous research areas.

This series of working papers is based on field research that took place during December and January 1998. The social, economic and technical feasibility of fish production in such systems were investigated and some preliminary constraints to the uptake of poverty focused aquaculture identified. Research included a 'Rapid Rural Appraisal' of two cascade systems in Puttalam and Kurunegala districts (incorporating a total of 21 tanks and 9 villages), and semi-structured interviews with representatives of Government fisheries departments, fisherman's co-operatives, marketing agents and other relevant institutional organisations throughout the country.

Field work was undertaken in collaboration with the, field staff of the NGO's CARE[3] IFAD[4] the Government *Samurdhi*' welfare programme and the Agricultural Economics department and Agribusiness Centre (AbC) of Peradeniya University.

List of working papers in the series:

SL1.1 The Lowland Dry Zone of Sri Lanka; Site forStudy of Aquaculture Development within Farmer-managed Irrigation Systems and Methodology for Participatory Situation Appraisal

SL1.2 Inland Fisheries Resources and The Current Status of Aquaculture in Sri Lanka and North West Province.

SL1.3 The Nature of Small-Scale Farmer Managed Water Resources in North West Province, Sri Lanka and Their Potential for Aquaculture.

SL1.4 Fisheries Marketing Systems and Consumer Preferences in Regional and Sub-Regional Markets of Sri-Lanka.

[2] Knowledge And Research
[3] Caring About Relief Everywhere
[4] International Fund for Agricultural Development

Glossary

AER	Agro Ecological Region
ARP	Aquaculture Research Programme (DFID)
CARE	Caring About Relief Everywhere (US NGO)
CPUE	Catch Per Unit Effort
DFID	Department For International Development
DoA	Department of Agriculture
DoF	Department of Fisheries
FAO	Food and Agriculture Organisation
IFAD	International fund for Agricultural Development
KAR	Knowledge and Research (DFID development branch)
Kawara	Fishing Caste
GoSL	Government of Sri Lanka
Ha	Hectare (= 2.47 acres)
Maha	Main cultivation season (October – March)
MEI	Morpho Edaphic Index
MOFARD	Ministry of Fisheries and Aquatic Resource Development
MSY	Maximum Sustainable Yield
NARA	National Aquatic Research Agency
NGO	Non Governmental Organisation
NWP	North West Province
RRA	Rapid Rural Appraisal
Rs	Rupees (Sri Lankan unit of currency; $1 = Rs 65)
SAT	Semi Arid Tropics
STC	Small Tank Cascade System
Velvidane	Traditional irrigation headman
Yala	Secondary cultivation season (April – June)

Executive Summary

The aim of this working paper was to evaluate the potential of different fisheries enhancement and aquacultural systems to benefit marginal farmers who manage small rainfed irrigation systems in the lowland Dry zone of Sri Lanka. Analysis was based on secondary data and key informant interviews with professional fishermen and marginal farmers in N.W Province.

A highly sustainable low output fishery based around small seasonal village tanks has played an important part in the subsistence economy of rural Sri Lanka since the earliest recorded history. It was the introduction of exotic tilapias into Sri Lanka's shallow and highly productive perennial reservoirs in the 1950's that led to the establishment of an artisanal fishery however.

Yields from this fishery increased progressively reaching 40,000mt in 1989 with 90% of production originating from only 74 major reservoirs. This constitutes one the most productive inland fisheries anywhere in the world with a mean yield of around 275 kg/ha^{-1}/year. A subsequent four-year withdrawal of state patronage has obscured the true status of the fishery and curtailed all official efforts to ensure its sustainability. Deregulation was accompanied by increasing intensification in fishing effort. Although accurate statistics are not available, all key informants agreed that there had been a dramatic decline in the catch of many of the larger indigenous species. The tilapia fishery has shown greater resilience, due to its prolific breeding capacity and adaptation to shallow reservoir environments where it faces little competition from a depauperate indigenous lacustrine fauna.

The tilapia *O. mossambicus*, and its hybrid with *O niloticus,* is estimated to constitute 70-95% of the overall inland fishery harvest representing a vital source of low cost, high value food to the rural poor. As both marine and inland fisheries in major reservoirs are estimated to have reached their maximum sustainable yield, new methods of increasing the productivity of inland waters, which will not compromise the existing tilapia fishery are urgently required. Two alternative strategies are suggested. The first relies on exploitation of a substantial biomass of hitherto unexploited indigenous minor cyprinids and the second on enhancement of fisheries using culture-based stocking programmes.

Some observers have estimated a yield potential of 250-300 kg/ha^{-1}/year for minor cyprinids, comparable to the productivity of the commercial tilapia fishery. Current research indicates a variety of marketing constraints are likely to be a major disincentive to uptake of this pathway.

Yields from tilapia and culture-based carp fisheries have been shown to be positively and negatively correlated to reservoir area respectively. In addition it has been suggested that the carp fishery impacts negatively on the tilapia fishery. Amerasinghe (1998) therefore suggests that future carp based culture fisheries should be restricted to reservoirs below 800ha. Other trials have indicated that culture-based fisheries may not be viable where established artisanal tilapia fisheries already exist even in smaller perennial tanks. Greatest technical potential has been demonstrated in the smallest seasonal tanks (from 0.2 to 20ha) that are highly manageable and exhibit high natural productivity. Many of the very smallest of these tanks are accessible to the lowest income groups. Although they are high potential systems, regular disruption of recruitment in drought years limits natural production. Where no tradition of aquaculture exists adoption of a low risk enhanced fishery based on seasonal stocking programmes may therefore be justified. It is recommended that stocking of hatchery seed should be prioritized for such seasonal tanks in contrast to current Government policy in which most are earmarked for stocking in larger systems.

During the 1980's stocking programmes utilising fast growing Chinese and Indian major carps and tilapias were attempted in both perennial and seasonal systems. Despite highly variable results early trials with carp and tilapia polycultures in seasonal tanks demonstrated potential to produce 750 to 1,000 kg/ ha^{-1}/year based on stocking alone with no supplementary feeding or fertilisation. Poor long-term performance of the programme was attributed to unprecedented episodes of drought, poor management, monitoring and evaluation, limited seed availability. The programme was finally curtailed by the government ban and this resource still remains to be harnessed effectively.

Attempts to revitalise the programme continue to be constrained by poor seed availability. No private sector production or market currently exists and most of the states production facilities have been long leased to a more lucrative ornamental export industry. This opportunity cost suggests that under current conditions, there is a low likelihood of private sector uptake of food-fish seed production. Government and NGO policy is now focused on community fingerling production schemes that will produce advanced fingerlings for 6-10 month growing seasons in seasonal tanks. Bighead carp and tilapias yielded the greatest productivity in early trials, though bighead carp appears to be constrained by it's poor marketability. It is likely that rohu and the more easily bred common carp, which also performed relatively well, will be most suitable for community production programmes. It is suggested that such programmes are undertaken at the wider watershed level to increase the flexibility of stocking programmes in the event of extreme climatic variation. Poor institutional cohesion, lack of private sector interest and poor scale economies associated with the seed requirements for small-seasonal tanks are identified as major constraints to uptake.

Further research is required on alternative low-input strategies based on sourcing of local seed from perennial systems and seasonal spill events. High predation pressure by drought resistant air breathers such as the snakehead *Channa striatus*, which represent a constraint to culture-based enhancements, is likely to prove advantageous where self-recruiting tilapias are stocked. This prey/predator synergy could reduce the incidence of stunting associated with overcrowding and increase net yields, including a valuable by-catch of snakehead, highly popular with consumers.

The potential for alternative aquaculture interventions in other irrigation subsystems is also considered. Pond aquaculture in the dry zone is envisaged as having little potential due to high investment costs associated with purpose built structures, set alongside the low overheads of the highly productive and adjacent capture fisheries. Agro-wells relying on ground and seepage waters, emanating from village tanks may offer some potential for advanced fingerling production. The feasibility of advanced fingerling production in flooded paddy fields is currently the subject of a bilateral research programme, however this is certainly not a viable proposition in the context of rainfed tank systems where there is often only sufficient storage for supplementary irrigation. Ornamental fisheries, which have a buoyant export market, require limited capital investment and water availability have been identified potential income generating activities for women's groups. Again, marketing constraints are identified as major constraints to uptake.

Indigenous species with good market demand are identified. Culture of these species may contribute to survival of species under intense secondary pressure from the tilapia gill-net fishery.

Future research recommendations are highlighted in the text and summarised at the end of the text.

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1 Introduction

Widespread malnutrition exists in Sri Lanka, particularly amongst lower income groups in rural areas. De Silva (1991) estimates that average protein intake is only about 28g compared to a requirement of 45g per day. Some 70% of animal protein intake in Sri Lanka comes from fish and in the dry interior most of this consumption originates from major reservoirs. The purpose of this working paper is to characterise the historic and current status of inland fisheries and aquaculture in the lowland dry zone of Sri Lanka and to evaluate the potential of different aquacultural systems to benefit marginal farmers who manage small rain fed irrigation systems.

2 Methodology

Rapid Rural Appraisals (RRAs) were undertaken in Galgamuwa and Anamaduwa Divisional secretariats (the smallest administrative divisions) of Northwest Province. These areas were representative of wider areas of an agro-ecological area known as Lowland Dry Zone. The area is characterised by high levels of rural poverty associated with limited rainfed growing seasons and degrading nutrient poor red soils. As a component of the RRAs, farmers in villages associated with two small tank cascade systems and professional fishermen in three local major perennial reservoirs were interviewed about the seasonal and historic catch trends in catch volumes and composition. Results were augmented with results from a field visit to the Southern province of Hambantota. Key informant interviews were undertaken with staff of government seed production stations and fisheries inspectors and an extensive search of the existing literature was also incorporated in the analysis.

3 History of the development of inland fisheries and aquaculture in Sri Lanka

With a coast line of 1585km and continental shelf area covering 26,000/km^2, the primary focus of fisheries development in Sri Lanka is on marine fisheries, yet highly spatially segregated markets for marine and inland produce mean that inland produce remains of utmost importance to the nutrition to of some of the poorest sections of society in rural inland areas. Inland fishery resources comprise rivers, estuaries, lagoons, brackish water ponds, floodplain lakes and major, minor and village tanks.

Inland fisheries appear to have played a significant role in the subsistence and self-sufficient economy of Sri Lanka from the earliest recorded history (Siriwera 1986). However no tradition of aquaculture or an organised freshwater fishery existed until the recent development of a high yielding commercial tilapia fishery following the introduction of the fast growing exotic cichlid, *Oreochromis mossambicus* during the 1950's. There remains no significant aquaculture activity in the State apart from the recent spurt in prawn culture in coastal belts and lagoon margins that are currently facing serious disease and environmental problems. Although there is no significant riverine fishery, Hettiarachchi (1983) estimated that the size of the 26 floodplains in the Mahaweli basin ranges from 9-976ha with an annual fish yield from 18 to 284kg/ha^2. However degradation of these productive ecosystems following river valley developmental activities mean that the by far the largest share of inland production now comes from man-made reservoirs. Extensive coastal lagoons along the East and Northwest coasts also support extremely productive fisheries, though this in areas already served by good marine resources.

A summary of the tilapia and other exotic introductions and their impacts are considered in the following sections. Further information on non-tilapia introductions, which have had more negligible impact on aquatic production are included in Appendix 1.

3.1 Exotic introductions in the Sri Lankan reservoir fishery and elsewhere

Despite the large number of species moved around the world successful introduction have been based on surprisingly few species, foremost among which are the tilapias: *Oreochromis* and *Tilapia*. In SE Asia introduced tilapiines have become one of the most important group of species for both subsistence and commercial exploitation. Production systems range from capture fisheries and extensive to highly intensive farming systems. Tilapias constitute some 24% of the 240,000mt of freshwater catch each year in the Phillipines and up to 95% the catch in some lakes in Indonesia (Petr 1987). In Madagascar, Mexico, Peru and Cuba tilapias and to a lesser extent common carp, *Cyprinus carpio* have contributed to the recent expansion of inland fish production in lakes and reservoirs. Mexico expanded its production from 2,000 to 123,000mt/yr in 1988, of which 65% were tilapia and 24% common carp. In Madagascar a tropical island with many parallels to the Sri Lankan situation, tilapia and common carp constitute the bulk of 40,000 of annual production. Production in 1988, in Cuba and Brazil stood at 15,000 and 17,000 of which 93% and 30% respectively are tilapias (Welcome and Bartley 1998). The rapid growth of the aquaculture sector in China, based largely on indigenous carps (*Cyprinidae*) tends to mask the growing importance of tilapiines. China now produces 47.8% of farmed tilapia in the world, five times more than the Philippines which rank second (Coward and Little 2001). The Indian sub-continent remains an exception to this success story. Here, tilapiines are widely considered as pest species. A common perception is that they have proliferated to the detriment of larger-growing, higher value carp species, which currently dominate commercial markets. This can be explained by the fact that unlike Sri Lanka, demand for inland fish also exists in urban markets, particularly for larger varieties. In India, although highly prevalent and even widely cultured in West Bengal where it is popular both amongst commercial producers and consumers, it remains officially banned as a result of this view. It is also important in the tanks of southernThis perception overlooks the value of smaller, lower cost species to poorer rural consumers.

In Sri Lanka, over the last two centuries 22 species have been introduced into the reservoirs, with few successes. Of these 19 were exotics and three were translocated within the country. Stocking events with significant impact on the reservoir fishery can broadly be divided into two phases (De Silva 1998):

- Phase 1: Stocking with *Osphronemus gouramy* in the 1940's followed by *O. mossambicus* in the 1950's. Stocking of tilapia still continues, though today *O. niloticus* is reared for this purpose.

- Phase 2: Stocking with three species of major Chinese carps commencing in the mid 1970's, followed by two species of Indian carps and common carp in the 1980's. Unlike the highly successful tilapias these have largely failed to establish breeding populations and require regular stocking.

Further details of these introductions are shown in Table 1 (also see Appendix 1).

Table 1. Important exotic introductions stocked in reservoirs (After De Silva 1988 and Sugunan 1999).

Species	Origin	Major Introductions	Self-recruiting?	Remarks (Max Size cm)
Exotics into reservoirs				
Oreochromis mossambicus	E. Africa	1952	Yes	Largest component of the reservoir fishery (30cm)
O. niloticus		1956, 1975	Yes	Common in a few reservoirs
T. rendalli	E. Africa	1979	Yes	Food fish
T. Zilli	E. Africa	1969		
Osphronemus gouramy	Indonesia/ Mahaweli	1939	Yes	No longer important as a food fish
Cyprinus carpio	Europe	1915,1950/80	Yes	Low level wild breeding
Ctenopharyngodon idella	China	1948, 1975	?	Hatchery stocking
Hypothalmichthys molitrix	China	1948, 1981	?	Hatchery stocking
Aristichthys nobilis	China	1948, 1975	?	Hatchery stocking
Cirhinus mrigala	India	1981	?	Hatchery stocking
Catla catla	India	1942, 1982	?	Hatchery stocking
Labeo rohita	India	1981	?	Hatchery stocking
Carassius carassius	Europe	1915		
Puntius gonionotus	S.E. Asia	1951		
Helostoma temmincki	Thailand	1969		
Local transplantations into reservoirs				
Etroplus suratensis	Estuaries/ lagoons	1910	Yes	Sustainable low yields in many reservoirs – close substitute for tilapias.
Mugil cephalus	Lagoon			
Chanos chanos	Lagoon		No	Into village tanks
Other Exotics				
Salmo trutta	Europe	1882		Into hill streams
O mykiss	N.America	1889		Into hill streams
Trichogaster pectoralis	Malaysia	1951		Into Lagoons

3.2 The status of inland fisheries and aquaculture prior to 1950

The earliest settlers to Sri Lanka extended along the course of rivers and streams and in the process irrigated paddy cultivation became increasingly important. Little fresh marine fish could have been transported inland due to the poor communications of the time. Instead fish must have been caught from rivers, streams, reservoirs and irrigation channels. Rock inscriptions show that such fishing was widespread during the early Anuradhapura period (prior to the 6th century AD). Beginning in this period, the construction of small village irrigation tanks brought into being a society based on a collective 'one tank one village' system. To this day the economic life of such villagers revolves around paddy and rainfed upland cultivation and subsidiary occupations including fisheries (Siriwera 1986).

Until the end of the 12th century a tax on fishing in the larger state owned reservoirs was levied by the king (who also leased fishing rights), indicating that fisheries was part of everyday life. Rivers were neither taxed nor leased probably due to the greater difficulties involved in policing such waters. Robert Knox a British visitor to the Island in the 16th century observed many traditional fishing techniques still being practiced by a residual Dry zone population, which had been decimated by wars and epidemics in the 13th and 14th centuries. Fishing systems included; hook, long basket (a kind of fyke trap), netting, poisoning, damming and bailing out of small streams.

In the case of communally constructed village irrigation works fish were the property of village assemblies. Smaller tanks were often privately constructed and individually owned. The most commonly held private water resources were small ponds constructed in garden homesteads and the channels that ran through or around paddy fields. Theft from these systems was punishable according to the amount of the fish caught. Buddhaghosa, an eleventh century Buddhist cleric, noted that people bought fish from large state-owned irrigation works and village irrigation works to grow in their homestead ponds, catching small amounts of fish for their own consumption (Siriwera 1986).

