presence of marine species that were introduced in the lake with the fishes that were transplanted from the Mediterranean Sea.

To compensate for the loss of the freshwater fishes, the Alexandria Institute of Hydrobiology* started in 1928 a program to transplant mullet fry from the Mediterranean into the lake. Fry of mullets, mainly *Mugil cephalus, Mugil capito* and *Mugil saliens* were introduced. In 1955 the mullet production contributed 21% of the commercial catch. Of the family Mugilidae, only *Mugil saliens* was able to spawn in the lake. *M. cephalus* and *M. capito* do not breed in captivity and, therefore, stocking the lake annually with these two species is continued.

It was found that the silverside, *Atherina mochon,* and the eel, *Anguilla* sp., were accidentally transplanted into the lake, along with the mullet fry.

The sole, *Solea vulgaris,* was first introduced in the lake in 1935. Additional plantings were made in 1943, 1945 and 1948. The young fish were collected from the coastal areas of the Mediterranean, eastern Alexandria and from Lake Idku in the region of the lake-sea connection. The acclimatization of sole was successful. It is now considered one of the main fishery resources of the lake. Additional plantings were made in 1977, with young fishes collected from the Lake Menzaleh-Mediterranean Sea connection, with the objective of renewing the stock of soles in Lake Qarun and improving the growth rate of the fish. Certain management measures are now being considered to protect the sole fishery of the lake against overfishing.

In 1970 the gilt-head bream, *Chrysophrys auratus,* was first introduced in the lake, but in relatively small numbers. The stocking rate was

PAGE 29

*Now called the Institute of Oceanography and Fisheries.

TROPICAL MAN-MADE LAKES, AFRICAN FISH AND CHEAP PROTEIN

C. H. FERNANDO
Professor, Department of Biology
University of Waterloo
Waterloo, Ontario, Canada

Reservoirs and Fisheries

THE FIRST man-made lakes (reservoirs) were built 6,000 yr ago in the Indo-Chinese region to irrigate rice fields. Reservoir construction then spread to many parts of the world, for water storage and crop irrigation. In modern times, reservoir construction with multipurpose objectives has been undertaken on a massive scale, especially since the advent of hydroelectric power generation. In many areas, however, the least utilized resource of reservoirs is the fishery. Often, no provision is made for a fishery. The most outstanding instance of such an unexpected fishery is that of Ubolratana reservoir in Thailand. This reservoir was built to produce electricity worth about $1 million a year, and it did. However, the fishery which developed unexpectedly was a bonus; it now is worth $1.2 million a year. Other instances of this type are not uncommon in the tropics.

Another success story in reservoir fisheries involves introduced African fish. This is also a case where a substantial amount of cheap protein is being produced from a relatively small reservoir. The reservoir is Parakrama Samudra. I shall use it because it is well documented. It also illustrates the importance of having the "right" type of fish in a reservoir, so as to get high yields. The reservoir is situated in the dry zone of Sri Lanka; it has a surface area when full of 2,246 ha. Records have been kept of the fishery in this reservoir since 1949. Up to 1953, the total fish catch varied from about 2-7 t/yr. The reservoir is 1,600 yr old.

In 1952 an African fish, a cichlid *(Tilapia mossambica),*[2] was introduced into Parakrama Samudra. By 1954, this fish started appearing in the fish catches. The fish yield rose spectacularly to over 500 t in 1966. There was another spectacular increase in 1974-1975 and, in the next few years, the yield hovered at around 1,300 t/yr. The yield in 1978 was about 900 t.

