Reservoir Fishery Management and Development in Asia

Proceedings of a workshop held in Kathmandu, Nepal, 23–28 November 1987
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Editor: Sena S. De Silva
ABSTRACT

This publication presents the results of an IDRC-funded workshop held in Kathmandu, Nepal, 23-28 November 1987. Representatives from 15 countries reviewed the status of reservoir fishery research in Asia under the following topics: existing fisheries, limnological aspects, biological and resource aspects, management aspects, and culture. Papers were presented on these topics, but the discussion sessions were the main element of the workshop. Summaries of these discussions as well as a series of general recommendations that were generated during the final discussion are presented in this book. The potential for increased fish production in reservoirs and the need for early involvement of fisheries scientists in the planning and preimpoundment studies before dam construction are emphasized.

RÉSUMÉ

Cet ouvrage présente les résultats d'un atelier financé par le CRDI à Katmandou, au Nepal, du 23 au 28 novembre 1987. Des représentants de 15 pays ont examiné l'état de la recherche sur l'élevage du poisson en étangs en Asie, en particulier les aspects suivants : les systèmes actuels, les aspects limnologiques et biologiques, les ressources, la gestion et l'élevage. Des exposés ont été présentés sur ces sujets, mais les discussions ont été l'élément le plus important de l'atelier. L'ouvrage présente également un résumé des discussions ainsi que les recommandations générales issues de ces discussions. On met l'accent sur la possibilité d'augmenter la production de poissons en étangs et la nécessité pour les ichtyologistes de participer très tôt aux études de planification, notamment de la mise en étangs du poisson, qui précèdent la construction d'un barrage.

RESUMEN

Esta publicación presenta los resultados de un taller auspiciado por el CIID en Kathmandu, Nepal, del 23 al 28 de noviembre de 1987. Representantes de 15 países analizaron el estado de la investigación sobre pesquería asiática en embalses desde los siguientes ángulos: pesquería existente, aspectos limnológicos, aspectos biológicos y de recurso, aspectos de manejo y cultivo. Las ponencias versaron sobre estos temas, pero las sesiones de discusión fueron el principal elemento del taller. Este libro ofrece los resúmenes de estas discusiones, así como una serie de recomendaciones generales emanadas de la discusión final. Se subraya el potencial para incrementar la producción pesquera en embalses y la necesidad de una participación temprana de los científicos del área en la planificación y los estudios de apropiación que anteceden a la construcción de represas.
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RESERVOIR BED PREPARATION IN RELATION TO FISHERIES DEVELOPMENT: AN EVALUATION

S.S. De Silva

Department of Zoology, University of Ruhuna, Matara, Sri Lanka

Abstract In Asia, the reservoir area is increasing significantly. In the planning and construction of reservoirs that are mostly built for irrigation or hydroelectric purposes, fisheries-development aspects are not being considered. There is increasing evidence that incomplete clearing of the reservoir bed is favourable for fisheries. However, most of the evidence has originated in the West. This paper evaluates the pros and cons of leaving wooded areas in reservoirs under construction for the development of fisheries and concludes that the available evidence favour retention of uncleared areas and that more research to quantify the positive effects of this practice in the Asian region is needed.

In almost all instances, major reservoirs are built for irrigational, hydroelectrical, or water-supply purposes. The secondary benefits of such water bodies are rarely considered in the planning stages or in the cost-benefit analyses. It could well be that, in spite of this situation, the secondary benefits outweigh the primary benefits. For example, the annual fish yield from the Ubolaratana Reservoir in Thailand is estimated to be worth USD 1.2 million; annual hydroelectric power output is estimated at USD 1 million (Fernando 1980).

Southeast Asia now has approximately $30 \times 10^5$ ha of reservoirs and $35 \times 10^5$ ha of natural and floodplain lakes (Fernando 1982). The reservoir area is expected to increase to $200 \times 10^5$ ha by the year 2000. Sir Lanka has about $1.75 \times 10^5$ ha of man-made reservoirs (Fernando and de Silva 1984). This area is expected to rise to $2.5 \times 10^5$ ha by the year 2000, resulting in an approximate reservoir density on the island of 4 ha/km².

