VI. FISH STRESS, HEALTH AND DISEASE

INTRODUCTION

A healthy population of caged fish is one where the fish are properly feeding, growing and otherwise normally functioning. Obviously then, good fish health and the maintenance of that condition are primary concerns and critical objectives of cage aquaculture. Fish stress, health and disease management may be simplistically compared, in human health terms, more to a public health officer concerned with health maintenance and disease prevention, rather than to a doctor of internal medicine at a hospital concerned with treating a disease to restore good health.

Health conditions of caged fish populations are direct products of management. The majority of fish health problems in cage fish populations, especially disease problems, are directly linked to stress on the fish from some environmental factor(s). Direct relationships exist between environmental quality, fish health and disease. Avoiding stress by maintaining good environmental quality through proper management is essential to the maintenance of a healthy, disease free fish population. Thus, emphasis in order of importance is on stress (from environmental quality factors), health and disease. Obviously, not all environmental stressors are under management control, and some obligate infectious diseases are not predisposed by an environmental stressor. Nevertheless, these and all health problems are subject to some measure of management.

The following are practical definitions of fish stress, health and disease specifically for this manual:

Stress is an abnormal physiological condition of fish resulting when its collective adaptive responses to an environmental factor(s) are extended to or approaching the fish's limit of tolerance for that factor.

Health is the standard or typical condition of the fish with the respect to normalcy of body functions and disease at any given time. A healthy fish is optimally functioning and free of abnormalities caused by stress and disease.

Disease is an abnormal condition of fish where body functions are impaired as a consequence of stress, inherent weakness or infection.

The direct relationships between stress, health and disease are obvious in the definitions. Their common factor is normalcy of function (Figure VI-1). Stress of fish will proportionally affect fish health and may lead to infectious disease of fish, especially if compounded by two or more stressors. Disease will then further impair fish health. The interrelationships react in back-and-forth directions as indicated by the solid and dashed arrows in Figure VI-1. However, for practical understanding and management one needs only to consider the solid line in this figure, which illustrates the clockwise cyclic relationship of stress impairing health, leading to disease, which adds further stress and further impairment of health.

Emphasis is on fish stress because stress predisposes fish to most diseases and effects fish health, thereby decreasing production performance (e.g. fish growth, yield, survival and feed efficiency). Stress can usually be avoided or minimized by practicing good management.

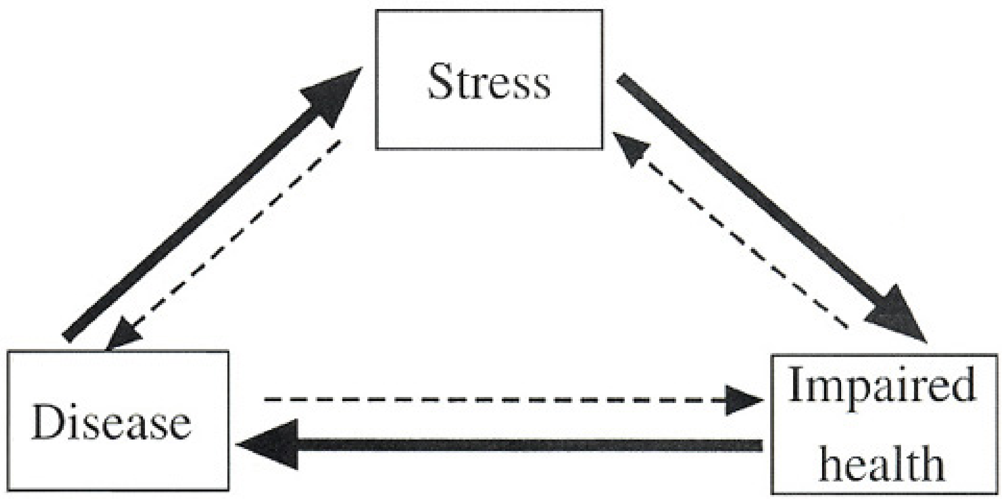

Figure VI-1. Illustration of the direct interrelationships between fish stress, health and disease.

