

III. FISH STOCK QUALITY AND QUANTITY

INTRODUCTION

Quality of fish stock is the third most important factor, after environmental (water) quality and fish nutrition, to successful cage culture. Stock quality primarily refers to a fish's genetic potential for cage culture including its species and strain characteristics. Genetic quality factors are among several criteria for choosing a species, strain or a specific group of fish for low volume, high density cage fish culture. Stock quality also refers to general health, relative size and other physical and physiological characteristics of a given group of fish being stocked. In addition to discussions on fish stock quality, this section also includes under separate headings discussions of stock density and stocking conditions.

CRITERIA FOR SELECTING FISH STOCK

There are more than 20,000 known species of fish in the world. Perhaps 200 of these have been successfully cultured for food, but only 20 to 25 species are cultured in significant commercial quantities. Although unknown hundreds or thousands of species have high potential for culture, they simply have not been screened for that purpose. Potential for culture fundamentally depends on the quality of the species measured by many criteria. Among the few species that are routinely cultured for food, only common carp and rainbow trout have been genetically selected to produce distinct, verifiable culture strains. Considerable research is underway to improve genetic potential of culture species. No known efforts are underway to selectively breed or otherwise create specific strains of fish for cage culture. Perhaps there is no need for a specific cage strain different from one selected for intensive aquacultures in general. One possible criterion for cage fish might be a greater than normal tolerance for close confinement and high density. Genetic improvements and domestication are becoming increasingly possible with new technologies in breeding and genetic alterations such as gene transfer.

Suitability of a fish species for aquaculture generally, and cage culture specifically, is dependent on many criteria related to marketability, availability, culture adaptability and stress tolerability. Principal criteria are discussed in the following paragraphs in no specific order of importance.

Marketability

Consumer acceptance is the first consideration in selecting a species for culture, because the last step in a successful culture operation is to sell the fish at a profit. Obviously an adequate market must exist if fish are to be produced profitably.

Availability

Adequate availability of fry, fingerlings and brood fish are critical to establishing an aquaculture industry. The ability to reproduce culture species in captivity, the age and size of culture species at maturity, the degree to which a species can be domesticated, and the seasonality of growth and reproduction are all critical factors.

Reproduction in captivity: Many major aquaculture industries have been developed using captured wild fish fry. Wild fry continue to be of major importance in many aquaculture endeavors, but only a few species-specific industries are still dependent on wild stock. Almost all major culture species spawn naturally or can be induced to reproduce in captivity. Captive reproduction capability is an essential criterion for an aquaculture species for the following reasons:

1. Naturally produced, wild fry are not generally available in consistent, sufficient quantities to support a large culture industry on a reliable basis;
2. Captured wild fry are generally more expensive than aquaculturally produced fry, and they are usually available only on a seasonal basis;
3. Culture of captured wild fry, for physical and economical reasons, must normally be conducted in the general area where the wild fry are produced;
4. Domestication and controlled genetic improvement of a species is not possible without aquacultural reproduction;
5. Transmission of disease, parasitic and "pest" organisms can be more effectively controlled with aquacultural reproduction;
6. Wild fish populations can be seriously depleted by over harvest of fry for aquacultural uses.

Age/size at sexual maturity: Ideally a culture species will attain sexual maturity after attaining minimum marketable size. Some fish species, such as some tilapia, are sexually mature and spawning at 3 or 4 months of age and 50 g in weight. Others, such as some of the carps, do not reach sexual maturity until 3 or 4 years of age and 3 or 4 kg in weight. The early, small maturing species such as tilapia are technologically more advantageous than the late, large maturing species such as major carps. The longer the maturing period and the larger the size at maturity, the greater the cost of feed, space, labor and other management items. Also, the longer the fish are held the greater the risk of loss to natural calamities, accidents, diseases and other causes of mortality not uncommon in aquaculture. Because of these factors and lack of serious breeding programs, genetic qualities of cultured fishes have universally been negatively affected or unimproved by hatchery management procedures of both early and late maturing species. Early maturing species and later maturing species have been both seriously inbred where breeding stocks were raised in captivity, and unimproved where fry and breeders were collected from wild stocks. Although early

maturity at a small size has many advantages, it may be disadvantageous in some situations. For example, some species, such as Nile tilapia, attain sexual maturity and begin reproducing in ponds several weeks before they reach marketable size. This may result in overpopulation and ultimately cause complete crop failure of a pond population unless preventive management practices are employed. Overpopulation resulting from reproduction is not a factor with any species cultured in LVHD cages in ponds or other environments, because they can not successfully reproduce under those conditions. However, growth and feed efficiency are reduced by sexual development, including gonadal development.

