Culture-based production systems: Options for the Chambo in Lake Malawi and Lake Malombe

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Abstract

The drastic decline of the Chambo in Lake Malawi and Lake Malombe has sparked interest in its restoration to reach its maximum sustainable yield (MSY). The paper reviews several options that are applied worldwide and provides a synthesis of what could be done for the Chambo. Experiences from several countries, especially in Asia, have shown that culture-based production systems have resulted in high production of fish such as Tilapia and hence, if adopted in Malawi, can provide an alternative approach to increased fish production in Lakes Malombe and Malawi. The paper analyzes and compares management and production methods that can be used to enhance the Chambo stock in Malawi.

Introduction

To achieve its national goal and international obligations to restore the Chambo (*Oreochromis* spp.) fisheries of Malawi to their 1980 status by the year 2015 (DOF 2003), the national government is encouraging fisheries practices that will both protect existing stocks and replenish depleted stocks. Protecting existing stocks requires a comprehensive enforcement program while the replenishment of depleted stocks is a function of enhancement. The most common approaches to fisheries enhancement for inland water bodies are to increase the stock size (stock enhancement), introduce new species to broaden the catch structure (species enhancement) and improve the water quality through artificial eutrophication (environmental enhancement). The purpose of this paper is to analyze and compare management and production methods of enhancing the Chambo stock in Malawi. In doing so, this paper will specifically review the following culture systems: pond, pen and cage, tank, and raceway. In addition, the paper will also review the use of fish aggregation devices and their potential in the Chambo production.

Culture systems

Pond culture

Pond culture refers to the stocking of fish in an artificial pond or stream impoundment. Water is supplied from a watercourse diversion, reservoir or groundwater into the pond, which is constructed as a dugout (no dykes) or with dykes made of earth and/or concrete (Figure 1). According to Gietema (1999), ponds vary in size depending on their primary functions, i.e., for broodstock, nursery or on-growing (fattening). Broodstock ponds are used to hold the parent fish and usually range in size from 1 000 m^2 by 1 m deep. Nursery ponds are used for fry rearing and fingerlings and are usually 100-1 000 m^2 in area. On-growing ponds hold maturing fish until they have reached marketable size; they can range in size from 25 m^2 to larger than 100 ha.

In general, there are three main types of pond operations: extensive, semi-intensive and intensive. An extensive system has low inputs and low yields (0.1–0.3 $t \cdot ha^{-1} \cdot year^{-1}$). A semi-intensive system requires some management and supplementary feeds to achieve higher outputs (1-5 $t \cdot ha^{-1} \cdot year^{-1}$) than extensive systems. An intensive system requires high skill and high levels of inputs to achieve its high output (5-50 $t \cdot ha^{-1} \cdot year^{-1}$) (Gietema 1999).

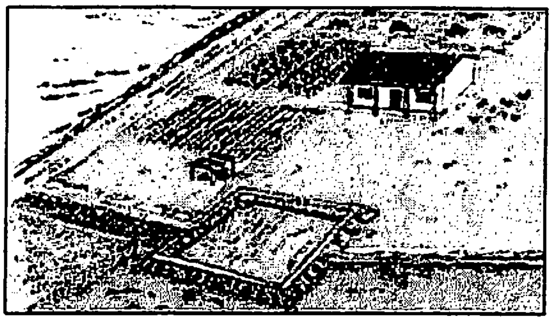

Figure 1. An example of a small-scale pond culture operation (from Coche 2000).

Bimbao and Smith (1988) summarized pond culture production systems in the Philippines reporting 0.4-1.5 $t \cdot ha^{-1} \cdot year^{-1}$, although the level of intensification was not identified. For Israel, Sarig (1990) reports 3 $t \cdot ha^{-1} \cdot year^{-1}$, 9 $t \cdot ha^{-1} \cdot year^{-1}$ and 20-50 $t \cdot ha^{-1} \cdot year^{-1}$ in extensive, semi-intensive and intensive ponds systems, respectively. Lazard et al. (1988) studied pond culture in Cote d'Ivore and found yields of 5.2–7.1 $t \cdot ha^{-1} \cdot year^{-1}$ depending on the feed type; yields of 15 $t \cdot ha^{-1} \cdot year^{-1}$ were also reported. ICLARM and GTZ (1991) report that in Africa yields of 0.1-0.5 $t \cdot ha^{-1} \cdot year^{-1}$ and 1.0-5.0 $t \cdot ha^{-1} \cdot year^{-1}$ are standard for extensive and semi-intensive systems, respectively.