FISH STRESS

Aquacultural ecosystems are innately unstable, unnatural water environments. In general, the greater the culture intensity the greater the environmental instability. All environmental components--chemical, physical and biological--are constantly changing. These changes, and the technology procedures involved in raising fish individually and collectively, stimulate abnormal physiological responses or stress in fish. Stress occurs when an environmental factor (stressor) extends to or beyond the normal optimum range of the fish and disrupts its physiology (Fig. VI-2). Stressors reduce the ability of fish to normally function physiologically and behaviorally. Stressors can be acute or chronic and their impacts on fish are additive and cumulative at least for a short period.

Fish response		Environmental factor		
		pH	NH_3	°C
Exhaustion & death	Death	11.0	0.5	34
Fatigue	Short-term tolerance limit	9.8	0.4	33
Adapt	Long-term tolerance limit	9.5	0.2	31
Escape	Upper optimum limit	9.0	0.0	30
Normal	Ideal	6.7-8.4	0.0	26-28
Escape	Lower optimum limit	6.0	0.0	15-24
Adapt	Long-term tolerance limit	5.5	0.0	<1
Fatigue	short-term tolerance limit	5.0	0.0	<1
Exhaustion & death	Death	4.0	0.0	0

Figure VI-2. Generalized illustration of how warmwater freshwater fish might respond to specific environmental factors under certain conditions.

Physiological responses to stress are numerous. Incidence and severity of disease are direct results of suppression of the fish's immune system caused by stress induced secretions from the endocrine system. Perhaps the most widely used physiological indicator of stress is the quantity of the hormone cortisol in the fish's blood. Generally, the higher the cortisol level, the greater the stress level. Other physiological indicators of stress include changes in blood glycogen, glucose, lactic acid and osmolarity. Observable indicators of stressed fish are changes in fish behavior (e.g. "gasping" at the water surface) and morphology (e.g. increased melanin pigment in skin).

A fundamental management objective of all aquacultures is to avoid and minimize stress on fish. This requires an understanding of stressors and their effects on fish and an ability to recognize fish that are under stress. Obviously, measuring cortisol levels and other physiological responses to stress is not a practical option to an aquaculturist. More practical knowledge and means of identifying stressors and stress are required.

Stressors cause a series of morphological, biochemical and physiological changes to occur in fish. Four distinct stages of stress are identifiable: 1) alarm reaction where the fish tries to escape the stressor; 2) <u>resistance</u> to the stressor through physiological adaptation; 3) <u>fatigue</u> where the fish is noticeably weak but responsive to stimuli, and 4) <u>exhaustion</u> where the fish's physiology is unable to sufficiently adapt to a persisting stress condition, and it can no longer respond to stimuli. The impact of stress on fish depends on the duration and magnitude of the stress condition. Death is the ultimate result, but sub-lethal stress conditions cause reduced fish growth, low yield, poor feed conversion and poor health, including pathological diseases. The stages of stress are illustrated in Figures. VI-2 and VI-3.