Organised attempts at improving fisheries and aquaculture beginning from the end of the 19th century involved expanding habitats for freshwater fish, introducing exotic species and more intensive fishing gears to exploit the fishery. Exotic introductions were required as no species with rapid growth and proliferation characteristics of commercial significance existed in the indigenous fauna. Brackish water culture stations were established in the 1950's at Pitipana and Manar. Mariculture effort focused on milkfish (*Chanos chanos*) and mullet (*Mugil* sp). Both stations are now defunct, though until recently the Fisheries Department continued to collect milk fish fry for fresh water stocking purposes. From the mid 1970's onwards the focus has shifted to fisheries enhancements based on the stocking major and minor tanks with carp and tilapia fingerlings. From this time new fingerling production stations were built to supplement the first station at Polonnaruwa with Chinese and subsequently Indian bilateral technical assistance. Despite such investment, today, the commercial inland fishery remains essentially an artisanal gillnet fishery exploiting naturally recruiting tilapia populations. Most of this commercial production emanates from less than 100 of the largest perennial reservoirs, all of which are shallow systems located predominantly in the lowland Dry zone (section 4).

3.3 Development of the modern commercial inland tilapia fishery

A planned commercial inland capture fishery is a development of the second half of this century. It was stimulated by the increased demand accompanying acceleration of Dry zone recolonisation post independence in 1948. *Oreochromis mossambicus* subsequently became known as the 'miracle fish' in Sri Lanka. The ability to self-recruit and exploit a wide range of feed niches low in the food chain, normally only exploitable by using polycultures of other culturable species and their good eating qualities, are the principle reasons for the success of tilapiines in meeting the needs of the poor, particularly where utilised in extensive fisheries enhancements.

Ideally adapted to Sri Lanka's shallow and highly productive perennial reservoirs, *O. mossambicus* filled this artificial lacustrine niche in a way that none of the slower growing, indigenous species of riverine origin could. Due to it's singular configuration of water resources and history of aquatic resource production, Sri Lanka presents a unique case in a worldwide spectrum of adoption for tilapiine enhanced fisheries (section 3.1), though one from which valuable regional lessons can be learned.

Initially the fishery represented a supplement to the agricultural income of communities living around the reservoirs. Coastal fishermen who began to migrate to reservoirs during the monsoon season (when the seas became to rough for traditional fishing craft) intensified exploitation. The wealth of experience brought by these migrants encouraged more local permanent agricultural settlers to take up fishing. This ultimately resulted in major conflicts between the two groups up to the 1960's after which time migratory fishing almost completely disappeared, though residual *Kawara* (a low fishing caste, mostly Christian) communities still remain illegally encroached around some larger reservoirs.

The absence of a commercial riverine fishery and this dependence instead on a mono-specific fishery in man-made reservoirs is unique to Sri Lanka. At it's peak in 1989, the inland fishery accounted for nearly 20% of total fish production (Fig. 1) on the island and is likely in the future to exceed this figure as the marine fishery reaches maximum sustainable yields.

3.4 Historic production trends in inland fisheries and Government intervention

Inland fisheries production showed a steady growth from 8,000 tons in 1970 to around 40,000 metric tons in 1989 (Fig 1). This growth was attributed to the successful introduction of appropriate exotic species and a government sponsored stocking programme, although the contribution of the stocking programme has never been adequately quantified (section 4.1.5).

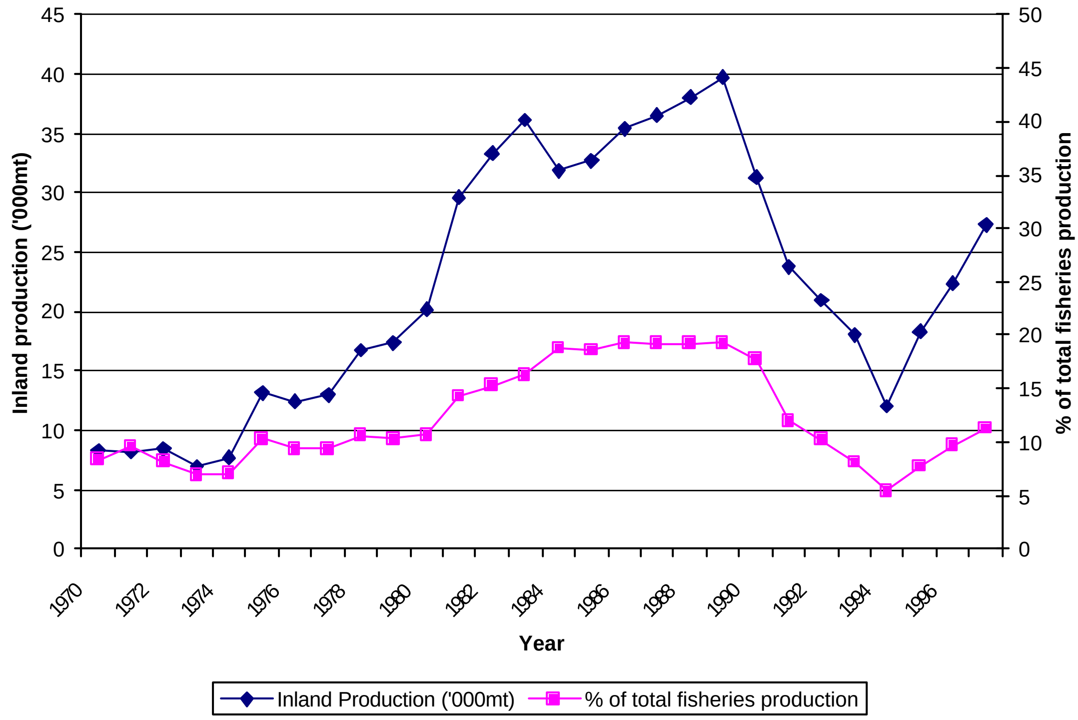


Figure 1. Inland Fish production in relation to total national production from all sectors (Source NARA 1997).

An abrupt politically inspired withdrawal of Government patronage to the inland fisheries sector from 1989-1994 caused a major setback to the inland fisheries development process. This was as a result of combined lobbying from Buddhist clergy and vested interests in the marine fish cannery sector. Despite the religious reasons cited for the ban, state involvement in the marine fisheries sector was not curtailed in any way. Existing seed production facilities were long leased to the private sector and converted to ornamental fish production, regardless of contractual obligations to continue food fish seed production. Meanwhile the capture fishery became an unregulated open-access fishery, which experienced a rapid increase in the number of full-time entrants and an intensification of fishing methods. Available government statistics are contradictory, indicating a crash in production immediately following this 'ban', with production falling to a low of 12,00mt in 1994, but probably reflect the effects of the ban on data collection. Three years after the ban was formally repealed following a change of government (1997) production was reported to have risen back to 27,250mt per annum. At 11% of total fish production, this still represents only half the contribution prior to the government 'ban'. The true condition of today's fishery remains uncertain, though it is highly likely that the contribution of the inland fishery is greater than these figures suggest, as they account only for commercial production from larger reservoirs. Further insights were gained from the perspectives of respondents whose livelihoods depend on commercial fisheries (section 4.1.5).

4 Capture and culture fisheries in Sri Lanka

Inland fish production in Sri Lanka can be divided into the capture and the culture fishery, both of which are essentially confined to man made-reservoirs. Apart from the export orientated prawn industry a viable pond aquaculture sector has yet to emerge. The culture fishery, which is still in its infancy, relies on annual stocking of small seasonal tanks, whilst the capture fishery is concentrated on larger perennial tanks (>100 ha). The imbalance in the contribution of these two sectors is reflected in the fact that an estimated 90% of total commercial inland production currently comes from capture fisheries in just 74 major reservoirs. Both systems show extremely high natural productivity. Amarasinghe (1998) reports average yields of 250-300 kg ha^{-1} per year in the perennial reservoir fishery, which compares to an average of between 15-150 kg ha^{-1} from carp based reservoir fisheries in India and China respectively (Haylor 1996, Oglesby 1985). Well-managed seasonal tanks can produce 800-1,000 kg/ha^{-1}, though for reasons that will be expounded, this potential remains largely unfulfilled. The capture fishery will be considered first.

4.1.1 *Oreochromis mossambicus* and *Oreochromis niloticus* in the reservoir fishery

Tilapiines are currently sub-divided into three generic groupings based principally on their mode of reproduction. These are *Tilapia, Sarotherodon* and *Oreochromis* which are substrate spawning, biparental mouth-brooding or maternal mouth brooding respectively (Coward and Little 2001). The two species of greatest importance to the commercial fishery both tilapias, belong to *Oreochromis* genera and these are considered in more detail below. A third species, *T. Rendalli,* a substrate spawner has become established in a smaller number of reservoirs, mostly in the South West of the country.

<u>*O.mossambicus*</u>: Since it's introduction in 1952, has become the most successfully established exotic species in Sri Lanka. This general success of tilapia has been attributed to a number of factors: high resilience and fecundity, ability to breed throughout the year, tolerance to a wide range of environmental conditions, including, oxygen tension, overcrowding and high pollution levels, ability to breed and disperse in sea water. In Sri Lankan three main factors have been linked with its success.

1. Low mean depth of reservoirs, enhancing nutrient cyclic and increasing availability of littoral areas with muddy substrates for nesting. This increased range also lessens the impact of frequent level fluctuations on nesting sites.
2. Reservoir water rich in ionic concentration as evidenced by its high specific conductivity (93 to 847 micro mhos – De Silva 1988).
3. The ability of tilapias to propagate themselves and adapt to a wide range of feeding niches low in the food chain, either as column filter feeders or benthic-bottom feeding omnivores (Coward and Little 2001). This is result of their ability to shift between detritivory and zooplanktivory which permits them to digest a wide array of ingested materials including

the abundant blue green algae populations found in lowland reservoirs, which remain poorly exploited by a depauperate endemic fauna (De Silva and Fernando 1988).

O. mossambicus was simultaneously the subject of an extensive introduction programme in the Indian States of Kerela and Tamil Nadu in 1952, where they appear to have failed to establish fisheries as productive as those in Sri Lanka despite many environmental similarities. Sugunan (1999) cites the combination of high productivity levels, as evidenced by chlorophyll concentrations and phytoplankton counts, and the unique ability of the tilapias to exploit this niche in Sri Lanka as central to this success relative to India and reservoirs elsewhere in Asia.

Fernando and Holcik (1992) classified the endemic inland fish fauna into riverine and lacustrine categories. As elsewhere the largest commercial species including *P. sarana* and *L. dussemiri* tend to be the most rigidly potadromous and must migrate back to their natural riverine environments to breed where they are more susceptible to pollution and environmental degradation. Tilapias, clupeids and many minor cyprinids are more flexible in both breeding and feeding habits. Finally, tilapias have the ability to regulate their fecundity in relation to fishing pressure (De Silva 1988) a critical advantage in the face of increasingly intensive exploitation.

O. niloticus: Since the late 1970's this has become the favoured species for stocking programmes, because of it's superior growth characteristics and body conformity. However, since it's introduction, introgressive hybridisation with established *O. mossambicus* populations has occurred in most reservoirs (Amarasinghe 1998). Even in recently impounded reservoirs stocked exclusively with *O. niloticus, O. mossambicus* has invariably gained entry through inflowing water supplies. De Silva (1998) and Amarasinghe (1998) found that hybridisation leads to an imbalance in sex ratio in favour of males and reduced fecundity, resulting in net losses to the fishery. Such hybridisation represents an as yet unquantified threat to the future productivity of the fishery. Furthermore, as high yields of *O. mossambicus* are a result of its proven adaptability to the local environment, complete replacement even in seasonal tanks is unlikely. Furthermore although smaller fish command lower prices than larger specimens (Working Paper SL1.4) they are more affordable and most commonly consumed by lower income groups, questioning the desirability of increasing average sizes in what is an artisanal fishery with an exclusively rural consumption base.

Compared to large dams elsewhere in Asia, the major reservoirs which support the commercial reservoir fishery in Sri Lanka are small extending to no more than 10,000ha in extent, whilst the great majority are less than 2,500ha (Fernando 93) and shallower with maximum depths in the lowland dry-zone usually under 5m[5] (see Working Paper SL1.3). Rainfed systems exhibit wide bimodal fluctuations in water spread and level, whilst fluctuations in system tanks receiving trans-basin supplies, though more erratic are typically less extreme. Extensive littoral zones in these systems are similar to natural marshes that form in the rainy season. This represents an ideal breeding environment for tilapia species, whilst the morphometric characteristics of the systems contribute to their high primary productivity and yield potential.

Nixon (1988) showed that the highest known natural production in aquatic systems, i.e. in shallow estuaries, is equaled by shallow tropical lakes. In the Parakrama Samudra, a major perennial reservoir in North Central Province the introduction of *O. mossambicus* increased productivity from under 10 kg ha^{-1} in the 1950's to over 500 kg ha^{-1} in 1978 (Fernando 1984). Based on government data, the maximum sustainable yield (MSY) for perennial Sri Lankan reservoirs is estimated at 256 kg ha^{-1} per year (De Silva *et al* 1991). This takes into account only

[5] Deeper pelagic zones of larger reservoirs are the most difficult areas for riverine fish to colonise.

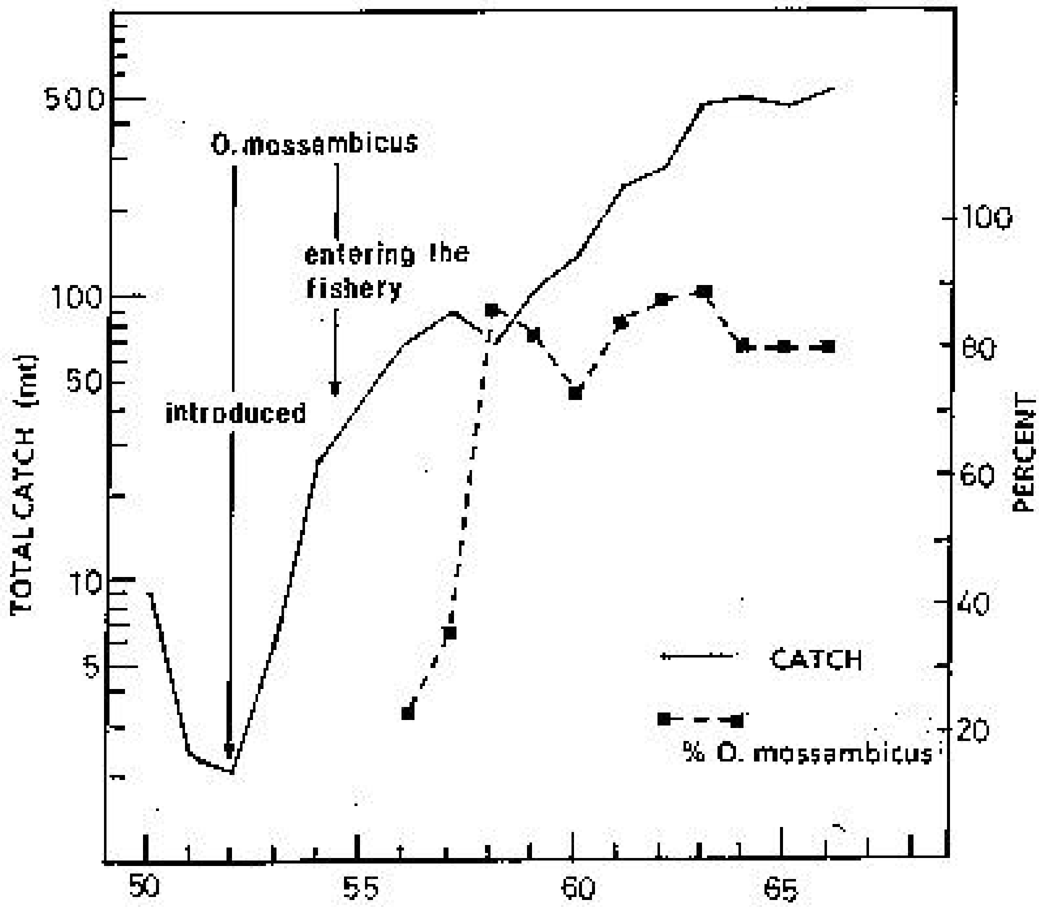
the fishery for introduced tilapias. Fig. 2 shows the dramatic nature of the impact of this introduction on the Parakrama Samudra, one of the first major reservoirs stocked early on in the 1950s.

In a detailed two year long study of Tissawewa, a major perennial tank in Southern Province (1991 to 1992), Pet (1995) estimated that *O. mossambicus* contributed 70%, *O. niloticus* 5% and stocked Indian carps 20% of the total catch by weight during this period. In view of its current importance conservation of the *O. mossambicus* fishery should therefore be accorded the greatest priority, yet he estimates in this fishery, the species is being exploited close to it's maximum sustainable yield (MSY) offering no prospect for substantial (>25%) future increases in productivity. Pet also found that the mean size of *O. mossambicus* at maturity has decreased from 16 to 13cm in recent years indicating that stunting is set to become a problem for the first time in the 50year history of the perennial tank fishery. He suggests that enforcement of a 76mm (3") stretched mesh size would increase the number of larger (>16cm) fish breeding and reduce stunting, whereas net sizes closer to 2" (52mm) nets are currently the norm. Having achieved suitable improvements in recruitment and yield (>10%) the minimum size should then be increased to 82mm. Larger mesh sizes would also encourage replacement of *O. mossambicus* by *O. niloticus* as the dominant tilapia species as *O. mossambicus* is capable of breeding at a smaller size.

Amerashinghe 1998 and De Silva and Sirisena (1987), have suggested that the Maximum Sustainable Yield for the fishery as a whole is 256kg/yr and optimum fishing effort is 3.2/km^2. This compares to current values of 283-307/km^2 and 3.1 boats//km^2. On the basis of gillnet sensitivity studies in a number of reservoirs; they concluded that the legal minimum mesh size should be increased from 76mm to 100mm to preserve an acceptable size of fish for the market. However current research shows that although many rural consumers prefer to consume larger fish, most continue to consume smaller fish (<150g) because of it's lower cost rather than reasons of availability (Working Paper 4). Furthermore, Sugunan (1999) reports that for self-recruiting species, the highest production can be achieved if fish are caught at the minimum marketable size. More wide ranging marketing studies are therefore required to clarify existing demand amongst different consumer groups.

