Bull. Fish. Res. Stn., Sri Lanka, Vol. 26, Nos. 1 & 2, pp. 83–95, June and December, 1975.

Reservoir Fishery Resources of South-East Asia*

By

C. H. FERNANDO[1] AND J. I. FURTADO[2]

Introduction

THERE is a long history of reservoirs (or man-made lakes) in South-East Asia, mainly for the purpose of irrigation in association with wet rice cultivation. Sophisticated reservoir systems served relatively intensive wet rice cultivation in several parts of this region such as in Sri Lanka, in the lower Mekong Basin, and in southern India. The number and size of reservoirs has increased in recent years, and is increasing rapidly, by the expansion of existing units or the construction of new multipurpose dams. This rapid increase is due to the rising demands for power and irrigation water for a growing human population and its industries. A very conservative estimate places the acreage of reservoirs by 1985 in South-East Asia at about 6 million hectares. In spite of this increase in reservoirs, the management of these resources has been delegated usually to authorities with restricted and specific goals such as irrigation, hydro-electricity or water supply. As such, the optimum utilisation of reservoir resources has not been realised fully in any part of South-East Asia.

Hitherto, reservoirs have been poorly exploited for fishery resources in South-East Asia in general. Fish yields from reservoirs vary greatly from one part to another in the region, and as expected even between individual reservoirs in the same part of the region because of ecological and edaphic differences. When considered as a whole, fish yields from reservoirs in South-East Asia have been lower than their potential. Although the comparative data available is meagre, recorded high fish yields are due either to a rich diversity of indigenous freshwater fishes, or to the introduction of " foreign " fish species. The most spectacular increases in fish yields are due to the introduction of African cichlid fishes of the genus *Tilapia*. These high yields are comparable to those observed in African reservoirs, and are much higher than that of reservoirs stocked naturally with indigenous species. The introduction of invertebrates into reservoirs to stimulate an increase in fish yield, has been considered but not implemented extensively, hitherto. The rationale for invertebrate introductions is the paucity of true limnetic species in South-East Asia. The fertilization of reservoirs or enhancing fish yield, has not yet been considered for South-East Asia, although some reservoirs have been eutrophicated by agro-industrial or other activities.

Although the management of reservoirs for optimum benefits, especially fisheries, is still to be realised fully in South-East Asia, it is more probable that an ecological basis for managing these resources for fisheries production will be more economical than other forms of comparable fish production such as pond culture. The reasons for this are that reservoir resources are becoming available primarily for other purposes, and that manipulating the reservoir ecosystem for optimum benefits requires a low energy subsidy. Such an economy is particularly important since reservoirs

---

*Paper presented at The 13th Pacific Science Congress Vancouver, Canada-August 1975.

[1] Department of Biology University of Waterloo, Waterloo and Canada.

[2] Department of Zoology, University of Malaya, Kuala Lumpur, Malaysia.