Domestication: Different strains of a given cultured species may perform differently under equal culture conditions. A "domesticated" strain that has been in continuous culture for several generations will generally produce higher yields with less management problems than a wild strain of the same species. This is especially important in cage culture where domestic strains are much more tolerant of high density confinement. Domesticated strains are also easier to manipulate with regards to reproduction procedures and harvest. Common carp is represented by numerous identifiable strains. While most cultured species have strains in various degrees of domestication, they are not usually identifiable as such.

Seasonality: Seasonality of stock may influence choice of an aquacultural production system, but a production system may also influence stock availability. An advantage of cages is the potential for year round marketing and restocking regardless of growing season period. Nile tilapia may reproduce year round, but it is not a potential fish for year round marketing and restocking in temperate climates when water temperatures seasonally drop below about 15°C. Channel catfish reproduce only once per year, but it has high potential for year round marketing and restocking in temperate regions.

Culture Adaptability

Growth rate/size: A cultured fish must grow to a minimal acceptable marketable size in a reasonable growing period or season. Different fish species with equal minimum marketable sizes may grow at differential rates varying as much as 100% or more. Other factors excluded, absolute growth rate is generally directly proportional to the maximum potential size attainable. Fish large at maturity generally grow more rapidly than fish small at maturity. Warm water species generally grow at a faster rate than cold water species of comparable maximum potential sizes.

Trophic level: It is conditionally true that terrestrial environments have a two dimensional food producing zone confined to the soil surface, while aquatic environments have a three dimensional food producing zone that includes the bottom surface, top surface and entire water column in between. Consequently, aquatic ecosystems contain more food sources (niches) and food source

levels (trophic levels) than terrestrial ecosystems. The quality and magnitude of each specific niche and the trophic level each cultured fish species occupies is the basis of all non-feed based and some feed based aquacultures. The Chinese fish polycultures in ponds are an excellent example of practical applications of these principles. A polyculture may contain filter (silver and bighead carps), foliage feeding herbivore (grass and wuchang carps), facultative omnivore (common and crucian carps), molluscivore (black carp), insectivore (tilapia) and piscivore (bass) species. However, in cages there is only one natural food niche (plankton) and an artificial niche (feed). Therefore, plankton filtering fish and feed taking fish may be raised in cages. An essential criterion for a fish species for intensive cage culture is that it readily take and perform well on pelleted feed. Some fishes, such as Nile tilapia, will utilize plankton as well as take pelleted feed. All omnivorous species will readily take pelleted feed while most specialized feeding fishes will not. For example, the highly specialized plankton filtering silver carp and highly carnivorous grouper do not take pelleted feed while the non-specialized omnivorous common carp will take manufactured feeds at all stages of its life cycle.

Feed acceptance of the species or life stage: A cage culture species should readily accept manufactured feed during post fry stages of its life cycle. Probably all omnivorous fishes and most herbivorous and carnivorous fishes will take feed beginning as advanced fry. Some filter species, such as silver carp, may be raised in cages to at least 90 kg/m³ in mesotrophic environments without feeds.

Stress Tolerance

Numerous conditions and situations encountered in aquaculture operations can be stressful to fish. Frequent causes of stress include poor water quality, handling, temperature and salinity change, disease, confinement and fright. The ability to tolerate stress influences the suitability of a species for aquaculture. Stress factors are discussed below in no order of importance.

Poor water quality tolerance: Tolerance to normal but relatively extreme changes in water quality and often persistent adverse water quality conditions are important criteria in selecting species for cage culture. Diurnal changes in pH levels, dissolved oxygen and free carbon dioxide concentrations and other water quality parameters are normal in culture environments, often to the point of causing fish stress, disease and death. Fish production performance, measured by growth rate, feed efficiency, incidence of disease, mortality rate, and fish yield, is adversely affected by decreases in water quality. Therefore, the greater the fish's tolerance for poor water quality, the less its production performance will be adversely affected.

Handling tolerance: Aquacultural species must be relatively tolerant to essential handling practices such as transporting, seining, holding in tanks, and sorting. The greater the tolerance the

greater the survival during handling and the less the incidence of disease and mortality after handling. For example, bacterial disease will usually be evident and cause some death in channel catfish but may not impact Nile tilapia where both are subjected to equal handling activity.