Although further increases in fishing effort should be discouraged, forced reduction in effort, which would reduce total yield and hence this vital protein source for the rural population is not recommended. In this respect it is important to note, that as the cost of fishing is very low in this fishery, fishermen's incomes are determined more by total catches rather than catch per unit effort.

Figure 2. The contribution of tilapia to the fishery of the Parakrama Samudra, a major perennial tank (Fernando and De Silva 1984).



In the absence of capacity for strong community-based fisheries management or effective Government regulation (Working Paper SL1.1) it is unlikely that improvement in self-recruiting tilapia yield will be realised in the short term. Therefore alternative options of increasing the output of the perennial fishery are required. Pet (1995) suggests two possibilities. Firstly further attempts at establishment of exotic carp culture fisheries based on stocking programmes. Secondly increased exploitation of hitherto neglected indigenous minor cyprinid fisheries. This could be direct (using species selective gill nets) or indirect (through the stocking of predatory species). He goes on to suggest reasons why such exploitation should not impact negatively on the tilapia fishery. These two options are considered in the following sections.

4.1.2 The Contribution of exotic carps to the reservoir fishery

De Silva (1988) reported that between 1968 and 1981, nearly nine million major carp fingerlings were stocked into Sri Lankan Reservoirs with no marked enhancement of total fish production. Major carps only began to enter the catch statistics in 1983. Today, the poor returns on earlier investments have resulted in carp stocking programmes becoming widely discredited (Fernando 2000) yet there use remains a cornerstone of inland fisheries development policy. Earlier failures can be attributed to a number of technical factors. Principle among these were the inadequacy in numbers and the sub-optimal size of fingerlings stocked (due to lack of adequate fry/fingerling nursing capacity) and poor management of stocking programmes. However, whilst biologically, the penalty of high mortality acts against the stocking of fish at too small a size, the exponentially increased cost of the stocking material with increasing size, still tends to favour stocking early life stages. The government hopes to overcome this constraint through encouraging NGO and private sector support for the construction of 'community-based nursing facilities' (section 6.1).

Technical successes reported in the literature tend to be associated with smaller minor perennial reservoirs (section 4.1.3). Chandrasoma (1992) found that stocking *Labeo Rohita* fingerlings into three perennial reservoirs >100ha in Southeast Province yielded highly profitable financial rates of return with an average 20% return on the stocked number.

Whilst all the introduced tilapias are capable of self-recruiting, of the various species of carp introduced into the food fishery, only *C. carpio* is known to have a self-sustaining population. It is now the only exotic occurring in headwater streams above 1500m. a.s.l. in the wet zone. Of six other introduced species; including three Chinese carps *(Hypophthalmichthys nobilis, H. molitrix* and *Ctenophyaryngodon idella*) and three Indian major carps (*Catla catla, Cirrhinus mrigala).* only *L rohita* is thought to be potentially capable of breeding in Sri Lankan waters at low level. This poor ability to breed naturally in tropical latitudes means that all these species have declined rapidly after state sponsored stocking was suspended in 1990. Common carp appears to be something of an exception. Larger individual becomes amenable to the gill-net fishery in modest amounts during certain periods of the year when they move up from the tank floor (Working Paper SL1.4). In the absence of recent stocking programmes, different cohort sizes observed in harvests from Rajangane and Usgala Siyambalangamuwa reservoirs in North West Province, suggesting that limited, low-level recruitment is also possible in low land reservoirs. In Hambantota District, Southern Province, both rohu and common carp were being marketed. These were mostly smaller specimens (500-1kg), in contrast to the mostly larger 5-20kg fish observed in NW Province. Whilst too small to be relics of earlier stocking programmes, it was likely that these were the result of more recent stocking efforts by the nearby Uda Wallawe Government hatchery. In one instance farmers interviewed near the other operational Government hatchery at Dambulla (NW Province) were paying 50 cents per carp fingerling (although entitled to free stock) for use in seasonal tank stocking, suggesting that some of the demand required to make community-based production viable may exist.

4.1.3 The dynamics of stocking and yield

Where fish are stocked into waters where natural reproduction occurs the dynamics of the process become less certain as a variety of density dependent factors come into play with impacts on nutrition, growth, mortality and reproduction. These effects will depend on the relative proportion of stocked fish to those originating from natural reproduction. In cases where there is adequate natural reproduction, stocking may well be superfluous. This has been reported to be the case for introduced tilapia fisheries in Cuba (Fonticiella et al 1995) and arguably also for perennial Sri Lankan reservoirs (see below).

Yield analysis from stocked systems stocked with carps reveals a complex situation involving the interplay of two main variables, stocking rates and the area of the system (Welcomme and Bartley 1999). These relationships are considered below.

Yield (Y) is related to stocking rates (D): Amarasinghe (1997) found yields in Sri Lankan reservoirs to follow the following relationship $Y = -1.829 + 0.3714\ D - 0.0011^2$ ($r^2 = 0.70$) i.e. yields rise initially but later fall as density dependent factors come into play. As stocking density increases, fish grow at a slower rate with a higher rate of natural of mortality. Consequently the mean weight of fish falls until they are no longer acceptable on the market, thus a balance must be maintained between the stocking rate and the size of fish produced.

Amarasinghe (1988) examined the relationship between the stocking density of Indian major carps in perennial reservoirs, yield and profitability. He found the optimal yield for carp species is only 30kg ha^{-1} y^{-1} (in a regulated gill net fishery using non-intensive fishing practices). This compares very unfavourably with the average yield of the natural (300 kg ha^{-1}) tilapia fishery. In practice, highly efficient fishing methods (encircling gears, trammel nets or beating the water to drive fish into gill nets) are often used to maximise the return from existing carp fisheries. This can also has negative impacts on the natural cichlid fishery. Creech (2000) also reported adverse interactions where stocking was practiced in smaller perennial tanks (20-39ha) with established artisenal capture fisheries (section 4.2.4). Therefore is would seem that establishment of culture based fisheries in perennial reservoirs, based on non-tropical major carps is irrational where such a strategy has to be implemented at the expense of the more productive cichlid fishery for which yields are positively correlated with reservoir area (De Silva 1998).

Yield is inversely related to the area of the stocked system: This relationship is usually assumed to be linear, however, in India, China and Cuba yields of all carp species have been shown to have negative curvilinear relationships with reservoir area (Amarasinghe 1998 –Fig. 3).

Establishment of culture-based carp fisheries is likely to be more feasible in smaller seasonal reservoirs, where natural recruitment of tilapias is low (section 4.2.4). Data sets from China (Li and Xu 1995), Sri Lanka (Amarasinghe 1997) and Mexico (FAO, 1992, 1993) all show strong inverse relationships between reservoir area and yield per unit area (Fig. 3), which are linear on log-log scales. This is relationship has been attributed to a number of factors including, the greater degree of control over smaller systems, the greater risk of predation and competition in larger ones and greater difficulty in restricting access to larger systems heightening the probability of losses through poaching and unreported catch (Welcomme and Bartley 1999).

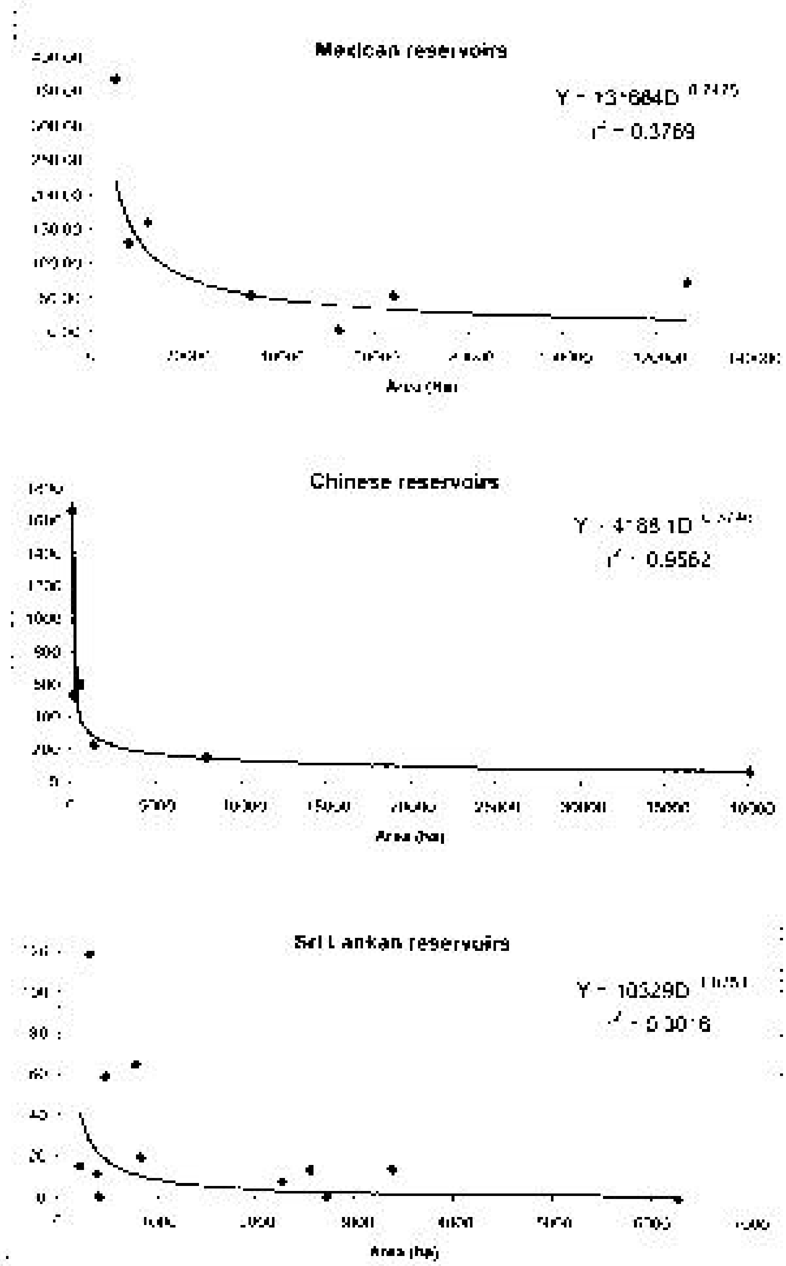
Where stocking is to be practiced in perennial systems, it should be limited to smaller reservoirs, certainly no greater than 800 ha, above which catch per unit effort rapidly declines. Despite these findings, much of the limited state fingerling production capacity still goes to stock minor and major perennial tanks (> 100ha), often for more political than pragmatic reasons.

Stocking is inversely related to lake area: Regardless of the relationships outlined above, there is a tendency in nearly all areas where stocking is practiced to stock at lower densities in larger water bodies (Fig. 4). This is typically justified by the assumption that:

- Competition and predation will be greater and survival rates falls. This is not borne out by the findings outlined above.
- Other aspects of enhancement i.e. fertilisation, removal of unwanted species are more manageable in smaller water bodies.

In reality this relationship probably holds true simply due to the unrealistically high number of fingerlings of non-recruiting species required to ensure good recovery rates in larger reservoirs.

Figure 3. Graphs of yield per unit area against area for reservoirs in three countries (Source, Welcomme and Bartley 1999).

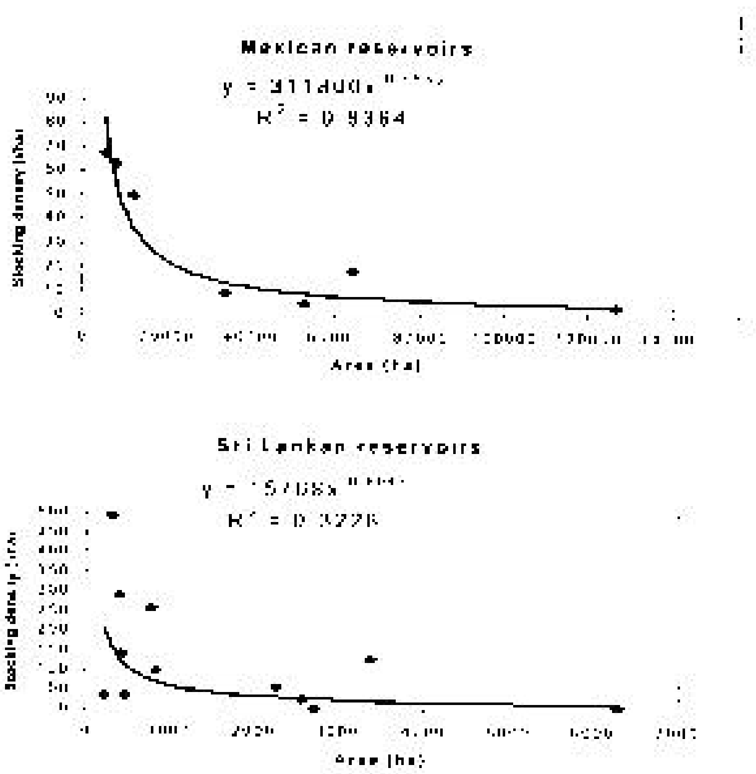


Stocking and yield predictive models: A model for determining the optimum stocking density in perennial waters is shown in Box 1 (Amarasinghe1998), this and similar models only hold for populations where there is either no reproduction or there is near total harvesting. Lorenzen (1995) has developed more realistic yield models for small water bodies based on work in SE Asia, which interpret stock recruitment, mortality and growth relationships allowing for interaction between native and stocked fish. Pet describes an optimised yield model in terms of effort, catch per unit effort (CPUE), and mesh sizes and species-specific distributions of the catch, which could be used to predict the effect of different management strategies. Other modeling systems incorporate a measure of the potential productivity of the water such as the morpho-edaphic index or specialized indices based on benthos or zooplankton densities.

> **Box 1. Amarasinghe (1998) suggests the following relationship to determine the optimal stocking densities (S as fingerlings ha^{-1}) of perennial reservoirs in Sri Lanka (200-800ha)**
>
> $S = (1000\ P / 0.5\ M\ W) \exp (M (t_1 - t_2))$. Where:
> M is the instantaneous rate of mortality,
> W = the mean species capture weight (kg).
> t1 – t2 = Time period in days.
>
> (A means of estimating M is included in the original text).

Most of the detailed scientific investigations on fish population dynamics have been conducted on the capture fisheries of the larger reservoirs such as the Parakrama Samudra and Udawalawe. These studies are confined in the main to tilapia or exotic carp species, ignoring any potential for exploitation of substantial minor cyprinid biomass (section 4.1.4). Greater emphasis should be placed on the modeling of multi-species fisheries such as that initiated by Pet (1995). Such work should also incorporate a wider range of tank sizes, especially the hitherto neglected semi-seasonal/perennial village tanks. Prior to any renewed attempts at enhancements, further research is also urgently required to assess the nature and current contribution of the smaller seasonal tank yields, (that are not channeled through commercial networks) to rural livelihoods.

Figure 4. Stocking rates into reservoirs of different areas in Mexico and Sri Lanka (Source, Welcomme and Bartley 1999).



4.1.4 The contribution of indigenous species to the reservoir fishery

Thirty indigenous species belonging to 11 families and 6 orders are known to populate Sri Lanka's perennial reservoirs including 12 cyprinids. Fifteen species are considered true food species whilst only 6 are caught in significant numbers (De Silva 1988). *Labeo dussumeri* and *Puntius sarana* were traditionally the two primary food fish. An inventory of these species along with some of their major characteristics is listed in Table 2.

The situation in Sri Lanka can be usefully contrasted to that in India, which has a far richer fish fauna comprising of carp minnows, clupeids and a variety of predators including catfish. The minnows sustain a variety of smaller predators that are in turn the prey species of larger predators[6]. This long chain results in inefficient energy conversion and low productivity. Predators in Sri Lanka are relatively few in number, and this low pressure is also contributory to the success of tilapia. Furthermore in India stocked major carps must also compete with a large number of indigenous species for food and breeding space explaining its relatively low yield performance.

Lacking from the commercial fishery in Sri Lanka are fishes of a size comparable to tilapia, which would be susceptible to the same gill net fishery. Of the larger secondary consumers, *Anguilla* spp., *Wallagu attu* and *Channa marulius* are excluded by their low frequency and their elusive habits, being more susceptible to long lining.

Schiemar and Duncan (1988) reported that the existing tilapia commercial fishery exploits only a small proportion of the available fish biomass in perennial reservoirs. Large stocks of indigenous minor (riverine) cyprinids are known to be highly prevalent, of which five species; *Ambylpharyngodon melettinus*, *Rasbora dandonicus. Barbus chola*, *B. dorsalis*, and *B. sarana* are the most abundant. Fernando and Holcik (1982), Newrkla and Duncan (1984) have suggested that a fishery for the small cluepid *Ehivara fluvitialis* could be as important as cichlids in their biomass production. This combined fishery currently forms only a minor (<20%) part of total landings, though Sugunan (1997) suggests that in many reservoirs the true figure is likely to be up to 50% of the total catch but these landings go unreported as they are caught illegally in small-meshed nets. Pet (1995) measured the biological fish production of different species groups based on size at harvest, in Tissawewa (see section 4.1.1). For the smallest group comprising two species, production totaled 3,600 kg /ha^{-1}/year (90% contributed by *A. melettinus* and 10% by *R. dandonicus)*, 1,100 kg/ha^{-1}/year for the combined *Barbus* spp group, 400 kg /ha^{-1}/year for *O. mossambicus* and 300 kg /ha^{-1}/year for all other species. Therefore the productivity of a single species *A. melettinus* was greater than the combined productivity of all other species in the fishery. Both *A. melettinus* and *R. dandonicus* were observed being trapped in the spill waters of seasonal tanks (in roughly the ration suggested above).

