Effects of Man-Made Lakes on Ecosystems

JOHN E. BARDACH[1]
School of Natural Resources, University of Michigan, Ann Arbor, Michigan 48104

BERNARD DUSSART
Muséum d'Histoire Naturelle, Limnologie Tropicale, Paris, France

Man-made lakes range from the size of a pond to the size of an inland sea. More than 400 artificial lakes have been created in the world to date; they represent 300,000 km^2 of new aquatic ecosystems with a total volume of 4000 km^3. Forty or so of them have a surface area of over 1000 km^2, whereas others are much smaller and exert only a very local influence on the terrestrial ecosystems that surround them. The frequently nonlinear processes in the life histories of man-made lakes, from the first predevelopment surveys to the aging of the lakes themselves, strongly influence the dynamics of the ecosystems in which they are located. Since man-made lakes are built to serve man, he must be of uppermost concern in the consideration of how they alter the ecological dynamics of their environs and what off-site effects they might have. Large expenditures are involved in their construction, and effects on the ecosystem should therefore be expressed in economic terms whenever it is possible. The following examples are selected accordingly.

Ecosystem changes have, in the past, frequently been neglected in cost-benefit considerations. Many are appraised only belatedly, as perturbations that should have been calculated as costs become apparent. The lack of ecological input is not altogether surprising, since most man-made lakes have as their primary purpose the generation of power. Political considerations aside, a favorable cost-benefit ratio for power production alone usually justifies their construction. Engineers and economists are perhaps fortunate that dam building and the forecasting of power are more easily quantified than the population dynamics of an often rich and varied biota in and around the intended reservoir site and in those off-site locations that may be affected. Perusal of the proceedings of the 1968 Conservation Foundation sponsored Arlie House conference on the ecological aspects of international development [*Milton and Farvar,* 1972] suggests that postimpoundment activities such as permanent irrigation agriculture are more easily quantified than those over which there can as yet be little or no manipulative control, such as the changes from a lotic to a lentic biota. Thus changes in ecosystem components and processes easily fall into the category of unforeseen side effects, a category of events that frequently confront technological societies.

Space limitations restrict the present treatment to examples of large rivers or river systems with wide impacts. It should be noted that the unused hydroelectric potential of the world lies largely in the tropics [*Warren and Rubin,* 1968], where life processes often proceed faster than they do in the temperate zone and ecosystem changes become more quickly apparent, a contingency that has to be considered in planning. Tropical areas are also stressed here because means to cope with ecological perturbations are less well known in these regions than in the temperate zone. There is still a great shortage of expertise and knowledge in tropical ecology, though two recent symposiums on man-made lakes [*Lowe-McConnell,* 1966; *Obeng,* 1969*a*] contain valuable information on which this paper can in part draw.

Ecosystem changes due to man-made lakes can occur on or off site. On-site changes include the watershed above the dam, or a part thereof, a section of the river below the dam, and the area

[1] Now at Hawaii Institute of Marine Biology, University of Hawaii, Honolulu, Hawaii 96822.

surrounding the dam that can or will be irrigated as a result of the existence of the dam. They also include the translocations of people. Off-site changes affect conditions far below the dam, such as alteration of the salinity in the estuary of the river and changes in the sediments that the river carries into the sea. Within these two categories, further divisions can be made according to the ecosystem components that may be affected directly, such as climate, the terrestrial and aquatic biotas (especially as they relate directly to man), and man himself.

CLIMATE

Few man-made lakes have been in existence long enough for the collection of meteorological data that would permit valid judgments on whether such climatic changes as may have been observed near them are indeed attributable to their having been established. In addition, there is often a lack of valuable meteorological information from periods antedating the dams.

Data from the Lake of Geneva [*Blavoux et al.*, 1962], and from at least one station on the 776,-994-ha Volta Lake [*De Heer Amissah*, 1969] suggest a lowering of the mean maximum monthly temperature and a rise of the mean minimum monthly temperature. Rainfall data from the same area are inconclusive. Truly arid zone lakes, man-made or natural, are not likely to contribute to increased atmospheric moisture in their environs. The air is usually so dry that the vapor will not form clouds because of the lack of dynamic processes capable of producing local ascending air motions. The enormous scale on which the hydrologic cycle operates further mitigates local measurable effects [*McDonald*, 1962].