Global Considerations

To obtain a perspective of fish yields from tropical reservoirs, we must look at comparative fish yields from lakes and reservoirs throughout the world. If we compare the fish yield in Parakrama Samudra with yields from temperate reservoirs and lakes, the fish yield is an order of magnitude higher in Parakrama Samudra (Table 1). Fish yields in tropical reservoirs on three continents exhibit a wide range in fish yields (Table 1). This range extends from 15 t in a tropical Indian reservoir of the same size to about 900 t in Parakrama Samudra. High

NEXT PAGE

[1]The ideas embodied in this article were presented in more detail, and with extensive scientific documentation, entitled "Tropical reservoir fisheries: a preliminary synthesis," at the Fifth International Society of Tropical Ecology (ISTE) meeting in Kuala Lumpur, April 1979. This paper will be published in the proceedings of the meeting. The present adapted version is published with the permission of ISTE.

[2]*Tilapia mossambica* is also known as *Sarotherodon mossambicus.*

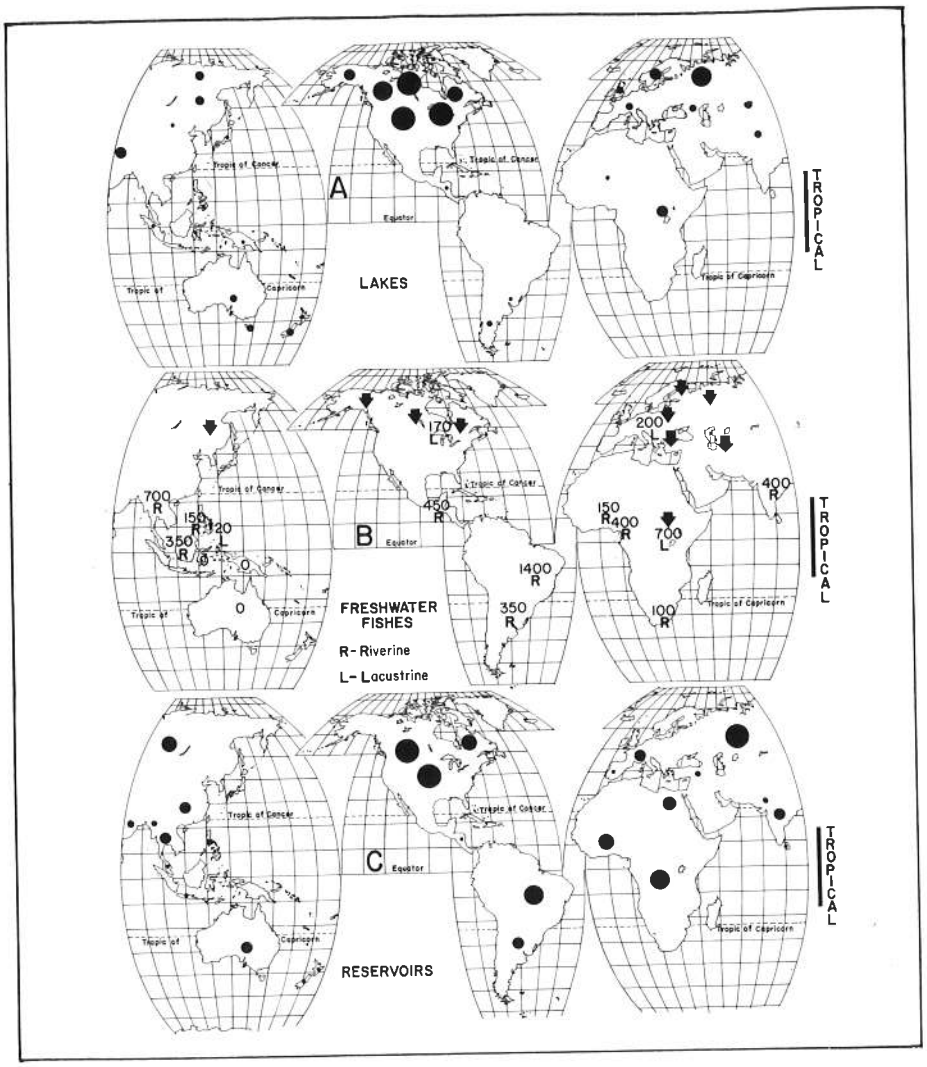

Fig. 1(A, C). Global distribution of natural lakes and reservoirs. Size of circles give approximate relative surface areas. (B) Freshwater fish species numbers in some regions of the world. Arrows indicate rich lacustrine fish faunas. Size of circles refer only roughly to water areas. Tropical lake areas outside Africa have been magnified to make them visible.

Table 1. Comparison of fish yields of some tropical and temperate lakes and reservoirs.[a]

Water body	Yield (t/yr) and composition
(a) Tropical	
Parakrama Samudra, Sri Lanka 1978	889 Herbivores, tilapia
Indian reservoirs	15 Indian carps
Thai reservoirs	159 indigenous carps mainly
African reservoirs	450 mainly tilapia
Brazilian reservoirs	247 Amazonian fishes, tilapia
(b) Temperate	
Canadian Shield Lake	2 carnivores mainly
US reservoir	57 sport, 27 commercial carnivores
USSR reservoir	67 (mean) herbivores and carnivores

[a]To assist comparison, the yield is given in each case from 2,246 ha, the area of Parakrama Samudra, Sri Lanka.

yields coincide with the presence of African Cichlidae.[3]

To understand the role of African Cichlidae in tropical reservoirs, we must look at the distribution of lakes and the fish faunas, now and in the past, in different regions of the world. Figure 1A shows the distribution of natural lakes in the world today. Almost all lakes occur out of the tropical zone, especially in the Northern Hemisphere. This situation has existed for a very long time. The few lakes in the tropics are concentrated in the rift valley region of East Africa and tropical lakes do not form one extensive area of lakes as in the North Temperate zone.

The tropical continents are also separated by oceans, while the North Temperate zone is contiguous by and large now, and has been contiguous in the recent past. The paucity of "lake" systems" in the tropics is reflected in the fish faunas. Only the rift valley lakes in Africa have lacustrine, or lake-dwelling, fish in any numbers, while these fish form a sizeable component of more Northern lakes. It should be mentioned that in the Philippines, Lake Lanao has 20 endemic cyprinids (carps) which have evolved during the 10,000 yr of its existence. Australia, New Zealand and New Guinea do not have true lacustrine fishes at all! (Figure 1B).

Unlike lakes, reservoirs are more evenly distributed on a global scale (Figure 1C). Also the tropics have many reservoirs on three continents. Man's reservoir construction has created a lacustrine (lake) habitat in regions where no lake fish are found. I shall not detail the differences between lacustrine, riverine, and marsh dwelling fish. Suffice it to say that lacustrine fish can produce more stable populations and maintain them at a high level in lakes and reservoirs. Riverine and marsh fish can only produce low fish yields in reservoirs.

It is clear now why African lacustrine Cichlidae give such high fish

[3]A family of fish found in tropical and subtropical Africa and America. Only three species occur in tropical Asia.

yields in tropical reservoirs in Africa and in other parts of the world. African Cichlidae are the only true lacustrine freshwater fishes in the tropics. I would like to qualify my statement by saying that in areas with flood lakes—e.g., the Mekong, the Amazon, Kapuas and Mahakam (Kalimantan), and the Niger rivers—semi-lacustrine fish occur and give moderate yields.

Pests or Miracle Fish

The high-yielding Cichlidae from African lakes have been widely introduced in other parts of Africa, throughout tropical Asia and America. Some call them "miracle fish" while others call them "pests." As is generally true in situations of this kind, both views are extreme.

Under suitable conditions, the African Cichlidae can give very high yields in tropical reservoirs. With good management practices, these yields can be ensured, I think, for any fishery in the tropics. One problem is the high reproductive rate which causes stunting (runting). Suitable predator pressure can obviate this to a large extent.

Economic Considerations

The most important consideration in tropical freshwater fisheries is the cost of fish to the consumer. It is clear from all the available evidence that African Cichlidae provide the cheapest fish protein in the tropics, due to their high yield and quality. Marine and cultured fish are far more expensive and almost invariably, out of reach of the average wage earner.