De Silva and Sirisena (1987 & 1989) estimated the yield potential of minor cyprinids as 35 to 2,191kg/ha/yr depending on hydrological and hydrobiological characteristics, with a mean of 907kg/ha/yr. They proposed an additional fishery using 15mm and 30mm gill nets to target *A. melettinus*/*R. dandonicus* and *Barbus* spp respectively, with no envisaged detrimental effect on the existing tilapia fishery. This was based on the premise that adult stages and juvenile stages of all species are spatially separated to pelagic and littoral habitats respectively. Therefore limiting the different size gill net fisheries to open water zones would result in little negative interaction. However, Pet (1995) found that the various *Barbus* spp. and larger *O. mossambicus* juveniles show considerable habitat overlap between the littoral and pelagic zones, concluding that such a

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[6] Including *C. striatus, Mystus aor, M. Seenghala, M cavasius, M. punctatus, Wallago attu, Silondia silonia, Nopterus chitala, N. notopterus, clarias bartrachus*, and *Hepteropneustes fossilis*

fishery is likely to be damaging to the tilapia fishery. Conversely the spatial separation of *A. melettinus* and the smallest stages of *O. mossambicus* vulnerable to a 15mm gillnet fishery is good. Based on the large biomass available, a subsidiary 15mm fishery for this species alone may equal the *O. mossambicus* fishery. However as enforcement of the existing mesh restrictions is already proving a formidable task, enforcement of spatial restrictions based on legalisation of smaller mesh sizes is likely to prove even more problematical.

A limited fishery for *A. melettinus* does already exist. Due to it's small size (max. 10cm) and appearance, this species is known locally as the '*wewas salaya*' or tank sardine, with very similar eating and keeping qualities to marine sardines and other small clupeids. Current research suggests that fresh small cyprinid stocks are not popular amongst the 2-wheeler vendor networks, due to the low price they command and their high perishability (see Working Paper SL1.4). During visits to reservoirs in Northwest province, many fishermen were observed landing such fish late in the dry season when other catches are poor. These are typically sun dried and sold to local boutiques or small-scale market vendors (often women – Working Paper SL1.4). As such, the species already represents the cheapest source of animal protein available to the rural poor.

An indirect means of exploiting of small cyprinid populations using prey-predator systems is considered in section 4.2.4.

Table 2. Important indigenous inland fish species for human consumption (Sources, Field observations NW Province, Siriwera 1986, De Silva 1989).

Latin name	English name *Sinhalese*	Feeding (Max. Size (cm))	Comments
Cyprinidae			
Rasbora daniconius	Common Rasbora *Dandia Kudamassu**	Zooplankton (15 cm)	'A poor persons meal'*. Small fish with dorsal yellow blotch. Common in streams, reservoirs and seasonal tanks
Amblypharyngodon melettinnus,	Tank Sardine *Wewa Salaya*	Phytoplankton and detritus (10)	'Trash' fish grows to 3" often dried. Common in reservoirs & seasonal tanks
Puntius barbus	Puntius *Pethiya*	Zooplankton (30cm)	All with white/silvery bellies – rivers, reservoirs
Puntius chola	*Podi pethiya*	Phytoplankton	Smaller carp – rivers, reservoirs
Puntius sarana	*Mas pethiya*	Phytoplankton	Larger carp – rivers, reservoirs
Puntius dorsalis	*Kata pethiya*	Phytoplankton	Rivers, reservoirs
Labeo dussemiri,	*Hiri kanaya*	Phytoplankton	Larger indigenous carp and important food fish. In decline.
Barbus chola		Zooplankton	Rivers, reservoirs
Barbus filamentous	*Dankola pethiya*	Zooplankton	Rivers, reservoirs
Anabantidae			
Anabas testudineus	*Kawaiya*		Air breather, seasonal tanks and reservoirs. Important food fish
Ophilicephidae			
Ophicephalus striatus	Snakehead *Lula*	Piscivore	Very important in the wild fishery. Max 360mm length. Rivers and freshwater ponds. Few bones. Prescribed for invalids – digestibility, little fat. Much prized as sun dried food. Air breather

Table 2. Continued.

Latin name	English name *Sinhalese*	Feeding (Max. Size (cm))	Comments
Channa marulius	Giant Snakehead *Gangara Gangaru, magura*	Piscivore	Grows to 2.5', Lives in streams rivers and irrigation reservoirs to 1,500'. V. popular inland fish.
Siluridae			
Wallagu attu	Fresh water shark (Wallaya)	Piscivore	Mainly in deep flowing waters occasionally reservoirs.
Ompok bimaculatus	*Pena walaya*	Piscivore	Reservoirs and tanks
Bagridae			
Mystus vittatus *M. gulio*	*Ankuta*	Zooplankton, Piscivore (adults) (30cm)	Reservoirs and tanks. Somehow survives desiccation.
Heteropneustidae			
Heteropneustes fossilis	Stinging catfish *Hunga*	Piscivore	Mostly low country ponds and reservoirs. Much feared due to pectoral spines. Air breather.
Mastambelidae			
Mastacembulus sp.	Spine Eel *Teliya*	Piscivore	Inhabits ponds, reservoirs, streams with muddy bottoms to flowing or static water up to 4,000'. Five species
Anguillidae			
Anguilla sp.	Eels *Anda*	Piscivore	Rivers and reservoirs.
Cichlidae			
Etroplus Suratensis (introduction)	Mal *koraliya*	Macrophytes, molluscs	Adapted to a diet of macrophytes after being introduced into inland waters from its normal estuarine environment.

4.1.5 Stakeholder perceptions of catch compositions and volume

As is the case in most other Asian countries, capture fisheries management in Sri Lanka is either absent or very inadequate. Aside from the successive stocking of different tilapia varieties the fisheries can effectively be considered as unmanaged. Although there are statutory restrictions on types of gears and fishing intensity, enforcement is poor as is monitoring capacity. Co-operative societies are not very effective in Sri Lanka and conflicts with 'outsiders' very often internally displaced persons is increasingly common.

Trends of production loss due to these factors have been indicated by various authors. To gain further insight into the status of the inland fishery, professional fishermen, fish vendors and fisheries officials around three major reservoirs in Putallam District, were invited to share their perceptions of historic changes in the volumes and species composition of catches during their careers.

Box 2. Intensive fishing methods employed in the commercial capture fishery

The commercial reservoir fishery in Sri Lanka is essentially a gill net fishery. Current government regulations permit fishing with a minimum diagonal (stretched) mesh size of 3.5 inches (87mm) and no use of mono-filament, trammel or cast nets in medium or major systems (trammel nets are a highly efficient 'sandwich' combination of large and small gill net mesh sizes, selective for a wide range of fish sizes). Mr Piyathilalke (Fisheries inspector - MOFARD) conceded that there was little he could do to enforce such regulations and the law was widely flouted (fishermen using trammel nets and 2" (52mm) mesh sizes were frequently observed by reservoirs). In addition over recent years most fishermen have adopted an intensive fishing practice whereby they 'beat' the water with sticks or weights to drive fish into previously laid nets. Furthermore, most fishing is undertaken at night when fish are more susceptible to gill netting. Cover of darkness also lends itself to increased poaching, interference with competitor's gears and related conflicts.

Catch volumes: Long-time co-operative members stated that in the past (prior to the withdrawal of government patronage) fishermen were expected to record their daily catches and return them to the Department of fisheries (DoF) on a monthly basis. Respondents stated that catches were invariably reported low to avoid potential for loss of benefits through taxation or loss of subsidies. Despite its shortcomings, this system has not been re-implemented due to a continuing lack of manpower in the fisheries department. A fisheries inspector encountered at a local market reiterated the conventional view that catches declined dramatically after the withdrawal of government patronage in 1989, but could not say how such statistics could have been gathered in the absence of official record keeping. Relying on public transport and covering 10 administrative divisions alone, he conceded that the best he could currently hope to achieve was a proxy assessment of landings via visits to the main trading points within his area. All fishermen interviewed reported infrequent visits from government officials at landing sites.

Although fishermen and merchants concurred on long-term trends on species composition, they were less clear about trends in catch volumes. All fishermen agreed that the number of fishermen and intensity of fishing methods (Box 2) had increased dramatically over this period. One fisherman said that catches increased immediately post de-regulation but most other fishermen and vendors indicated that long-term trends were obscured by inter-annual variations and were only aware of seasonal trends. Such reservation is hardly indicative of the dramatic crash reported in landings after 1989. Rather than the immediate decline reported, one could expect an initial surge in landings accompanying de-regulation, followed by a decline over subsequent years as the effects of over exploitation and cessation of stocking were felt. In 1985 it was estimated *that O. mossambicus* comprised between 70-90% of inland landings (De Silva 1998), whilst available statistics show that a maximum of 10million fry per annum of mixed species were stocked prior to 1989 (Jayasekera 1989) a far from substantial amount. It is therefore unlikely that the withdrawal of the stocking programme could have contributed significantly to a crash where over 75% of landings were purported to have been lost by 1994.

Catch Composition. Whilst the true state of the fishery can only be guessed at, catches of indigenous species and carps have undoubtedly declined whilst it would appear that prolifically breeding tilapias have been far more resilient in the face of increased exploitation pressure. Several respondents independently suggested that the introduction of 'golden' (common) carp 10-15 years ago has coincided with the rapid decline of many indigenous species, including *puntius sarana*, *ompok bimaculatus*, giant snakehead, snakehead and in particular the endemic carp species *Labeo dussemiri*. The latter species was highly valued for consumption by villagers who confirmed it's recent decline in availability[7]. The real interplay of causes responsible for this decline requires further investigation, however secondary pressure from the tilapia gillnet fishery, which intensified dramatically over the same period likely to be one of the most serious culprits. Other environmental factors such as habitat modification and increased pollution have also been implicated. Agrochemicals applications especially those of pesticides, too have increased significantly over this period with most serious consequences likely to occur in the riverine spawning grounds of endemic species.

Further research is required to investigate consumer perceptions towards the various carp species, market conditions, yield potentials and stakeholder participation in villages where stocking programmes have been resumed and existed prior to the government 'ban'. Such villages are most likely to be in the proximity of one of the two operational government hatcheries discussed above. Results should be compared with a similar study in villages with no historical access to carp fingerlings.

4.2 Capture and culture fisheries in seasonal reservoirs

Sri Lanka is endowed with a vast area of seasonal tanks mostly below 20ha ranging to less than 1ha. Large numbers of these tanks have been rehabilitated under bilateral development programmes (Working Paper SL1.3). Such tanks are comparable in many respects to fishponds. They may dry up for 3-4 months of the year, usually between July-September, filling again by the following December to January during the Northeast Monsoon. Subsequent draw down tends to take place gradually over the next 4-5 months (depending on rainfall, evaporation and irrigation usage) with rapid drying occurring from June onwards. Such high turnover rates and the presence of vast draw down areas grazed by domestic animals makes such water bodies highly productive and ideal for extensive fish culture. Such tanks are also strategically located close to villages in rural areas, which are home to some the lowest income groups in the country. In the following sections, the traditional systems of subsistence management, more recent state intervention initiatives and the potential of different culture systems for enhancing production are examined.

4.2.1 Traditional management of seasonal tank fisheries

Traditionally, seasonal tank fisheries in the dry zone have been managed to exploit naturally recruiting stocks on a subsistence basis, in a highly extensive though sustainable manner. Historical evidence suggests that at one time male members of almost all families in a village would be involved in occasional fishing to supplement their diet. The main characteristics of this management system are presented below.

Ecology: The ecological set up of small tank irrigation systems favoured the survival of fish during the dry season. Fish surviving in larger tanks that retained a residuum of water could migrate upstream to colonise and breed in smaller seasonal tanks. Trees allowed to grow around and within the seasonal perimeter of the tank, provided: shelter against temperature extremes and the micro-climates required by certain species, Fallen leaves provided nesting materials, hide-outs and refuges from predators. Trees also provide direct and indirect provision of feed materials, through addition of leaves fruits and attraction of insects.

Traditional fishing methods: Although often relatively inefficient, these tended to be size and species selective, permitting juveniles to escape thus preventing over-exploitation of the fishery. During RRAs in NW Province, many farmers interviewed were still using the traditional wicker

[7] The wide popularity of this species which has similar eating qualities to many of the exotic carps, reflects a good demand that persists for these species alongside the more recently developed preference for tilapias (Working Paper ??).

traps (*karaka* and *kamana*) characteristic of this kind of fishery, though today, these usually only supplement more efficient modern gears.

Access arrangements: Under the smallest, often private irrigation tanks, only owners had fishing rights. Where tanks were common property resources only villagers within the village had the right to utilise the fisheries within them under the management of village assemblies. Conversely they often had no access to outside resources, compelling them to conserve the fishery resources within the village boundary. A family's right to fishes was determined by the extent of its paddy lands in the same way as the irrigation requirement for water (Working Paper SL1.3). The practice of collective fishing ensured equitable distribution of catches. This was undertaken under the leadership of the village irrigation leader (*velvidane*), an elderly member of a respected family whose principal duty was to execute the rules and regulations pertaining to the maintenance and management of the irrigation system. Fish were caught to supplement the household diet, very rarely for the market.

The *velvidane* was also responsible for imposition of fishing taboos, which conserved stocks prior to collective fishing. This also reduced potential for conflicts between groups using water for alternative purposes (Working Paper SL1.3). With the exception of rod and line all the traditional fishing techniques could be practiced only in shallow water and these methods have graphically been described as 'mud-fishing' (Fernando 1963). When the water level drops during the rice-growing period the *velvidane* imposed a prohibition on fishing. This also prevented muddying of the tank water (making it unsuitable for bathing and livestock consumption) and allegedly prevented the seepage of tank water through penetration of the bottom layer by fisherman's feet.

On a date set by the headman all able-bodied males were expected to participate in collective fishing using their own equipment. Catches were then divided amongst participants, 'respectable non-participant families, female headed families, the sick and the local Buddhist temple. This also had the benefit of reducing fish populations before mass death due to over-crowding could pollute the shrinking water body. Normally such fishing was restricted to the smaller tanks to conserve the water supply in the larger tanks for the dry season. This has the additional benefits of providing refuges for fish that will subsequently breed and migrate, so conserving diversity in the whole tank system.

Cultural attitudes: Various cultural beliefs also contributed to the sustainability of the system. A belief that it is wrong to catch fishes that struggle to survive in the mud, contributed to continuity of the fish community during the dry season. Other villagers looked down upon people breaking this taboo or upon those practicing fishing as a primary occupation. Such perceptions are still widely encountered (Working Paper SL1.3). Although fishing was not traditionally the preserve of any caste or social group in inland villages, a *Kawara* or fishing-caste originating from coastal areas continues to be one of the lower caste groups today.

Due to increased population pressure and the modernization and commercialization of agriculture, the ecological and social conditions that contributed to the traditional sustainable utilisation of fishery resources have changed dramatically over the last few decades. Local institutions have collapsed over the centrally planned economic era; traditional value systems have changed with the adoption of a market economy, whilst heavy reliance on agro-chemical inputs threatens the continued existence of many species. Consequently villagers now depend heavily on the external market for fish (Working Paper SL.1.4). Most villagers interviewed during RRAs were familiar with many of the customary practices, and some such as bans on fishing during the driest months, remain in operation, though most are being progressively abandoned.

Although many traditional practices may not be applicable today, the principles behind them may still be usefully incorporated into a new system better suited to the modern situation. Traditional subsistence systems were extensive and low yielding. Levies on more intensive culture-based fisheries might be used to fund maintenance of neglected tanks or for development of other village infrastructure. This could result in the whole community becoming stakeholders in the fishery, serving to strengthen social capacity in the process. However, unlike most other countries in South Asia, Sri Lanka lacks any tradition of fish culture at the small-scale farmer level and this knowledge gap is a critical constraint to the adoption of enhanced fisheries and aquaculture in seasonal tanks.

4.2.2 Fishery enhancement or aquaculture in seasonal tanks?

An enhanced fishery can be considered as an intermediary between fishery and aquaculture and can be defined as follows:

'Enhancement of the fish production of a natural or man-made water body, by manipulation of the existing fish population, and or optimalisation of the aquatic environment for fish production' Rothius (1993).

Box 3 shows three conditions where the adoption of such a fishery is justified all of which are highly prevalent in the Sri Lankan context. Such systems can give a good balance between investment in individual effort, physical resources and profit. This is an important aspect of risk management in seasonal tanks, which though highly productive have demonstrated highly erratic production levels in early trials. Essential for success are good community based organisations (a major constraint in the Sri Lankan context – Working Papers SL1.1 and SL1.3) and a reliable source of fish seed, which could be wild sourced (tilapia), or possibly produced in community-based hatcheries. Consequently it is recommended that more intensive aquaculture strategies are restricted to the production of advanced fingerlings and / or seed for seasonal tanks.

Box 3. Conditions for adopting enhanced fisheries rather than aquaculture (after Rothius 1993):

- Improvements to a traditional fishery will be easier accepted than the novel introduction of aquaculture for which the socio-economic, cultural and educational setting is not ready.
- Investment and production costs for conventional pond based aquaculture is too high.
- Regular stocking with fish seed is necessary to compensate for low natural recruitment, or disruption of recruitment in the case of seasonal water bodies.

Recognised methods for favorably manipulating the existing fish population are as follows

- *Environmental enhancements:*
    - *Physical modifications* i.e. hydrological modifications facilitating natural fish migration and recruitment or conversely reducing the risk of culture-based losses, construction of dry season refuges, environment modifications promoting habitat diversity (Working Paper SL1.3)
    - *Nutrition:* Enhancement of primary productivity through addition of organic and inorganic fertilisers. Rather than reliance on off-farm inputs, this might best be achieved through manipulation of livestock grazing patterns i.e. through improving pasture or placement of other attractants such as urea licks in drawdown areas.
- *Species composition manipulation*: Stocking of favourable species or selective removal of undesirable species. This aspect of enhanced fisheries manipulation is considered in the following sections.

