RESERVOIR FISHERIES IN SOUTH EAST ASIA: PAST, PRESENT AND FUTURE

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Abstract

Reservoirs are being constructed at an accelerating pace in South East Asia adding vastly to ancient and more recently built reservoir systems. At present the reservoir area for the region is 3.0 million hm^2 and the figure will increase to 15 million hm^2 before the turn of the century. Natural lakes in South East Asia are few and some of these are atypical (flood lakes).

Fisheries in South East Asian reservoirs are of very recent origin and poorly developed. Fish yields are low in most areas. Indigenous fish species in South East Asia are mostly riverine. Introduced African cichlid fish (mainly *T. mossambica*) have increased spectacularly fish yields in some areas. This can be attributed to their more efficeint exploitation of the lacustrine habitat. It is suggested that introduction of lacustrine species is necessary if fish yields from reservoirs in South East Asia are to be increased to levels comparable to those found in tropical Africa.

Some adverse effects due directly or indirectly to the introduction of *T. mossambica* have been reported. These include interference with culture in fishponds and the spread of parasites.

The effect of introduced fish on fish yields in deep and up-country reservoirs has so far been small. It is suggested that deep water African cichlids be introduced into deep reservoirs and cold water tolerant species into reservoirs at high altitudes. It is suggested that introduced foreign lacustrine fish may not take easily in areas like the Mekong where the indigenous fish fauna is rich in species.

Cooperation between the different countries in South East Asia is desirable in developing reservoir fisheries. The sharing of expertise and facilities will enable a more realistic and viable approach to research on and management of reservoirs. The potential for increased fish yields from South East Asian reservoirs is high. A rough estimate of the total reservoir yield by the end of this century is 1.25 million tons. This fish yield will also be available at relatively low cost, on a sustainable basis and in regions where protein shortage is greatest.

CONTENTS

1. INTRODUCTION

If the age of reservoirs is of any significance, South East Asia has the oldest. Reservoir building is supposed to have commenced about 4 000 years ago and they are being built at an accelerating pace in many parts of the world. This is true of South East Asia where the present reservoir area of about 3 million hm^2 will increase to about 15 million hm^2 by the turn of this century.

South East Asia is conspicuously poor in natural lakes compared to any other region except arid areas and South America. However, both South America and South East Asia are rich in running waters; hence they possess a high potential for reservoir construction.

Fisheries in reservoirs of any magnitude date back only a very short time in South East Asia and the potential for fish production has been realized only to a very limited extent. The failure of indigenous fish species to give high yields in reservoirs is due to the lack of a lacustrine component among South East Asian fishes. The paucity of natural lakes in the region is certainly a major cause for this lack. However, in the last 20 years or so, reservoir fisheries have assumed considerable importance in limited areas like Sri Lanka, and this tendency is spreading throughout the region. Marked increases in fish yields from reservoirs have been noted in areas where *Tilapia* spp. (mainly *T. mossambica*) have been introduced.

In the present paper I shall discuss the extent of reservoirs in South East Asia in relation to other standing waters and the fish production from these reservoirs in the past, present and future. The composition of the indigenous fish fauna and the role of introduced fish species on fish production in reservoirs in South East Asia will be evaluated. Based on past experience, and the present situation, an attempt will be made to assess future fish yields.

The data I have used are drawn mainly from Sri Lanka, but I have included the available published and unpublished data from other parts of South East Asia. The reservoir fisheries of India have been summarized by Jhingran (1975). Fernando (1965, 1971, 1973) and Fernando and Indrasena (1969) have dealt in detail with the reservoir fisheries of Sri Lanka. Achmad (1970) gives some data on an Indonesian reservoir. Yap (1974) gives fish production data for a Malaysian reservoir and Oopatham Pawaputonon (1976) gives data on fish production in Thai reservoirs. The earlier data on reservoir fisheries in South East Asia have been summarized by Hickling (1961). Fernando and Furtado (1976) have summarized the more recent data.

2. RESERVOIRS: AREAS AND DISTRIBUTION

In 1952 the reservoir area of South East Asia was estimated at less than 1 million hm^2 (IPFC report quoted by Dussart, 1974). The total area of standing water in the region was estimated in the same report as 3.2 million hm^2. This included rice fields, estuaries, natural lakes, brackishwaters and fishponds. The present extent of reservoirs in the region is about 3.0 million hm^2 (Table 1). At the turn of the century this figure is expected to increase to 15 million hm^2 (Table 1).

The total area of natural lakes in the region amounts to only 1.8 million hm^2. However, this figure includes the flood lakes of Cambodia and Kalimantan and the high altitude lakes in India and Pakistan. The first type is not typical and the second group not tropical. Only Indonesia and The Philippines have sizable areas of natural lakes. A good portion of Indonesian lakes is located in Sulawesi (Table 2) which is on the wrong side of Wallace's line for Cyprinidae and Siluroidea—fishes which are the mainstay of Asian freshwaters.