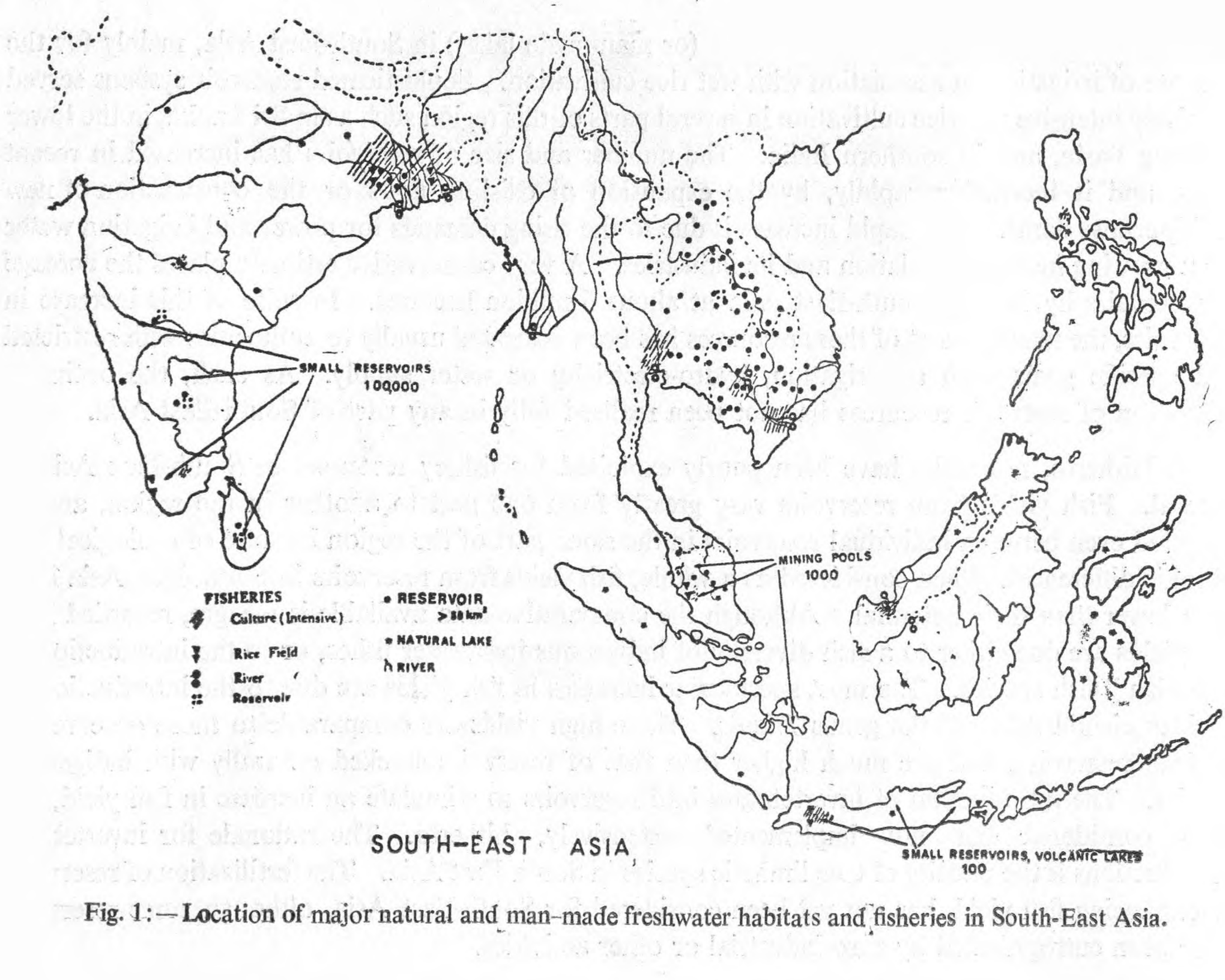

Fig. 1:—Location of major natural and man-made freshwater habitats and fisheries in South-East Asia.

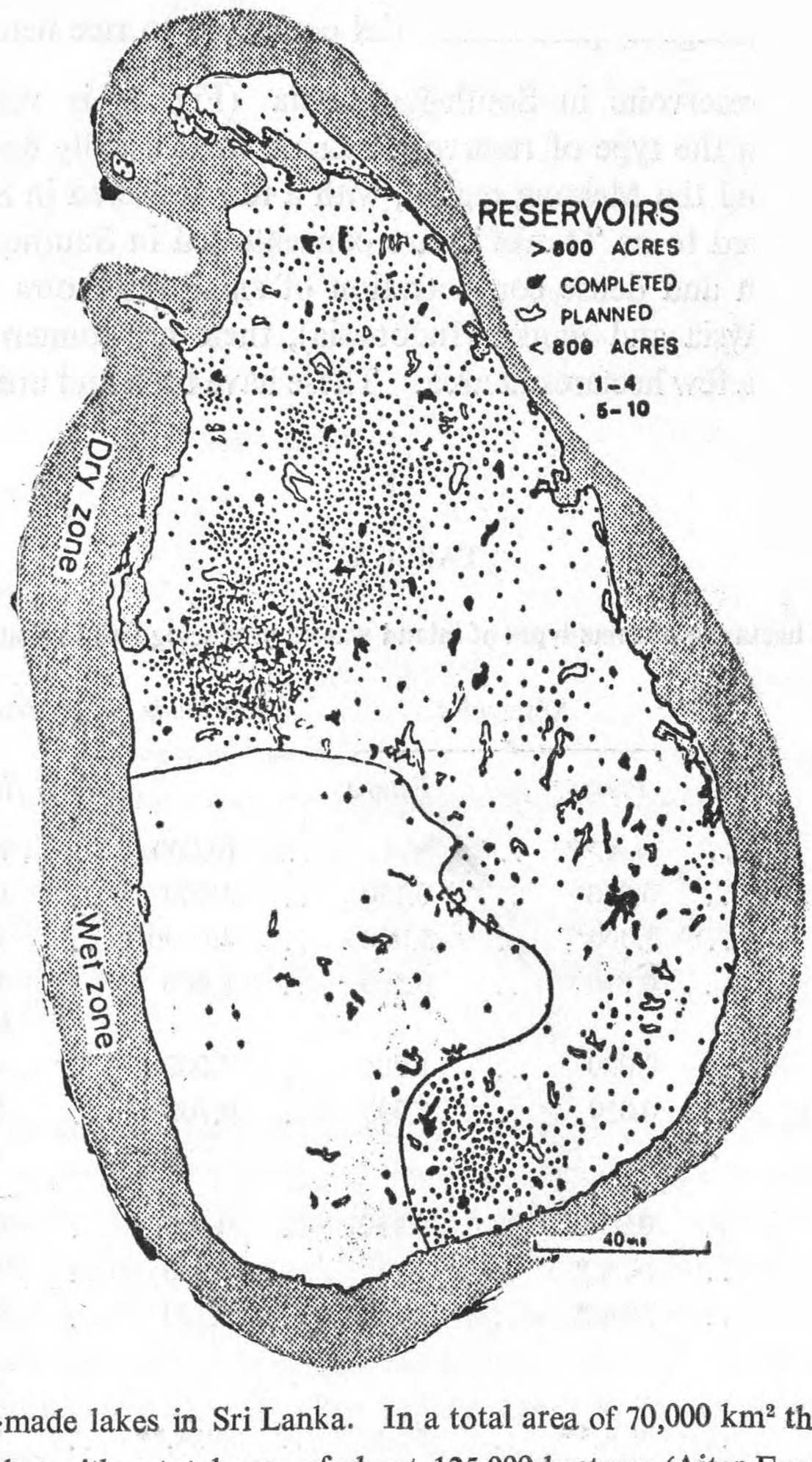

Fig. 2.—Man-made lakes in Sri Lanka. In a total area of 70,000 km² there are over 10,000 such lakes with a total area of about 125,000 hectares (Ajter Fernando 1970).