4.2.3 Manipulation of prey-predator ratios in culture fisheries.

In the natural system indigenous carnivorous air-breathing fish surviving in residual refuges or migrating in rainy season spill waters re-colonise seasonal tanks (Working Paper SL1.3). These include *Ophiocephalus* spp. *Clarias tesymanni* and *Heteropneustes fossilis*. Another predator, the catfish *Mystus vittatus* survives drought by an as yet understood method. The first of these, the snakehead was found to be most significant in terms of yields from seasonal tanks. Predation pressure in seasonal tanks can be expected to be particularly intense, especially during the dry season when shrinking water spread and loss of vegetation in littoral areas makes prey species more vulnerable to attack from a wide range of fish, bird, mammal and reptile species. Farmers perceived this as serious constraint to early season stocking options.

To enhance fingerling survival, the earliest stocking strategies involved the eradication of 'nuisance' predatory fish species with biodegradable toxins. However this strategy was soon abandoned due to the expense involved and realisation that an almost equally valuable product was being lost.

> **Box 4. Traditional methods of poisoning or stunning fish (Siriweera 1986).**
>
> - Crushed leaves of the Timbiri tree (*Diospyros embryopteris*),
> - Crushed fruit of the Kukuru Maha bush (*Ranolia clumetorum*),
> - Kala Vael or creeper root (*Derris scandeus*).

Pet (1995) suggested that an alternative means of indirectly exploiting the substantial biomass of small 'trash' cyprinids in perennial tanks and reservoirs (section 4.1.4), would be to introduce a culture fishery based on large non-reproducing (i.e. fully controllable) predators with high commercial value. Introduction of naturally breeding species would be highly risky within perennial tanks. With the exception of low densities of *Channa striata* and *Ophiocephalus spp*. large predators are reported to be hardly present in Sri Lankan reservoirs and smaller species are not popular with consumers. Naturally recruiting indigenous pisciverous species contributed 5% of total weight in experimental catches (Pet and Peite 1993) and have only a small impact on minor cyprinid populations in larger perennial systems at least. A good candidate is suggested as *Lates calcarifer*, an estuarine predator that grows well but does not breed in landlocked situations (Sennanayake and Fernando 1985). This is a prized consumption species all over Southeast Asia though unknown in Sri Lanka. Pond experiments with a close relative *L. niloticus* have been shown to have a positive effect on the stunting of *O. niloticus*. However, Pet (1995) estimates that the resulting increase in catch from this option would be an order of magnitude lower than the direct exploitation of small cyprinids. Therefore such a strategy would have little relevance to poverty focussed development programmes, especially where other lower input, direct means of exploitation are possible.

Current research indicates the situation may be very different in seasonal tanks where many farmers report productivity levels of snakehead (*O. striatus*) can come close to matching those of tilapia under certain conditions. Further research is therefore required to assess the positive and negative impacts of prey - predator interactions on fisheries enhancements in seasonal tanks, particularly with respect to snakehead The following areas are recommended for further investigation.

- *Interactions of different species combinations*: i.e. high predation pressure on tilapia may reduce stunting, whereas reduction of predation pressure would favour carp production. Several farmers reported feedback in the opposite direction, observing that tilapia also consume the eggs and juveniles of the snakehead *O. striatus* (Working Paper SL1.3).

- Contribution of indigenous 'trash' species (i.e. *R. dandonicus* and *A. melletinus*) to predator diets and predation pressure on different size cohorts with respect to potential protection conferred through the stocking of advanced fingerlings.

- *Methods of manipulating prey-predator ratios:*
  - Locally available plant toxins instead of more persistent and expensive inorganic toxins used to eliminate prey species (Box 4). These plants tend to stupefy rather than kill allowing selectivity in species removal.
  - Selective fishing methods (i.e. use of the traditional, traps or gill nets to remove larger predators throughout the growing season.
  - Removal of residual water (i.e. by pumping or bailing) in smaller semi-seasonal water bodies where bathing or other water uses are not a priority, or seine netting of residual waters.
  - Screening of spill waters during the rainy season – this is likely to be impracticable during major spill events that are associated with the largest migration events.

- *Cost benefit analyses* to calculate the optimum ratios of prey-predator populations in respect of market price, stocking costs and effort required to manipulate ratios.

- *Cultural perceptions* to removal or elimination of prey species.

Such manipulations will have varying consequences for the fisheries in tanks at higher and lower levels in cascading tank systems (Working Paper SL1.3) which should be carefully assessed. These may be positive i.e. recruitment of escaped stocked fingerlings, or negative i.e. impediments to the natural movement of fish through the cascade during spill episodes.

The impacts of wild sourcing large numbers of young fish on the donor systems must also be considered. Welcome and Harborg (1977) note that in certain circumstances, such as floodplain fisheries, a considerable proportion of the young of the year can be removed due to overproduction of 0+ fish from such fluctuating systems. This suggests that there would be no likely conflict in the collection of seed from seasonal spill events. However fish populations in regulated rivers, lakes and reservoirs are less tolerant of large-scale removals. The removal of small numbers of fish and fry for in-situ breeding purposes as proposed in this instance are less unlikely to have any serious impact on tilapia populations with their prolific breeding rates. However, where these fry are netted from the same littoral nursing grounds as other endemic species in perennial reservoirs, there may conceivably be more detrimental impacts (section 10).

4.2.4 Stocking programmes in seasonal tanks

This is the most common means of manipulating fish populations. Stocking is defined as; 'a management measure undertaken to enhance and optimise the yield of lacustrine species' (Bhukswan 1983). Welcome (1976) suggested the following criteria for deciding on the suitability of a stocking programme:

1. Stocking is usually not economical in larger bodies of water where excessive numbers of fish must be stocked to achieve a balance between stocking and capture, or where natural reproduction of a variety of species occur (see section 4.2.3).
2. Continuous restocking of large lakes and rivers is only practiced when the species is of great value, or the juveniles do not require an expensive high protein diet.
3. Stocking is most useful for the management of small or seasonal waterbodies.

Suitable species for stocking should be able to utilise naturally available food resources within the tank and reach an acceptable size for local consumers within 6-8 months. Zooplankton species diversity and its relative contribution to the plankton population is low in Sri Lanka, consequently there are no true indigenous Zooplankton feeders. This suggests that phytoplankton specialists will perform best though again few candidates exist in the indigenous fauna. Results of preliminary trials with *Labeo Dussumieri* and *Barbus sarana* resulted in poor survival and small harvest sizes. The choice then becomes one between the faster growing exotic carps and tilapia. Unlike the tilapias, all the carps are sub-tropical species, and none have been proved to be able of breeding successfully at this latitude (see section 4.1.2). Therefore each of these species requires continual restocking. The potential of these two groups and indigenous candidate species are considered in the following sections.

4.2.5 Suitability of indigenous species for aquaculture in seasonal tanks.

Unlike the tilapias, most of these species are seasonal spawners and must migrate back up to their natural riverine environments to breed. Many of the species dependent on these habitats have gone into dramatic decline over recent decades.

With the exception of *Etroplus suratensis*g that feeds on macrophytes but can also subsist on molluscs, all the other Sri Lankan Primary consumers are cyprinids. With the exception of *L fisheri* a very rare mountain species, the largest of these fishes (greater than 25cm standard length) are *T. khudree*, *L. dussumieri* and *L. porcellus*. *T Khudree* is essentially riverine and only rarely do larger specimens descend to reservoir areas. *L porcellus* is the only true marsh species it's suitability for aquaculture has not been investigated. *L dussumeri* is primarily a benthic detrivore, primarily of rivers, and still has a place (though rapidly declining) in the perennial reservoir fishery. It is also the only indigenous primary consumer to be investigated for aquaculture potential. *L dusumeri* It is a phytoplankton feeder and induced breeding is straightforward with good fry survival rates. However it's slow growth rate (300g per annum) make it a poor candidate for culture in seasonal tanks.

Of the secondary consumers, *Channa striata*, *Ophicephalus striatus* and *clarias bartrachus* have been identified as candidates for semi-intensive culture. These species prefer shallow marshy marginal waters therefore are more suitable for smaller tanks than a pelagic reservoir fishery. However, as piscivores they are expensive to feed and unsuitable for extensive culture unless large numbers of 'trash' fish are available (section 4.1.4). *Ophiocephalus striatus*, *anabas testudineus* and *Heteropneustes fossilis* are air-breathing predators and are extremely important in the ecology of seasonal tanks. The snakehead *O. striatus* is a high value species with high demand and it's predation pressure may inhibit the stunting of tilapia in confined seasonal tanks. The minor cyprinids *Rasbora daniconius* and *Amblypharyngodon melatinnus* are unusual in that they are capable of breeding in cascade systems. Farmers reported that numbers of *R. dandonicus* increased in relative prevalence with movement up the cascade reflecting its tolerance to a range of environmental conditions.

Mystus vittatus, a small cat- fish and predator in adulthood is also capable of breeding in tanks and surviving drought conditions by a method not yet understood (Ulluwishewa 1985) though its small size means it is only moderately popular with consumers (Working Paper SL1.4).

These species present few opportunities for poverty focused culture-based fisheries. However species capable of breeding naturally in cascading seasonal tank systems may yield important by-catches in tilapia/carp culture systems.

4.2.6 Carp polyculture in seasonal tanks.

The potential of the seasonal tank resource for increasing inland fisheries production was identified as early the 1960's though extensive trials based on the recommendations of an FAO/UNDP mission which aimed to produce a national development strategy, only commenced in the early 1980's. The mission recommended a seven species combination; Chinese carps (bighead and grass), Indian major carps (catla and rohu), tilapia and milkfish, as suitable stocking candidates. Mrigal, silver and grass carp and the indigenous carp; *Labeo dussemiri* were subsequently included. Results of stocking trials employing combinations of these species under a variety of different tank conditions are summarised in Table 3. Despite promising early results, for reasons that will be discussed the modern state continues to be incapable of harnessing this resource effectively in a manner comparable to the perennial fishery.

Early experiments were undertaken with carp polycultures. Grass, bighead, silver carp, catla rohu and mrigal were stocked in equal proportions envisaging the utilisation of all possible feeding niches in the water body. Chandrasama and Kumarasiri (1986) collected results from 15 community managed seasonal tanks practicing such a fishery where entire stocks were harvested using encircling nets (5-8cm fingerlings were harvested after 7-10 months). Yields based on 50% of max waterspread, ranged from 220 to 2300 kg ha^{-1} (mean 892 kg ha^{-1}). Although results were extremely variable between reservoirs and years, the potential of this approach was demonstrated. Chakrabarty (1983) suggested that a stocking density of 2,000 fingerlings per ha^{-1} could produce an average yield of 0.75-1.0mt/ha^{-1}. Amarasinghe (1998) proposed the equation shown in Box 5 to estimate the number fingerlings required to stock a typical seasonal tank. The lower table shows worked examples for composite culture of six exotic carp species using data collected by Chandrasoma and Kumarasiri (1986). Species with high mortality rates produce low yields and high stocking rates are wasteful for such species. Bighead (*A. nobilis*) and Rohu (*L. Rohita*) show the lowest mortality rates, highest yields and therefore a requirement for higher optimal stocking densities. Amarasinghe suggests this model could be used in community-based fisheries to progressively optimise stocking densities based on historic harvest and stocking data.

Box. 5 Model for estimating optimal fingerling stocking density for seasonal ponds (Amarasinghe 1998) and worked examples for six exotic major carps (source data Chandrasoma and Kumarasiri 1986).

$S = (1{,}000\ Y/W) \exp(Z\,\Delta t)$,

S = No. of fingerlings to be stocked per ha,
Y = Potential fish yield of reservoir (Kg ha^{-1})
W = Mean weight of fish at capture (g)
Z = Instantaneous rate of total mortality
Δt = Culture period in years.

Species	Mean Z (range)	Mean yield (Kg ha^{-1})	Est. Stocking (fish ha^{-1})
A. nobilis	0.97 (0.41-1.97)	302.1	965
C. catla	1.19 (0.44-1.93)	108.1	163
L. rohita	1.10 (0.09-1.99)	205.3	732
C. carpio	1.93 (0.16-1.81)	139.6	607
C. mrigala	1.14 (0.29-2.42)	111.3	512
C. idella	2.39 (0.81-4.44)	27.7	194

Note: Z based on Δt of 0.75yrs.
Data collected from 15 reservoirs.

Chakrabarty (1983) presents production summaries of the earliest stocking trial undertaken in seasonal tanks (Table 3). Stocking consisted primarily of polycultures of carps in seasonal tanks. Other species employed in stocking trials included tilapia and milkfish (*chanos chanos*). Common and grass carp performed poorly, yielding from 8 to 64 kg/ha/yr, with stocking densities as high as 5,000/ha. Such variability was attributed to poor survival of fingerlings with slow moving carps being more susceptible to predation. This is particularly true of common carp, whose tendency to browse at the margins increases it's susceptibility (this species is perhaps more suitable for stocking in deeper tanks). In poorly managed tanks, the net result is production of a small number of fish of high average weight. Poor availability of submerged vegetation also compromised grass carp performance. *Labeo dussemiri* and milkfish showed both poor survival and poor growth rates (milk fish were observed being harvested from coastal tanks in Hambantota district during this study). Of all the species utilised, Bighead carp demonstrated the best performance achieving over 1 ton/ha in composite yields of polycultures. Average harvest weights rarely dropped below 0.5kg, reaching as high as 2kg in some instances. Thus although tilapia yields were greater in certain instances, bighead were of a more marketable size, resulting in greater reported profits. These results are largely in agreement with Amerasinghe's later findings. De Silva 1983 suggests a return of 35-40% of the stocked number is required to make a stocking programme viable.

Subsequent trials (Tenekoon *et al* 1989) found an improvement in common and grass carp performance when stocked at sizes above 10cm (3-5cm fingerlings being the norm in earlier trials) at which point they are better able to resist predation. In the case of grass carps larger fingerlings are better able to able to utilise macrophytes and juveniles of 18-24 cm are best able to utilise encroaching aquatic weeds such as *Salvinia molesta* which reduces the overall productivity of many small tanks in the dry zone (Working Paper SL1.3). Such encroachment also makes tank harvesting extremely difficult. By bringing partially digested vegetable matter into the food chain, grass carp can also increase the productivity of seasonal tank systems to the benefit of other species. It is recommended that further research is undertaken on the potential of this and other macrophyte consumers to counter the increasing incidence of such encroachment.

More recently Creech (2001) reported yields from 3 seasonal tanks in Southern province (6, 8 and 12ha) stocked with big-head, rohu and common carp (totals of 252-774/ha) ranging from 373, 675 and 8 kg/ha respectively. The highest yield was obtained where a staggered harvesting rather than single collective harvesting event was adopted. Stocking interventions in two larger perennial tanks (20 and 39ha) with established tilapia gill net fisheries failed completely, yielding only a small number of juveniles early in the season. Fishermen here were unwilling to change to larger gears, which may have permitted increased carp production. These observations again reflect the incompatibility of self-sustaining tilapia fisheries and culture-based carp enhancements. In the most successful tanks, bighead carp which grew most rapidly under local conditions constituted some 46-78% of the catch, but their continued use was declined by fishermen due to poor consumer preference and associated marketing difficulties. The relative performance of Rohu and common carp were also comparable to the findings of Chakrabarty (1983) and Amerashinghe (1998). Other reported production constraints included sub-optimal stocking levels, aquatic weed encroachment / submerged obstructions and high predation levels from marine birds.

Table 3. Fish production from polycultures in seasonal tanks under the UNDP/FAO programme 1979 to 1983 (after Chakrabarty 1983)

Year	Tanks Stocked	Water area (ha)	Yield Kg/ha	Tanks > 500kg/ha	Tanks @ 250-500 kg/ha	No. Aband -oned	Remarks
1979/80	5	26.7	615	3	-	1	3 seasonal tanks
1980/81	23	31,323	226	10	6	1	20 seasonal tanks
1981/82	53	27,565	155	6	8	28	26 seasonal tanks. Severe poaching. And drought losses. Harvest impeded by rains.
1982/83	76	46,858	228	11	9	21	72 seasonal tanks. Severe drought, early harvesting.

Notes: All tanks with areas of 5-6ha at FSL within the Lowland dry zone.
Severe drought in 1981/82//83 resulted in premature harvesting or abandonment of many tanks.
Fertilisation, feeding and liming of tanks took place only rarely in any of these trials, reflecting the high natural productivity of these systems.

In the absence of replicable trials of different polyculture combinations in the Sri Lankan seasonal tank context, it is recommended that equal numbers of available species with complementary i.e. non-overlapping feeding habits should be stocked. The following combinations should be avoided; bighead and catla, mrigal and tilapia. Chakrabarty (1983) recommends that catla and silver carp should be stocked in a ratio of 2:1. Short growing seasons with receding water spreads, mean that stocking densities at full supply level (FSL) may be kept low, or conventional stocking densities based on 50% water spread as a rule of thumb. The Ministry of fisheries recommends a density between 1,500 and not exceeding 2,500 fingerlings ha-^{1} using equal numbers of available species. Chakrabarty (1983) found poor correlation between stocking density and production despite losses to predation with stocking densities of less than 1,000 /ha^{-1} and 2,500 /ha^{-1} giving comparable yields of approximately 0.5mt/ha^{-1} in many instances. Where aquaculture becomes more intense with the addition of supplementary feeds and fertilisers, this figure should be increased.

4.2.7 Tilapia culture in seasonal tanks

Consumer preference for tilapia is far greater than for carp and it's seed can be wild sourced reducing the financial risks involved in fish culture for poor farmers. Potential for stocking in seasonal reservoirs requires further investigation.

