In exchange for the costs to resources downstream, reservoirs may offer considerable benefits to people living around them in terms of fish protection. Benefits could often be considerably bigger, if the reservoirs and reservoir fisheries are managed properly. But how to manage them? There is no easy way out, the author emphasises in this article, which is one of a series on reservoir fisheries management in Catch and Culture.

Reservoirs are very rarely or never impounded for their fisheries; fisheries are a secondary user of reservoir resources, and an increasingly important one for that. In this era of sustainable development, hand in hand with the ensuing emphasis on conserving bio-diversity, fish and fishery-related aspects at the planning stages of reservoir impoundment are given increasing consideration. It would have been unthinkable 20 years or so ago for reservoir engineers, politicians, planners and developers to have consulted fishery scientists and administrators prior to impoundment. In essence, a new challenge is being thrown to fishery scientists, and accordingly I see it as a rare window of opportunity for fishery scientists to strive to work for the benefit of the poor fishers in a sustainable manner, and provide leadership in conserving bio-diversity and environmental integrity.

Hoover Dam was the First

Historically, reservoirs have been in existence for over 2,000 years, almost solely for irrigation in function, and inscriptions indicate that fishery activities in these impoundments were encouraged. Indeed, these water bodies would have provided a source of much needed animal protein for the populations, that were living in their vicinity, as it is today. However, proliferation of big dam building is relatively recent, and is reputed to have started with the Hoover Dam on the Colorado River, U.S.A., in 1935. In Asia, almost every major river has or is being dammed, the latest being the Yangtze in the P.R. China. Modern, large dams are constructed amidst much controversy relating to displacement of human settlements, potential major environmental perturbations, and loss of livelihood, productive flood plains and bio-diversity, and even at the risk of increasing water-borne diseases, to name a few.

As stated before, the input of fishery scientists in the planning stages, if at all, is very minor. This input is essentially with regard to the incorporation of fish ladders. Unfortunately, in Asian reservoirs, as far as the author is aware, a fish ladder on a large dam has been provided only in the case of the Pak Mun Reservoir in Thailand. If such action had been taken during the building of weirs and numerous impoundments in the Ganges System in South Asia, perhaps the once prolific hilsa fishery would not have suffered its present fate. This is only one such example.

Fisheries become an important asset, economically and socially, once a reservoir fills to capacity, generally a few years after the closure of the dam. In Asia, unlike in certain African reservoirs such as Lake Kariba, the subsequent development of fisheries tends to be rather a subsistence, artisanal one; large, commercial vessels and gear are rarely or never used. The reasons for this may be twofold. Firstly, Asian reservoirs, by world standards, tend to be rather small. Secondly, and perhaps more importantly, the Asian reservoirs often lack a sufficiently large biomass complemented with a regular, intense recruitment of a single fast growing species. Needless to say, there are exceptions. For example the rather controversial case of Nile perch in Lake Victoria.
**Small Sardines (clupeids) Successful in Reservoirs But Not Always**

In the case of Lake Kariba for instance, a commercial purse seine fishery based on the fast growing, small, pelagic, freshwater clupeid, *Strolothrissa tanganyikae* exists. This clupeid, however, is not indigenous to the Zambesi River System, but to Lake Tanganyika. The closest example to this is the clupeid *Clupeichthys goniognathus* in Asian reservoirs, for which a small "commercial purse seine fleet" exists in the Ubol Ratna Reservoir in Thailand. However, attempts to transplant this species, with the expectation that it would occupy a supposedly vacant niche in reservoirs of other river basins elsewhere in Asia has not been successful. It also needs to be pointed out that on a unit area basis Asian reservoirs, in most instances, are generally more productive than their African counterparts.