are located usually in the rural areas where the need for an abundant cheap protein source is most critical to the human population. For example, in Sri Lanka, fish introductions have stimulated a fishery industry in reservoirs with an overall average yield of about 100 kg/ha/annum. Some reservoirs have shown a sustained yield of about 200 kg/ha/annum for a period of about 20 years.

Inland Standing Waters and Reservoirs

The available data on reservoir acreage in South-East Asia is far from reliable (Table 1) and is based on data obtained from local publications and/or from discussions with local fishery officials. Nevertheless, the reservoir acreage is quite substantial compared to rice fields and lakes.

The distribution of reservoirs in South-East Asia (Fig. 1) is very uneven both in the concentration of units and in the type of reservoir. Large (and usually deep) reservoirs are found almost exclusively in India and the Mekong region, with a few scattered in Sri Lanka and Malaysia. Small reservoirs (often referred to as " tanks ") are concentrated in Southern India and Sri Lanka. Fig. 2 shows the distribution and dense concentration of small reservoirs ($<$ 300 hectares) in Sri Lanka. In Peninsular Malaysia and Banka (Indonesia), there are numerous tin mining pools of varying size but usually only a few hectares in area. These have been and are used for fish production in Malaysia (Jothy 1968).

TABLE 1

Areas (in $\times 10^6$ hectares) of some types of inland waters producing fish in South East Asia

Types/Country	*Reservoirs*		*Ricefields*	*Natural lakes and flooded areas*
	Present	*Future*		
Bangladesh	N.A.**	N.A.	10,000	N.A.**
Burma	0.010	0.150	5.000	0.050 FP
India	3.000	5.000	40.000	N.A.**
Indonesia	0.050	0.500	8.000	1.000 NL 0.100 FP
Khmer	0.080	1.000	2.000	0.400 FP
Laos	0.050	5.000	0.700	N.A.
Malaysia :				
Malaya	0.020	0.150	0.500	0.008 FS
Sabah	N.A.*	N.A.	0.050	N.A.
Sarawak	N.A.*	N.A.	0.120	0.010 FP 3.187 FS 0.006 FL
Philippines	N.A.**	N.A.	N.A.**	0.100 FP & NL
Singapore	0.000	0.000	Nil	N.A.
Sri Lanka	0.125	0.250	0.600	0.020 FP
Thailand	0.150	2.500	6.700	N.A.
Total (approximate)	3.5	13.0	70.0	1.650

N.A. = No data available
** Considerable
NL = Natural lakes
* Negligible
FP = Flood plain
FS = Freshwater swamps

TABLE 2

Inland Fish Production (1970-73) in South East Asia in metric tons per annum

Country	*Capture Fisheries*		*Culture Fisheries*
	Lakes and Reservoirs	*Rivers, Marshes, etc.*	
Bangladesh	N.A.***	N.A.***	N.A.***
Burma	N.A.*	N.A.***	1,500
India	40,000 (Reservoirs only)	25,000	480,000
Indonesia	300,000		140,000
Khmer	120,000		5,000
Laos	N.A.***	N.A.***	N.A.*
Philippines	N.A.***	N.A.*	2,000+BRW
Sabah	N.A.*	5.000	300
Sarawak	N.A.*	N.A.***	1,000
Sri Lanka	8,400 (Reservoirs only)	N.A.*	N.A.*
Singapore	N.A.*		N.A.*
Thailand	52,000		63,000
West Malaysia	16,000		4,000
Total (Estimated)	Capture : 450,000		Culture : 700,000

Reservoirs 60,000
Natural lakes (including flood fisheries) 220,000
Rivers, marshes, etc. 180,000

N.A. = No data available
BRW = Brackishwater fishculture 95,000 metric tons.
*** considerable
* negligible

Natural lakes are few and localised in South East Asia (Fig. 1). With the exception of a few in Sulawesi, all these lakes are relatively young and the vast majority are the volcanic lakes in Indonesia. A few large flood lakes occur in the Khmer Republic and the Kapuas region in Kalimantan. Smaller flood lakes are found in Sri Lanka, Burma and Thailand. Peninsular Malaysia has two dystrophic lakes. In comparison to the reservoirs, lakes (even in the broadest sense) form only a small fraction of their acreage. Because old natural lakes are absent in many parts of South East Asia, the evolution of lake fish species and limnetic invertebrates has not occurred unlike in Africa, except for cyprinids in Lake Lanao, Philippines.