Unfortunately, in most instances, potential uses for these reservoirs (e.g., fisheries) are not considered during the construction or preparation of the reservoir beds or associated channels. Moreover, there appears to be a controversy and an uncertainty, mostly unwritten, regarding reservoir bed preparation in relation to fisheries development as a secondary benefit.

This paper reviews the available data on suitable methods of reservoir bed preparation aimed at establishing a reservoir fishery.
This study was prompted by one of the biggest river-diversion and associated reservoir-construction projects ever undertaken in the region: the Mahaweli Ganga (river) Diversion in Sri Lanka. In this project, all the reservoir beds, amounting to nearly 20,000 ha, were completely cleared of vegetation; in certain cases, even the grass was burned.

The Problem

From the point of view of developing a fishery, the greatest uncertainty lies in whether the area to be impounded should be cleared of its vegetation and, if so, to what extent. Other provisions to facilitate fish production must also be examined. Bhukaswan (1980) dealt with these problems and further evidence has accumulated with respect to the need for leaving a substantial proportion of the vegetation in the reservoir beds. The effect of preimpoundment clearing on reservoir ecology and fisheries in North America was recently evaluated by Ploskey (1985). This study favours the retention of some uncleared areas for fisheries development.

The extent of vegetation clearance is primarily determined by the irrigational and hydroelectrical engineering requirements of the system. In general, complete clearing is needed only in the region of the spillway and the sluices and perhaps in the dead-storage area. It must be remembered, however, that depending on the primary purpose of the reservoir, some effects could be considered as both detrimental and, from another point of view, useful.

Detrimental Effects

Impedence to Fishing

Submerged vegetation impedes fishing and limits the diversity of useful fishing gear; only drift nets, traps, and longlines can effectively be used. In most Southeast Asian reservoirs, except perhaps Indian reservoirs where fishery operations are conducted by shore seines and drag nets (Bhukaswan 1980) and those reservoir fisheries based predominantly on benthic species, the need to use bottom, dragging gear rarely arises. Southeast Asia does not contain indigenous species that could form the backbone of a lacustrine fishery.

Water Quality

It is often claimed that submerged wood causes a deterioration in water quality. Ploskey (1981), however, found little difference in water quality between wooded and cleared coves in reservoirs. Standing, submerged timber provides only a small reactive surface in comparison to its volume. This, together with the cellular characteristics (the presence of lignin, cellulose, etc.), is likely responsible for the slow decomposition of the submerged tree trunks. This slow decomposition is unlikely to have a major impact on the accumulation of potential carcinogenic precursors or other chemicals impacting the colour, odour, or taste of the water.
Eutrophication

Eutrophication is the process, either natural or artificial, by which water becomes rich in nutrients (Rohlic 1969). Eutrophication may cause changes in the faunal and floral communities and interfere with reservoir use, particularly, if the water is meant for drinking. The most apparent visible effect of eutrophication is an increase in the algal or macrophyte population, which could result in fish mortality through deoxygenation. It is now known that blooms of blue-green algae are primarily due to climatic conditions (Stepanek et al. 1963) and that such blooms often coincide with a nutritional deficiency (Pearsall 1932).

The direct effects of eutrophication on fish populations have been reported from reservoirs in the United States. Larkin and Northcote (1969) suggested that eutrophication could limit the habitat for many desirable species, thereby directly impacting foraging sites, spawning sites, and protective sites.

There is no evidence to indicate that the submerged wood releases sufficient nutrients to cause eutrophication. As pointed out, the rate of nutrient release from submerged wood is slow and, by itself, is unlikely to cause eutrophication.

Trihalomethane Precursors

Trihalomethanes are precursors to many mutagenic and carcinogenic compounds (Layher 1984). Their presence is important only for those reservoirs whose water is used for drinking. Nevertheless, bearing in mind that, in Southeast Asia, communities living around reservoirs utilize the reservoirs for domestic purposes, the water should be monitored for trihalomethane precursors.

Kraybill (1978) demonstrated that 42% of carcinogenic compounds come from natural products. The majority of these chemicals originated from allochthonous inputs from agricultural and industrial practices. In Sri Lanka, a series of reservoirs are generally found in a particular river system, one reservoir feeding the other reservoir. The reservoirs found lower down in such a series are bound to receive irrigation run-off, which invariably carries a high load of agricultural chemicals and carcinogens, possessing detrimental properties.

Beneficial Effects

Extra Riches, etc.