As a system becomes more intensive, there is an increasing level of risk associated with the capital gains and losses. Capital is needed in the intensive system for infrastructure, processed feeds, skilled labor, higher stocking densities, disease control, fertilization, and machines for aeration and water circulation. Thus, the operation is less accessible to people without financing or expertise (ICLARM and GTZ 1991). In the intensive system there is also a corresponding risk associated with environmental degradation depending on how the inputs are obtained (e.g., stream diversion) and how wastes and other outputs are processed (e.g., downstream impacts) (Edwards et al. 2000). Depending on the design of the pond, possible environmental impacts include the disruption of the hydrological cycle, blockage of sediment transport, and the accumulation of effluents may cause high suspended solid counts and lack of oxygen in the water (ICLARM and GTZ 1991).

Pen and cage culture

Pen culture (Figure 2) refers to the use of framed net structures fixed to the substrate in open water environments (i.e., lake, river or ocean) and are widely used for rearing and fry production in marine "sea-ranching" industries in both Japan and North America (Piper et al. 1982). Cage culture (Figure 3) systems utilize a similar structure as pen culture, only in this case, the structure floats at the surface level and is anchored to the substrate.

Cage and pen culture is applicable where water cannot be drained (i.e., from a pond) or where harvesting a large area is inefficient. The overall costs of constructing a pen or cage is often lower than pond construction (ICLARM and GTZ 1991; Lazard et al. 1988) although finding a suitable site may prove difficult along high-energy shorelines.

Yields vary by a wide range in pen and cage culture systems around the world. Tantikitti et al. (1988) mention results of a pen culture growth experiment of *Tilapia* (*O. niloticus*) in Thailand at 5–17 $t \cdot ha^{-1}$ depending on the feed type. Morissens et al. (1988) report a production of 60 $t \cdot ha^{-1} \cdot year^{-1}$ in pen culture systems in brackish waters in coastal Benin. ICLARM and GTZ (1991) state that production can range from 25 to 220 $t \cdot ha^{-1} \cdot year^{-1}$ in African cage and pen systems.

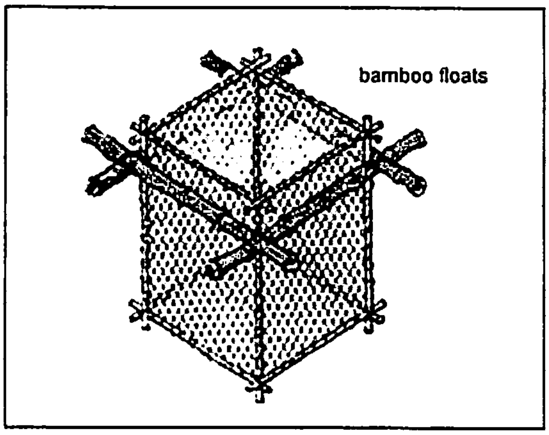

Figure 2. An example of a net cage (from Coche 2000).

While the construction costs of pen or cage culture suggest low start-up capital requirements, there is a risk of incorporating higher costs in other portions of the production cycle and in areas adjacent to the pen or cage itself. With an increase stocking density relative to many pond culture systems, disease management becomes a more

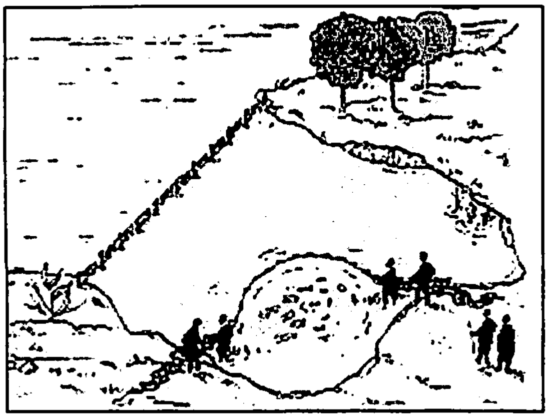

Figure 3. A shoreline fish pen (from Coche 2000).

prevalent issue limiting production and increasing the costs of maintenance (i.e., treatment). Muir et al. (2000) point out that in Israel 30-60% of *Tilapia* spp. aquaculture production is lost due to the *Streptococcus* bacteria in intensive systems. Such intensive systems can also cause anoxia in the benthos where circulation is inadequate, thus, limiting feed, oxygen and nutrient availability (ICLARM and GTZ 1991).

Management of pen and cage culture systems must address the cumulative impact of closely grouped operations or face reduced production in downstream users and other stakeholders in the aquatic resource (e.g., drinking water). Capture fisheries may also suffer if pens are sited in traditional fishing, fry rearing or breeding areas along the shoreline (ICLARM and GTZ 1991).