Reservoir Fisheries

Reservoir fisheries in South East Asia is of little importance at present, except in Sri Lanka where almost the total freshwater fish catch is from reservoirs and in southern India where both large and small reservoirs produce a sizeable fish catch. The location of different types of freshwater fisheries is shown in Fig. 1, and the fish catches from different types of freshwater fisheries in South East Asia is given in Table 2. Although we do not have reliable or detailed data on fish

catches, the approximate total fish catches from reservoirs is about 60,000 metric tons. It is not possible in most instances to discriminate fish catches for the different types of fishery with the available data.

TABLE 3

Reservoirs in South East Asia having negligible fish yields

Reservoir and Location	*Nature*	*Area(ha)*	*Fish Yield Kg/ha/an*	*Source*	*Remarks*
Nalanda, Sri Lanka	Deep	273	nil	Fernando 1973	Very little littoral Only indigenous fish species Low elevation
Castlereagh, Sri Lanka	Deep	363	nil	Fernando 1973	Elevation 1,500 m. Indigenous spp. and common carp only
Ringlet, West Malaysia	Deep	400	nil	Pers. obs.	Elevation 0,000 m. Indigenous spp. and Chinese carps
Karangates, East Java	Deep	1,500	nil	Pers. obs.	Indigenous spp. only Low elevation

Assuming that the total reservoir acreage for South East Asia is 3.5 million hectares and the fish yield is 60,000 metric tons /annum, then the overall average yield is about 20 kg /ha /an. This overall average production in reservoir fishery shows considerable variation between the component reservoirs. High production in the shallow reservoirs in south India, Sri Lanka and Indonesia account for about half the total fish catch, and very low to negligible fish yields are common in most reservoirs throughout South East Asia. Reservoirs may be classified into three broad categories on the basis of fish yield. Negligible, low and high. In addition highly eutrophic small reservoirs resemble fishponds and have similar fish yields, thus constituting a fourth category. The fish yield of some reservoirs belonging to these four categories are given in Tables 3–6.

In a large number of deep (>10m. mean depth) reservoirs in South East Asia fish yields are negligible (Table 3). Although deep reservoirs can be expected to give low fish yields, the total lack of fish production in some is surprising. Some of these lakes are at high elevations, e.g. Ringlet and Castlereagh reservoirs, while others are at low elevations, e.g. Karangkates and Nalanda. In all these instances, a lack of suitable fish species seems to be the main cause for the negligible fish yields, although other factors such as low ionic concentrations and the lack of a littoral zone, are also operative.

Reservoirs with a low fish yield are usually either deeper reservoirs or dystrophic (Table 4). Their fish yields are about 10–40 kg/ha/an., and are of similar magnitude to fish yields in more temperate regions, such as 10–12 kg/ha/an., for the U. S. America (Jenkins 1967) and 18–36 kg/ha/an., for the U.S.S.R. (Frey 1967). It is worth noting that before the introduction of *Tilapia mossambica* in Sri Lanka, the yields from shallow reservoirs was less than 10 kg/ha/an., and the present yield of indigenous species in reservoirs intensively fished for *Tilapia mossambica* is 10–20 kg/ha/an.

TABLE 4

Reservoirs in South East Asia having low fish yields

Reservoir and Location	*Nature*	*Area (ha)*	*Fish Yield Kg/ha/an*	*Source*	*Remarks*
Large Reservoirs in South and Central India	Deep	1 million	20-40	Anon 1969	Indigenous carps only
Senanayake Samudra, Sri Lanka	Deep	7,700	20	Fernando 1973	*Tilapia mossambica* and indigenous spp.
Djuando, Djatiluhar, West Java	Deep	8,300	15	Achmad 1970	*Tilapia mossambica* as indigenous spp.
Bukit Merah, West Malaysia	Shallow	circa 2,000	35	Fisheries Department	Indigenous carps, catfish, snakeheads, *Trichogaster pectoralis*. No *T. mossambica*
Subang, West Malaysia	Shallow	900	90	Yap 1974	Indigenous carps
Kanijiri Duwar, S. India	Deep	circa 5,200	84	Hickling 1961	Indigenous spp. only

TABLE 5

Lakes and reservoirs in South East Asia having high fish yields

Habitat and Location	*Status and nature*	*Area (ha)*	*Fish yield Kg/ha/an*	*Source*	*Remarks*
Lake Lombotto Sulawesi	Lake Shallow	4,050	432	Hickling 1961	*Tilapia mossambica* *Trichogaster pectoralis* introduced indigenous shrimps form half of catch
Lake Tempe Sulawesi	Flood lake Shallow	9,500 - 20,000	161 800-900	Hickling 1961 Achmad 1975 Pers. Comm.	*Tilapia messambica* *Puntius javinicus and* *Trichogaster pectorolis* introduced
Tjiburug, West Java	Reservoir	23-40	500-600	Hickling 1961	After stocking with *Tilapia mossambica*
Solerojo, East Java	Reservoir Shallow	100	100	Pers. obs.	Almost entirely *Tilapia nilotica*
Parakrama Samudra, Sri Lanka	Reservoir Shallow	2,262	225	Fernando 1973	*Tilapia mossambica* about 80-90% catch
Moragaswewa, Sri Lanka	Reservoir Shallow	12	130	Fernando 1973	*Tilapia mossambica* introduced annually
Rewa Pening, central Java	Reservoir Shallow	2,200	250	Achmad 1975 Pers. Comm.	*Tilapia mossambica* major component of catch