There is no doubt as to the importance of submerged tree trunks in providing extra niches, food resources, spawning sites, etc., to various fish species (Table 1). In certain countries, such as Sri Lanka, shelters are created by sticking large twigs known as brush piles into the reservoir bed; these remain a main mode of fishing (Senanayake 1982). Apart from the periphyton and faunal elements associated with submerged vegetation, littoral vegetation could also provide a direct food source for fish species in reservoirs (Dudgeon 1983; De Silva et al. 1984).
Table 1. The creation of new habitats, food resources, etc., in wooded areas in various reservoirs.

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Speciesa</th>
<th>Observation/Function</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull Shoals Reservoir, USA</td>
<td>Spotted bass</td>
<td>Preferred brush area for spawning</td>
<td>Vogele and Rainwater (1925)</td>
</tr>
<tr>
<td></td>
<td>Black crappie</td>
<td>Vegetation crucial for spawning</td>
<td>Ginnelly (1971)</td>
</tr>
<tr>
<td>Smith Mountain Lake, U.K.</td>
<td>Largemouth bass</td>
<td>Highly associated with structure</td>
<td>Prince and Maughan (1979)</td>
</tr>
<tr>
<td>Lake Kariba, Africa</td>
<td>No. of species</td>
<td>Additional food material in submerged tree trunks</td>
<td>Boon (1984)</td>
</tr>
<tr>
<td></td>
<td>No. of species</td>
<td>Submerged dead trees were associated with higher densities of chironomid larve,</td>
<td>McLachlan and McLachlan (1971)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>oligochaete worms, etc., and act as a food source for a no. of species of fish</td>
<td></td>
</tr>
<tr>
<td>Lewis and Clark Lake, SD, USA</td>
<td>Largemouth bass</td>
<td>Young of the year in August was related to the number of acre-days of timber</td>
<td>Aggus and Elliot (1973)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inundation earlier in the year</td>
<td></td>
</tr>
<tr>
<td>Missouri reservoirs</td>
<td>-</td>
<td>Chironomid density was 11 times higher in adjacent bolt in areas</td>
<td>Cowell and Hudson (1967)</td>
</tr>
</tbody>
</table>

Species of fish that are influenced by the wooded area, if known.
Influence of Birds

Aquatic predatory birds are known to remove substantial amounts of the ichthyomass in lakes and reservoirs. Vareschi (1979) estimated that the great white pelican (*Pelecanus onocrotalus roseus*), which roosts on a nearby salt lake, harvested 16,000-20,000 kg fish (fresh weight)/day from Lake Nakuru, Kenya. He estimated that this removal amounted to 10% of the lake's total annual phosphorous load. In Parakrama Samudra, Sri Lanka, it is estimated that the fish consumption by three species of cormorants (*Phalacrocorax carbo*, *P. fuscicollis*, and *P. niger*) was 696 kg/day and the nutrient export as a result of these birds could reach one-third of that lost through outflow (Winkler 1983). The final analysis of the impact of predatory birds on nutrient cycling remains controversial.

Most of the work on the role of birds in nutrient cycling has been carried out on water bodies larger than those found in Southeast Asia. In most reservoirs in Sri Lanka, for example, where the flushing rate is very high, even small changes in the nutrient export/import balance could have significant effects on productivity. Whether there are emergent tree trunks or not, predatory aquatic birds will prey on fish. It is argued, therefore, that tree trunks would provide roosts for colonies of certain species and that there would be a certain amount of nutrients cycled back into the water, thereby resulting in a reduction of the nutrient exportation from the system. Quantitative data for the above hypothesis is not yet available and admittedly will be difficult to obtain.

In Sri Lanka, it has also been postulated that the predatory role of aquatic birds is important in preventing, retarding, or stunting the growth of *Oreochromis mossambicus* and other cichlids (Fernando and Indrasena 1969).

Standing Stock of Ichthyomass

There is considerable evidence to indicate that reservoirs with submerged vegetation or tree trunks have a higher standing stock of ichthyomass and that, within a reservoir, the standing stock is less in those regions without tree trunks or submerged vegetation (Table 2). Table 2 clearly shows that fish production in wooded areas is higher than in nonwooded areas.