Reservoirs are by no means evenly distributed in South East Asia (Table 1, Fig. 1). The highest concentration of ancient reservoirs is found in Sri Lanka (Fig. 2). Recently constructed (mainly large) reservoirs are concentrated in India and the Mekong region (Fig. 1). Active reservoir construction at an accelerated pace is going on in Indonesia, Sri Lanka, India and the Mekong region. Details of reservoir areas in the region are available for some countries only. Jhingran (1975) has given a list of major Indian reservoirs and their areas. Fernando (1973) has given a detailed list of all reservoirs over 300 hm in Sri Lanka. Data from Thailand and Indonesia are given in Tables 2 and 3. Fernando and Furtado (1976) have made estimates where possible of reservoir areas in the region (Table 1), but there is a gap in our knowledge of reservoir areas in Burma, Bangladesh, Vietnam, Laos and Cambodia.

3. THE FISH FAUNA

3.1 Indigenous fish fauna

The tropics form three widely separated, faunally distinct areas, as far as freshwater fish are concerned. Lowe McConnell (1969) has reviewed this subject in detail and has discussed the reasons for this difference and its implications. Of the three areas, only Africa has a lacustrine component in its fish fauna. The number of indigenous freshwater fishes in each country of South East Asia is shown in Fig. 3. They vary from the very rich fauna of Thailand to the very poor fauna in Sri Lanka. Lowe McConnell (1969) gives figures for African lakes, the Amazon Central America, Argentina and South Africa. Some African lakes have over 200 species and the major African rivers are rich in species too. The Amazon has over 1 000 species. Although riverine fish are numerous, both South (and Central) America and South East Asia have few lacustrine freshwater fishes, although Myers (1960) found a species flock of Cyprinidae in Lake Lanao, The Philippines.

Tropical Asian and South American freshwater fish faunas are dominated by Cyprinoidea and Characoidea respectively. Fishes of these families often breed only during high water following floods. Lowe McConnell (1969) points out that the lacustrine cichlids of Africa breed throughout the year giving more stable populations of all sizes. Seasonal fluctuations in food occur to a lesser extent in lacustrine than in riverine conditions. Planktonivorous species can be expected in lacustrine conditions but hardly in riverine conditions. The net result of these adaptations is that when reservoirs are built in South East Asia the fish recruits available are only poorly adapted for lakes.

The indigenous fishes that colonized reservoirs in Sri Lanka include practically the whole spectrum of available species except torrent dwellers and some small stream fishes. A similar situation probably exists in other parts of South East Asia. The dominant fish in the catch were the larger carps and large predators. However, in no reservoir in the whole of South East Asia was the fish yield of indigenous species comparable to the high yields recorded in African reservoirs stocked with African cichlids (Hickling, 1961). Unfortunately, we do not have much data from reservoirs where only indigenous fishes were present in South East Asia. One of the reasons for this gap in data is certainly the very low yields which made fishing unprofitable and not worth reporting. Where data are available, low values have been reported for catches of indigenous species (Oopatham Pawaputonon, 1974; Jhingran, 1975; Fernando and Furtado, 1976). It is interesting to note in this connexion that Holcik (1970) found that the standing crop of fish in Cuban lakes was dominated by two introduced North American lacustrine fishes. The "aboriginal" fish species which were present formed only a small percentage of the total fish catch, and in a backwater where only "aboriginal" species were present the standing crop was much lower. Lin (1953) noted that 80 percent of the catch in Haiti consisted of introduced *T. mossambica*.

3.2 Introduction of foreign fish species into reservoirs

Introduction of warm water food fishes into South East Asian freshwaters was begun relatively recently, although carp and trout had earlier been introduced mainly into hilly regions. Schuster (1951) gave a list of fish species introduced into the Indo-Pacific region. Sreenivasan (1967) gave an excellent review of the status of *Tilapia mossambica* introductions in India and also mentioned the status of this fish introduced into other parts of the tropics. Fernando (1965, 1971) gave a detailed list of species and the dates of their introduction into Sri Lanka. In all, 15 species had been introduced between 1882 and 1969 into Sri Lanka freshwaters. Four of these were African cichlids, two were from Indonesia, three from Europe (into upland reservoirs) one from Thailand, one from Malaysia and two from mainland China.

Apart from trout and common carp, very little fish introduction has been done in South East Asia prior to 1940. During the second world war an unknown fish (later shown to be *Tilapia mossambica* Peters) was found and distributed widely throughout the Malaysian region as a culture species. Thus *T. mossambica* made its entrance into South East Asia in an area almost devoid of reservoirs. It was later introduced into other parts of South East Asia with varying success. Chimits (1955, 1957) has provided an excellent summary of *Tilapia* species, their culture, biology and introduction into countries both within and outside Africa. On the basis of the success of *Tilapia mossambica* in small low-country reservoirs Fernando (1965) suggested the addition of complementary species of *Tilapia*. This was done later (Fernando, 1971). The example of Sri Lanka reservoirs is particularly instructive. There are no natural lakes in Sri Lanka. However, of over 10 000 reservoirs

some are as old as 1 500 years. Any stabilization of fishstocks could have occurred in this period to give the highest yield possible. However, before the introduction of *Tilapia mossambica* the fish yields from reservoirs were very low (Fernando, 1971).

From an examination of the available data on indigenous freshwater fish fauna in South East Asia it is evident that "lacustrine" species are rare. Some riverine species may live in lacustrine conditions apparently successfully. But fish yields under these conditions are low where only indigenous species are involved. Data from Thai reservoirs show low standing crops (Table 3). Whether these figures will be any higher with stabilization remains to be seen. Under the semi-lacustrine conditions of the flood lakes of Cambodia and Kalimantan high fish yields of indigenous species are recorded but it is not known whether any of the species from these regions can be successfully acclimatized to reservoirs.