De Silva 1998 suggests that the tendency to switch from somatic to gonadal growth with consequent stunting is largely a function of stocking density and this can make tilapia unsuitable for seasonal reservoirs. *O. mossambicus* will stunt at a smaller size than *O. niloticus* under similar stocking conditions (Amarasinghe pers comm). However in the 15 reservoirs used for carp culture experiments described in the previous section, catches of *O. mossambicus* which had entered naturally through adjoining waterways, ranged from 0.4 to 408 kg ha^{-1} indicating good potential. Where tilapias are stocked in small waterbodies, the relationship between stocking levels, waterspread and harvesting policy must be considered carefully. Photoperiod and light intensity influence early maturity (Balarin 1979) and *O. mossambicus* females may spawn whilst still as little as 5cm in length. Precious breeding under conditions of low water availability and low oxygen could impact negatively on other species combined in polycultures. Periodic harvesting of larger individuals is advisable under such circumstances. De silva (1988) suggests that the size and density of nest sites can be used as an indicator of the condition of the population.

A seasonal harvest using gill nets was observed taking place in a seasonal tank near Dambulla (North West Province). Although described by villagers as dry (meaning as it transpired for irrigation purposes!), a substantial area of shallow water remained which acted as a refuge for self-recruiting species, including tilapia. We were informed that carp had been earlier stocked and harvested. Only tilapia (150-500g) and snakehead remained, which were being harvested in sizeable quantity and at a ratio of 50:3. This would suggest that the predator was reducing the incidence of stunting in the tilapia population. Competition for nest space will also feed back negatively on recruitment in receding water bodies. The cost effectiveness of carp polyculture must be compared with that of tilapia stocking alone (see section 4.2.7)

In earlier government funded stocking programmes *O. niloticus* rather than *O. mossambicus* was the species predominantly stocked, despite the faster growth rate and propensity of the former species to stunt at a larger size. Chakrabarty (1982) reports that production levels between 440 and 550 kg /ha/yr. were achieved after stocking O. niloticus alone. Only in one trial were size distributions recorded, where three different size groups of *T. niloticus* were harvested after 6 months culture with average size 104cm and the smallest size around 5cm. It is unlikely that such fish are accounted for in the production statistics. Appraisal of performance is further complicated by the likelihood of carry over of residual populations from previous seasons or migrations in floodwaters. This results in further complication in respect to the determination of suitable stocking densities.

4.2.8 Polyculture of carps and tilapias in seasonal tanks

Table 4 shows the results of stocking four seasonal tanks with various combinations of carps and tilapias. In two of the tanks it will be noted that tilapias contributed significantly to the catch even where they were not included in the stocking programme. The variation in total yield in part reflects the wide variability in stocking practices. However in most of the tanks the total yield and the contribution of carp species was high showing a good return on stocking. Because of the relative ease with which they can be produced, it is likely that only common carp and tilapia will be the species widely utilised in community fingerling production programmes. Although juvenile tilapia have the unique ability to consume blue green algae the species may switch between phytophagy, zoophagy and detriphagy thus some overlap with the feeding niche of other specialists other than macrophyte feeders will exist. However it is likely that polyculture will result in a net increase in production over individual populations of carp or tilapia stocked alone. The high contribution of the indigenous *Labio dussemiri* is also notable in this instance.

Table 4. Stocking and harvest summaries for polycultures in 4 seasonal tanks in Hambantota District (Source Beveridge et al 1986).

Tank size (ha)	Stocking totals (by species*)	% Yield by species *	Total catch (kg)	Kg/ha
10	8,000 (cc,r,bhc,m,ga)	t =28, r =39, gc =18, cc =5, bhc =10, m =0.5	7852	785
5	1,600 (100gc, 300bhc, 500sc, 600cc, 100t)	cc =21, gc =31, h =38, sc =11	530	106
2.5	2,400 (900bhc, 1000cc, 500gc)	bhc =15, cc =46, gc =24, t =16	2850	1032
2.5	500gc	carps, tilapias	1000	400

* Species details: t = tilapia, bhc = bighead carp, gc = grass carp, cc = common carp, r = rohu, m = mrigal, h = *Labeo dussemiri*.

4.2.9 Reasons for poor performance of the UNDP/FAO seasonal tank-stocking programme

Over the whole 4-year cycle of the UNDP/FAO program (1979-1883) production from the seasonal tanks averaged slightly over 200kg/ha. Natural productivity levels of 50-150kg/ha/yr reported by Mendis (1977), are only slightly lower than this level. However this figure masks extremely high regional and seasonal variation, with a maximum yield 2,594kg/ha/yr. achieved in one instance. The principle reason for the generally poor performance was the highly erratic water availability during the trial period. Severe droughts were experienced during the 1981/82 and 1982/83 seasons when the largest numbers of tanks were recruited into the programme (Table 3). This resulted in premature harvesting or abandonment of the harvest in many instances and reductions in the scope of the programme. Conversely in some cases, heavy periodic rains impeded harvesting of the tanks. Whereas little could be done to overcome such climatic variability, deficiencies in tank management were more avoidable. Chakrabarty (1983) noted that in many instances little effort was expended on prevention of stock losses through poaching, predation by birds and animals and escape of stock through sluices and spill ways. Thayaparan (1982) also noted that poor preliminary tank surveying; data collection and documentation have limited the usefulness of results. Whereas it has been possible to draw comparison between different species combinations and tank areas, little inference can made regarding other production variables, including a wide range of factors affecting natural productivity i.e. soil type, morphometry, catchment characteristics, livestock resource flows, aquatic weed encroachment etc.

Trade-offs between productivity and tank seasonality were revealed during the trials, from which lessons for tank selection and management were drawn:

- Tanks that retain water for longer periods are less desirable in terms of tank preparation i.e. regarding removal of predators, tank bed obstructions, etc resulting in poorer ability to harvest the tank effectively.
- Smaller tanks (0.4-4 ha) give better yield per unit area due both to their higher manageability and natural productivity; more complete drying of the tank bed also improves mobilisation of nutrients and increases the relative area available for cattle grazing.
- In many instances extension of the growing period beyond a six-month period i.e. growth windows commonly experienced in the smallest seasonal tanks, did not give correspondingly higher yields, though insufficient controls were in place to explain the cause of this observation.

The two principal criteria for tank selection should be duration of water retention of adequate depth, the latter characteristic being more critical for maintenance of high productivity levels. Chakrabaty (1983) suggests that only tanks retaining a minimum of 1m of water depth for at least 6 months should be selected for aquaculture purposes. A compromise will exist between optimal tank size, manageability and seasonality. The upper limit will also be determined by water retention. In this instance, the extent to which the tank dries up to facilitate harvesting at the end of the growing season and this limit will be increasingly critical as culture becomes more intensive. Thayaparan (1982) suggests that tanks with an effective area (i.e. at least 1m depth) between 0.2 and 20ha are likely to be most suitable.

The likelihood of suitable water retention could be predicted from the amount of water stored in the tank at the end of the rainy season and historic data on drawdown for irrigation purposes. This would allow smaller productive but highly seasonal tanks to recruited for stocking during wetter years. However where community advanced fingerling production programmes are envisaged such predictions must be made several months earlier. In this respect linkages between communities at wider cascade level would be beneficial (Working Paper SL1.4) giving potential for selective stocking of larger and smaller tanks depending on the outcome of the seasons 'rain harvest'. It is recommended that further research should be undertaken to examine the relevance and potential of establishing such community fingerling production programmes at the watershed level.

4.2.10 Harvesting options in seasonal tanks:

As stocked fish will not grow uniformly periodic netting or 'staggered harvesting' of table size specimens is likely to yield the greatest net returns. This occurs through a reduction in intra and inter-species productivity, reducing poaching losses and spreading the marketing over a greater period of time hence increasing both yield and profitability. Staggered harvesting of small quantities of fish is also likely to increase the amount of fish consumed locally (Creech 2001). The periodicity of harvesting will be related to water retention, density and species ratios stocked and feed availability. Conventional harvesting patterns are based on a collective effort usually over 1-3 days at the height of the dry season when catch effort is lowest. Much of this harvest takes place during two months between July and August, when production from the Perennial tank fishery is also at a maximum and seasonal prices lowest. Constraints to staggered harvesting regimes include increased labour requirements and more critically, potential for creating conflicts with other water users, especially bathers and irrigators (Working Paper SL1.3)

Driving fish into seine and gill nets requiring a collective effort, represent the most effective way of harvesting seasonal tanks. Seine nets should be rigged with bottom weights to catch bottom dwellers including predators such as snakehead. This will be facilitated in tanks with fewer obstacles on the bottom or encroaching vegetation. Dramatically improved rates of harvest are demonstrated where complete drying takes place.

5 Strategic development plans for reservoir aquaculture and fisheries

Since the mid fifties, successive governments have completed six planning cycles aimed at enhancing the productivity of the inland fisheries sector. Most of these plans were indicative and merely served to strengthen the role of the public sector under a centrally planned economy. The last three plans contained a seasonal tank development component, all of which met with limited success. Details of the principle components of these programmes are presented below:

1978-1983. A five-year government development plan drawn up in 1978 foresaw a rapid increase in consumption from 11.3kg per person in 1977 to 20kg in 1983. At the end of the plan production levels of 30,000 13,800 and 8,000mt were estimated to come from major tanks, seasonal tanks and brackish water respectively. Inland production from perennial systems rose from 16,700 to 25,000mt over this period, whilst seasonal tank production failed to yield any growth. This was attributed to institutional weaknesses, resulting in poor cooperation between research, extension and training programmes and limitations in seed production capacity.

1984-1989: After a UNDP funded experimental feasibility study evaluating the production potential of seasonal tanks; the Asian Development Bank (ADB) financed the 'aquaculture development programme of Sri Lanka'. Commencing in 1984, this envisaged production being enhanced in some 10,000 ha of seasonal water spreads over a 5-year period. This was to be achieved through increasing the fingerling production capacity of inland fish breeding stations, improving technical capacity and strengthening of extension services. This plan depended on the annual production of 20 million fingerlings. As less than half this figure was produced and this was destined for both major and seasonal tanks, the programme failed to meet its objectives. Never the less, overall production continued to rise substantially during this period (peaking at

40,00mt in 1989. The main contribution continued to come from the perennial reservoir capture fishery. This can be attributed to an increasing number of entrants and the provision of over 4,519 fiberglass canoes (up to 1990) under a producer subsidy scheme, which served to intensify the fishery. The programme also included 50 pond excavation subsidies, which attracted limited uptake and no sustained production in the wetter hill country (see section 7). Under the aborted 1990 master plan, some 340 perennial reservoirs (12 – 5,330ha) in 24 districts and 233 seasonal village tanks in 14 districts were to be stocked with some 8million Indian carp fingerlings. It was envisaged that this would increase inland yields by 8,500mt.

1995-2000: In 1994, the 'ban' (section 3.4) was reversed by the present Government. Thereafter the Aquaculture Development Division (AQD) of the Ministry of Fisheries and Aquatic Resources Development (MOFARD) was established. This body has produced another 5-year 'Aquaculture Development Plan 1995-2000', a strategic plan for the aquaculture sub-sector, which has the following primary objectives:

- 'To increase freshwater fish production as a cheap source of protein for rural communities.'
- 'To promote income generation and create employment generation activities through aquaculture and inland fisheries.'
- 'To improve GDP through the export of high value species.'

Major functions of the AQD will include seed production, stocking of water bodies, training of personnel in aquaculture practices, development of adaptive research, creation of awareness in environmental aspects and transfer of technology to the private sector.

Seasonal tanks: The AQD perceives shortage in fingerling nursing capacity and the fostering of an inefficient dependency culture based on the earlier policy of free seed supply as the major constraints to increased production in seasonal tanks. In line with current trends in economic liberalisation, the AQD aims to address the problem through stimulation of private sector production. NGO's are being encouraged to work with the government sector to stimulate community based seed production programmes. These will employ pond based 'mini hatcheries' and cage grow-on of fingerlings in perennial water bodies. In the absence of any existing private sector market for seed, the government has undertaken to continue supply of free seed to on-growers and will guarantee to purchase back all fingerlings produced. Indian carp varieties and training will be supplied from the recently revitalised aquaculture centers at Udawallawe and Dambulla Other incentives such as tax holidays, duty free imports and proportionate reduction in lease rentals are also envisaged for the promotion aquaculture ventures. These benefits will be phased out over a fixed period until the envisaged market develops.

Perennial Reservoir fisheries: The three main components of the development strategy are:

- Conservation of the tilapia fishery. Envisaged to be close to MSY, emphasis will be on strict adherence to mesh regulations and fishing effort controls rather increased production.
- Development of subsidiary fisheries for minor cyprinids and clupeids (section 4.1.4).
- Development of culture based fisheries of Indian and/or Chinese carp, based on the population dynamics models being refined by local scientists.

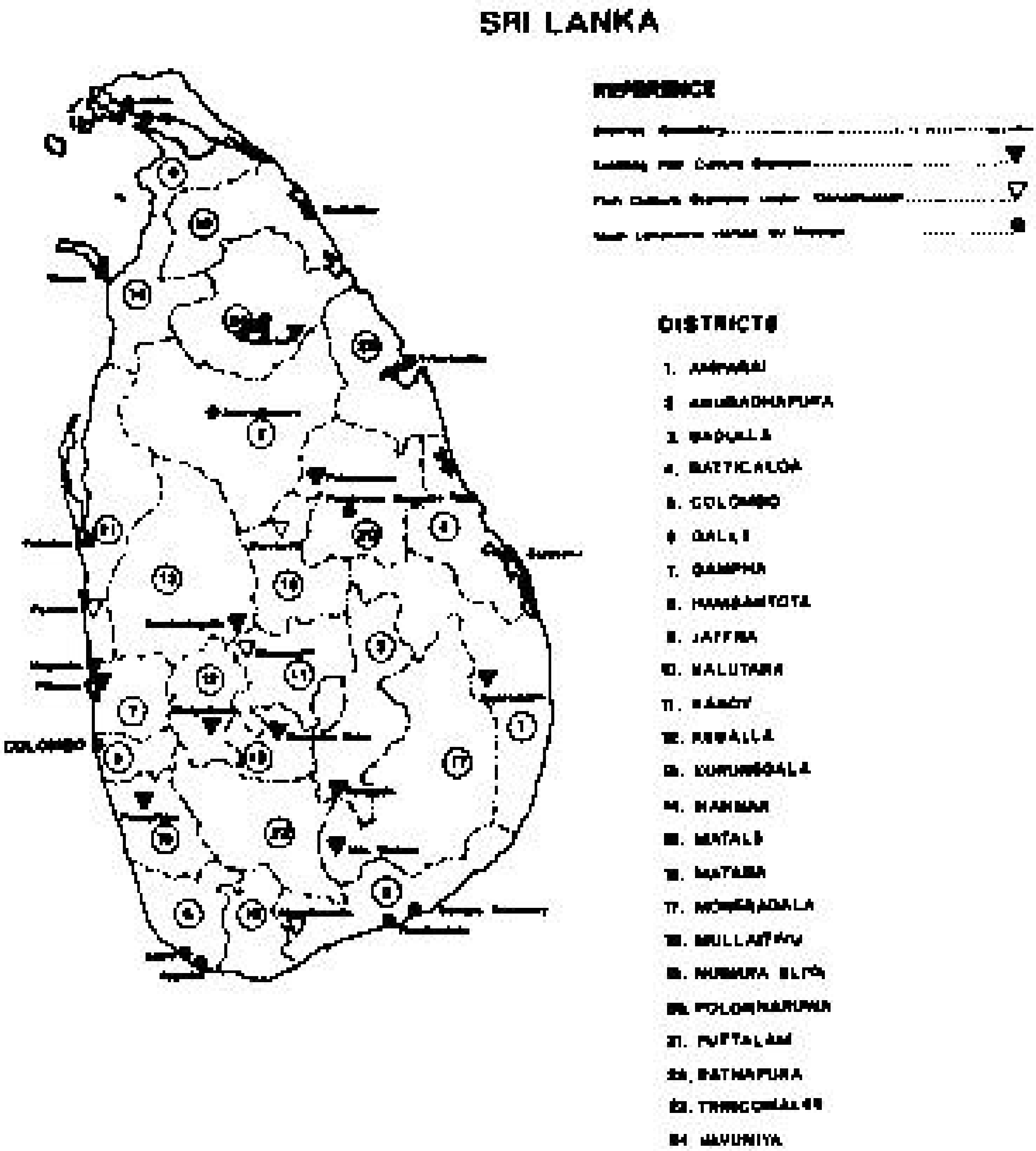
In addition to aquaculture in seasonal tanks, the Department of Agriculture (DoA) and the National Aquatic Resources Agency (NARA) are researching integrated agri-aquaculture options including 'fish in rice' systems. Options are to be tested for their suitability in the three major agro-ecological zones of the country (Working Paper SL1.1).

6 Seed production capacity in Sri Lanka

Between 1968 and 1980, available statistics show that less than nine million fry were stocked (Thayaparan 1982). This increased from 5 million in 1982 to a maximum production of 10 million fingerlings per year in 1989, a still far from considerable amount and indicative of a poorly planned stocking programme. This poor availability imposed a selection bias on UNDP/FAO stocking programme, most of the tanks selected being in close proximity to government breeding stations.

In 1989, eleven freshwater breeding stations in operation under the then Inland Fisheries Division, were privatised. A legal obligation remained with owners to retain limited production capacity for food species. However most hatcheries switched entirely to ornamental fish production, severely depleting broodstock resources in the process. To increase capacity the government has taken back four privatised breeding stations; Udawallawe (Southern province), Dambulla (Central province), Inginamitya (Uwa Province) and the Nura Eliya trout hatchery in the hill country (now switched to common carp production). Several others are in the process of reversion. At the time of writing, only the first two of these stations were operational and only Udawallawe close to capacity, the other units requiring major rehabilitation. Locations of these and the other former state operated stations are shown in Figure 5. Since 1995 government and residual private sector production amounted to only 3.3 million carp fingerlings and 1 million tilapia fingerlings (Amarasinghe 1998).

