

VII. ENVIRONMENTAL IMPACT OF CAGE FISH CULTURE

Sustainable cage fish culture is dependent on both long-term environmental and economic viability. Environmental viability is dependent on maintaining water quality at or above a minimum standard. In turn, maintenance of a water quality standard is dependent on the collective amount of wastes introduced into the water, resulting from the quantity and quality of feed and other nutrients used to culture the fish, and from all other sources. Cage culture inevitably enriches the surrounding water environment with metabolized feed waste as would organic fertilization. As with fertilization, amounts of feed waste up to a certain threshold are beneficial in the environment because of the increased production of non-caged fish that results from the enrichment. Beyond that threshold, however, the enriching elements become pollutants. The threshold is not an absolute amount that can be predicted for any situation as, for example, a road bridge engineer could predict the load limit for a specific support structure. Ecological systems are too complex and dynamic for that degree of accuracy. Also, the threshold is variable based on limits one wants to set on change of the environment. Consequently, thresholds for added enrichment with fish feeds vary with the prevailing trophic state of the environment. For example, the safe feeding threshold for a nutrient-poor oligotrophic environment will initially be higher than for a nutrient-rich eutrophic environment. Other influencing factors include water surface area, water depth, seasonal fluctuations, amount and seasonality of flow-through, and other uses of the environment.

The enriching-polluting substances resulting from cage fish culture are primarily the phosphorous and nitrogen contained in the feed. The fish, i.e. species, numbers and weights, are relatively incidental to the environment except as they relate to the amount of feed used to produce them. The quantities of phosphorus and nitrogen in fish feeds vary somewhat with feed quality, but are usually about 12 kg and 55 kg, respectively, per ton of pelleted feed (Table VII-1). Fish will assimilate some of these nutrients (about 5 kg and 14 kg, respectively, at FCR = 2.0) leaving the remainder to enter the environment as metabolic waste. These wastes enrich phytoplankton production, which stimulates increased biomass at all trophic levels, including the levels occupied by non-caged, wild fishes in the open water. However, increases in biomass result in comparable increases in respiration causing proportional declines in nighttime dissolved oxygen levels. This water quality problem is worsened by a syndrome of chemical, physical and biological changes that accompany increases in biomass.

The primary enriching-polluting nutrient in freshwater aquacultural environments is phosphorus. Phytoplankton biomass in fish culture environments is usually proportional to the amount of phosphorus, expressed as phosphate (P_2O_5), entering the environment. The quantities of phosphorus in pelleted fish feeds and resulting metabolized feed wastes are relatively constant at

about 12 kg and 7 kg (= 16 kg P₂O₅) per ton of feed, respectively. Therefore, the threshold for the amount of fish production in cages in a given environment can be generally determined based on the amount of pelleted feed required to produce the fish.

Table VII-1. Useful information for assessing environmental impact (eutrophication) of P and N from metabolized feed wastes.

1. Fish dry weight	= 20-25% wet weight
2. Phosphorous (P)	= 1.2% of feed (varies from about 0.8-2.2%) = 12 kg/ton of feed = 4.1% of fish dry weight
3. At FCR = 2.0 (2.0 kg feed to produce 1.0 kg net wet weight gain of fish)	a. 1.0 ton feed produces 500 kg fish wet weight = 125 kg fish dry weight b. fish assimilate 5 kg P (125kg fish dry weight x 4.1% P) c. therefore, metabolic P waste = 7 kg (12 kg P/ton feed - 5 kg P assimilated) d. 7 kg P x 2.29 (1.0 kg P = 2.29 kg P ₂ O ₅) = 16 kg P ₂ O ₅ waste /ton feed
4. At optimum fertilization in ponds, P ₂ O ₅ = 2.8 kg/week; therefore, 1 ton feed results in enough P ₂ O ₅ (16 kg) waste to optimally fertilize a 1-ha pond for about 6 weeks.	
5. Nitrogen (N)	= 5.5% of feed (varies from about 4.5 to 7.0%) = 55 kg/ton = 11.2% of fish dry weight
6. At above conditions, the 55 kg in 1-ton feed	a. is assimilated in fish at 14 kg (125 kg dry fish x 11.2% N) b. is released as waste into the environment at 41 kg/ton (55 kg total N - 14 kg N in fish) c. results in enough waste N to optimally fertilize a 1-ha pond at 2.8 kg N/week for approximately 15 weeks.

A standard maximum "safe", or sustainable, feeding amount for channel catfish in ponds without aeration is 30 kg feed/ha/day. This quantity of feed would result in a daily release of about 0.54 kg of P₂O₅ waste/ha/day into the environment, causing it to become eutrophic. A pond in this condition would be very rich in phytoplankton (water visibility index of about 30 cm), thermally and chemically stratified at about 120 cm, anaerobic in the hypolimnion, dissolved oxygen supersaturated to about 130% in the epilimnion in the afternoon and critically unsaturated to about 25% at dawn. These would be dangerous conditions for fish in a pond, but would be worse in open water lakes and reservoirs.

Similar eutrophic conditions in an open water environment would greatly reduce native species diversity, destroy species balance and destabilize the physical, chemical and biological relationships of the ecosystem. Those changes would not be permanent if feeding were discontinued, because the original, or very similar, ecosystem would reestablish itself relatively soon after feeding was stopped. However, in the eutrophic state, most human uses of the water would not be greatly affected. Some recreational uses, especially swimming, would be less desirable. The water would also be less desirable for municipal purposes because of the phytoplankton. Fishing, on the other hand, would be measurably improved although fish community composition might change.

At a rate of 15 kg feed (0.27 kg P₂O₅ waste)/ha of open water/day, the water would be visibly changed, but the amount would probably be an acceptable threshold from every point of view. However, since there is usually no pressing need to take unnecessary risks, a reasonable threshold of 8 kg feed (0.13 kg P₂O₅ waste)/ha/day could be set as a safe, sustainable level at which ecological impact measurements would be evaluated before the threshold could be raised. The 8 kg feed/ha limit would be an average for the collective sum of feeds used over a multiple hectare area and not an actual amount for each specific hectare.

In addition to feeding limits per hectare based on the total area of the water environment, limits for designated specific cage culture areas within the total environment may be imposed (Table VII-2). Standing fish biomass of 20 mt and 60 mt in 1-ha and 10-ha designated areas, respectively, of a large oligotrophic or mesotrophic reservoir are the maximum standing crops recommended. These correspond to feed limits of 500 kg/day for a 1-ha designated area and 1,500 kg/day for a 10-ha designated area within the total environment. These numbers would need to be adjusted downward for more eutrophic environments, i.e. environments with visibilities less than about 80 cm. Cage fish culture should not be practiced in environments where visibilities would drop below 30 cm during the culture period.

Table VII-2. Base for predicting feeding rate thresholds for low volume (1- to 4-m³) cage fish culture in a hypothetical 10,000-ha mesotrophic lake.

Area of lake considered	Maximum volume of cages (m ³)	Feed maximum (kg/day)	Fish (kg) produced or supported *	Kg feed fed/ha of total lake/day
Total 10,000 ha (collective area)	20,000	80,000	3,200,000	8
Total 10,000 ha as per ha mean	2	8	20	8
Designated 1-ha cage area	125	500	20,000	8
Designated 10-ha Cage area	375	1,500	60,00	8

* Optimum carrying capacity is expected to be about 160 kg/m³ of cage. Maximum feeding rate per culture period would be about 4.0 kg feed/m³ of cage/day.