In Sri Lanka there is an in situ experiment in an ancient reservoir (Parakrama Samudra) that exemplifies this point. This reservoir has three distinct basins: the northernmost basin, known as the Thopawewa (652 ha), the middle basin, known as the Eramuduwewa (1538 ha), and the southern basin, known as the Dumbuttawewa (362 ha). The characteristics of these three basins and fishery aspects of the reservoir have been dealt with in detail by Schiemer (1983) and De Silva and Fernando (1980), respectively. The middle and southern basins of this reservoir went into disuse and were only restored in the second quarter of this century. Suffice to say that, except in the northernmost basin, the reservoir has an extensive amount of emergent trees that are in various degrees of degeneration (Fig. 1). Nevertheless, in this reservoir, which has an average annual yield of 200 kg/ha (De Silva and Fernando 1980) and provides the livelihood for nearly 2000 fishermen, fishing activities are more concentrated in the middle and southern basins (Table 3).
Table 2. Ichthyomass yields of wooded areas and cleared areas of various reservoirs.

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Speciesa</th>
<th>Mean annual standing crop (kg/ha)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rybinsk Reservoir</td>
<td>All species</td>
<td>No quantification given; highest fish catch from submerged floodplain</td>
<td>See Ploskey (1981)</td>
</tr>
<tr>
<td>Bull Shoals Reservoir, USA</td>
<td>Predatory species</td>
<td>3430</td>
<td>See Ploskey (1981)</td>
</tr>
<tr>
<td>Parakrama Samudra, Sri Lanka</td>
<td>3 primary species (O. mossambicus)</td>
<td>Fishery least intensive</td>
<td>Amarasinghe and Pitcher (1986)</td>
</tr>
</tbody>
</table>

*aDominant species of the fishery is given in parentheses.
Fig. 1. Emergent trees in the middle basin of Parakrama Samudra.

Table 3. Concentration of fishing activities in the three basins of Parakrama Samudra.

<table>
<thead>
<tr>
<th>Basin</th>
<th>Boats registered/ha</th>
<th>Boats operated/ha&lt;sup&gt;a&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td>Northern</td>
<td>0.90</td>
<td>0.53</td>
</tr>
<tr>
<td>Middle</td>
<td>1.18</td>
<td>0.90</td>
</tr>
<tr>
<td>Southern</td>
<td>1.32</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Source: Amerasinghe and Pitcher (1986).
<sup>a</sup>Operating at any one time.

A survey of the fishermen of Parakrama Samudra indicated that although the rate of damage to the nets is high (must be replaced once every 6-8 months) and fishing is difficult in the middle and southern basins, all of them agreed that the yield of the northern basin (cleared basin) is not sufficient. Therefore, it is apparent that even though vegetation and standing tree trunks impede fishing, fish tend to congregate in such areas and commercial fishing is viable.

Erosion and Siltation

Although erosion is retarded by the presence of forests (Hulsey 1959; Ilina and Gordevyev 1970), wooded areas may increase the rate of siltation. Submerged trees may also aid in filtering out trees, limbs, and debris drifting downstream during high water (Nelson et al. 1978). When standing timber falls over after several years, there is no threat of clogging intakes or outlets as the timber tends to remain sedentary for many years because of its waterlogged condition.

Conclusions

A quantitative evaluation of the detrimental and beneficial effects that submerged vegetation has on a reservoir fishery is difficult, if not impossible, in most instances. Furthermore, it is
There is, however, convincing evidence available to indicate that the standing stock of ichthyomass is higher in a wooded area of a reservoir. This indicates, at least indirectly, that submerged wood enhances overall fish production. As such, it would be desirable to leave some wooded areas when impounding a reservoir.

There is only limited data available indicating to what extent wood should be left intact in a reservoir bed. If one considers the Sri Lankan example, Parakrama Samudra, it would be desirable to leave approximately 50% of the forest cover of the reservoir bed; however, this approximation has little scientific basis. Hopefully, future comparative studies on Sri Lankan reservoirs completely and partially cleared of vegetation will permit a better quantitative evaluation of this question.

This brief evaluation has not considered other provisions needed for the establishment of a reservoir fishery (e.g., fish passages and artificial spawning grounds). These aspects have been dealt with in detail by Bhukaswan (1980). The cost aspects of clearing as opposed to the value of timber have also not been considered. This is because of the immense variability in timber types and commercial values, both locally and from one country to another.

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