High fish yields in reservoirs in South East Asia have been recorded almost without exception in reservoirs stocked with *Tilapia* spp. However, some South East Asian species like *Etroplus suratensis*, *Puntius javanicus*, *Trichogaster* spp. and *Labeo* spp. have contributed to these high yields. Unconfirmed reports from Thailand indicate that a newly constructed reservoir there has given a "high" fish yield. High yielding reservoirs and lakes in South East Asia show average yields of 100-900 kg/ha/an. (Table 5). All these reservoirs listed are shallow lakes, and all of them have been stocked with introduced species which now form the bulk of the fish catch. Two of the habitats listed in Table 5 are natural lakes ; both these had very few indigenous fish and even totally lacked Cyprinidae, so that the introduction of foreign species has contributed to relatively high fish yields (Hickling 1961).

Some small reservoirs (called "tanks" in India and Sri Lanka) have many biological features in common with fishponds. They are highly eutrophic and their fish yields are very similar to those in fishponds (Table 6).

TABLE 6

Very high fish yields in South-East Asia from different types of habitats

Habitat and Location	*Status and nature*	*Area (ha)*	*Fish Yield Kg/ha/an*	*Source*	*Remarks*
Temple tank, South-India	Pond Man-made Shallow	<1	2500	Sreenivasan 1964	Highly eutrophic *Tilapia mossambica* present as bulk of catch
Beira lake, Sri Lanka	Reservoir Man-made Ornamental	65	2230	Mendis 1969	Highly eutrophic *Tilapia mossambica* present as bulk of catch
Fishponds, West Malaysia	Ponds Man-made	<1	2000	Pers. Comm.	Chinese carps and *Puntius javanicus*
Fishponds, Java	Ponds Man-made	<1	2500	Pers. Comm.	Chinese carps and *Puntius javanicus*
Fishponds, Calcutta	Ponds Man-made Experimental	<1	8000	Pers. Comm.	Chinese and Indian carps
Fishponds, S. India.	Ponds Man-made	1	1150-4050	Ganapati 1972	Indigenous carps *Chanos*

Introduction of Fish and Invertebrates Species

Reservoir fisheries in South-East Asia have been influenced greatly by the introduction of "foreign" fish species. These introductions have been either within the country or region, or from Africa. The most spectacular increase due to fish introductions has been in Sri Lanka where *Tilapia mossambica* Peters was introduced in 1952. The negligible reservoir fish harvest rose to 8,400 tons per annum, and has been maintained at this level for about twenty years. This has been documented

very thoroughly by Fernando (1965, 1970 and 1973) and Fernando and Indrasena (1969). The phenomenal increase in fish yield here has been attributed to *Tilapia mossambica* occupying a vacant niche in a fauna lacking lake or pelagic species. The absence of stunting which is reported for *T. mossambica* in South-East Asia generally, is probably avoided by the high predation pressure and restriction of breeding sites. Indigenous fish species have not shown any decrease in yield through this introduction. On the contrary, the intensive exploitation of *Tilapia mossambica* has actually increased the total catch of indigenous fish.

In Indonesia, *Tilapia* spp. have been responsible for high yields in the natural lake, Lake Lombotto, Sulawesi, which previously possessed only gobies and shrimps. The introduction of *Tilapia mossambica* and *Trichogaster pectoralis* stimulated a spectacular increase in fish yield (Hickling 1961). In another Sulawesi lake, Lake Tempe, the introduction of foreign species also caused a great increase in fish yield (Hickling 1961). The effect of introduced species in stimulating fish yield in reservoirs poor in indigenous species has also been noted in Cuba by Holcik (1970). Hickling (1961) lists a number of instances in Indonesian reservoirs where introduction of *Tilapia mossambica* has increased fish yields considerably. In a recently constructed shallow reservoir in Solerojo, East Java, the fish yield is around 100/kg/ha/an., and consists entirely of *Tilapia nilotica*, while in Rewa Pening reservoir, Central Java the yield is about 250 kg/ha/an.

The impact of introduced species on Indian reservoirs has not been so spectacular, because most of the introductions have been confined to indigenous carps and *Tilapia mossambica* has been considered a pest. Sreenivasan (1967) in an excellent review points out that, where high predator pressure exists, *Tilapia mossambica* reaches a large size and produces high fish yields in South India.

It appears that the diversification of exploitable fishes in South-East Asia by introductions will enhance fish yield considerably in reservoirs. Different strategies will be required for each particular reservoir in different regions of South-East Asia, until some general principles emerge from such experimentation. It is evident that exploitable lake fish species adapted to deeper waters are lacking in South-East Asia. This has been stated specifically for Sri Lanka by Fernando (1965, 1970, 1973) and Fernando and Indrasena (1969), and is probably applicable with some reservations to other parts of the region. It is likely that the most spectacular increases in reservoir fish yields will be recorded in Sulawesi, Sri Lanka and to a lesser extent India, by the introduction of deep-water fishes. This is important because of the construction of large deep dams. The rich indigenous fish faunas of the Mekong region, Kalimantan and Malaysia may supply a greater variety of fish recruits to reservoirs in these areas stimulating high fish yields, but so far this has not occurred.