Yet speculations have been made about on- and off-site climatic effects of reservoirs much larger than those now in existence or contemplated for the near future. In fact, such effects would be intentional, rather than accidental, should very large man-made lakes be constructed within a century or two to counteract such technologically induced warming of the atmosphere as might arise as a consequence of large increases in energy production by man [*Fletcher*, 1969]. Prominent here are the ideas of creating a Siberian sea by damming of the Ob, Yenisei, and Angara rivers and the attendant transformation of arid zone reflectivity by irrigated areas to the south of the gigantic lake. In the tropics, there has been speculation about the feasibility of creating Congo and Chad seas by damming the Congo at the Stanley Canyon and at the same time diverting the Congo tributaries into the present Lake Chad basin. The water surface so created would cover 10% of the African continent and would furnish vast irrigation possibilities for desert areas, which would in their turn add to atmospheric moisture.

There is no question that man-made lakes of such magnitude would radically affect the climate of the region concerned. The Siberian project and particularly the African project would be sited in regions of relatively low rainfall, where a lowering of the temperature and an increase in air moisture would be beneficial. The direct economic impacts of such climate changes might be difficult to quantify, but attempts to do so would be helped by the continued and often reinforced accumulation of climatic data from existing reservoirs.

ON- AND OFF-SITE EFFECTS OF CHANGES IN RIVER FLOW

An early consequence of reservoir building is the modification of the river flow and hence of its sediment-carrying capacity. Sediments are deposited in the man-made lakes; if the lake is large, like Volta Lake, it may nevertheless have very clear water and a lowered productivity at the downstream end [*Entz*, 1969]. Furthermore, turbidity currents can become established, and their deposits may lead to anaerobic sediments of little value to aquatic life. Especially in monsoon climates these same sediments have been deposited to a great part on the floodplains, where they have supported a rich, albeit seasonal, agriculture before the construction of the dam. More permanent and stable agriculture demands different and larger economic inputs than more traditional practices do. The loss of these sediments to the floodplain agriculture, which is often called primitive but is nevertheless ecologically sound, has not received the attention that it deserves.

Further downstream the changed river regime can often affect deltaic and even marine fisheries, which thrive because of seasonal loads of nutrient and silt in the effluent cone of the river. Southeastern Mediterranean fish concentrations, mainly of sardines, have declined since the closure of the Aswan High Dam.

The southeastern Mediterranean fish concentrations and the fishery resources of the Nile delta lakes, which were similarly affected, are valued at US$20 million annually [*George*, 1972]. It is debatable whether the income from Lake Nasser fishery, which is still to be established, will equal this sum. The changed regime of the Nile also caused the deltaic coastline to retreat and thereby endangered man-made coastal structures.

PLANT COVER

The change in the flow pattern of water and the depth of standing water leads to considerable transformation of the plant cover. Low-lying soils and plant associations show much change; certain species disappear, whereas others (that are more hygrophilic) find conditions that favor their development greatly. A major change in vegetation also results from the opportunities for irrigation that a man-made lake confers to its downstream areas.

The inventory and study of biotic communities prior to impoundment is an exercise that not only facilitates prediction of change but also enables a more rational exploitation of the areas surrounding and downstream of the new lake. Study prior to impoundment also provides a base line by which zonal changes after flooding can be evaluated and thereby assists greatly in the planning and development of agriculture and forestry.

BIRDS AND TERRESTRIAL WILDLIFE

Shortly after the closure of a dam the establishment of a man-made lake results in two prominent types of effects on birds and mammals. The first may enhance the carrying capacity of the watershed region for the mammalian and avian fauna by providing new nesting, feeding, and watering possibilities, but the second will counteract the first through the flooding of valuable mammalian wildlife habitats. (The effects of inundation on insect and other invertebrate components of the land fauna have to date received little consideration.)

Most information on interactions between man-made lakes and wildlife is available from the temperate zone, where the value of the fauna is considered to be mainly recreational. In the tropics, mammalian and avian wildlife may have recreational importance (e.g., the African Game Reserves), but the animals also still provide a major source of protein. A sizable part of the U.S. hunting take of aquatic game birds (valued at over US$100,000,000/yr) is taken from man-made waters of various kinds, mostly marshes, which also contribute to the abundance of fur-bearing species. The amount of shallow water strongly influences the carrying capacity for semiaquatic and aquatic warm-blooded wildlife, and the frequent fluctuations in water level resulting from reservoir operations mitigate the value of man-made lakes as bird and small-mammal habitats [*International Union for the Conservation of Nature and Natural Resources*, 1964]. The fluctuations in water level have to be considered in the overall planning for a multiple-use water regime for the reservoir.