3.3 The impact of introduced fish species

A phenomenal increase of fish yields in reservoirs following the introduction of foreign species has been noted in Sri Lanka. Fernando (1965, 1971, 1973), Fernando and Indrasena (1969) and Fernando and Furtado (1976) have documented this very thoroughly. Spectacular increases in reservoir fish yields following the introduction of *Tilapia mossambica* have also been noted in Indonesia (Hickling, 1961; Fernando and Furtado, 1976). In India where the introduction of this species has been restricted to certain areas only (Chauduri, 1964), large sized tilapias have been noted in reservoirs by Sreenivasan (1967).

There is considerable confusion regarding the suitability or otherwise of foreign fish introductions in South East Asia. This applies especially to African cichlidae which are somehow considered more foreign. Incidentally, there are three species of cichlidae indigenous to South East Asia and one of them, *Etroplus suratensis*, (Bloch) is of some importance in reservoir fisheries. Anon. (1955) advised against introducing *T. mossambica* because of its aggressive nature. Chauduri (1964) mentions that in India its introduction was restricted to some areas only. Somehow the idea remains that South East Asia must be self-sufficient in fish species for its own reservoirs.

When a new reservoir is constructed the colonizing fish species are drawn from the rivers and streams that drain into it. In areas where natural lakes exist with an established lacustrine fish fauna, these species gradually establish themselves in the reservoir (Naidenow, 1972). Sometimes less valuable species (for food and sport) attain numerical superiority and the addition of predators does not seem to help much. Sin e theoretical principles for hydrobiological forecasting are not yet elaborated, analogous deduction with the help of present knowledge of reservoir biology must be used (Naidenow, *loc. cit.*).

When reservoirs are built in regions without a true indigenous lacustrine fish fauna, their exploitation by the available riverine species is only partially successful. One of the misleading factors in this situation is that some of the riverine species make good culture species in ponds, e.g., *Catla catla* (Hamilton), *Cirrhina mrigala* (Hamilton), *Labeo rohita* (Hamilton), *Puntius javanicus* (Bleeker), and various carps throughout the region. But in reservoirs these species do not give high fish yields.

Tilapia mossambica has been introduced most widely in South East Asia. It is found to "runt" in ponds. Sreenivasan (1967) found this to be so in India. However, in reservoirs it does not runt (Fernando 1965, 1971) 1973). The coefficient of condition K and the mean size of *T. mossambica* in Sri Lanka are given in Table 4, which shows that in reservoirs it is not stunted and has a high K compared to fishponds and a saline lagoon. Crowding and food availability seem to be the factors determining K, since Canagaratnam (1966) found that *Tilapia mossambica* grows faster in saline than in fresh waters.

In Sri Lanka of the 12 warm water foreign species introduced only *Tilapia mossambica* has had a major impact on fish yields in reservoirs. Table 5 gives the fish yields from reservoirs in some South East Asian countries. Sri Lanka has the highest yield. Fish catches from different types of reservoirs in Sri Lanka (Table 6) show a wide range. The species composition shows a preponderance of *T. mossambica* in the catches. Indigenous species include *Etroplus suratensis*, an indigenous estuarine cichlid introduced into reservoirs; *Labeo dussumieri* (Val.); *Puntius* spp.; and predators like *Wallago attu* (Bloch and Schneider). The goramy, *Osphronemus goramy* (Lacepede), a riverine Indonesian species appears in the catches but hardly any common carp were caught despite the release of millions of fry into reservoirs (Table 7). It is interesting to note that within

a small country like Sri Lanka considerable differences exist in the species composition of fish catches in reservoirs, e.g., no *Wallago* or *Labeo* are caught in southern reservoirs (Table 7). It is noteworthy, though, that indigenous fish species have not been eliminated by *T. mossambica*. The exploitation of indigenous fish species in reservoirs has become feasible only because of the large standing crop of *Tilapia*. Incidentally, Alfred (1961) states that of the 70 species of indigenous freshwater fishes recorded in Singapore, only 32 are now found. This is due to the effect of high human densities. Mani (1974) and Fernando (1975) have pointed out that the Indian freshwater fauna has been reduced by human interference.

Apart from African cichlids (mainly *T. mossambica*) other fish species have been introduced in South East Asian reservoirs. These belong to three categories: (i) riverine species, e.g., *Labeo* spp., *Catla catla*, *Puntius Javanicus* and *Osphronemus goramy*; (ii) marsh and local estuarine species, e.g., *Trichogaster pectoralis* (Regan) and *Etroplus suratensis* and (iii) domesticated and semi-domesticated species used in fish culture, e.g., *Cyprinus carpio* L. and Chinese carps. The so-called Indian carps have increased fish yields in Southern Indian reservoirs. *Etroplus suratensis* and *Osphronemus goramy* are caught in some quantity in Sri Lanka. Although some indigenous marsh dwellers seem to thrive in the shallow littoral of reservoirs, their overall contribution to the fish catch is generally low. Hardly any impact has been made on reservoir fisheries by domesticated or semi-domesticated fish.