**Fisher Communities Must Take Part in Management**

In general, and for the above mentioned reasons, Asian reservoir fisheries tend to be somewhat multi-species. The detailed nature of the fishery is dictated by the original ichthyofauna of the dammed river, the success of any exotics, if present, and the management strategies that are in operation. Strategies such as restrictions on the fishing pressure, the nature of gear (mesh size of passive gear), enforcement of closed seasons and the like are very common measures that are employed in some reservoirs in Asia. However, since Asian reservoir fisheries are predominantly artisanal, effective enforcement of managerial measures become easier only when done in conjunction with the fisher community. Instances where enforcement of governmental regulations became ineffective are numerous. However, in such instances, and almost without exception, the failure can be attributed to lack of fisher involvement in the management structure.

No two reservoirs behave similarly, however closely located they may be. They often differ significantly in their catchment characteristics, limnology, hydrology and fishery aspects, all of which either singly or in combination influence fish production and hence fish yield, amongst others. As such, information gathered from one reservoir may not be directly applicable to another, and therefore it is imperative that detailed fishery management strategies are developed on them individually. Needless to say, this is a big task, particularly with the limited technical resources at hand in developing countries, where most new reservoir constructions are coming into being or planned. On the other hand, the differences between reservoirs do not entirely preclude the development of such models, which has been successfully done for Asian reservoirs. In my view, the development of such models is basic to introducing reservoir fishery management on a scientific basis. When fishery management is not done in this way, more often than not it results in the collapse of the fishery and sub-optimal yields, inducing the poor fishers to indulge in desperate actions which worsen the situation as time progresses. At this juncture it is not opportune to dwell on this rather specialized aspect, as much has been written on the development and applicability of yield-predictive models in reservoir fishery management, including Asian reservoirs.

**Management Based on Scanty Information**

It is also common in Asia for authorities to introduce managerial measures based on scanty information. For example, fishing may be banned for a number of months in a year (closed season), which are perceived to be the breeding season of the stocks, often based on a preliminary study in one or two reservoirs and on only one or two major species. Such a ban may be enforced on all reservoirs in the country, without due consideration of the species (major) composition and the relative contribution of each species to the fishery, and other relevant reservoir characteristics including geographical location and the like. Such decisions do not necessarily benefit the fish stocks or the livelihood of the fishers. Indeed, they could be detrimental because the most intensive fishing may coincide with the true spawning season, contrary to the perceived or extrapolated one. The above generalities, drawn from existing practices, are highlighted to reiterate the need to treat the management of the fishery of each large reservoir as a separate entity. This could be achieved only through measures become easier only when done in conjunction with the fisher community. Instances where enforcement of governmental regulations became ineffective are numerous. However, in such instances, and almost without exception, the failure can be attributed to lack of fisher involvement in the management structure.

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**Cage Culture with High Return -And High Risk**

Apart from the exploitation of the naturally recruited fish stocks, aquaculture, primarily cage culture in reservoirs, is advocated as a means of increasing fish production and, in some instances, as a way of providing alternative employment to displaced persons from impounding. Such practices may be seen in some newly impounded reservoirs. There is no doubt that these activities, at least in the initial years, would increase fish production. But it is opportune to evaluate who are likely to be the long-term beneficiaries and what are the detrimental effects of proliferation of unplanned cage culture in large reservoirs (>5,000 ha for example). One does not need to go far to find answers; they are all available in Asian reservoirs!

Although cage culture in reservoirs is often mooted as a means of providing a better livelihood for displaced persons, as the practice gets established and the markets are secured, more often than not the original practices tend to be bought up by bigger entrepreneurs. In fact the expansion of cage culture activities in reservoirs takes place unabated, and in most ways it parallels shrimp culture developments in Asia. The desire to get quick return from investments leads to over-feeding, which over time results in the development of an anoxic layer in the bottom due to accumulation of excess feed and waste. When the bottom anoxic water is overtaken during weather changes, it results in mortality of not only the caged fish but also the naturally recruited stocks, the latter being the resource that is harnessed by poor fishers for a livelihood. Needless to say, the big entrepreneurs will not be deterred by loss of stock in one year, and will continue their environmentally unfriendly practices because the financial returns at stake are quite high. The above is one extreme example. In addition, other changes such as accelerating eutrophication of the water body may also bring about undesirable results in the long-term.