Large deep man-made lakes can reduce the area of wildlife habitat in their watershed. The best niches for wildlife usually exist along river courses, and most species of large and small game have territories, home ranges, and feeding circuits associated with the mainstream and/or its tributaries. These will disappear in the flooded area. As the behavior traits of the animals make them cling tenaciously to their home grounds, the arrival of the water spells death for most terrestrial creatures. The biomass destroyed is often considerable, appearances notwithstanding. At Lake Afobaka (Surinam), on the Brokopondo, more than 10,000 land animals, turtles, tapirs, snakes, sloths, and so on, were collected after sampling had led zoologists to believe that the region to be inundated no longer harbored any more large animals [*Leentvaar*, 1966; *Walsh and Gannon*, 1969]. Native hunters may further decimate wildlife stocks when flooding begins, a kind of salvaging that might well be condoned since rescue operations, well-organized as they may be, are likely to be woefully inadequate [*Asibey*, 1969].

It is certainly possible that large dams might be instrumental in eliminating unique wildlife habitats and might endanger the survival of rare space-restricted species. The cuprey (*Ovibos moschatus*) of northern Cambodia might be so affected if the Mekong dam at Stung Treng were to be built. Although such rare wildlife species would be considered in the planning of man-made lakes, there are other wildlife-related effects that are not.

Savanna and grassland regions in the tropics support a large biomass of herbivores, part of which can be managed for harvest on a sustained yield basis [*International Union for the Conservation of Nature and Natural Resources*, 1963;

Talbot, 1968]. Through this ecologically sound land use pattern, such yields can exceed or equal those obtainable from raising cattle in the same locations. Inundating the land eliminates these possibilities for all time, and the management of the lake substitutes the production of water-derived proteins for game use. The potential benefits and costs of game farming versus fishery management might well receive greater attention in the planning and decision-making process.

For instance, the northern Cambodian plains adjacent to the Mekong and the large tributaries of the Mekong below Khone Falls are thought to support concentrations of ungulates as dense as those in Africa. The Stung Treng Dam envisaged there would cover around 8000 km^2 of such land. By analogy with still speculative considerations of African game farming, sustained game yields of US$600–900/$km^2$/yr are possible [*Stier*, 1970].

At a prospective fish yield of around 50 kg/ha under semi-intensive management, probably comparable in intensity to that that would have to be established for game farming, 1 km^2 of Stung Treng Lake would produce at least 5 metric tons of fish. These may be valued conservatively at US$0.10/kg (after management costs are subtracted) and thus represent an income of US$500/$km^2$/yr. Thus the potential for protein production in this particular case seems to be of the same order from game ranching as it is from fisheries with the proviso that neither the savanna nor the lake would produce uniform yields over a large area [*Holden*, 1969]. Game ranching has other economic benefits. A selective harvest of horn- and antler-bearing males would add to the profits obtained from meat, a good set of antlers fetching about the same revenue as the flesh of the animal. Hides represent an additional potential benefit. Finally, sustained yield game ranching and tourism are compatible to each other, and in Kenya the tourist industry, based on national parks, is now the country's largest single income earner, totaling several billion dollars a year.

CHANGES IN THE AQUATIC BIOTA

When a river is changed into a lake, the ecological effects on aquatic organisms fall into beneficial and harmful categories. A representative beneficial effect is a rapidly changing limnology with the possibility of tapping new fishery resources. Harmful effects include the blocking or interruption of fish runs, sometimes the diminution of marine fisheries as a result of changes in the discharge characteristics of the barraged river, and the possible spread of water-borne diseases.

The inundation by water of the terrestrial flora and resident fauna leads to the proliferation of bacteria and a depletion of oxygen soon after inundation not only in the deeper regions of the man-made lakes but also sometimes in some of its shore regions. Later, aerobic production increases, and the oxygen content per unit surface area rises substantially. *Entz* [1969] documented such an increase in Volta Lake from 25 to 160 $g/O^2/m^2$ during the first 4 years. The action of winds then tends to distribute the oxygen and to counterbalance the previously mentioned effects of organic decomposition. The resultant high but later declining organic productivity is eventually translated into secondary and tertiary consumers, which are harvestable by man.

Much has been written about the dynamics of fish and invertebrate populations in a new man-made lake contained by a dam. A larger river and its tributaries usually represent more varied habitats than a large lake does, particularly in the tropics; consequently, the number of species often diminishes.