Some adverse effects have been reported as a result of fish introductions to reservoirs. Fernando and Furtado (1963) and Fernando and Henek (1973) found that helminth and copepod parasites had been introduced into Sri Lanka with introduced fish species and these parasites now infested indigenous fish species. Sreenivasan (1967) reported that the introduction of *Tilapia mossambica* had had adverse effects on the pond culture of the milkfish *Chanos chanos* and the common carp *Cyprinus carpio*. Zaret (1974) reported that the introduction of a new predator caused a serious depression in the fish population in a Central American lake.

4. PRESENT FISH PRODUCTION IN RESERVOIRS

Taken as a whole, reservoirs in outh East Asia have a low fish yield. Only about 60 000 metric tons are harvested from over 3.0 million hm^2 (Fernando and Furtado, 1976). This gives an average of 20 kg hm^{-2} $year^{-1}$. The range of fish yields is 0-600 kg hm^{-2} $year^{-1}$ (excluding some very eutrophic, shallow lakes). Table 5 gives the fish yields in some South East Asian countries.

Fernando and Furtado (1976) have given the fish yields from a wide range of reservoirs throughout South East Asia. In the present paper, I have added data from Thailand (Table 3) and southern reservoirs in Sri Lanka (Table 6). All the reservoirs having high yields are (a) shallow and (b) stocked with African lacustrine cichlidae (mainly *T. mossambica*). India and Thailand, which between them have about 75 percent of the total reservoir area in South East Asia, have low fish yields at present. Sri Lanka has high yields and Malaysia and Indonesia have few reservoirs. Fish yield in some Indonesian reservoirs is, however, quite high. Deep reservoirs and upland reservoirs have low to negligible fish yields in general. Perhaps this can be remedied to some extent with deep water cichlidae from the African great lakes and low temperature-tolerant *Tilapia* species like *T. sparmanni* (Castelnau) and *T. galilaea* (Ardeti).

5. FUTURE FISH INTRODUCTIONS

The questions that must be raised are: (i) whether any more fish introductions should be made into reservoirs in South East Asia and (ii) if introductions are to be made, what selection of fish is most suitable. From the experience of the past 35 years it is evident that indigenous fish do not give high yields in reservoirs under any circumstances in South East Asia. It is necessary, therefore, to introduce lacustrine fish if exploitation of reservoirs for fisheries is to be intensified.

Tilapia mossambica has been introduced widely into South East Asian reservoirs. This fish has raised fish yields (often spectacularly) in shallow reservoirs. However, it has not had such a marked impact on the fish yields in deep reservoirs. Caulton and Hill (1973) have shown that *T. mossambica* is unable to adapt to depths of over 13 m. Fernando (1965) proposed the introduction of deep water *Tilapias* into deep, South East Asian reservoirs and complementary species of *Tilapia* into shallow reservoirs. Based on the recommendations of Fernando (*loc. cit.*) three complementary species were introduced into Sri Lanka reservoirs (Fernando, 1971). Eccles (1975) has proposed the introduction of cichlids from the African great lakes into large (presumably deep) tropical reservoirs. Fernando (1971) also proposed the introduction of *T. galilaea*, a deep

water *Tilapia* and *T. sparmanni*, a cold water-tolerant species for deep up-country reservoirs. An excellent account of the cichlidae of the African great lakes is given by Fryer and Iles (1972). Lacustrine cichlidae of Africa offer a wide range of size, food preference and breeding behaviour.

While the introduction of *Tilapia* spp. has taken place in some areas of South East Asia, they have not been successful in others, e.g., Ling (1953) states that they were eliminated from open waters in Thailand. It will not be surprising if there is great difficulty in establishing foreign species in reservoirs in the Mekong region due to the very large number of indigenous species and the semi-lacustrine conditions in the Grand Lac. This area probably has fish species adapted to lacustrine conditions found in reservoirs. Predator pressure has eliminated *T. mossambica* in other parts of the world, e.g., in Guyana sugarcane fields (Lowe McConnell, 1969).

It is important that a careful study be made of the impact of the present introduction before future introductions are undertaken on a large scale. However, the air must be cleared of suspicions as regards introduction of *foreign* species. If introductions are decided against, in any particular area, this should be based on careful scientific study and evaluation.

6. BIOLOGICAL STUDIES ON RESERVOIRS

The extent of biological studies on reservoirs at a global level can be assessed by the research in this field over the last 30 years or so. Although a field of recent scientific endeavour, three international symposia have already been held on reservoirs. (Lowe McConnell, 1966; Obeng, 1969 and Ackermann *et al.*, 1973). In the U.S.A. two symposia have been devoted to reservoirs (American Fisheries Society, 1967; Hall, 1971). The Soviet Union has led the world in reservoir construction and research. The earlier work has been reviewed by Zhadin and Gerd (1961). Frey (1967) gave a summary of reservoir research in the Soviet Union, and Baranov *et al.* (1973) show the possibilities for enhancement of yields by fertilization and the introduction of invertebrates. The Indian Council for Agricultural research organized a symposium on reservoirs in 1969 (Anon., 1969) at which over 50 papers were presented. Reservoir fisheries in Sri Lanka have been reported on by Fernando (1965, 1971, 1973), Fernando and Indrasena (1969) and South East Asian reservoir fisheries have been summarized by Fernando and Furtado (1976). Wong and Ku (1970) refer to three papers on reservoir biology in mainland China. This list is probably incomplete. Although South East Asia has a sizable reservoir area, very little is known about their biology and despite some excellent work in India (see Jhingran, 1975 for summary), we still know practically nothing of their zooplankton and benthos. Outside the South East Asia region there is a monograph on an African reservoir Lake Kariba, by Balon and Coche (1974) besides a considerable amount of work on the biology and fisheries of African reservoirs.