**Keep Cages Away From Upstream Areas**

One would argue that the solution to the above problems lies in determining the carrying capacity of each reservoir and introducing a strict quota system with regard to the caged biomass that could be sustained in a reservoir, with- out overly effecting the environmental integrity of the water body. This contention holds good in theory. However, it may not be that easy to determine the carrying capacity of large reservoirs through short-term studies, where the changes in limnology and hydrology are rather unpredictable, particularly in the initial to 7 years after impoundment. Even if the carrying capacity is determined satisfactorily, implementation of the findings may not be that straightforward. I personally would advocate a moratorium on cage culture, indeed all forms of
aquaculture, until the reservoir settles down to a more routine hydrological regime and the capture fishery management strategies are determined and instituted.

An even more important consideration with regard to cage culture is the avoidance of setting up such activities upstream in a large reservoir. More often than not a reservoir ichthyofauna would reflect that of the original riverine one. Most of the larger species, which are also likely to be important for the capture fishery, would migrate upstream to the original river and its tributaries to breed. The resulting larvae and fry would drift to the reservoir and find feeding grounds and shelter in coves and bays in the upper reaches of the reservoir. It so happens that when cage culture is encouraged among fishers, who usually tend to live in the vicinity of the main basin of the reservoir and/or in the upper reaches, they tend to utilise coves and bays in the upper reaches of the reservoir. Materials for cage and/or pen construction are generally obtained from the vicinity of such coves and bays, with resultant changes in the nature of available habitats and the like. Such a practice would further perturb the environment and would adversely influence the nursery grounds of important species, which in the medium to long-term could be detrimental to the fishery. Here again one might argue that hard scientific data are lacking in support of such a stance. Data are not always needed when basic knowledge in fish biology and experience in reservoir fisheries can be extended to make logical and pragmatic conclusions.

Biologists and Dam Managers Must Meet

What I have endeavoured is to consider aspects that do not always get the attention they deserve. By the same token, rarely do reservoir fishery managers have much in common with other reservoir resource users such as managers of hydroelectricity generation and irrigation. By virtue of the act that reservoir fishery managers (are secondary users of the reservoir water) resource I, for one, believe the burden is on them to initiate a dialogue. It is heartening to know that in the instances (e.g., in some Indian reservoirs) where a dialogue exists, fish yields in these reservoirs have been increased significantly, and without detriment to the primary users.

Gap Between Supply and Demand

It is common knowledge that the gap between supply and demand for aquatic products in the world is widening. It is also believed that aquaculture would account for the shortfall, to some degree. Reservoirs, on the other hand, are also expected to contribute increasingly to world food production in the ensuing years, as management strategies are set in place. Indeed, inland capture and culture-based fisheries are currently considered to be one of the fastest growing areas of fish production in the world. It is also important to note that reservoirs in general tend to be located in remote, rural areas. As such, the fisheries in these regimes are doubly important as they provide a cheap and much needed animal protein source to a poor sector of the community. As pointed out earlier, reservoirs are created for purely economic reasons, and the greatest degree of such development in the next two decades would occur in Asia. It is estimated that the reservoir acreage in Asia would increase from the present levels of 5.46 x 106 to 22.74 x 106 ha by the year 2010, approximately a five-fold increase in reservoir acreage in two decades or so. It is also noteworthy that a significant proportion of this targeted increase is likely to occur in the Mekong Basin. In this regard it is important that the countries involved get their act together in reservoir fishery management so that benefits of the fishery resources could be reaped fully to benefit the relatively poorer sectors of the society, and make a significant contribution to food security and poverty alleviation. It is, however, unfortunate that these benefits are a result of development activities which, on the balance of evidence, appear not to be conducive to the long-term well-being of the associated river systems and their biota. However, there is very little we fishery scientists could do in this regard, other than to make the best of an undesirable development.