VII: FISH STRESS, HEALTH AND DISEASE

INTRODUCTION

A healthy population of cultured fish is one where the fish are free of disease, 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 fish farming. 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 maintenance is usually achieved by practicing the following guidelines.

1. Stock only healthy, unstressed, disease-free fish.

2. Feed only nutritionally complete, high physical quality feeds in proper amounts.

3. Maintain water quality at non-stressing levels.

Health conditions of cultured fish populations are direct products of management. Compared to traditional Chinese polyculture technologies, management of nutrition and water quality are much healthier for fish under 80:20 technology for various reasons, but especially because of greatly reduced organic wastes. The majority of fish health problems in pond fish, especially disease problems, are directlylinked 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 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.

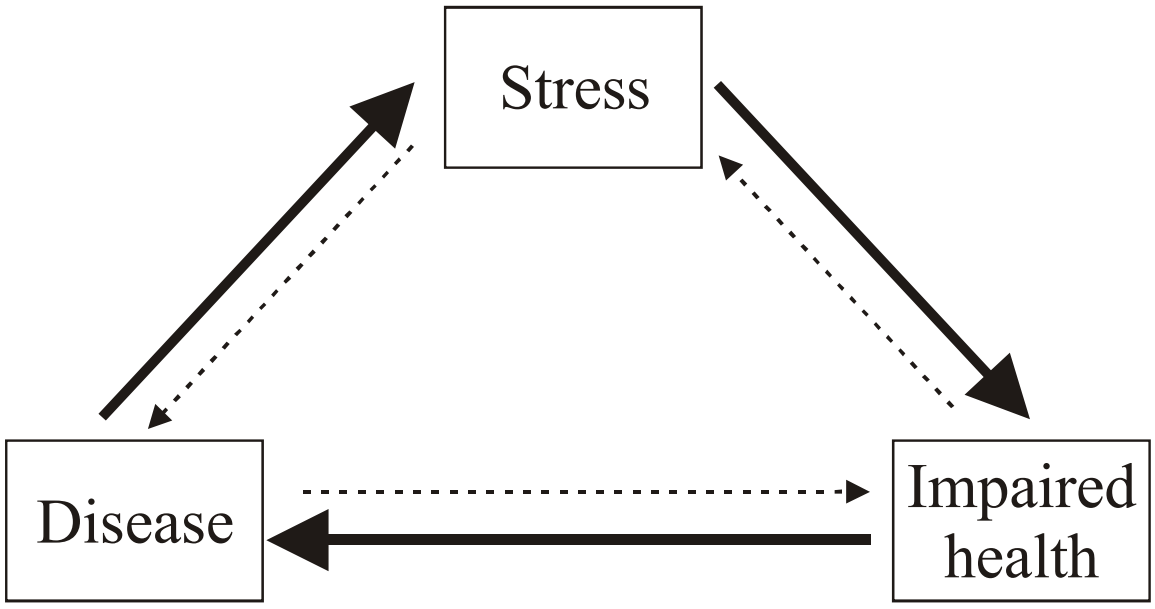
Stress is an abnormal physiological condition of fish resulting when its collective adaptive responses to an environmental factor(s) are extended to or approaching the fish's limit of tolerance for that factor.

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 of 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 (Fig. VII-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 VII-1. However, for practical understanding and management, one needs only to consider the solid line, 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 affects fish health, thereby decreasing production performance (e.g. fish growth, yield, survival and feed efficiency). It can usually be avoided or minimized by practicing good management.



FigureVII-l. 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 component - schemical, 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. VII-2). Stressors reduce the ability of fish to normally function physiologically and behaviorally. Stressors are acute or chronic and their impacts on fish are additive and accumulative at least for a short period.

The physiological responses 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. In laboratory techniques perhaps the most widely used physiological indicator of stress is the quantity of the hormone cortisol in fish 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. Practical, on-farm 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).

Fish response		**Environmental factor**		
		pH	NH3	°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 VII-2. Generalized illustration of how warmwater freshwater fish might respond to specific environmental factors under certain conditions.