7. MANAGEMENT OF RESERVOIR FISHERIES

It is important to the development and management of reservoir fisheries in South East Asia that a co-operative effort be made to pool the information available for the whole region. We need more reliable and complete statistics of reservoir areas, fish yields, species composition and seasonality of fish catches and the effects of introduced species. This will enable better planning and management of reservoir fisheries.

An attempt should be made to standardize data from this region. For example, fish yields have been calculated on the basis of half the total (full supply) area of a reservoir by Sreenivasan (1969). Fernando (1971, 1973) has, however, used full supply levels for areas in calculating fish yields. Reservoir levels do fluctuate considerably as shown for two Sri Lanka reservoirs by Fernando (1967, 1971).

Although the problems of reservoir fisheries in South East Asia are unique in some respects, the extensive results from research and management in other parts of the world can help in formulating research and management programmes for South East Asian reservoirs. This literature, which has been reviewed earlier in this paper, combined with other work already done or being done in South East Asia, can form a solid base for planning and further studies.

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TABLE 1

AREAS (hm^2 x 10^6) OF SOME TYPES OF INLAND WATERS PRODUCING FISH IN SOUTH EAST ASIA (MODIFIED FROM FERNANDO AND FURTADO, 1976)

Country	*Types*	*Reservoirs*		*Ricefields*	*Natural lakes and flooded areas*
		Present	*Future*		
Bangladesh ...	...	N.A.a/	N.A.	10.000	N.A.a/
Burma ...	...	0.010	0-150	5.000	0.050 FP
India ...	...	1.3	5.000	40.000	0.2b/
Indonesia ...	...	0.050	0.500	8.000	1.000 NL 0.100 FP
Cambodia ...	...	0.080	2.000	2.000	0.400 DP
Laos ...	...	0.050	5.000	0.700	N.A.
Malaysia:					
Malaya ...	...	0.020	0.150	0.500	0.008 FS
Sabah ...	...	N.A.c/	N.A.	0.050	N.A.
Sarawak ...	...	N.A.c/	N.A.	0.120	0.010 FP 3.187 FS 0.006 FL
The Philippines ...		N.A.a/	N.A.a/	N.A.a/	0.100 FP & NL
Singapore ...	...	0.0002	0.0003	Nil	Nil
Sri Lanka ...	...	0.125	0.250	0.600	0.020 FP
Thailand ...	...	1.2	2.0	6.700	N.A.
Total (Approx). ...	...	3.0	15.0	70.0	NL: FP: 1.850 FS: 3.2

N.A = No data available
a/ = Considerable
NL = Natural lakes
b/ = High elevation lakes in India and Pakistan
c/ = Negligible
FP = Flood plain
FS = Freshwater swamps

TABLE 2

DATA ON AREA AND MAXIMUM DEPTH OF SOME INDONESIAN LAKES AND RESERVOIRS (FIGURES SUPPLIED BY S. ACHMAD, DIRECTOR, FISHERIES STATION, JATILUHUR, INDONESIA)

Lake/Reservoir	*Area (hm^2)*	*Depth (m)*
SUMATRA		
Toba	112 970	450
Ranau	12 590	229
Singkarak	10 780	269
Maniniau	9 800	169
Diatas	1 220	44
JAVA		
a/ Jatiluhur	8 300	90
a/ Cigombong	30	17
a/ Ciburuy	40	6
Darma	400	8
a/ Rawa Pening	2 200	10
a/ Rawa Jombor	180	5
Telaga Ngebel	150	44
Ranu Klakah	34	28
Ranu Pakis	45	156
Ranu Klindungan	190	134
Ranu Bedali	12	11
a/ Rawa Jahung-Mlangi	2 500	3
Telaga Pasir	28	23
a/ Karangkates	1 500	75
a/ Selorejo	400	46
Waduk Bumder	83	2
Waduk Bureng	12	2
Waduk Prijetan	231	13
Waduk Kalen	45	3
Waduk Pacal	387	32
SULAWESI		
Tempe	35 000	5
Towuti	56 108	203
Matana	16 480	590
Manalona	2 440	73
Lindu	3 150	100
Poso	32 320	450
a/ Rawa Aopa	250	10
Limboto	4 950	5
KALIMANTAN		
Luar	3 000	—
Sekentut	100	3
Sumbu	250	4
Arawan	200	9
Termabas	150	7
Siawan	1 500	3
Panggang	6 000	—
LESSER SUNDA ISLANDS		
a/ Rawa Taliwang	1 500	—
Bratan	380	23
Batur	1 590	88

a/ Reservoir

TABLE 3

FISH PRODUCTION IN RESERVOIRS IN THAILAND (ADAPTED FROM GOPATHAM PAWAPUTONON (1974)