Temperature tolerance: Temperature is a major controlling factor in aquaculture. It is imposed by nature and endured with few alternatives by the fish culturist. One of the few ways culturists can cope with temperature is to select fish species with temperature tolerances that match the temperature range in the culture area. Salmonids (salmon and trout), cichlids (tilapia) and cyprinids (carps) are excellent examples for comparison. Salmonids are temperate fish that cannot be cultured in warm tropical waters. Cichlids are tropical fish that cannot be cultured in cold temperate waters. Cyprinids, on the other hand, may be raised with salmonids in cold temperate waters, or with cichlids in warm tropical waters, or in waters between the temperate-tropical extremes. Certain individual species have a greater tolerance for cold or warm water than other species of their respective genus or group. Nile tilapia can tolerate lower temperatures than Nile tilapia, and rainbow trout can tolerate warmer temperatures than brook trout.

Salinity tolerance: Salinity is a factor to be considered by culturists in coastal regions and in some arid inland areas where salt concentrations in soil or water exceed 3 to 5 parts per thousand (ppt). Each species has its specific salinity tolerance. Most freshwater fish can tolerate up to 10 ppt but will not grow in salinities above 5 to 7 ppt or reproduce in salinities above 3 ppt. Many marine fish cannot live in salinities outside the range of about 15 to 45 ppt. On the other hand, some marine fishes, e.g. milkfish, and some freshwater fishes, e.g. Mozambique tilapia, can live in salinities ranging from freshwater to ≥ 95 ppt (open ocean water is about 35 ppt). A fish's tolerance to sudden changes and extremes in salinity concentrations must be a consideration in selection for culture.

General environmental tolerance: Cultured fishes are subjected to numerous stressors in addition to handling, temperature extremes and poor water quality variables. Caged fish, for example may be stressed by their inability to escape confinement, light, sound, movement of people or animals above the cage and other factors that may or may not be obvious to the culturist. Therefore, a general tolerance to all types of environmental stressors is a desired characteristic.

Adaptability to aquacultural environments: Related to stress tolerance is the ability of a fish species, strain or life stage to adapt to the aquacultural environment to which it is subjected. To adapt means to adjust to the environment to the extent that production performance is normal or unaffected. Larger fish of a species are less adaptable to cage confinement and cage culture than smaller fish. Also, some species, e.g. Nile tilapia, adapt to cage culture faster and apparently more completely than others, e.g. silver carp.

Disease resistance: Diseases, especially from protozoan ectoparasites and bacteria, are problems in aquaculture. Diseases affect aquaculture in cages in such adverse ways as decreasing growth, survival, feed efficiency, yield, reproduction and profit. Some fishes, such as milkfish, have high resistance to pathogenic diseases. Others, such as brown bullhead, are so susceptible to disease that they are impractical to culture. Aquacultural management practices are necessarily more demanding in terms of major inputs and costs for fish with low disease resistance than for ones with high resistance.

A perfect aquacultural or cage culture fish species that ideally meets all of the above criteria does not exist. Numerous fish species have been successfully raised in cages. However, channel catfish, common carp and Nile tilapia were chosen as model species because they meet practically all of the criteria for selecting species for culture in cages. Numerous other species are undoubtedly suitable and probably all omnivorous fish species successfully raised in ponds can be successfully raised in cages as well. Selective breeding would likely improve cage culturability for many species.

FISH STOCK QUALITY

The production performance of fish in cages or any culture environment will be directly related to the quality of fish stocked. Selection is critically important to culture success, and should be done with concern for quality relative to genetic history, general health and individual size.

Genetic history should be assessed relative to the potential production performance of a specific fish species, strain or group in cages in a specific environment. The aquacultural ecosystem concept of "fitting the fish to the environment" is demonstrated in this process. The concept is to stock the most appropriate strain, which has been genetically improved through selection for a specific environment appropriately modified. Each is purposely modified to best match the other. In practice, the cage culturist can not genetically modify his fish stock but should try to obtain stock already modified. This is accomplished by interviewing the fish supplier and other farmers to determine how well a specific strain or group has actually performed under culture conditions.

Fish for stocking cages should be in good general health and "disease free." Inspection by a certified fish disease specialist is recommended. In lieu of inspection, some key indicators of good health are uniformity of skin color among the group, absence of sores, blotches, spots, frayed fins and deformities, and vigorous avoidance to capture by all of the fish.

Individual size of fish is important only as it relates to uniformity and cage mesh size. Fish for stocking cages should be of relatively uniform size and too large to escape through the mesh (minimum of 20 g for 13-mm bar mesh). Smaller fish (15 to 50 g) adjust to cage confinement more readily than larger fish. Effects of handling and confinement stresses on fish during the first

5 to 10 days after stocking generally increase with increasing size of the fish. Fish stocked at a uniform size will tend to grow uniformly. However, with non-uniform stock the size difference will become progressively greater during culture. The larger fish in the group will grow normally while the smaller fish will grow at a less than normal rate and may not grow at all during the culture period. Reasons for the differential growth are not clear, but are assumed to be associated with size intimidation ("bullying") and pheromone repression.