Figure 5. Locations of inland fisheries stations (state and private sector) in Sri Lanka (ADCP 1980).



Under the current fisheries development plan, a target of 10k ha of seasonal reservoirs will be developed for culture-based fisheries. Assuming an optimal stocking density of 2,000 fingerlings ha^{-1} for carp polyculture, this will require the annual production of 20 million fingerlings. Maximum capacity is estimated currently estimated at 5 million fingerlings per annum, when the existing stations become fully operational (Jaysekea ADQ Pers Comm). This obviously still leaves a major deficit. Furthermore transport limitations mean it is unlikely that fish can be grown to the optimal predator resistant size in these stations, without access to more decentralized fingerling nursing facilities. However, little incentive exists for the private sector to convert production facilities for food fish production in the face a much more lucrative and guaranteed ornamental market and as most of these stations are long leased the government has little potentia l for increasing capacity in the near future.

Government hatcheries currently maintain the following broodstocks: Tilapia (*O. mossambicus and O.niloticus*), Catla, Rohu, and small amounts of mrigal, common, grass bighead, and silver carps. Some of these represent residual 'pre-ban' broodstocks, additional carp broodstock have been imported from India and red tilapia was imported from Thailand in 1996. The possibility of importing GIFT tilapia (ICLARM) is currently under review, though it's role in the Sri Lankan context is unclear. Broodstocks of the indigenous *L dusemerii* are held at both hatcheries though negligible seed production currently exists. In the private sector, principle ornamental species produced include; goldfish, guppies, angels and gouramis. Mostly destined for export, these stocks generated some Rs 300 million FOREX last year (Jayesakara pers comm).

Indian carps and Chinese carps are produced in Udawallawe (Southern Province) and Dambulla (North West Province) respectively due to their favourable local water conditions. Each station also holds a reserve broodstock for the other. Both hatcheries are constrained by a surplus of broodstock holding capacity at the expense of fry and fingerling nursing capacity. Currently fry and post larvae are offered free for stocking or on-growing purposes, but demand significantly outstrips supply and stocking practices are based on fingerling availability rather than sound management practices. Sustainable adoption of culture-based enhancement strategies by communities managing seasonal tanks requires assured access seed supplies. Many instances of sporadic stocking attempts were observed during field tours. Initiated in every instance by external development organisations, interventions ranged from 1-3 years in duration. Activities were either terminated with withdrawal of the intervention agency and with it assured seed supply, or equally commonly due to unforeseen access conflicts associated with poor pre-intervention stakeholder understanding (Working Paper SL1.3).

6.1 Community-based seed production programmes.

In an attempt to overcome seed deficits through implementation of community based seed production initiatives (section 5), the government is working directly with the following NGO's: Small Fisheries Federation, FORUT and IMMI funded programmes in the NW, Sewa Lanka, Sri Lanka Candian Development fund (SLCDF) and German technical cooperation) GTZ in the south (see Appendix 3). The government is implementing a sixth programme in Anuradhapura District. Initiatives will focus on common carp and tilapia production, which can be bred through much of the year, without a requirement for hypophysation. Most of these programmes are still in the inception phase. SLCDF and small fisheries production programmes were visited during the course of fieldwork. Lack of technical capacity was identified as a major constraint. More seriously lack of effective participation and control by community members also raises doubts as to the sustainability of these initiatives. In a third instance a farmer had abandoned fingerling production after receiving only partial payment under the government buy back scheme.

In reality the likelihood of individual communities adopting 'community-based' seed production or even nursing activit ies is low due to the unfavorable economies of scale associated with production in small seasonal tanks ranging from 0.2-20ha identified as suitable for such enhancements (section 4.2.4). Such options also imply intensive to semi-intensive or intensive production systems with a correspondingly high requirement for feed and labour inputs, high risk options in themselves, but especially so in the context of a subsequent grow-out phase in a common property resource typically having poorly enforceable access restrictions. Scaling up with federation of such communities into more viable seed production units also appears unlikely at least in the short term due the weak institutional context (Working Paper SL1.1), socio-cultural barriers to such inter-community cooperation (Working Paper SL1.3) and uncertainties over assurances related to Government fingerling by-back schemes.

In the meantime NGO efforts remain poorly coordinated and production orientated with poor cognizance of the lessons already learned from earlier trials. In reality ‘Community based fingerling production’ effectively means a decentralisation of production from state to NGOs with adoption pathways for ultimate community hazy at best. Such a strategy can only hope to be effective with long-term stability, financial commitment and co-ordination between and within the NGO and State sectors, demanding preconditions in the current socio-political and economic climate (Working Paper SL1.1).

6.2 Technical capacity

Lack of suitably trained personnel and poor extension capacity has been identified as a serious constraint to seed production. MOFARD plans to recruit 30 Graduates to be trained in breeding technology. Many experienced staff employed prior to the ban have retired or found employment abroad contributing to the loss of institutional capacity. A national training facility exists at the Udawallawe hatchery. Historically, training of most fisheries officers in Sri Lanka has been through bilateral initiatives with China and subsequently India. This lead to a virtual cessation of research work on tilapia in the 1960’s, in favour of carps, the area of expertise specialized in by both these states. In future, the allocation of resources and research capacity should consider consumer preferences; tilapia is much more widely accepted than carp in Sri Lanka, rather than simply adopting available technologies.

Fisheries monitoring capacity: Pet (1995) suggests that an accuracy of 30% in catch and effort data is needed for a timely detection of a serious decline (reduction of 50%) in total catch. Accuracy is improved by a well-designed sampling programme, increased sampling effort and removal of bias. In Sri Lanka, lack of human capacity, systematic bias and inaccuracy in existing reporting systems, means there is little potential for timely detection of such a crisis situation. Assimilation of good catch and effort data should be the first priority when it comes to investment in information gathering for any kind of fishery.

6.3 Fingerling requirements for seasonal tank stocking

Table 5. Timing of seasonal inputs and outputs for seasonal tank production (after De Silva 1988).

Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
←	North-East Monsoon			→	←	SW Monsoon	→		
	←	←	Stocking	→					
				Growth Period		→			
					←	Tank Drying			→
					←	Harvesting			→

Table 5 shows a typical production cycle in a seasonal tank with a culture cycle of 6-8months. For fingerlings to be stocked at a suitably advanced size to reducing predation and increasing growth potential, peak breeding should occur around July to August. This will yield 7-10cm fingerlings available for stocking in November (i.e. after the onset of the main maha rains in the dry zone). Li (1988) recommends an optimal size of 10cm to reduce juvenile mortality. A major constraint is the lack of suitable fry-fingerling production holding capacity for this seasonal requirement; consequently fingerlings size of 5-cm is the norm Sri Lankan hatcheries. As indicated above it is the policy of the Government policy to overcome this constraint through the initiation of community fingerling production programmes, using cages, cove or pens in perennial reservoirs or earthen ponds.

All of the Chinese and some of the Indian major carps can be spawned more than twice a year increasing latitude in seed production timing and production strategy. Indian major carps show a less favourable post-larval production cycle for seasonal tank production, as the minimal production periods occur between July to September (See Table 6).

Table 6. Peak spawning times for artificial spawning of exotic species for stocking seasonal tanks (Source: Tennakoon 1988).

Species	Peak Spawning Time
Bighead Carp	June – July (31%), Sept – Oct (11.7%)
Grass carp	Sept – Oct (40%), June (11%)
Silver	April – May (41%), Aug-Sept (31%)
Rohu Catla	Jan- March (46.3%), Oct to July March (34%), Dec (42.4%)
Mrigal	May – July (75%)

The reproductive biology of indigenous cyprinids and *O. mossambicus* in Sri Lankan reservoirs is strongly influenced by climatic factors (Chandrasoma and De Silva 1981). Spawning tends be far more asynchronous in the tropics, compared to the sub-tropics, due to the lack of marked seasonal temperature variation (Coward and Little 2001). Consequently, although *O. mossambicus* reproductive activity peaks during the rainy seasons, it also spawns readily throughout the rest of the year when environmental conditions are favourable. Seed survival will be lowest during the dry season when little vegetation exists around the littoral zone and predation pressure is higher. This variation in survival produces well-defined cohorts in perennial waters with spawning peaks occurring during May and November (Pet 1995). Such asynchronous breeding patterns, whilst unfavourable for more intensive pond-based farming, present a wide window of opportunity for farmers to wild source seed for fisheries enhancements in seasonal tanks.

7 Fish culture in Ponds

Despite favourable ecological conditions no tradition of pond aquaculture exists in Sri Lanka. To encourage uptake by small holders, the government introduced a pond subsidy scheme in 1980. These amounted to 50% of construction costs (ponds 0.5 to 2 acres in size) and free supply of fingerlings. Estate plantations, particularly those in the highlands, which are home to some of the poorest communities in the country, were focus areas. A total of 1575 ponds (192ha) were created up to 1983 and production rates over 1,000 kg/ha^{-1} were recorded using carp and tilapia polycultures. No subsidy schemes currently exist though 'plantation ponds' (products of the old subsidy scheme and older ponds once used for local power generation) have been identified as having potential to generate aquaculture opportunities for unemployed youth. Demonstration units for integrated fish farming still remain at Udawallawe fisheries station. In the dry zone, fingerling production ponds excavated in the seepage zone of perennial tanks were observed.

These are pumped out for harvesting and management purposes. Beveridge (1986) reported visiting two ponds, receiving gravity fed water from abandoned irrigation tanks. The ponds were 600m2 by 1300m2, 1m deep and drainable at certain times of year. Recommended stocking ratios were used: 40% plankton feeders (silver carp, bighead carp, catla), 40% bottom feeders (mrigal, common carp) and 20% grass carp or rohu at stocking densities between 6-7,000 fingerlings per ha. Better results were obtained with bottom and macrophyte feeder than phytoplankton feeders. Cow dung (3-6 kg per week) was used as a fertiliser, whilst *kankong* (*Ipomea reptans*), rice bran and copra cake were added at 1kg per day. Two harvests per year were possible with fish weighing between 800g -1.5kg. Harvests equivalent to 2.25 t/ha/yr were reported, though survival was modest, estimated at 36% due to predation. In the dry zone access to surface water would be rare and retentivity (without costly pond lining) would be poor. Therefore without access to ground or seepage waters and construction subsidies it is unlikely that the use of ponds in the dry zone will be a viable proposition. Borrow pits below or above bunds offer potential as fish refuges in seasonal tanks or areas with potential for advanced fingerling production. Subasinghe (1993) suggests that pond culture should be confined to highland areas where low-income groups currently have relatively poor access to cheaper inland fish resources and water availability is less of a constraint.

8 Integrated fish in rice production.

Integrated production of rice and fish has been shown to be an economically viable activity and an efficient use of resources in other countries in the region, generating modest income or improved nutrition to small holders. Rice fish production also represents an Integrated Pest Management (IPM) strategy, reducing reliance on pesticides whilst simultaneously improving fertility an rice yields by up to 15% (Pillay 1962).

Rice fish production in the field sub-system of irrigation systems is currently the subject of collaborative feasibility study by the Ministry of Agriculture and Lands, MOFARD and the FAO. Two areas of potential have been identified; in the dry zone for production of fingerlings to be stocked in grow out operations, whilst in the wet zone greater water availability could allow production of table fish for human consumption.

Rice lands represent the most important on farm water resource, with over 65% of the population involved in producing this staple crop on 860,000 ha of irrigated (42%), rainfed lowland (52%) and flood prone (6%) rice growing areas (IRRI world rice statistics 1995). However prices have stagnated and where off-farm employment opportunities are available some farmers have abandoned production completely. Yet most farmers continue to produce rice for the following reasons:

- Rice is a traditional subsistence crop grown for home consumption
- Large areas which are inundated during monsoons can not be used for other crops
- Rice can be stored easily and for longer periods than many alternative cash crops, which carry high risk due to erratic marketing opportunities.
- Off-farm employment opportunities are rare in most areas.

The growth period of rice in the dry zone is mostly between 3-4.5 months. This is insufficient for table production due lack of advanced fingerling nursery capacity in the country (section 4.1.2). Although rice field could themselves be used for nursing, as the rice harvest period from the major growing season is February to March, such fingerlings would be suitable for stocking only perennial and not seasonal ponds.

However fundamental reasons exist as to why rice-fish production is likely to remain unadopted in Sri Lanka. Access to assured irrigation supply is the major constraint. Eighty percent of rice is directly sown (20% transplanted). Most rainfed farmers in the dry zone only flood their fields during the early stage of the growing season to control weeds and later during the flowering stage. Even under major systems with 'assured' water supplies, deliveries frequently deviate from planned releases. In the Mahaweli H system, it is not unusual for deliveries scheduled on a 7-day release to extend to 14days (Bandara, pers. comm.). Furthermore, such technologies are most widely practice in less water-stressed environments. In the lowland dry zone, maintenance of water levels in fish rice systems could increase consumption of already limiting water supplies.

Other constraints include:

- Strong predation pressure, by a rich avifauna, and reptiles.
- Restrictions on pesticide application and possible contaminated run off from neighbouring fields.
- Lack of suitable extension expertise.
- Escape of stock during flash floods
- In some areas (i.e. Batticaloa on the east coast), low soil clay content results in poor water retention.

Prior to the widespread use of pesticides, farmer harvested a limited quantity of indigenous air breathing species (tolerant of the conditions described above) in their paddy fields. These included *Anabas testudinius, Ophiocephalus Sp.* (snakeheads), *Clarias teysmanni,* and *Heteropneustes fossilis*. These species still contribute to the seasonal tank fishery, though no farmers reported any current-day fishery in the farm sub-system.

In conclusion, although there may be some potential for farmers in wetter districts or those with assured water supplies, fish in rice integration is not likely to be a viable option for farmers cultivating rainfed paddy under small-scale seasonal tanks and also a highly questionable practice under major perennial schemes in the dry-zone.

9 Ornamental fish production

At first sight, production of ornamentals would appear to have many attractions for poverty focused aquaculture, in particular the ability to generate income throughout the year. As an activity that requires minimal space and water it would appear to be suitable for women who could culture ornamentals in their homesteads, and it could potentially contribute to preservation of biodiversity.

Although many of the principles of ornamental and food fish production are the same, the two sectors are virtually divorced in Sri Lanka. Separate markets and the ease with which ornamental fish can be grown are the main reasons, but also cultural considerations whereby ornamentals are not destined to be killed for human consumption.

Commercial production of ornamental freshwater fish only began in Sri Lanka in the mid 1980's. The success of neighbouring countries in this field such as Singapore and the demand from foreign buyers who wished to complement already existing exports of marine species fuelled this growth. In the 1980's major disease problems facing the primary producer, Singapore allowed Sri Lanka to enter previously closed markets and the sector has continued to expand since (lost markets are difficult to regain and particularly when dealing with a live commodity reputation is crucial). Sri Lanka to date has faced only minor disease outbreaks, but this should be seen as a major potential constraint under intensive production practices. By 1990 200 agro farmers were producing ornamentals and by 1997, the entire ornamental trade generated Rs 300mill FOREX (Jayasekera AQD pers comm).

Broodstock availability, ease of culture, water quality and site-specific predator concerns are key production variables. Most production is semi-intensive and takes place in mud ponds using conventional pond production techniques (drying, liming, fertilisation). Best grow out results are obtained by the addition of supplementary feeds, with most farmers using brine shrimp. Because low biomasses of high value product are produced, input costs need not be high.

The industry has a portfolio of 50 exotic cultured species in addition to an indigenous capture fishery for 58 species (see below) supply a smaller specialist market. Table 7 shows prices of some of the most popular ornamental species grown at Muruthavela inland fisheries station, a site with 16ha of pond space long-leased to the private sector in 1990. Other specialist species include gouramis and several cichlid species. The entire portfolio is of exotic origin. Of 200,000 pairs (fish are sold in pairs) 50% are sold to the John Keels Company, one of the countries largest businesses, export and the rest to the private aquarium trade. The most pressing husbandry problems identified in this instance were *argulus* and *lernea* infections and predation by frogs. Polythene screens had been erected to counter this problem and it was estimated that this reduced losses from as high as 50% down to 15-30%.

Table 7. Wholesale Prices of popular ornamental species cultured at Muruthavela inland fisheries station 1999

Species	Price per Pair	Comments
Koi gold fish	Rs 15 /5cm pair	
Mollies	Rs 9	Species with greatest demand
Shubumpkins	Rs 10	
Guppies	Rs 5	
Sword tail	Rs 9	Most susceptible to fungal infection

Fifty-eight wild species (including 3 accidental exotic introductions) have been collected for the ornamental trade (Pethiyagoda 1993). This fishery employs an estimated 500-1000 seasonal part time collectors in Sri Lanka (Mee 1983). Pethyagoda (1991) states that because collection of ornamental fishes in the wild focuses only on larger specimens it is self-limiting and if a species becomes rare it becomes un-economical to collect. Further more collection pressure is generally lowest during the monsoon-breeding season. Non of the endangered species in the IUCN red list (see section 8) are ornamentals, though several species classified as vulnerable are and their collection is known to go on illegally. However habitat conservation is more critical to the survival of these species and the collection of these species is not perceived as a significant threat to their existence. Their culture could be positive step in the preservation of bio-diversity (see section 10). Approximately 10 of these species dominate this section of the export market, the most important of which are shown in Box 6. It is recommended that the aquaculture potential of these indigenous species in dry zone water bodies be investigated in addition to the more conventional exotics. Promotion of such unusual species through forums such as collectors clubs could be a proactive means of gaining a competitive market advantage and sustaining future market share.