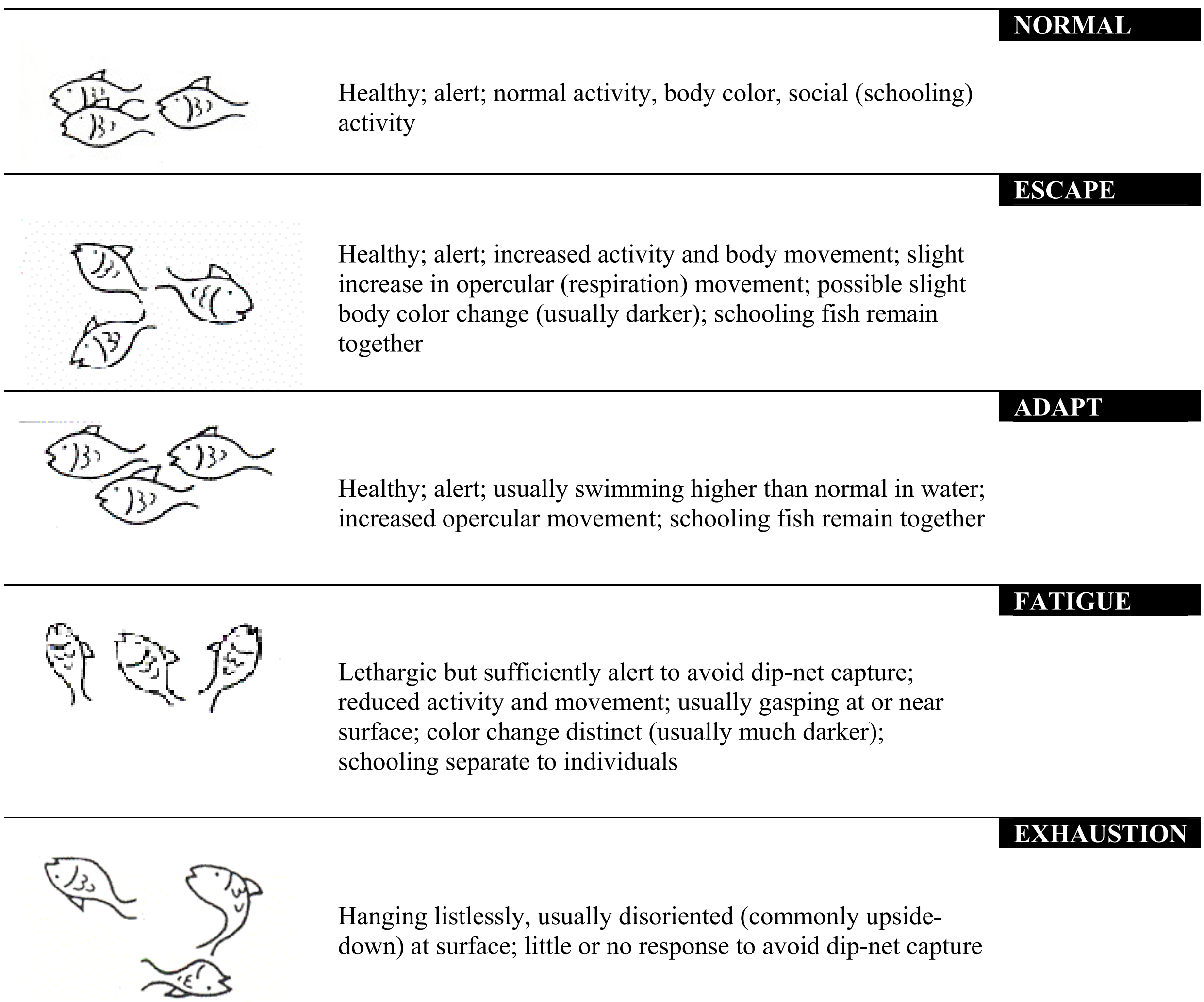

Figure VI-3. Typical appearances of fishes at different stages of stress.

The many known types of stressors may be grouped under four main stressor categories as shown in Figure VI-4. Some of the most common are briefly discussed below.