STOCK DENSITY

Fish stock density refers both to the number or weight of fish per unit volume of cage and to unit area of water environment. Fish could be stocked so densely that restricted individual or collective space could become limiting to production performance. However, as density increases both water quality and feed access decrease and limit production performance before restricted space becomes a factor. Therefore, an overstocked fish population is one where its density is negatively affecting production performance through its effect on water quality and feed access.

Relative to water quality, the primary concern about overstocking is the impact on water quality of the total environment directly and the cage indirectly. With proper water exchange, water quality inside a cage will not be significantly different from that of the external water environment. Metabolic wastes are directly proportional to stock density. With proper water exchange the wastes are diluted and disbursed to approximately equal concentrations inside and outside the cage. Therefore, the principal concern for overstocking, relative to effects on water quality, is fish weight per area of total environment rather than number or weight per volume of cage.

Stock density per volume of cage has direct impact on potential feed loss from the cage and feed access by the fish. As density increases feed loss potential increases because of increased fish-induced water turbulence at feeding time. With increasing fish density above 150 to 200 kg/m³, access to feed at feeding time will become increasingly limited to all fish because of the amount of biomass separating some fish from the feed container. Feed loss and limited access resulting from high fish density can be reduced but not eliminated by feeding more than the fish will consume at one time (>100% satiation) and by more frequent feeding. This will reduce feeding frenzy and feed loss, and feed access to all fish will increase with increased feed amounts and exposure time. However, feed efficiency will likely decline.

Feed access may be influenced by fish behavior and physiology as well as by the physical biomass factor. Caged fish populations typically have some individuals (3 to 5%) that either grow poorly or not at all, although they may maintain their general health and condition, while the other fish grow normally. This phenomenon is thought to be caused by physical aggressive behavior and possibly by pheromone secretions by dominant individuals, resulting in repressed feeding activity among

the most subdominant individuals. The phenomenon appears to be exacerbated by poor water quality. Territorial responses, especially aggressive behavior, are observed to be much more prevalent at low stock densities ($\leq 200/\text{m}^3$). Therefore, feed access may be limited by factors related to both overstocking and understocking.

NUMBERS OF FISH TO STOCK

For stocking purposes fish density is measured in numbers per cage volume (fish/m^3) or total water environment area (fish/ha). Measures of fish density for expressing standing crop, carrying capacity and yield are given in weight per cage volume (kg/m^3) and total water environment area (kg/ha). Numbers of fish to stock in cages are dependent upon total yield and mean weight expected at harvest:

$$\text{Nc (Number of fish to stock}/\text{m}^3 \text{ of cage)} = \frac{\text{Wc (Expected total fish weight}/\text{m}^3 \text{ of cage at harvest)}}{\text{w (Desired mean fish weight at harvest)}}$$

Expected optimum cage fish yield is usually equal to optimum cage carrying capacity, and both will vary directly with environmental water quality and inversely with cage volume. Expected optimum cage carrying capacities given in Table II-1 generally reflect expected water quality conditions based on the nutrient enrichment (fertility) level of the water. Highest optimum carrying capacities and yields would be in low nutrient, oligotrophic water environments. Carrying capacities will decline with increased cage volume, but will remain relatively constant for cage volumes of 1 to 4 m^3 .

Fish mortality in cages during culture is usually insignificant ($\leq 4\%$) when healthy fish are stocked and proper management provided. Therefore, the above equation is applicable without compensation for mortality. Higher mortality (6 to 8%) is common after stocking at water temperatures above approximately 22°C.

Numbers of fish to collectively stock in cages per area of water environment must be considered if collective yields are expected to approach carrying capacity of the environment. The numbers of fish to stock are determined using the same equation as for cages except the expected weight (yield) per water environment area at harvest replaces the expected weight per cage volume. Suggested maximum yields of caged carp and catfish per pond area are 2,250 kg/ha without emergency aeration and 4,200 kg/ha with emergency aeration. Expect approximately 20% higher yields for caged Nile tilapia per area of pond. Maximum standing biomass for all caged fish per area of open lakes and reservoirs is 300 kg/ha of total water area, 20 mt in a 1-ha designated cage culture area and 60 mt in a 10-ha designated culture area.