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 a farmer. 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) resistance to the stressor through physiological adaptation; 3) fatigue where the fish is noticeably weak but responsive to stimuli, and 4) exhaustion 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 VII-2 and 3.

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

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.

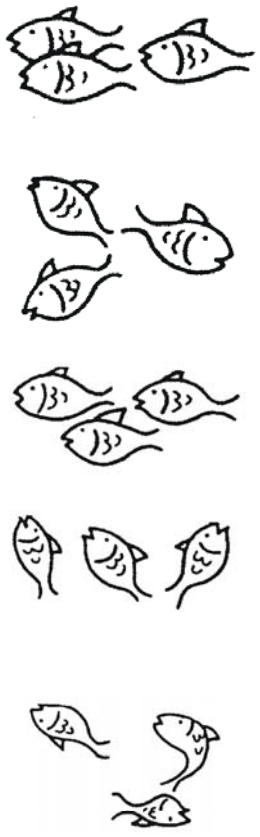
1. Acidity ranging from about pH 6.5 to 8.5 is ideal for fish habitat and between pH 6.0 to 9.0 is optimum; pH levels £ 5.5 and ³ 9.5 are stressing; and pH levels of 4.0 and 11.0 are lethal to cultured fish.

2. Alkalinity is unlikely to be a stressor but 20 mg/1 (=CaCO3) 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/1 (=CaC03), 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 water, are stressing at concentrations as low as 0.05 mg/1 and toxic at 0.1 mg/1.

5. Metabolic wastes are major stressors of intensively cultured fish. Un-ionfzed ammonia (NH3) and nitrite (NO2-) are the most serious. NH3 concentrations as low as 0.02 mg/1 (chronic) and 0.05 mg/1 (acute) can cause stress in fish; growth may be reduced by 50% at 0.4 rng/1 and mortality may begin at 0.5 mg/1. NO2- is stressing at 0.1 mg/1 and causes "brown blood disease" and mortality at concentrations as low as 1.0 mg/1.



NORMAL

Healthy; alert; normal
Activity, body color, social
(schooling) activity

ESCAPE

Healthy; alert; increased activity and body movement; slight increase in opercular (respiration) movement; . possible slight body color change (usually darker); schooling fish remain together

ADAPT

Healthy; alert; usually swimming increased higher than normal in water; increased opercular movement; schooling fish remain together

FATIGUE

Lethargic but sufficiently alert to avoid dip-net capture; reduced activity and movement; usually gasping at or near surface; color change distinct (usually much darker); schooling fish separate to individuals

EXHAUSTION

Hanging listlessly, usually disoriented (commonly upside down) at surface; little or no response to avoid dip-net capture