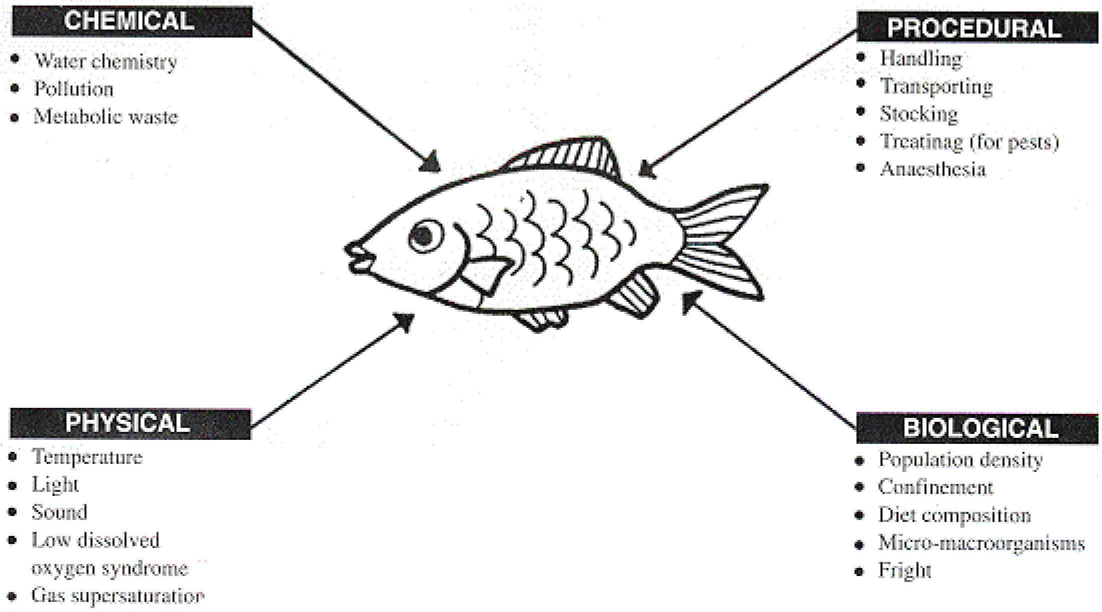

Figure VI-4. Chemical, biological, physical and procedural environmental factors that can cause stress in cultured fish.

Chemical Stressors

Water chemistry and pollution factors that may cause stress in fish are broadly diverse and numerous. The following are some examples of the most important factors and levels at which they stress fish in general.

1. Acidity ranges between pH 6.7 to 8.6 are ideal for fish habitat, and ranges between pH 6.0 to 9.0 are optimum; pH $\leq$5.5 and $\geq$9.5 are stressing; and pH 4.0 and 11.0 are lethal to all fish.

2. Alkalinity is unlikely to be a stressor but 20 mg/l (=$CaCO_3$) is considered a minimum level for normal environmental functions, including buffering against potentially stressing pH fluctuations.
3. Hardness, like alkalinity, is usually not a stressor but helps prevent other factors from becoming stressors. However, at concentrations below about 10 to 20 mg/l (=$CaCO_3$), lack of sufficient Ca and low hardness in general will be directly or indirectly stressing to fish.

4. Heavy metals, especially soluble Cu and Zn in low alkaline waters, are stressing at concentrations as low as 0.05 mg/l and toxic at 0.1 mg/l.
5. Metabolic wastes are major stressors of intensively cultured fish. Un-ionized ammonia (NH_3) and nitrite (NO_2^-) are the most serious of these. NH_3 concentrations as low as 0.02 mg/l (chronic) and 0.05 mg/l (acute) can cause stress in fish. Fish growth may be reduced by 50% at

0.4 mg/l NH_3 and mortality may begin at 0.5 mg/l NH_3. NO_2^- is stressing at 0.1 mg/l and causes "brown blood disease" and mortality at concentrations as low as 1.0 mg/l.

Biological Stressors

1. Diet composition is a stressor when food is lacking or limited and the feed provided is deficient in any essential nutrient, especially an essential amino acid or vitamin. Low quality nutrition and insufficient quantity of feed offered can be direct or indirect stressors by causing the fish to be more susceptible to other stressors.

2. Population density in cages is probably a biological stressor more often at low density than at high density. In cultural ecosystems, especially at low density, members of some fish species will try to establish hierarchy of dominant and subdominant individuals of which subdominant ones are chronically stressed. Pheromones are probably involved with the establishment of most and perhaps all of those territorial hierarchies. In culture situations population density stressors are from LODOS, metabolic waste build-up and social interactions such as pheromone-related hierarchies, and not from spatial limitations of high densities.