No.	*Region*	*Name*	*Water Surface Area* (10^3 *hm*^{2})	*Standing Crop*[a] *kg hm*$^{-2}$	*Annual Crop*[b] *kg hm*$^{-2}$ *year*$^{-1}$
	Northeast				
1		Lam Praperng	10.3	92	13
2		Lam Takong	24.6	14	9
3		Lam Poa	127.7	13	13
4		Oon	47.8	14	4
5		Sirinthorn	162.4	11	17
6		Ubolratana	228.8	22	—
7		Nong Han	43.2	24	—
8		Kaeng Lurn Chan	1.7	16	—
	North				
9		Bhumipol	162.0	6	—
10		Sirikit	158.4	14	—
11		Kwan Phayao	9.4	25	—
12		Chew Lom	11.2	3	—
	Central				
13		Kaeng Kachan	27.5	26	—
14		Bung Borapet	118.1	18	—
		(Total)	1 133.7	(Average) 21	(Average) 11.6

[a] From Rotenone Sampling
[b] From fish landing statistics

TABLE 4

THE STATUS OF TILAPIA MOSSAMBICA IN SOME HABITATS IN SRI LANKA (FROM FERNANDO, 1971)

	Habitat			*Fish*			
Name of Habitat	*Max. Depth* (*m*)	*Area* (*hm*^{2}) *F.S.L.*	*Description*	*Mean Length* (*cm*)	*Mean Weight* (*g*)	*Coefficient of condition* (*k**)	*Fish catch* (*kg hm*$^{-2}$ *year*$^{-1}$)
Beira lake	6.1	60.75	Brackish highly fertilized	15.9	93	2.25	2 244
Batticaloa lagoon	18.3	11 950	Brackish	20.4	144	1.70	(28-56)
Fish ponds	1.22	0.10	Freshwater	17.6	90	1.79	1 795
Karapola villu	9.15	810	Freshwater marsh, connected to river	26.8	443	2.10	84
Tabbowa Tank	9.15	461.7	Freahwater lake (shallow)	24.8	338	1.95	(56-84)
Parakrama Samudra	12.2	2 264	Freshwater lake	28.4 (34.2 in 1957)	443	1.88	180
Minneriya Tank	18.3	2 552	Freshwater lake (deep)	29.4	598	2.00	118
Kandalama Tank	21.35	984.2	Freshwater lake (deep)	31.4	651	2.02	(56-84)
Senanayake Samudra	45.75	77 939	Freahwater lake (very deep)	—	400	—	9

All samples taken in 1964-65
Fish production values for 1963
Figures within brackets are rough estimates

*$K = W \times 10^3$ / L^5

W = weight in grammes
L = length in millimetres

TABLE 5

FISH PRODUCTION (YIELD) FROM RESERVOIRS IN SOME S.E. ASIAN COUNTRIES. FIGURES ARE BASED ON FULL SUPPLY LEVEL AS TOTAL AREA. ACTUAL YIELDS SHOULD THEREFORE BE SOMEWHAT HIGHER

Country	*Reservoir Area* (10^6 *hm*^{2})	*Range (Yield)* (*kg hm*$^{-2}$ *year*$^{-1}$)	*Mean (Yield)* (*kg hm*$^{-2}$ *year*$^{-1}$)	*Source*
[a] India	1.3	0 – 250	6—6	Jhingran, 1975
Sri Lanka	0.125	0 – 610	100	Fernando, 1973
Indonesia	0.050	0 – 600	About 50	Achmad pers. comm.
[b] Thailand	1.2 14 Reservoirs	32 – 90[c]	20	Oopatham Pawaputonon, 1974
[c] W. Malaysia ...	0.020	0 – 90	20	Fernando and Furtado, 1976
South East Asia ...	3.0	0 – 600	20	Fernando and Furtado, 1976

[a] African cichlids very restricted
[b] African cichlids not established
[c] Standing crops

TABLE 6

FISH CATCHES IN DIFFERENT TYPES OF LAKES IN SRI LANKA (MODIFIED FROM FERNANDO, 1973)

Reservoir	*Area* (*hm*^{2})	*Max. Depth* (*m*)	*Total Catch* (*kg*)	*Catch* (*kg hm*$^{-2}$ *year*$^{-1}$)	*Years (s)*	*Standing Crops*[a] *Dry Wt.* *Plankton* (*kg hm*$^{-2}$)	*Benthos* (*kg hm*$^{-2}$)
Large shallow lowcountry reservoirs :							
Parakrama Samudra ...	2 262	9.7	1 511 995	225	1961—64	534	27.0
Minneriya Tank ...	2 550	13.1	564 247	75	1955—67	242	19.9
Kantalai Tank ...	1 912	14.3	96 501	50	1961—62	60	1.60
Giants Tank	1 840	4.3	26 195	14	1961—62	169	...
Large deep low-country : reservoirs							
Senanayake Samudra ...	7 770	38.1	497 060	20	1961—64	275	27.0
Nalanda Reservoir ...	273	22.9	nil	nil	1960—70	181	22.0
Up-country reservoirs :							
Castlereagh reservoir...	368	35.0	nil	nil	1960—70	146	3.5
Small low-country reservoirs :							
Dalukanawewa ...	41	4.6	3 175	70	1963	...	...
Beira Lake[a] ...	65	7.9	320 000	2 230[b]	1963	249	24.0
Moragaswewa ...	12	3.0	1 587	130	1963	304	5.2
Thimbrirgaswewa ...	10	3.7	1 587	150	1963	...	...
Small up-country reservoirs :							
Gregory's Lake ...	47	6.1	sport fishing is negligible		1900—70	...	...
Kande Ela Tank ...	44	8.2	no fishing		1960—70	30	1.7
Southern reservoirs :							
Muruthuwelawewa ...	522	15.0	21 223	41	1974		
Udukiriwelawewa ...	263	?	48 008	182	1974		
Udawalawe Reservoir ...	1 091	15.2	473 597	434	1974		
Ridlyagamawewa ...	888	7.0	541 641	610	1974	185.6	26.8
Badagiriyawewa ...	354	1.8	646 485	1 826[c]	1974		
Chandrikawewa ...	439	11.6	33 570	76	1974		