A number of South-East Asian fish species have proved valuable for introduction into reservoirs. *Etroplus suratensis* Bloch, an estuarine cichlid introduced into reservoirs in Sri Lanka, has contributed to increased fish yield. Carps belonging to the genera *Labeo*, *Puntius*, *Cirrhina* and *Catla* have provided exploitable fish stocks when introduced into reservoirs in India and Indonesia. *Trichogaster pectoralis* (Regan) has contributed significantly to the fish yield in reservoirs in Malaysia and Indonesia. *Osteochilus hasselti* (C. and V.) has contributed significantly to fish yields at Bukit Merah and Subang reservoirs, Malaysia. Clariid Catfishes and Channid Snakeheads are important predators in fish catches. However, all these species are river or marsh fish, mostly detritivores or browsers and some predators, and their yields have been much lower than that of the African cichlids introduced, which are pelagic and planktivores.

Although there has been no planned introduction of invertebrates into reservoirs in South-East Asia, this subject has been discussed with reference to Sri Lanka by Fernando (1974).

In an examination of over 1,000 samples of zooplankton from different parts of South-East Asia, from the whole spectrum of freshwater habitats, two features emerge regarding the limnetic plankton of reservoirs in South-East Asia : (1) the paucity of true limnetic zooplankters, and (2) the raity of *Daphnia* spp. Only three species of Cladocera are at all common in the open waters in reservoirs in South-East Asia ; these species are *Diaphanosoma excisum* Sars, *Ceriodaphnia cornuta* Sars and *Moina micrura* (*Kurz*). . All three species are cosmotropical and are equally common in other types of habitats besides " lakes ". Two cyclopoids, *Mesocyclops leuckarti* (Claus) and *Thermocyclops crassus* (Fischer) (=*T. hyalinus*) are the only common cyclopoids in reservoirs. The Rotifera are represented however, by a large number of species of *Brachionus, Keratella, Filinia* and cosmopolitan species like *Lecane bulla* (*Gosse*). The taxonomy of calanoids is in a confused state. *Phyllodiaptomus annae* Apstein is the commonest calanoid form in reservoirs in Sri Lanka. It is also the commonest species found in other types of habitats, e.g., ponds, marshes. Brandlova, Brandl and Fernando (1972) listed 22 species of Cladocera alone as limnetic in lakes in Ontario, Canada in comparison.

There are only two species of *Daphnia* recorded from tropical South-East Asia. These are *Daphnia lumholtzi* Sars and *Daphnia similis* Claus (=*D. carinata* King of many authors). *D. similis* is a pond species (Brooks 1957), and *D. lumholtzi* is much commoner in reservoirs. There is a claim that a Japanese *Daphnia* species has been stocked in some reservoirs in Indonesia, e.g., Jatiluhur reservoir, West Java. Since *D. similis* is very unlikely in a reservoir and since it is not *D. lumholtzi*, the possibility remains that the *Daphnia sp.* was actually introduced from outside the area. In areas bordering tropical South-East Asia, more *Daphnia* spp. have been recorded. Shirota (1967) records 4 species in South Vietnam, and Arora (1931) found five species in Lucknow, India. The paucity of *Daphnia* throughout most of South-East Asia is rather surprising and a number of factors probably contribute to this situation : (*a*) High prevalent temperatures throughout the year, (*b*) High fish predation, and (*c*) Lack of natural lakes.

The rationale for considering the introduction of invertebrates into reservoirs in South-East Asia is the paucity of limnetic species. It is likely that such introductions will enable a diversification of the fish fauna and increase fish yields. Ivlev (1961) considers *Daphnia* one of the most important fish food items. Fernando (1974) has discussed invertebrate introductions into reservoirs in South-East Asia and has also reviewed Soviet work on invertebrate introductions. Other Soviet work reporting increases in fish production as a result of invertebrate introductions are Tiutenkov (1963), Gasunas (1970) and Kochalova and Ladzdya (1970).

The introduction of fish and invertebrates into reservoirs must be carefully monitored, and precautions taken to avoid the introduction of fish parasites. Fernando and Furtado (1963) and Fernando and Hanek (1973) have found fish parasites introduced into Sri Lanka with imported fish.

Reservoir Fertilization

Some of the shallow reservoirs in South-East Asia receive considerable quantities of organic and inorganic fertilizers. Fernando (1973) has noted the fertilization of reservoirs in Sri Lanka and lakes in Africa by large herbivorous mammals. In Singapore, one of the drinking water reservoirs (Seletar) is so highly enriched by pig faeces that the bighead carp is fattened successfully without any additional feeding, this reservoir also has a flourishing fishery of *Tilapia mossambica*.

Fertilization of reservoirs with a view to increasing fish production has however not been practiced so far in South-East Asia. Such fertilization may prove economical when suitable fish are present. Baranov, Bauer and Pokrovskii (1973) have reviewed the Soviet work on fertilization of reservoirs. Fertilizers containing Calcium, Nitrogen and Phosphorus have been used successfully to increase fish yields.