3. Confinement is at least temporarily stressing to fish. When first confined in cages fish will generally show signs of stress. It appears that older and larger fish and those least accustomed to confinement are the most affected after stocking into cages.

4. Microorganisms and macroorganisms are major stressors of fish as well as being pathogenic to fish, often as a result of stress. These include especially the microbial disease organisms and endo- and ectoparasites.

Physical Stressors

1. Temperature is one of the most common environmental stressors in aquacultural ecosystems. Temperature is a stressor when it ranges to near the fish's high, long-term tolerance level and when it fluctuates rapidly by more than a few degrees (e.g. 3 to 5°C in less than one hour), especially if it is an increasing temperature.
2. Light is a stressor when fish embryos or fry are exposed to direct sunlight, ultraviolet light and white light of moderate to high intensity ($\geq$ 850 Lx (= 80 FC) when confined in enclosed facilities (e.g. cages in direct sunlight), and when fish are being subjected to other stressors.

3. Sound waves are known to reduce embryonic development of some fishes. Fish growth and reproduction are negatively affected by some sounds perhaps because of the fright factor.

4. LODOS is usually the most critical stressor in aquacultural environments. LODOS is low DO with any combination of likely simultaneous environmental and physiological conditions, such as high CO_2 and decreased water pH, increased blood lactic acid and decreased blood pH, high NH_3 or NO_2^-, and numerous other factors. If all other factors are disregarded, reduced DO levels become stressing to fish at about 70% saturation for embryos and young fry, and at about 60% saturation for larger fishes.
5. Gas supersaturation is stressing to most cultured fishes at about $\geq$110% total gas saturation. Gas bubble disease is caused by supersaturation.

Procedural Stressors

Procedural stressors are those associated with handling, holding, transporting and treating cultured fish. Procedural activities include induced spawning, stocking, harvesting, holding fish in tanks, and all other short-term activities that supplement routine culture. Procedural stressors also include all the chemical, physical and biological stressors already discussed. Other critical stressors include: 1) the crushing effect of gravity when handling fish out of water, which is particularly stressful to larger fish and groups of fish lifted together en masse out of water (fish are morphologically and physiologically adapted to the pressurized, buoyant environment of water but not to the opposite conditions out of water); and 2) the various effects of herbicides, parasiticides and other chemicals, such as formalin and copper sulfate used to prevent or control pests in aquacultural environments. Anesthetics, such as MS 222 sometimes used when handling and transporting fish, may cause greater stress rather than lesser stress for which they were intended.

Caged fish are subject to all of the above stressors, and caged fish may be more vulnerable than pond cultured fish to some of these stressors. However, incidence and severity of stress and resulting poor health are more easily recognized and managed in LVHD cages than in ponds.

FISH HEALTH

A primary objective of cage culture is to maintain healthy fish populations that are optimally feeding, growing and normally functioning. The key to achieving this objective is through stress management; preventing and minimizing stress to fish in the culture environment by understanding and managing the various environmental factors that cause stress. One may argue that "fish culturists do not actually culture or raise fish; they actually culture or manage the environment (ecosystem) and the fish raise themselves." Maintaining fish health then is accomplished by individually and collectively managing environmental quality factors as near to optimum for the fish as practical and essentially within the fish's range of tolerance.

Techniques for preventing and minimizing stress are the principal techniques of any aquaculture technology system. Principal technology components of high density cage fish culture and their purpose relative to stress management are presented in Table VII-1. By managing those specific chemical, biological and physical factors discussed earlier that may cause stress, fish health is almost assured but not guaranteed. Diseases do occur in fish that have not been stress mediated.

Table VI-1. Principal technology components and their relationship to stress management of fish in LVHD cage culture technology.