Box 6. Indigenous species with good potential for export ornamental trade

Species	English name
Danio malabaricus	Giant Danio
Puntius cumingii	Cummings barb
Puntius filamentosus	Filamented barb
Puntius nigrofasciatus	Black ruby barb
Putius titteya	Cherry barb
Mondactylus argenteus	Scat
Scatophagus argus	Mono

Most export buyers indicate that they are often unable to meet increasing demand, with foreign buyers increasingly becoming aware of the quality of the Sri Lankan product. There are six large breeders including John Keels, who are progressively becoming moving towards vertically integrated production including export of their own product, as they expand.

Foreign demand is greatest during June to August holiday periods in Western countries. Production is possible year round in Sri Lanka, though greatest husbandry difficulties occur in the driest and wettest months. The net result of these conditions has been good price stability over the last two decades. A possible threat to which is a 'loss leading' market strategy being adopted by one of the new large breeder/exporters (John Keels). This company is undercutting existing market prices by as much as 50% to gain market share, which may generate a price war amongst other exporters.

Smaller farmers who sell to exporters tend to keep only a small number of species in stock and monoculture or simple polycultures of the most popular, hardy species is the norm. The ease with which production can be initiated is an obvious attraction to new entrants; instead marketing issues represent the major constraint small-scale producers. Size of operation and proximity to Colombo, from where all exports are air freighted, are the major marketing factors which determine ability to market produce at a fair price. Smaller producers located some distance from Colombo must deliver their fish themselves. Fish are typically transported on public transport in oxygenated bags in which they can be held for up to 10hrs. These marketing factors represent the major constraints to the adoption of ornamental production by for the poorest rural groups. Early attempts by development organisations to encouraging women's groups to participate in pond-based ornamental production (including the Small Fishers Federation, and the Anuradhapura Dry Zone Development Programme) failed because suppliers were dissatisfied with the low return on the number of fry provided, the unreliable timing of harvests, packaging problems and the potential of these groups to culture only the simplest and most common varieties when mixed consignments are most popular with over-seas customers.

A negative impact of existing ornamental production on the poor that has already been discussed is the loss food fish seed production facilities to the ornamental sector. This may conceivably represent a constraint to community based fingerling production (section 6.1), as farmer groups with access to subsidised on-growing facilities may find it more economically rewarding to switch to contract on-growing of ornamentals for the larger producers.

In conclusion, marketing rather than technical issues currently represent the main constraints to adoption of ornamental production by poorer groups.

10 Bio-diversity and the status of endemic freshwater species in Sri Lanka.

A common course in the past has been to promote aquaculture to increase protein production at the expense of bio-diversity. Freshwater habitats in particular have been widely neglected in the past being relatively inconspicuous compared to terrestrial habitats. The significance of bio-diversity preservation to sustainable development is discussed in Appendix 2.

Sixty-two freshwater (26 endemic), 26 saltwater dispersant and 20 exotic fishes have been recorded from Sri Lankas inland waters. The discovery of nine new species during the last decade suggests that further discoveries can be expected. Revision of the confused state of taxonomy of South Asia could demonstrate a higher level of endemicity than the 42% currently estimated.

Pethiyagoda (1994) concluded that eight freshwater species are endangered and a further five vulnerable. In addition three species are rare, 18 common and 3 abundant. These estimates based on a survey of all the islands major river basins suggest a more critical situation than the IUCN endangered and vulnerable species estimates of 1990 and unless immediate remedial action is taken extinction's may follow.

Table 8. IUCN endangered and vulnerable species in Sri Lanka 1990.

Endangered	Vulnerable
Lepidocephalichthys jonklaasi	*Puntius cumingii*
Labeo fisheri	*P. nigrofasciatus*
	P. pleurotaenia
	P. titteya
	Rasbora vaterifloris
	Malpulutta kretseri

Endemic species are largely restricted to the wet zone, which can be divided into two ichthyofaunal provinces (Pethiyagoda 1994). The remaining dry-zone province of the island contains mostly species shared with the India subcontinent and the Sri Lankan wet zone. Greatest biodiversity is found in the lowland wet zone (between 1,000 and 2,000m above sea-level). Twenty of the 29 endemic species are restricted to this area. These wet zone provinces have been defined as a 'freshwater biodiversity conservation hot spot' (Myers 1988). They are defined as 'regions with high concentrations of endemic species experiencing unusually rapid rates of habitat modification or loss'. Due largely to the diversity found in these areas, Sri Lanka ranks as the country with the country with the 7th highest freshwater fish diversity in the world (Kottelat and Whitten 1996).

Senanayake and Moyle (1982) identified a number of factors contributing to habitat modification and the decline of native fish populations in Sri Lanka:

- Deforestation
- Urbanisation
- Gem mining
- Water diversion
- Pesticides
- Exploitation
- Introduction of exotic species (see section 10.1).

The most serious short-term consequences of these activities, are the secondary effects on habitat through loss of shade and siltation. Such degradation increases suitability for habitat generalists and exotic species resulting in overall decreases in biodiversity (Lowe-McConnel 1987). Twenty-five of the 62 Sri Lankan freshwater species have at least two strong habitat preferences (shade usually being one), whilst 32 species are habitat generalists (mostly non-endemic).

Although Sri Lanka has no natural lakes (and therefore no specialised lacustrine fishes) a few endemic species have a strong association with still-water habitats. Marshland species include*: P. cumingii, P vittatus, Horadandia atukorali, Heteropneustes microps, Pseudosphromenus cupanus*, whilst species adapted to slow flowing water include: *P. titteya, M. Kresteri, Macrognathus aral*. Such species have faced extreme pressure due to the conversion of almost all the lowland wet zone marshes to rice cultivation and the associated agrochemical inputs and annual dessication.

The biology of these species (particularly *Barbus* Sp.) has been studied mostly in their natural environment and require further studies in reservoirs to assess their fisheries potential. De Silva (1983) suggested that the larger indigenous minor cyprinid species are unlikely to spawn in reservoirs. Instead they would migrate to their natural riverine habitats during the spawning season (usually with the onset of the rains).

One implication of this is that the minimum catch effort would occur when body condition is lowest, and therefore immediately prior to spawning.

P. sarana, P. filamentous, L. dussumieri and *R. daniconius* have been identified as littoral feeders, *P. doraslis* and *P. chola* as zoobenthos feeders. A high degree of overlap exists amongst members of each group. *P. chola* feeds off shore through a 24hr period, whilst *P. dorsalis* feeds mostly at night. *P. filamentous* is poorly adapted to feeding on macrophytes alone. *Ehirava fluviatilis*, a clupeid has also been found to inhabit reservoirs, feeding almost exclusively on rotifers, this species has been implicated in the natural variation of rotifer populations (Newrkla and Duncan,1983).

10.1 The threat of exotic introductions to endemic and indigenous species.

The range of *O. mossambicus* now extends throughout the dry zone and up to 600m (a.s.l) in the wet zone, where it is the most abundant species of most brackish waters, larger streams and reservoirs. During the last 40yrs its dispersion has been uncontrolled and generally viewed with complacency by fisheries personnel as it is commonly viewed as a lacustrine herbivore filling a niche unable to be occupied by any indigenous species.

Although the natural habitat of *O mossambicus* in the Zambesi basin is fluvatile (Trewavas 1983), breeding takes place in pools and it is generally treated as a lacustrine species. However it can withstand fast moving water and increasing siltation of lowland streams could result in its invasion of the wet zone forests where populations are already established in pockets. Although largely a zooplankton feeder, it is also an opportunistic predator of small fish; it breeds all year, but predominantly during the rainy season at the same time as most indigenous species. More extensive invasion of the wet zone would almost certainly bring extinctions according to Pethyigoda (1994). The increased fishing effort, which this species has brought about, also places additional indirect pressure on indigenous species. Fernando (1991) argues that in low land reservoirs, tilapias probably reduce predation pressure on indigenous cyprinids and their introduction has been beneficial. Whereas the population of some lowland indigenous species has increased, others have declined. Until the 1970's the population of the indigenous cyprinid *L porcellus* was sufficient to warrant a fishery in dry zone reservoirs. Its condition has now become critical as a consequence of direct competition with tilapia (Pethiyagoda 1991).

O. niloticus has been introduced over 100 tropical and sub-tropical countries including Sri Lanka (Coward and Little 2001). Although it generally believed to have had no negative impacts Kottelot and Whitten (1996) suggest this is more indicative of the lack of any critical monitoring.

More exotics are likely to be added to the fishery. Proposals for the introduction of Nile perch *Lates niloticus* and the largemouth bass *Micropterus salmoides* were curtailed with advent of the government ban (Jonklass 1989).

The citing of a lack of pressure to indigenous Asian species elsewhere is often used to explain the generally casual approach to exotic introductions in Sri Lanka (e.g. De silva 1998). However the poor state of taxonomic knowledge, the lack of systematic assessments (with reliance predominantly on selective catch data) and a bias to the economically beneficial exotics, probably means that many extinctions may never be known. In Sri Lanka where the tilapia fishery has contributed towards rural protein requirement in such an affordable manner, it is difficult to conceive of the situation that would exist without it. However, introductions took place on an *ad hoc* basis with no impact assessment or remediation plans and the benefits have the result more of luck than design. The longer-term impacts of bio-diversity losses may still remain to be felt.

11 Summary and conclusions

At the same time as population driven demand for fish is increasing in the lowland dry zone, marine and perennial reservoir fisheries are close to their maximum sustainable yields. Sri Lankas vast acreage of small farmer managed seasonal tanks represents an as yet unharnessed resource with tremendous potential for increased fisheries production. Constraints to the exploitation of this resource and research recommendations are identified in the text and summarised below.

1. It is recommended that further research is aimed at improved understanding of current production patterns of seasonal tank fisheries, and their contribution to the livelihoods of the rural poor.

2. It is recommended that further research should directed at clarifying the reasons for the demise of larger indigenous species in the reservoir fishery and possible remediation strategies

3. It is recommended that further research should investigate perceptions towards carp consumption, market conditions, yield potentials and farmer participation in the fishery in villages where stocking programmes have been resumed and existed prior to the government 'ban'.

4. It is recommended that further research be directed finding means of strengthening village institutions to manage collective fisheries in village tanks. Building social capacity should be one of the key goals of interventions aiming to improve management of seasonal tank resources.

5. It is recommended that further research be directed at investigating the positive and negative impacts of prey - predator interactions in seasonal fisheries (particularly with respect of O. striatus. Cost benefit analyses to calculate the optimum ratios of prey-predator populations in respect of market price, stocking costs and effort required to manipulate ratios and means of manipulating ratios should identified.

6. It is recommended that the cost effectiveness of common carp and tilapia polyculture combinations (i.e. considering fingerling size, stocking density and susceptibility to predation) be investigated, these being the most suitable species for use in community fingerling production programmes.

7. It is recommended that simple methods of enhancing spawning success and advanced fingerling production of tilapias and carps be identified (i.e.using portable mini-hatcheries for community based fingerling production programmes).

8. It is recommended that further research be directed at understanding seasonal availability of wild seed sources, particularly tilapia and snakehead, including catch effort, access and bio-diversity considerations.

9. It is recommended that the potential for community fingerling production programmes undertaken at the wider watershed level are investigated for potential to improve the efficiency of stocking programmes in drought years.

10. It is recommended that a simple method for predicting the potential yield of fish from individual tanks is devised. This will be consider primary productivity (natural and enhanced), composition of the fish population and stocking levels, predation and will also require an effective means of calculating the water area available for aquaculture.

11. It is recommended that the potential of aquatic macrophyte consumers such as grass carp to counter the threat of aquatic encroachment by emergent aquatic macrophytes such as salvinia, water lily and lotus.

12. It is recommended that the potential for women's groups to undertake culture of ornamental species be further investigated. This should include a survey of current market conditions and an assessment of it's longer term stability. The potential for culture of indigenous species in addition to the more common exotics should be investigated

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Appendix 1. Current status of exotic introductions into the reservoir fishery.

Few off the twenty species of exotic fish species indiscriminately introduced into Sri Lanka's inland waters have become well established. Of these four species of poeciliids (introduced for malaria control 1930-1960) are known only from small-localised populations. The most important introductions are as follows:

<u>Cyprinids</u>: Of the various species of carp introduced into the food fishery, only *C. carpio* is known to have a self-sustaining population. It is now the only exotic occurring in headwater streams above 1500m. a.s.l. Six other species have been introduced; three Chinese carps *(Hypophthalmichthys nobilis, H. molitrix and Ctenophyaryngodon idella*) and three Indian major carps (*Catla catla, Cirrhinus mrigala).* These species do not appear to be capable of breeding naturally in Sri Lanka or any latitude South of 110 25'N. Their numbers have been declined rapidly after state sponsored stocking was suspended in 1990. *L rohita* though potentially capable of breeding in Sri Lankan waters at low level, has similarly declined. An eighth species, *Carassius auratus* was regularly cultured and introduced until the 1980's but no longer appears in inland catches (Pethiyagoda 1994).

<u>Anabantoids</u>: Of four species introduced, only *Trichogaster pectorlis* has a population high enough to warrant a fishery restricted mostly to coastal marshes. *Osphronemus goramy*, has only several localised populations. It's large size and breeding requirements restrict it to larger water bodies.

<u>Salmonids</u>: Oncorhynchus mykiss originally introduced as a sport fish in 1882, survives only in the Horton Plains (2,000m a.s.l), where it is now strictly protected. Day 1989, suggests that the destructive nature of this fish may have already been responsible for several species extinctions.

<u>Cichlids</u>: Five species of tilapias (and a number of hybrids) have been introduced into Sri Lanka since 1952 (*O. mosambicus, O. niloticus, T. rendali, T. melanoplura* and T. Zilli). Of the annual freshwater catch in 1984, 56-99% (depending on location) was tilapia (De Silva 1985). Of these species *O. mossambicus* has been by far the most successful (see section 4.1.1). Considered to have superior growth and flesh characteristics than *O. mossambicus*, *O. niloticus* continues to be introduced into new reservoirs and its relative yield is progressively increasing. The macrophyte feeding *Tilapia rendalli*, introduced in 1969 is also recorded in significant numbers in landings of some reservoirs, particularly in seasons of high water level (Chandrasoma 1986).

Appendix 2. The importance of fresh water diversity in development programmes

'Biodiversity refers to the abundance and variety among flora and fauna as well as to the ecosystems and ecological processes to which they belong and is usually considered at the ecosystem, species and genetic levels.' (Kottelat and Whitten 1996).

The effects of development on freshwater habitats have been extreme. In no other set of habitats have complete faunal communities been wiped out by ill-advised management. For example an estimated 200 to 400 species of fish disappeared from Lake Victoria after the introduction of a single exotic species; the Nile Perch, with serious consequences for the commercial fishery (Coulter et al 1986). Many freshwater habitats are under serious threat with large numbers of aquatic organisms in them facing extinction. By comparison with terrestrial environments, which benefit from charismatic flagship species, freshwater habitats are largely ignored (even in wide ranging reviews of biodiversity). Despite such perceptions freshwater biodiversity is an important issue with tremendous economic, social and environmental impacts, impinging on human welfare in terms of nutrition, water quality, recreation, control of infectious diseases and other resources. Therefore it cannot be dealt with only as a subsection of fisheries management.

Such concerns have only recently started to be addressed in international development policy. In 1995 the World Bank launched an initiative to help its developing country partners to mainstream biodiversity in environmentally sustainable development. Agenda 21 of the 1992 Rio de Janeiro Conference on Environment and Development (signed by most Asian countries including Sri Lanka) contains the following objectives: 'to put in place strategies for the environmentally sound management of freshwaters considering an integrated approach to fisheries, aquaculture, animal grazing, agricultural activities and biodiversity. In 1996 the Ramsar Convention (the first modern global inter-governmental treaty on conservation and wise use of natural resources) facilitated the adoption of five-year strategic plan stressing the need to integrate the conservation of wetland biodiversity and sustainable development.

In terms of nutrition a change in food species can be highly significant. In Bangladesh small capture fish are usually eaten whole by subsistence fisherfolk and provide a rich source of vitamins and minerals. Large pond cultured fishes cannot be eaten whole and provide less than one half of the calcium and iron and only 2% of the smaller and more widely available fishes (Hill and Hanchet, 1995). A similar preference for smaller fish amongst the poorest sections of the community (primarily due to their lower cost) was found in during RRAs in villages of N.W province in Sri Lanka. Local knowledge of fish diversity is generally very good in rural communities who depend on local fisheries and such communities often use traditional resource management practices, especially when they depend heavily on them and the resource is limiting. Fisheries and aquaculture development planners must consider socio-cultural factors such the potential for loss of food diversity and associated traditional knowledge. However in Asia, to date there has been little work carried out on the potential to mitigate the losses to freshwater biodiversity arising from development programmes.

Appendix 3. Organisations involved in seasonal tank stocking programmes

The NGO's Agent, CARE, International fund for Agricultural Development (IFAD), German Technical Cooperation (GTZ) and the Small Fisheries Foundation (SMF) have also funded fingerling-stocking programmes in the district with limited success. The NGO Sewa Lanka is in the process of establishing carp hatcheries in Southern Province after initiating trials with limited stocks available from the Government hatcheries. Attempts to establish similar stocking initiatives by both Sewa Lanka and the *Action Contra La Faim* (a French NGO) have failed due to a variety of logistical and technical constraints. A Government organisation the Wayamba Development Authority is proposing a stocking programme involving 22major, 3-400 seasonal and 100-150 private fishponds in Kurunegala district, with the object of stimulating local private sector fingerling production, through provision of extension advice and subsidised fingerlings to producers in the first instance. Other integrated rural development programmes such as the Anuradhapura Dry Zone Development programme, although incorporating fisheries enhancements amongst their intervention activities are not explicit about specific objectives and strategies to be adopted.