Fish Yields in Relation to Primary Production

Primary production in most tropical reservoirs is high. Ganapati (1972) obtains values of about 3-10 gC/M²/day for Indian reservoirs, both shallow and deep. Sreenivasan (1968) reports a value of about 3 gC/M²/day for one upland reservoir and a much lower value for another in India. Sreenivasan (1969) found a conversion rate of 0.25% of primary production to fish in a South Indian Lake. McConnell (1965) found a 10% conversion of primary production by *Tilapia.*

The very high production of fishponds and highly eutrophic standing waters with suitable fish species (Table 6) indicates that present fish yields in tropical reservoirs is much lower than potential values.

SUMMARY AND DISCUSSION

Although the reservoir area in South-East Asia is considerable, the fish production is low in the majority of reservoirs. This situation is not universal, however, and high fish production has been recorded in a number of individual reservoirs in Sri Lanka and Indonesia, and in Sri Lanka as a whole. High fish production in reservoirs (and natural lakes) in South-East Asia has with few exceptions resulted from introduction of typical lake species from Africa. It appears very likely that addition of further lake fish species especially into deeper reservoirs will increase present fish yields. Diversification of the " lake " fish fauna can be achieved by introduction of species indigenous to the region like *Etroplus suratensis* and carps in combination with African cichlids. In this introduction of fish species, three points may be noted with specific reference to *Tilapia* spp. : (*a*) Lakes without indigenous cyprinids and fish fauna (e.g., L., Tempe Sulawesi) show marked fluctuation in fish catch with the introduction of *Tilapia*, and this could be stabilised by the introduction of predators and more diverse species. (*b*) Lakes with a moderate diversity of fish fauna including cyprinids and predators (e.g., Sri Lanka) show a high stabilised production with the introduction of *Tilapia*, presumably because of the effect of predator pressure on excessive *Tilapia* breeding. (*c*) Lowland lakes with a rich diversity of indigenous fish species colonising lakes including cyprinids and predators (e.g., Mekong basin, Malaysia), may not require the introduction of *Tilapia.*

Introduction of invertebrates into reservoirs in South East-Asia has not been done deliberately so far. However, the experience in other parts of the world notably the Soviet Union, indicates that such introductions are likely to prove beneficial and to increase fish production. The natural paucity of the zooplankton species in typical lake forms has been noted throughout tropical South-East Asia, and careful monitoring of introductions is recommended. Perhaps a combination of invertebrate introduction and fertilization can be used especially in smaller reservoirs.

The potential for a considerable increase in fish production from reservoirs exists in South East Asia. Proper management is likely to cost less than what is required for fish culture. Rural areas are likely to benefit most from increased fish production in reservoirs, and this might be a way provide cheap protein where it is most urgently needed.

ACKNOWLEDGEMENTS

We wish to thank the following for providing facilities for our work. Mr. A. S. Mendis, Deputy Director (Research), Department of Fisheries, Sri Lanka ; Dr. V. G. Jhingran and V. R. P. Sinha, Inland Fisheries Research Institute, Barrackpore, India ; Mr. Pong Suwignyo and Dr. A. J; Hanson, Institute, Penang, Malaysia ; Mr. Ong Kee Bian, Director of Fisheries, Sarawak, Malaysia e Mr. Chin Phui Kong, Director of Fisheries, Sabah, Malaysia. Part of this work was carried out while one of the authors (C.H.F.) was a Visiting Professor at the Department of Zoology (formerly the School of Biological Sciences), University of Malaya, Kuala Lumpur under a grant from the International Development Research Centre, Ottawa. Mr. S. Achmad, Director of the lake fish station, Jatiluhur, Indonesia kindly supplied data on Indonesian reservoirs.

REFERENCES

ACHMAD, S. 1970. Some notes on fisheries of lake Djunada, Djatiluhur. *Inland Fisheries Research Station, Djatiluhur*, Report No. 2, 12 pp.

ACHMAD, S., 1975. Pers. Comm.

ANON, 1969. The ecology and fisheries of fresh water reservovoirs. *Papers presented at Seminar, Indian Council on agricultural Research, Barrackpore, Nov. 27-29 (1969). 34 pp.*

ARORA, G. L., 1931. Fauna of Lahore 2. Entomostraca (water fleas) of Lahore. *Bull. Dept. Zool. Panjab Univ.* (India), 1, 62–100.

BARNOV, I. V., BAUER, O. N. and POKROVSKI, V. V., 1973. Biological basis of increased fish productivity of the USSR lakes. *Verh. Internat. Verein Limnol.*, 18, 1951–1863.

BRANDALOVA, J., BRANDL, Z. and FERNANDO, C. H., 1972. The Cladocera of Ontario with remarks on some species and distribution. *Can. J. Zool.* 50, 1373a1403.

BROOKS, J. L., 1957. The systematics of North American *Daphnia. Mem. Conn. Acad. Arts Soi.*, 13, 1–180.

FERNANDO, C. H., 1965. The development of Ceylon's fisheries 11. The role of inland waters in relation to the development of Ceylon's fisheries, and a note on the pearl oyster fishery. *Bull. fish. Res. Stn. Ceylon* 17, 29–297.

FERNANDO, C. H., 1970. The role of introduced fish on fish production in Ceylon's freshwaters. In *the scientific management of animal and plant communities for conservation.* Edit. E. B. Duffey and A.S. Watt, pp. 295–310. Blackwell, Oxford.