Technology component	Stress management component
1. Select a high quality, relatively stable environment for culture	1. Water quality variables fluctuate well within tolerance ranges of fish
2. Construct rectangular or square cages of 1- to 4-m^3 volume; enclose with net with ≥ 13mm mesh	2. Water exchanges maintain water quality inside cages within tolerance ranges of fish
3. Place cages in open water, with individual cages spaced apart	3. Same as 2
4. Stock select, healthy fish	4. Fish have natural resistance to stressors and pathogens
5. Feed proper allowance of nutritionally complete feed of good physical quality in special feed enclosure	5. Nutritional requirements are for growth and good health. Minimum pollution potential wastes are lost to the environment
6. Opaque cover over cage	6. Prevent light stress and minimize fright stress

FISH DISEASE

Disease was earlier defined as an abnormal condition of fish where body functions are impaired as a consequence of stress, inherent weakness or infection. The causes of disease include:

1. Stress
    a) LODOS, temperature, light
    b) pollution
    c) nutritional deficiencies
    d) handling, physical injury

2. Inherent weakness
   a) genetic defects
   b) congenital, non-genetic defects (all stress related)
3. Infection (collectively all obligate and non-obligate pathogens)
   a) viruses
   b) bacteria
   c) parasites
4. Combination of causes
   a) stress from LODOS and infection by the bacterium Aeromonas hydrophila
   b) stress from vitamin deficiency and infection by the bacterium Cytophaga columnaris

All fish under certain circumstances are subject to disease. However, healthy fish, whether in natural or aquacultural environments, have a strong resistance to disease as long as they are not weakened. "Crowding" of fish in cages does not in itself increase the incidence, spread and severity of disease as sometimes supposed. Healthy, unstressed channel catfish, common carp, nile tilapia and perhaps all commonly cultured fish "crowded" at densities of 400 to 700 fish/m^3 with total weights of 150 to 250 kg/m^3 and higher in low-volume cages are unlikely to become diseased. No evidence exists that indicates that "crowded" fish in cages are more susceptible to infectious diseases, or that incidence and severity of disease is greater than for lower culture densities in cages or open water of the same water environment. This does not mean that disease epizootics will not occur in caged fish unless the fish are first predisposed to stress. Such epizootics are not common because obligate disease pathogens are manageable and should be eliminated from the population at the hatchery, nursery or elsewhere before stocking in grow-out cages.

Infectious organisms are constant, ubiquitous components of every cage culture environment, and healthy caged fish will normally harbor some of the potentially pathogenic organisms. However, clinical signs of disease may not occur as long as the fish remain unstressed. The process of infection into disease first requires an abnormal disruption of the fish's physiology (stress), lowering its natural resistance to the invading pathogen. The most common stressors to cage fishes that lead to disease are, in order of observed occurrence and disease severity, fish handling (pre-stock seining, holding, transporting and stocking and post-stock sampling), LODOS and poor nutrition, especially vitamin deficiency. Disease epizootics will be uncommon in caged fish populations where the above stressors are absent. The most common pathogenic diseases observed in cages and ponds are listed in Table VI-2.

Table VI-2. Most prevalent infectious diseases of cage and pond raised fishes in Alabama, USA, and probably in China.

Disease (and pathogen)	Comments
Motile aeromonas (hemorrhagic) septicemia (Aeromonas hydrophila (=liquifaciens))	Bacterial disease that is definitely stress-induced, (opportunistic pathogen); bacterium occurs naturally (free-living, primarily in throughout the world; disease peak of growing season.
Enteric septicemia (Edwardsiella ictaluri)	Bacterial disease of channel catfish that is not stress induced (obligate), primarily infecting young fish; infection is synergized by stress; disease incidence greatest in spring and fall but may persist throughout growing season
Columnaris ("Saddleback", "tail rot" and "gill rot") (Cytophaga columnaris)	Bacterial disease that is stress-induced (opportunistic); often associated with other pathogens; disease incidence greatest in spring and throughout peak of growing season
Trichodinosis (Trichodina spp.)	Protozoan disease that is stress-induced (opportunistic); disease incidence greatest in young fish in late winter and spring.