The impact of impoundment on the mussel fauna of the Kentucky Reservoir on the Tennessee River is an example [*Bates*, 1962]. The family Unionidae, represented in the river by 11 species, was reduced to one species in the postimpoundment fauna, and the total number of mussel species was approximately half that of the unmanaged river. The unanticipated economic effect of this faunal simplification was the eradication of mussel species that supported a thriving button trade and that provided most of the inserts that were exported to Japan for cultured pearl production. Numerous people with special skills had to find new occupations, and a trade that earned foreign currency was virtually eliminated. *Bates* [1962] concluded that 'the early natural assemblages (of mussel species) may suffer to the point of extinction.'

Comparable reductions in the number of species have been noted in the fish faunas of rivers and their associated man-made lakes [*Sidthimunka et al.*, 1968]. However, the numbers of individuals of those fish species that are able to adjust to the new lentic regime can increase greatly in the first few years after inundation, when nutrients from the previously aerated soils become dissolved in the water.

Whether the new fisheries that may result are well exploited or not depends on the adjustment of the human populations to the new situation. The lack of detailed quantitative information on the processes that accompany impoundment still poses difficulties for optimal management decisions, especially if potential benefits are not anticipated. On the Nam Pong Reservoir in Thailand, for instance, the production of 65 $\times$ 10^6 kw hr/yr was expected to provide a revenue of about US$750,000.

The additional US$500,000/yr from a fish harvest of 1200 metric tons in the third year of the existence of the lake, almost doubling the anticipated revenue, was entirely unexpected. There are other examples of changing fish faunas in man-made lakes. Sometimes the new limnological characteristics lead to high pelagic plankton production, but, if no plankton feeders of appropriate spawning habits existed in the riverine species complex, such fishes would have to be introduced to use the primary production of the lake. Plans are in hand for such introductions in several Mekong reservoirs. Introductions have already been made in Lake Ayamé (Ivory Coast), where *Tilapia nilotica* and *Heterotis niloticus* were established after it had been ascertained that no preadapted species were present [*Reizer*, 1968]. The measures were successful. A fisherman on this lake can, in theory, now earn 8 times the wages of an agricultural laborer.

There is often a reduction in organic productivity as a new lake becomes stabilized. After a peak in fish biomass, reached in 3–4 years, the fish yield declines after a variable number of seasons to a lower steady level. The entire period of stabilization may extend over a period of 20 years or more depending on the size, edaphic characteristics, and type of use of the reservoir [*Holden*, 1969]. These conditions are reflected well in the fish catch from Lake Kariba, which was nearly 800 kg/km^2 4 years after the dam was closed and dropped to about 270 kg/km^2 after 7 years.

Man-made lakes with different substrates and different limnological conditions have different stabilization histories, which may include the highly deleterious spread of floating vegetation. Unfortunately, too few details of the sequences in man-made lake maturation are known to enable valid predictions of potential fish production and therefore to facilitate the planning of optimally efficient fishery management provisions for any new lake.

In general, deeper lakes seem to be less productive than shallow ones are. Conditions vary widely, even in one lake. Although Lake Albert is not a man-made lake, it illustrates this characteristic, the annual catch being 33 kg/ha in the deep south end and 182 kg/ha in the shallow more easily fished north end [*Holden*, 1969].

Correlations of fish production with both depth and specific patterns of lake stabilization must be considered in the planning for optimal management and exploitation of fish stocks of reservoirs.

Immediately below the dam the river is also altered profoundly. The water is usually colder there than in the surface waters of the lake. It may also flow faster and in a more turbulent manner than it does in the river above the lake, and reservoir management exigencies may impose a pattern of diurnal and/or seasonal water fluctuations. These changed patterns of flow can attract certain fish species more than others and have led in some temperate zone reservoirs to the establishment of new salmonid sport fisheries. Corresponding data from tropical rivers below dams cannot as yet be found in the literature, though some data on this topic have in fact been obtained [*Sreenivasan*, 1968].