Tank and raceway culture

The most capital-intensive method of fisheries enhancement is the use of metal or concrete tanks with flow through water, high stocking densities (e.g., 50 $kg \cdot m^{-3}$), processed feeding, and control over physical and chemical water qualities. This system has been in use for *Tilapia* spp. in Kenya since 1975 and in other African countries such as Nigeria, Egypt, and Zambia (ICLARM and GTZ 1991). Productivity of the tank and raceway system is the most efficient means of producing fish protein at 2 000 $t \cdot ha^{-1} \cdot year^{-1}$ (ICLARM and GTZ 1991).

High capital costs for these systems make financing difficult and an ample market demand must be in place to make the venture profitable. The consumption of inputs such as freshwater and electricity (e.g., to operate pumps and quality control equipment) and the removal of waste outputs (i.e., effluents) require consideration in any environmental impact analysis. The suitability of the Chambo to this system is also questionable.

The prevailing view among aquaculture researchers is that the Chambo is difficult to grow to marketable size in captivity due to early maturation. Masuda et al. (2004) argue that if placed in suitable environmental conditions, then *Tilapia* spp. fishes can avoid early maturation and reach marketable size. Tank and raceway culture presents the best opportunity to deliver ideal conditions in intensive production systems as complete control over inputs is possible, unlike cage, pen or pond culture. The economic advantages of this approach must then be compared to ranching for which inputs are less intensive but with reduced productivity as well.

Habitat and fishery enhancement

Fish aggregation devices

Fish Aggregation Devices (FAD) are used in open water systems to attract prey species, target species and increase the production of the aquatic community. In freshwater environments this system is used widely in Mexico, Ecuador, Southern Asia and in some countries in Africa, namely Benin, Madagascar, Liberia, Cote d'Ivore, Sierra Leone, and Malawi (ICLARM and GTZ 1991). While these systems around the world with differ with various cultural and biophysical factors at play, the underlying principle of a FAD is the deliberate manipulation of sub-aquatic structures to attract target species. When it is time to harvest a net is encircled around or placed within the FAD, which is then removed to allow for the capture of the fish.

The main types of FAD in Africa are known as brushparks in West Africa, *acadja* in Benin and *vovomora* in Madagascar (ICLARM and GTZ 1991). In general, these systems utilize woody vegetation 2-2.5 m in length planted in the substrate to attract fish, and use some type of fence surrounding the brush to trap them. Thus, the start up capital is low for infrastructure, and, although supplementary feeding can be utilized, these systems are generally considered semi-intensive.

According to Balarin (1987) production rates from FAD, depending on the design, can range from 5 to 38 $t \cdot ha^{-1} \cdot year^{-1}$. Owing to the addition of brush wood over time, productivity of the brushpark increases as older vegetation decays and adds nutrients to the system. Experiments in Malawi with brushparks in Lake Chilwa (Jamu et al. 2003) and on fish farms (Chirwa 2004) have met with only minor or negligible increases in productivity compared to the control.

With a brush wood replacement rate of 30-75%, the demand for forest products to support the brushwood system is high, up to 60 $t \cdot ha^{-1} \cdot year^{1}$(ICLARM and GTZ 1991). In coastal Benin where this practice is widely used, deforestation has become a serious problem and the subsequent siltation of the fishing areas has had further drawbacks to the productivity of this aquatic ecosystem. As with the cage/pen systems, occupation of the near shore areas by brushpark operations can reduce the availability of spawning and rearing habitat for capture fisheries.

Fish ranching

Fish ranching is an integration of aquaculture with capture fisheries in which the young are hatched and reared in a controlled environment such as a pond, net cage or pen until they reach a target size, and then they are released into open waters to grow to marketable size. This is a common enhancement technique used in marine fisheries such as the salmon fisheries of North America and the Baltic countries (Piper et al. 1982).

Because fish are released into open waters, productivity is low per unit area, approximately 0.05-0.3 $t \cdot ha^{-1} \cdot year^{1}$ (ICLARM and GTZ 1991). However, this does not reflect the overall productivity of the fishery as traditional capture fisheries using efficient harvesting technologies can be employed in the open water environment.