FISH HEALTH MANAGEMENT

The maintenance of good fish health is critical to profitable cage fish culture. Slow growth, poor feed efficiency, low yields, increased disease incidence and mortality, and consequently low profitability are the results of poor fish health. Since physiological stress is the fundamental cause of most fish health problems, practical health management is based on the premise, "avoid fish stress and avoid fish health problems." Good management is the key to avoiding essentially all health problems whether stress related or not. The following is a check list of management guidelines to avoid fish health problems.

1. Select good fish stock. Fish with poor genetic composition or in poor health and physical condition will grow slowly, convert feed poorly and general production performance will always be lower than for fish of select quality. Guidelines for choosing good stock include:

a) Choose proper species for culture environment
b) Use only selectively bred stock
c) Use only fish in good general condition and free of disease

2. Handle fish with special care when collecting, holding, transporting, stocking and sampling. Improper handling of fish is one of the most serious and common stressors that cause poor fish production, disease and death. Guidelines for proper handling include:

a) Identify and minimize individually all chemical, physical and biological stressors for each handling situation
b) Be especially conscious to avoid the most common stressors. For example:

i) Never remove fish from water unless absolutely necessary
ii) Do not hold fish out of water longer than absolutely necessary
iii) Do not stack layers of fish out of water in nets and containers (e.g. baskets)
iv) Do not hold fish at high densities in closed water containers (e.g. tubs and tanks) without proper aeration and water quality control
v) Do not change water temperature around fish by more than 4°C at one time and by 2°C/hour over long periods of time
vi) Do not measure and weigh individual fish unless there is some specific need for that information and the fish are expendable
vii) Avoid using chemicals, including anesthesia, when handling fish

3. Choose and maintain a high quality water environment. Continuous good water quality is critical to fish production in cages. Start culture in a good quality environment, and assure good water exchange between the cage and the environment by properly locating the cages in the environment with proper spacing between cages. Guidelines include:

a) Nutrient poor water environments are healthier for cage culture than nutrient rich waters
b) Avoid water environments containing pollution from domestic, agricultural, industrial and other sources
c) Select sites with good water circulation for placing cages so that water circulation will not be affected; cages positioned in a single line with at least one cage width spacing between cages is preferred

4. Feed caged fish with good quality feeds. Proper nutrition is essential not only to good growth and feed efficiency, but to good health as well. Good quality feeds prevent nutritional diseases and are critical to prevention of pathogenic and other stress related

diseases. Guidelines for feed quality include:

a) Use manufactured sinking or floating pelleted feeds
b) Use only nutritionally complete feeds containing:
    i) Approximately 32% protein (depending on species and fish size), with complete balanced amino acid composition
    ii) Vitamin and mineral fish feed supplements fortified with vitamin C and phosphorus
c) Use freshly manufactured feeds and avoid feeds older than 4-6 weeks
d) Do not give molded, spoiled or otherwise degraded feed to caged fish

5. Never apply drugs or chemicals to fish or to their water environment unless it is absolutely necessary to treat some specifically identified pathogen or pest. A 2 to 3% NaCl solution as an external disease prophylactic is an exception.

TREATMENT OF DISEASED FISH

Fish of good genetic quality, handled properly, stocked disease-free in ponds or cages with good water quality, and fed properly with nutritionally complete feed are very unlikely to become diseased. However, disease epizootics in pond and caged fish do occur, usually caused by bacteria or protozoa. These epizootics usually correct themselves if the fish are in a relatively stress free environment and receiving good nutrition. However, sometimes chemotherapeutic treatment may be necessary. The treatments may be necessary in holding and handling facilities before stocking, in ponds, but not in large reservoirs and lakes where cages are suspended, and directly in cages.