FERNANDO, C. H., 1973. Man-made lakes of Ceylon : A biological resource. In *Man-made lakes. Their problems and environmental effects. Geophysical Monograph Series, Vol.. 17, Edit. W. C. Ackermann et. al. Washington.* D. C.

FERNANDO, C. H., 1974. Guide to the freshwater fauna of Sri Lanka (Ceylon) Suppl. 4. *Bull. Fish Res. Stn. Sri Lanka (Ceylon)*, 25.

FERNANDO, C. H. and FURTADO, J. I., 1963. A study of some helminth parasites of freshwater fishes of Ceylon. *Z. Parasitenk.*, 23, 141–163.

FERNANDO, C. H. and HANEK, G., 1973. Some parasitic Copepoda from Sri Lanka (Ceylon) with a synposis of parasitic Crustacea from Ceylonese freshwater fishes. *Bull. Fish. Res. Stn. Sri Lanka (Ceylon)*, 24, 63–67.

FERNANDO, C. H. and INDRASENA, H. H. A., 1969. The freshwater fisheries of Ceylon. *Bull. Fish Res. Stn. Ceylon*, 20, 101–134.

FREY, D. G., 1967. Reservoir research-objectives and practices with an example from the Soviet Union. In *Resevoir fishery resources Symposium.* Athens, Georgia (1967). pp. 26–36.

GANAPATI, S. V., 1972. Organic production in seven types of aquatic ecosystem in India. In *Tropical Ecology with an emphasis on organic productivity.* Edit. F. B. Golley and R. Misra. Athens, Georgia (1971). pp. 313–350.

GASUNAS, I., 1970. Acclimatization of valuable invertebrates—the important way to increase the biological productivity of lakes (Russian). *Trudy Vsesoyuzn. Sympoz, po osnovnym problemna presnovodnykh ozer Vilnus*, 3, 190–198.

HICKLING, C. F., 1961. *Tropical inland fisheries.* Longmans Lond. 287 pp.

IVLEV, V. S., 1961. *Experimental ecology of the feeding of fishes.* Transl. from Russian by Douglas Scott. Yale Univ. Press New Haven. 302 pp.

JENKINS, R. M., 1967. The influence of some environmental factors on standing crop and harvest of fishes in U. S. Reservoirs. *In Reservoir fishery resources Symposium.* Athens, Georgia (1967) pp. 298–321.

HOLCHIK, J., 1970. Standing crop, abundance, production and some ecological aspects of fish populations in some inland waters of Cuba. *Vest. Cs. spol. Zool.*, 34, 184–201.

JOTHY, A. A., 1968. Preliminary observations of disused tin-mining pools in Malaya and their protential for fish production. *proc. Indo-pacif. Fish Counc. 13th Session, Brisbane Occ. Pap. 69/11, 21 pp.*

KACHALOVA, O. L. and LAGZDIN, G. S., 1970. Acclimatization of mysids in the water bodies of the Latvian SSR (Russian). *Tezisy Dokl.* 11. *Siezda Vsesoyuznogo gidrobiol obshchestva Kishniev*, 1969–170.

MCCONNELL, W. J., 1965. Relationships of herbivore growth to rate of gross photosynthesis of microcosms. *Limnol Oceanogr.*, 10, 539–543.

MENDIS, A. S., 1964. A contribution to the limnology of Colombo lake. *Bull. Fish. Res. Stn. Ceylon*, 17, 213–220.

SHIROTA, A. and TRAN-DINH-AN, 1966. Some studies on Cladocera. *Institut Oceanographique de Nhatrang (Vietnam) Saigon 47 pp.*

SREENIVASAN, A., 1964. The limnology, primary production and fish production in a tropical pond. *Limnol. Oceanogr.* 9, 391–396.

SREENIVASAN, A., 1967. Tilapia mossambica : *Its ecology and status in Madras State, India Madras J. Fish.*, 3, 33–43

SREENIVASAN, A., 1969. Primary production and fish yield in a tropical impoundment, Stanley Reservoir, Mettur Dam, Madras State, South India. *Proc. Nat. Inst. Sci. India (B)*, 35, 125–130.

TITUTENKOV, S. K., 1963. Acclimatization of mysids and possibility of introduction of other Ponto-Caspina invertebrates in the lake Balakash (Russian). *Trudy Instiuta Ikhtiologii i rybnogo khozyaistra Akademii Nauk Kazakhskoi SSR*, 4, 152–174.

YAP, S. Y., 1974. The ecology of some freshwater fishes in Subang Lake, Malaysia with special reference to the feeding *of Cyclocheilichthys apogon* Valenciennes (Cyprinidae). 65 pp. B. Sc. Honours (Ecology) Thesis, School of Biological Sciences, University of Malaya.

LEGENDS TO TEXT FIGURES

Fig. 1. Location of major natural and man-made freshwater habitats and fisheries in South East Asia.

Fig. 2. Man-made lakes in Sri Lanka. In a total area of 70,000 sq. km. there are over 10,000 such lakes with a total area of about 125,000 hectares (After Fernando 1970).