Conclusion

The choice of system to adopt must take into account the goals of the operation (i.e., profit, integration, or supplementary diet), availability of resources (i.e., expertise, labour, finances, raw resource inputs or waste disposal resources) and the suitability of the Chambo to be produced within a particular enhancement system. A comprehensive research plan that addresses the suitability of these enhancement systems to the Chambo production must be developed, including the analysis in both closed and open water systems. Furthermore, policy makers, donors and resource managers must carefully examine the impacts of each approach on the surrounding economies and environments where enhancement programs are planned. Lastly, each enhancement system requires a corresponding resource management strategy to ensure its sustainability and compliance with regulations from local communities and external investors. Benefits of enhancing the Chambo stocks in Malawi can be realized but these gains must be weighed against the environmental and socio-economic costs of intensifying production.

References

Balarin, J.D. 1987. Aquaculture practices in Africa: an overview, p. 242-282. *In* Anon (ed.) Proceedings, SADCC workshop "The Development of Village Level and Commercial Aquaculture in the SACC Region", Kariba, Zimbabwe, 29 September-3 October 1986, 373 p. Fisheries Department, Lilongwe. (mimeo).

Bimbao, M. and I. Smith. 1988. Philippine tilapia economics: industry growth and potential, p.539-552. *In* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Mclean (eds.) The second international symposium on tilapia in aquaculture, Bangkok, Thailand, 16-20 March 1987. ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center of Living Aquatic Resources Management, Manila, Philippines.

Chirwa, B. 2004. Preliminary study on the utilization of bamboo substrates to enhance heterotrophic food production in fishponds for the growth of *Tilapia rendalli* in Malawi. Technical Report No. 9:72-76. *In* K. Masuda, B. Chirwa and G. Ntenjera (eds.) A contribution to the development of rearing techniques in fish farming in Malawi. National Fisheries Center, JICA and Domasi, Malawi.

Coche, A. 2000. Handbook on small-scale freshwater fish farming. CD-Rom. FAO Training Series, Rome,

Department of Fisheries. 2003. Ten-year national strategic plan for the restoration of the Chambo fishery in Malawi. National Stakeholders' Consultative Workshop, 14-16 May 2003, Boadzulu Holiday Resort, Mangochi, Malawi.

Edwards, P., C. Lin and A. Yakupitiyage. 2000. Semi-intensive pond aquaculture, p. 377-404. *In* M. Beveridge and B. McAndrew (eds.) Tilapias: Biology and exploitation, Kluwer, 505 p.

Gietema, B. 1999. Fish farming in tropical fresh water ponds: Book 1. STOAS, 175 p.

ICLARM and GTZ. 1991. The context of small-scale integrated agriculture-aquaculture systems in Africa: a case study of Malawi, 302 p.

Jamu, D., K. Chaula and H. Hunga. 2003. A preliminary study on the feasibility of using brushparks for fish production in Lake Chilwa, Malawi. Naga, The WorldFish Center Q. 26(1):4-8.

Lazard, J., P. Morrisens and P. Parrel. 1988. Artisanal aquaculture of tilapia in Africa: comparative analysis of different culture systems and their level of development, p. 41-52. *In* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J. Mclean (eds.) The second international symposium on tilapia in aquaculture, Bangkok, Thailand, 16-20 March 1987. ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines.

Masuda, K., B. Chirwa and G. Ntenjera. 2004. A contribution to the development of rearing techniques in fish farming in Malawi JICA, Malawi, 253 p.

Morissens, P., P. Tauzes, P. Roche and C. Aglenglo. 1988. Net pen rearing of *Oreochromis* spp. in the lagoons of Bénin, p. 587. *In* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Mclean (eds.) The second international symposium on tilapia in aquaculture, Bangkok, Thailand, 16-20 March 1987. ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines.

Muir, J., J. van Rijn and J. Hargreaves. 2000. Production in intensive and recycle systems, p. 405-446. *In* M. Beveridge and B. McAndrew (eds.) Tilapias: biology and exploitation, Kluwer, 505 p.

Piper, R., I. McElwain, L. Orme, J. McCraren, L. Fowler and J. Leonard. 1982. Fish hatchery management. USDoI, Washington, 517 p.

Sarig, S. 1990. The development of polyculture in Israel: a model of intensification, p. 302-332. *In* J. Shepardand N. Bromage (eds.) Intensive fish farming. BSP Professional Books, 404 p.

Tantikitti C., N. Rittibhonbhun, K. Chaiyakum and R. Tansakul. 1988. Economics of tilapia pen culture using various feeds in Thale Noi, Songkhla Lake, Thailand, p. 569-574. *In* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Mclean (eds.) The second international symposium on tilapia in aquaculture, Bangkok, Thailand, 16-20 March 1987. ICLARM Conference Proceedings 15, 623 p. Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines.