ENVIRONMENTAL RISKS OF AQUACULTURE IN THE SAO FRANCISCO RIVERBASIN, BRAZIL

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Executive Summary

Environmental impacts of fish farming depend mostly on the culture method, stocking intensity, water supply, choice of species, and the physics and chemistry of the soil and water; even apparently minor factors such as pond depth and its exposure to wind and light matter. In general, the more intensive the culture, the more water and feed needed, the heavier the pollution load, and the greater the damage when things go wrong. Fortunately, complete disasters are rare.

The form of culture must reflect the resources available to the farmer. As a part-time job, a pond is best stocked for greatest efficiency with native plant-eating or omnivorous species that can consume the inevitable weed growth (and garden waste). Environmental impacts will be generally slight. Water supply, fish feed, the type of species that will be reared (exotic or native), availability of seed or broodstock, whether the fish will be sold whole in local markets or processed on-site for export and how legislation will affect operations are also questions that need to be addressed.

Experience with *Tilapia zilli* reveals the successful characteristics that have helped the fish establish itself in favourable environments. Essentially, tilapia breed over an extended season in relation to most other fishes, care for their young after birth (reducing predation), and so quickly expand their populations (Courtenay, 1997). However, the prolific breeding of the species can itself become a menace to other species and a drawback to culture as it may result in a pond of small, stunted fish. To limit damage from escapes, strains of tilapia are being domesticated to have little chance of surviving in the wild. The creation of all-male populations, through hybridization and other techniques, would also theoretically prevent breeding populations from forming in the wild (Fitzsimmons, 2001).

While the physical occupation of natural sites exposes the environment to greater immediate change, artificial sites require greater investment in infrastructure, are more expensive to operate and may have a greater effect on the environment than a lower-key extensive or semi-extensive pond system. Water requirements of cultured species differ, and must be known to ensure there is enough water at the site for that species, whose territorial requirements for breeding and feeding must also be known.

The most popular system in Latin America is the pond system, cheap to build and not demanding to manage at semi-natural levels of production. The major drawback to the

pond system is the possibility of uncontrolled breeding. The easiest solution for this is to raise the fish in fine-mesh net cages within the pond. The most intensive system involves tanks and raceways which are expensive to build, demand a lot of water and expertise in maintaining water quality and preventing diseases.

Because of their large areas and deep water, large reservoirs are recommended by Saha *et al.* (2003) to be one of the best environments for cage culture, whereas small irrigation reservoirs can be used for extensive culture. Ponds around 0.5 ha or less or that are seasonal can be used for rearing fingerlings. Various tilapia-rearing systems and systems for other species in Brazil are discussed: extensive, semi-extensive, semi-intensive, intensive, super-intensive, cages and net-tanks, and monoculture vs. polyculture.

Water quality is affected by the innate quality of available water (clear water low in nutrients, muddy water which may need a settling pond before use, bright green water high in phytoplankton and nutrients, and brown water which is generally acidic). Subsequent influences on water quality are stocking density, feed conversion ratios, the presence of bottom-feeding detrivores that stir up the sediments and increase turbidity or of planktivores that by feeding on the algae help limit turbidity and blooms. Parameters of water quality are oxygen levels, levels of ammonia, phosphorus, pH, alkalinity, hardness, carbon dioxide, salinity, chlorine, turbidity, and hydrogen sulphide. Factors that influence water quality are levels of fertilization, feeds, presence of organic waste, sediment chemistry, nutrient ratios in the water column, the presence of chemicals (antibiotics, hormones, medicines, detergents), and metal contamination.

Pond chemistry is also influenced (and signified) by aquatic plants, which if well managed, are highly beneficial to fish culture; by irrigation, recirculation and the use of settling ponds.

Introductions, transfers and escapes of cultured species have far-reaching consequences both on fish culture and the wider environment. Escaped species may prey on native species, compete for habitat or food, introduce new diseases or invasive parasites, and alter the local habitat. They also contribute to genetic pollution. Even where escaped fish are not capable of breeding, large numbers may overwhelm local wild populations which may have relatively few breeding adults in any one year. To avoid the problems associated with genetic and exotic pollution it is widely recommended that the production of non-native fish be avoided, unless they already exist in the river. Hatchery production could be regionalized, as a way of limiting disease transmission. Where farmed fish may escape at serious risk to the environment - for example, genetically modified individuals – complete containment, with multiple safety measures on the effluent water, is the only option. However, the cost of such containment makes it rare for all but the most juvenile life stages.

Fish resistance to infection can be aided by good nutrition and lowered stress, and water-borne pathogens can generally be removed in settling ponds. Naturally-occurring poisons can also be used to kill parasites or unwanted fish in a pond that cannot be drained.

To reduce risks from uncontrolled breeding there are several options: Induced sterility, same-sex populations, reliance on all-male or all-female cultivars. However, none of the methods is completely successful (Fishelson 1987; Lovshin *et al.* 1990).

Sterile fish may grow faster and larger than normal individuals, and do so by consuming less feed, lowering production costs and getting the fish to market more quickly. One experiment with three-spined sticklebacks to test the hypothesis that faster growing fish would have a competitive advantage over slower growing fish found unexpectedly that the fastest growing fish developed the largest parasites, having proved to provide a superior environment for the parasites (Barber, 2005).

The risks of releasing fish generated by recombinant DNA technology in order to produce faster growth are unknown. It is also not yet clear whether copies of growth hormone gene introduced into tilapia remain stable over many generations, or what other effects they may have on the physiology of the tilapia (Kocher, 1997). In summary, the potential environmental risks of transgenic fish are suspected to be greater than the risks of releases of wild or hatchery-reared fish because organisms that possess novel genetic combinations may be able to exploit novel niches (Strandberg *et al.*, 2003, citing Tiedje *et al.* 1989).

For a semi-intensive to intensive monoculture of herbivores that results in heavily polluted waste water, a combined system using settling ponds with duckweed (the smallest of all flowering plants, existing as a single flat, ovoid frond) has been suggested as efficient and cost-effective and very suitable for tropical climates (Skillicorn *et al.* 1993; Chaturvedi, 2003). Duckweed is very low in fibre (5%) and high in protein (up to 43% dry weight), can be fed directly to fish (Leng *et al.*, 1995) and can be harvested with poles or nets. Because it floats, it can be entirely consumed by fish before it joins bottom sediments; and fish such as tilapia and carp convert it to meat very efficiently. Its drawbacks include sensitivity to temperature extremes and high light intensity, occasional insect infestations, and a susceptibility to rot soon after harvest.

Includes Table 1, 'The effects of some characteristic aquaculture-related introductions in Africa', Table 2, 'Fish species cultured in the five aquaculture centres of CESP in Sao Paulo State', Table 3, 'Water requirements for different species', Table 4, Feeding and spatial niches of possible polyculture species', and Appendix I, 'Table of species native to the Sao Francisco River.'