[a] Data from Mendis (1964, 1965) [b] Highly eutrophic [c] Probably highly eutrophic

TABLE 7

SPECIES COMPOSITION OF FISH CATCHES FROM DIFFERENT RESERVOIRS AND A VILLU IN SRI LANKA

Reservoir or Villu	*Year(s)*	*Total Catch (kg)*	*Percent Fish Catch by Weight*							
			Introduced		*Indigenous to Freshwaters*				*Introduced*	
			Tilapia	*Etroplus*	*Labeo*	*Wallago*	*Other Predators*	*Puntius*	*Goramy*	*Common Carp*
North Central Province										
Parakrama Samudra	1964—66	1 516 010	77.4	6.6	15.3	0.7	1.0	0.6	0.1	0
Minneriya Tank	1964—67	563 906	90.7	1.4	5.0	0.4	1.2	0.6	negligible	0
Karapala Villu	1964- 67	84 490	65.0	3.7	10.3	5.4	8.3	2.3	4.9	0.06
Eastern Province										
Senanayake Samudra	1961—64	498 592	40.3	8.5	44.7	4.5	0.05	1.6	negligible	0
Southern Province										
Muruthawela Tank	1974	21 223	81.0	4.0	0	0	5.6	6.4	2.7	0
Ridiyagama Tank	1974	541 641	95.0	1.3	0	0	2.0	1.0	0.08	0
Badagiriya Tank	1974	648 485	91.0	2.7	0	0	2.6	1.4	1.3	0
Udirkirwewa	1974	48 008	2.0	71.0	0	0	10.7	11.4	4.8	0
Java Province										
Chandrikawewa	1974	33 570	84.0	5.2	0	0	3.7	3.5	3.7	0.001
Java-Sabaragamuwa provinces										
Udawalawe Reservoir	1974	473 597	96.0	0.5	0	0	2.0	0.3	0.7	0.02