In Indonesia the most common fish cultured is the common carp. However, when one looks at the retail cost of this fish, one is in for a shock. A kilogram of common carp costs anything from US$4-12. The average Indonesian family income cannot be more than US$80 a month. You can draw your own conclusions. In Indonesia tilapias caught in reservoirs sell for about US¢.30 a kilogram. In Sri Lanka tilapia sells for about US¢.10-20 a kilogram, which is cheaper than most vegetables. Marine fish, on the other hand, sell for about US¢.50 to US$1 a kilogram. No fish culture has been practiced in Sri Lanka commercially although attempts have been made to raise common and Chinese carps for 30 yr. I hate to think of the cost of cultured fish in Sri Lanka.

Western and Eastern Attitudes

In North America and Western Europe, freshwater fishing is primarily a sport. It is important that sport fish be carnivorous. Otherwise, one would have to fish with algal pellets! It is almost invariably true that fisheries in U.S. and European reservoirs are dominated by predators. In the tropics, however, freshwater fish often comprise the most important source of animal protein. In China, Eastern Europe, and other parts of the tropics, freshwater fish are an important source of food. I have noticed that in such countries as Indonesia, Thailand, Malaysia and Sri Lanka, very small fish are quite acceptable and sometimes even preferred as food. The use of predators to crop coarse fish is therefore not, in my opinion, a desirable management practice for tropical reservoirs, though some predator pressure may be desirable.

Important Considerations for the Future

Some basic questions must be raised as to the reasons for the differences in fish yield and composition (carnivores-herbivores) between tropical and temperate freshwater fisheries. The first question is whether the predator-dominated (by weight) fishery is inevitable or induced in temperate regions. There is no doubt that partially, at least, it is induced. There are herbivore-dominated reservoir fisheries in Eastern Europe and China. Why is the fish yield so high when African Cichlidae are present in tropical reservoirs? This question has been partially answered by saying that African Cichlidae are the only true lacustrine fish in tropical freshwaters. However, the inordinately high yields need further explanation. Perhaps, the nature of trophic cycling and the quantity of individual food items must be considered. Fish can be obligate herbivores in the tropics, which shortens the food chain, giving high yields of fish. Blue-green algae often dominate in shallow tropical lakes and reservoirs. African Cichlidae are the only freshwater fish which can assimilate these algae. This is the major reason for the very high yields of tilapias.

Summary

Tropical reservoirs (man-made lakes) have evened out somewhat the distribution of standing waters on a global scale. Natural lakes are well represented in the North Temperate and Arctic regions. In the tropics, the only region with a sizeable lake area is the rift valley region of East Africa. Man's reservoir building activities have created the potential for a rich source of cheap fish protein. This potential is best realized when lacustrine tilapias from Africa are present. Introduction of these fishes to reservoirs has sometimes given spectacular increases in fish yields, as in Sri Lanka (Ceylon).

The fish faunas of reservoirs outside Africa are essentially riverine, though semi-lacustrine species may occur in a few regions which have flood plains. These fish have lower yields than true lacustrine fish in reservoirs.

Unlike other freshwater fishes tilapias have the ability to digest and assimilate very efficiently, blue-green algae which predominate in shallow tropical reservoirs. The very high yields of tilapias in tropical reservoirs are due largely to these factors.

Further reading

Fernando, C.H. 1977. Reservoir fisheries in South East Asia: Past, present and future. Proceedings, Indo-Pacific Fisheries Council, 17th Session, Part 3. p. 475-489.

Hickling, C.F. 1961. Tropical inland fisheries. Longman's, London. 287 p.

Moriarty, D.J.M. 1973. The physiology of digestion of blue-green algae in the Cichlid fish *Tilapia nilotica*, J. Zool. Lond., 171: 25-39. ●