When the watershed harbors anadromous headwater-spawning species, the dam or dams pose barriers to such migrations. The migrations of the Atlantic and Pacific salmon are the best documented. Blocking of spawning migrations can be alleviated by enabling some fish to pass upstream by means of fish ladders or fish lifts or by establishing hatcheries or new spawning runs below the respective dams. Much money, time, and ingenuity went into the circumvention of man-made salmon barriers, but the devices developed to date by and large still leave much to be desired. The species of salmon primarily affected number five, all with somewhat similar habits. Large tropical rivers have an incomparably large number of commercial and anadromous species with widely differing migration habits [*Chevey and Le Poulain*, 1940]. Consequently, environmental triggers or conditions for migration also differ for various groups of species in such a river, so that it is almost impossible to design and extremely costly to build ladders to accommodate them all, or even only the most important 10 or 12 kinds. Higher dams on mainstreams in the tropics would therefore require research on the artificial propagations of migrant stocks rather than on providing physical access to the lost spawning grounds if important parts of threatened downstream fisheries are to be saved.

Apart from direct blocking of spawning runs a changed water regime below the dam may also eliminate or alter environmental triggers for the successful spawning of downstream populations. Thus *Hilsa* fisheries were eliminated from certain Indian rivers, probably through warming and a lowered flow rate. Detailed fishery biology investigations over many years prior to dam building are indicated if direct fish gains from man-made lakes are to be weighed against the possible fish losses of constructing a barrage in the river.

The change from a more or less rapid to a much slower water flow in a man-made lake and its associated waters, such as irrigation canals, affects yet another component of the aquatic fauna, namely, the various small invertebrate carriers of several tropical diseases. Among these, schistosomiasis is by far the most serious. Some of these diseases may be reduced when the carrier prefers a rapid rather than a slow water flow; for example, *Simulium*-carried blindness-producing onchocerciasis on Volta Lake [*Obeng*, 1969*b*] and others, including schistosomiasis-carrying snails, are favored by current reduction.

Bilharzia, present earlier to an unknown extent, may conservatively be expected to infect around 50% of the predominantly rural population of Egypt when constant irrigation, made possible by the High Dam, is available in most of the Nile Valley and the delta. This infection could easily result in a 30–50% reduction of work in each infected male [*Wright*, 1951]. If the infection figure was 50%, the work per man-day was evaluated at US$0.10, a man was estimated to work for only 150 days of the year, and 7 million among the 14 million working males were assumed (from infection expectations) to be afflicted, the losses could well amount to more than US$100,000,000/yr. Popular press reports tell of manual snail eradication in the Peoples' Republic of China, but chemical eradication is at present only possible against dense foci of snails; even then it is costly and cumbersome. The chemical treatment of the disease itself, notwithstanding promising developments by several prominent drug manufacturers, is not yet sufficiently advanced to consider mass application. Even when this can be done, it will probably be prohibitively expensive, at least for several years, and it always necessitates the knowledge of the distribution of the mussels in the lake and of the evolution of the biomass of these mussels during the same time. Early and complete ecological assessment can help greatly in this problem [*Wright*, 1951], particularly in forecasting probable contingencies and therefore costs.

These then are just a few examples of the ecosystem effects of man-made lakes, though they have perhaps been considered in a more encompassing manner than planning agencies have been wont to do, at least in the past. No mention has been made of the rescue operations for ecologically displaced humans, called resettlement, which are necessary when man-made lakes are built. Resettlement has strong ecological connotations [*Chambers*, 1970; J. Ingersoll, unpublished manuscript, 1968], since the resettled people are likely to exercise a different resource use pattern after their displacement. Here the ecologist must cooperate with the sociologist, the economist, the public health official, the agricultural expert, the civil servant, and the politician. Ecologists have often stressed the value of biotic diversity. Unmodified ecosystems are usually more diverse and more resilient than man-dominated ones are. Perhaps planning considerations for man-made lakes ought to include options of minimum as opposed to massive interference in ecosystem balance. The application of the systems approach to the planning and management of man-made lakes is clearly indicated, but this can only be effective if the data fed into such an analysis are adequate. To date, inputs to the planning and cost accounting of man-made lakes have been slanted in favor of the more easily quantifiable consequences, often computed in a random and piecemeal fashion. In order not to repeat costly schemes that are eventually abandoned or whose benefits prove to be far less than those anticipated, it is imperative to make provision for early and intensive fieldwork by ecologists prior to the construction of man-made lakes and to ensure the participation of ecologists in the planning and decision-making councils that consider the feasibility of river regulation.

REFERENCES

Asibey, E. O. A., Wildlife in the Volta basin, in *Man-Made Lakes, The Accra Symposium*, edited by L. E. Obeng, pp. 366–372, Ghana Universities Press, Accra, 1969.

Bates, J. W., The impact of impoundment on the mussel fauna of Kentucky Reservoir, Tennessee River, *Amer. Midl. Natur.*, *68*(1), 232–236, 1962.

Blavoux, B., B. Dussart, H. Maneglier, and C. Salvetti, La région du Leman au point de vue hydrométéorologique, *Le Globe*, *102*, 49–68, 1962.

Chambers, R. (Ed.), *The Volta Resettlement Experience*, Pall Mall Press, London, 1970.

Chevey, P., and F. Le Poulain, La pêche dans les eaux douces du Cambodge, annexes and 3, 168 pp., Trav. Inst. Oceanogr. Indochine, Gouv. Gen. Indochine, Saigon, 1940.

De Heer Amissah, A. N., Some possible climatic changes that may be caused by the Volta Lake, in *Man-Made Lakes, The Accra Symposium*, edited by L. E. Obeng, pp. 73–82, Ghana Universities Press, Accra, 1969.

Entz, B., Caractéristiques limnologiques du lac Volta, le plus grand lac artificiel d'Afrique, *Nature Ressources*, *5*(4), 10–17, 1969.

Fletcher, J. O., Controlling the planet's climate, *Impact Sci. Soc.*, *19*(2), 151–168, 1969.

George, C., The role of the Aswan High Dam in changing the fisheries of the southeastern Mediterranean, 1968, in *The Careless Technology: Ecology and International Development*, edited by J. P. Milton and M. T. Farvar, Doubleday, New York, 1972.

Holden, M. J., Problems in forecasting sustainable yields, in *Man-Made Lakes, The Accra Symposium*, edited by L. E. Obeng, pp. 190–194, Ghana Universities Press, Accra, 1969.

International Union for the Conservation of Nature and Natural Resources, Discussion of wildlife utilization in 'Conservation of nature and natural resources in modern African states,' *Int. Union Conserv. Nature Natur. Resour.*, *New Ser.*, *1*, 19–24, 1963.

International Union for the Conservation of Nature and Natural Resources, Discussion of wildlife utilization of man-made aquatic habitats, Project MAR, The Conservation and Management of Temperate Marshes, Bogs, and Other Wetlands, *Int. Union Conserv. Nature Natur. Resour.*, *New Ser.*, 358–396, 1964.

Leentvaar, P., Artificial reservoirs, The Brokopondo lake in Surinam, *Verh. Int. Ver. Limnol.*, *16*(6), 680–684, 1966.

Lowe-McConnell, R. H. (Ed.), *Man-Made Lakes*, Academic, London, 1966.

McDonald, J. E., The evaporation precipitation fallacy, *Weather*, *17*(5), 1–9, 1962.

Milton, J. P., and M. T. Farvar (Eds.), *The Careless Technology: Ecology and International Development*, Doubleday, New York, 1972.

Obeng, L. E. (Ed.), *Man-Made Lakes, The Accra Symposium*, Ghana Universities Press, Accra, 1969*a*.

Obeng, L. E., The effects of inundation on the *Simuliidae* of the Volta basin, in *Man-Made Lakes, The Accra Symposium*, edited by L. E. Obeng, pp. 361–365, Ghana Universities Press, Accra, 1969*b*.

Reizer, C., Aménagement piscicole du lac artificiel d'Ayamé, *Cent. Tech. Forest. Trop. Nogent sur Marne Fr. Publ.*, *30*, 1–108, 1968.

Sidthimunka, A., M. Potaros, C. Booson, and O. Pawapootanon, Observation on the hydrology and fisheries of Ubolratana Reservoir (1965-1966), *Indo Pac. Fish. Counc. Publ.*, *C68/TECFIS*, 1968.

Sreenivasan, A., Limnology of tropical impoundments, 1, Studies of two upland impoundments in Nilgiris, Madras State (India), *Phykos*, *7*(1/2), 144–160, 1968.

Stier, J. C., An economic approach to African game cropping, M.Sc., Univ. of Mich., Ann Arbor, 1970.

Talbot, L. M., Wildlife in developing countries, in *Wildlife Resources in a Changing World*, pp. 46–55, The Conservation Foundation, Washington, D. C., 1968.

Walsh, J., and R. Gannon, *Sauvés des Eaux*, Stock, Paris, 1969.

Warren, M., and N. Rubin, *Dams in Africa*, Cass, London, 1968.

Wright, W. H., Medical parasitology in a changing world, What of the future?, *J. Parasitol.*, *37*, 1–12, 1951.