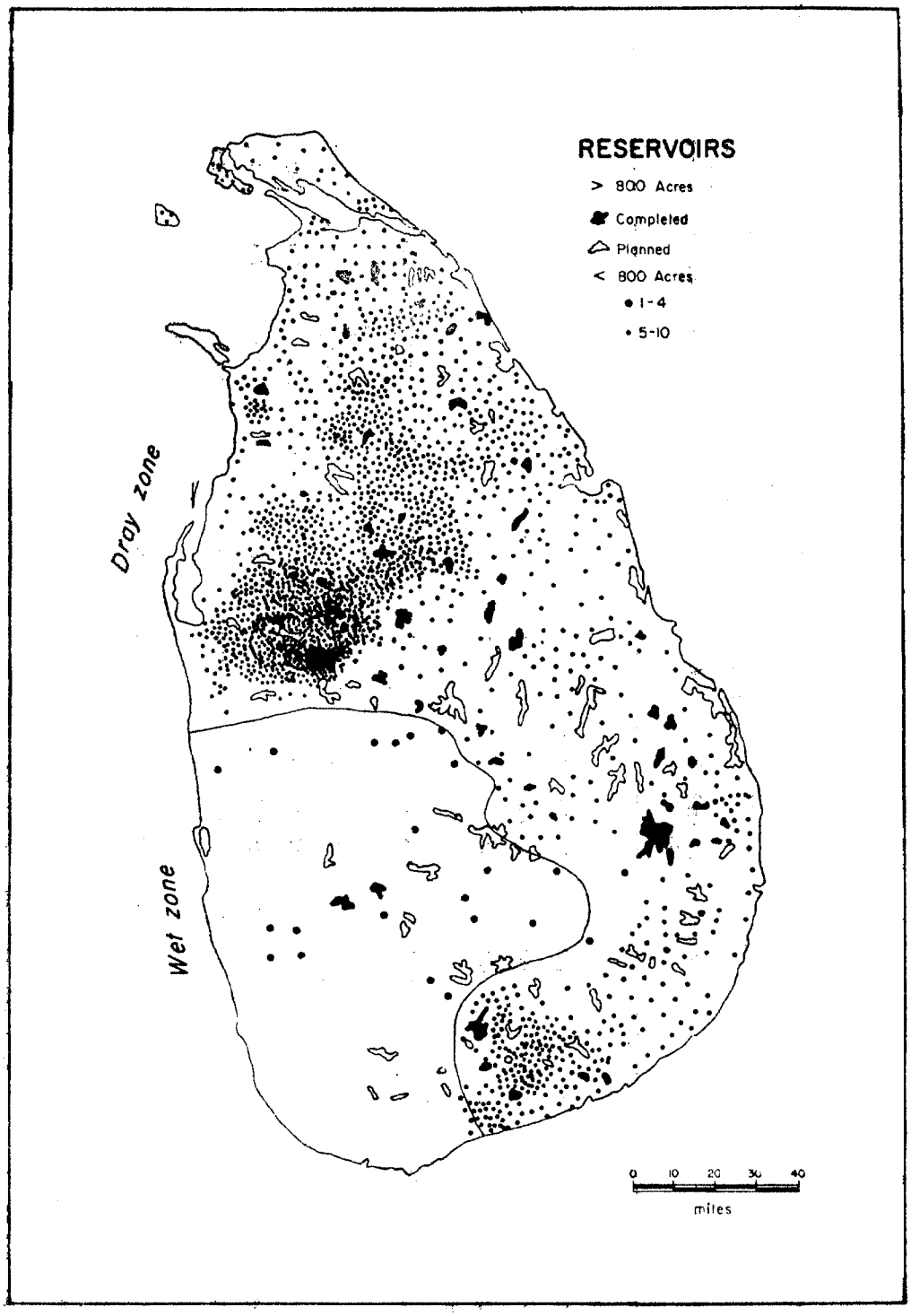

Figure 2: Reservoirs in Sri Lanka showing high density mainly of ancient reservoirs (after Fernando, 1971).

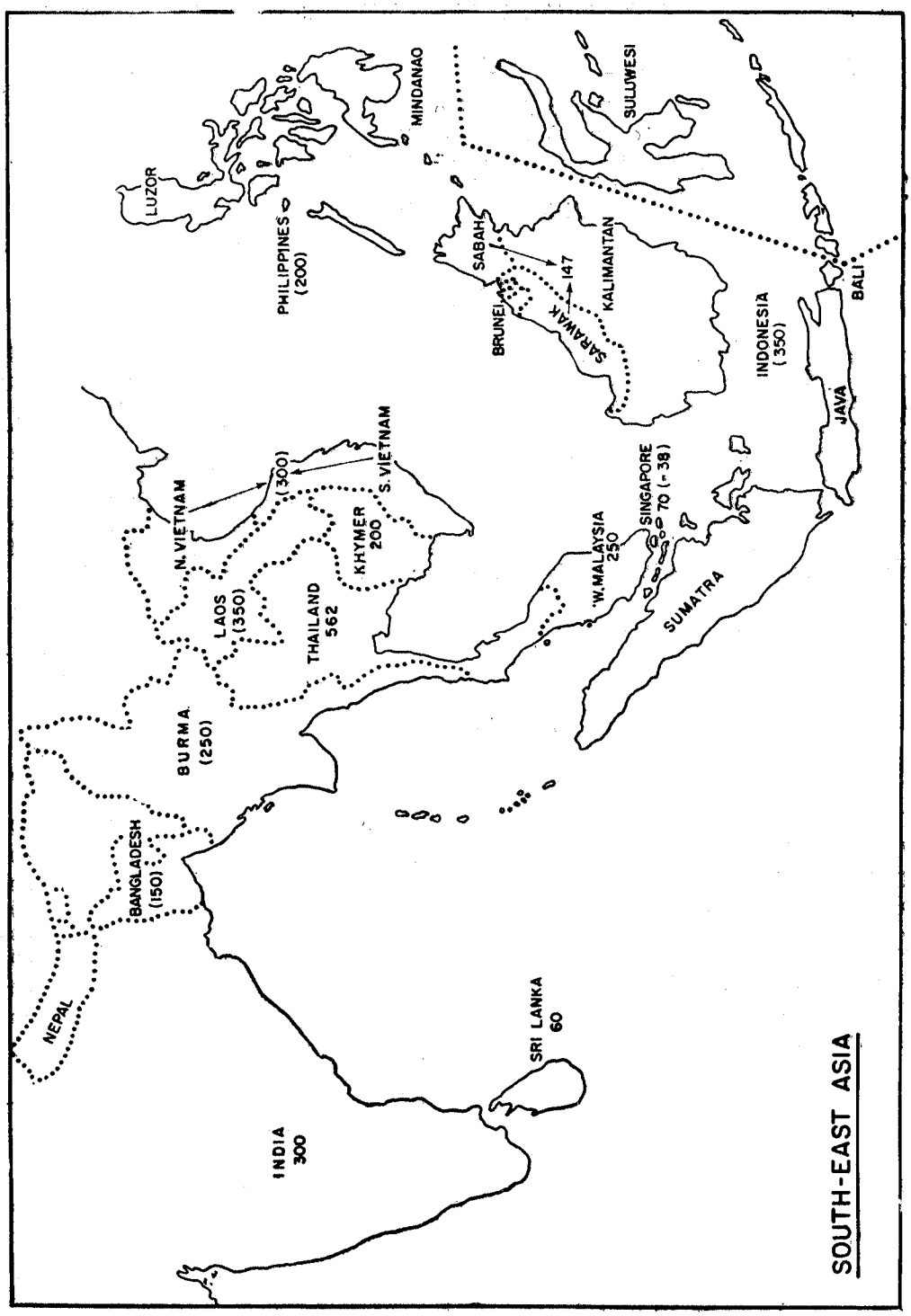

Figure 3: Indigenous fish species in South East Asia. Data from Alfred (1961), Dussart, (1974); Fernando (1971), Inger and Chin (1962), Jhingran (1975) and Smith (1945). Numbers within brackets are only very rough estimates. Singapore has lost 38 indigenous freshwater species during this century according to Alfred (1961).