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

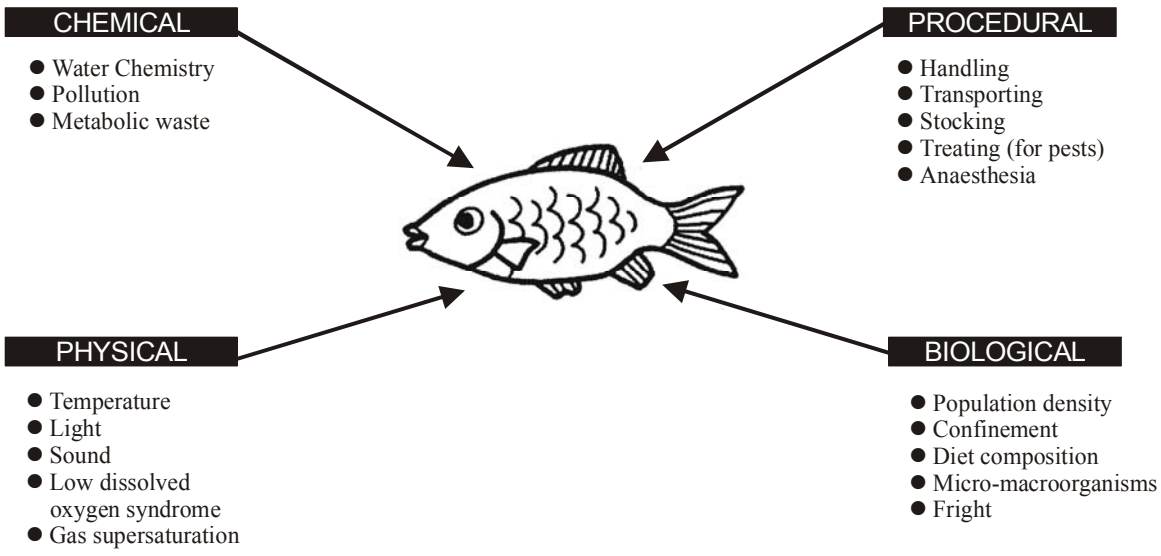


Figure VII-4. Chemical, biological, physical and procedural environmental factors that can cause stress in cultured fish.

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 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 ponds 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. 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 1 hr), especially if it is an increasing temperature.

2. Light is a stressor when fish embryos or fry are exposed to direct sunlight, ultra-violet light and white light of moderate to high intensity (3 850 Lx or 80 FC), when fish are confined in enclosed facilities (e.g. in cages or holding tanks 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 important stressor in aquacultural environments. LODOS is low DO with any combination of likely simultaneous environmental and physiological conditions, such as high CO2 and decreased water pH, increased blood lactic acid and decreased blood pH, high NH3 or N02- 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 above about 110% saturation. Gas bubble disease is caused by supersaturation of water with dissolved gases.

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 stressors include especially: 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, gravity-less 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. Anaesthetics, such as MS 222 sometimes used when handling and transporting fish, may cause greater stress rather than lesser stress for which they were intended.

During all handling activities, avoid or minimize all stressors of fish such as:

1. Working with fish that have consumed food within 24 hours;

2. Taking fish out of water, especially for more than a few seconds;

3. Working with fish during warm temperatures, especially when water temperatures are above 23°C;

4. Stocking fish when water temperatures are above 16°C (tilapia below and above 18° and 22°C, respectively);

5. Exposing fish to temperature differences of more than 3°C without adequate acclimation (consider difference between water and air temperatures when temporarily taking fish out of water);

6. Exposing fish to LODOS conditions and preferably not to DO levels below 65% saturation;

7. Exposing fish to chemicals and pollutants;

8. Holding fish temporarily in tanks and similar strict confinement for longer than absolutely necessary.

FISH HEALTH

A primary objective of fish culture is to maintain healthy fish populations that are optimally feeding, growing and normally functioning. The key to achieving this objective is 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 aquacultural technology system. By managing 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.

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 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

Infectious organisms are constant, ubiquitous components of every fish culture environment, and healthy pond fish will normally harbor some 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 pond 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 cultured fish where the above stressors are absent. The most common pathogenic diseases observed in ponds are listed in Table VII-1.

Table VII-1. 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	Bacterial disease that is definitely stress-induced (opportunistic pathogen); bacterium occurs naturally
(Aeromonas hydrophila (liquifaciens))	(free-living, primarily in organic muds) in fresh-waters throughout the world; disease incidence greatest in spring and during 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 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 are:

    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;
        1) Never remove fish from water unless absolutely necessary,
        2) Do not hold fish out of water longer than absolutely necessary,
        3) Do not stack layers of fish out of water in nets and containers (e.g. baskets),
        4) Do not hold fish at high densities in closed water containers and tanks without proper aeration and water quality control,
        5) Do not change water temperature around fish by more than 3.5°C at one time and by 2°C/ hour over long periods of time,
        6) Do not measure and weigh individual fish unless there is some specific need for that information and the fish are expendable,
        7) Avoid using chemicals including anesthesia when handling fish.

3. Feed cultured 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;
        1) Approximately 32% protein (depending on species and fish size) with complete balanced amino acid composition,
        2) 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 use molded, spoiled or otherwise degraded feed.

4. 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 2-3% Nacl solution as an external disease prophylactic is an exception.

TREATMENT OF DISEASED FISH

Fish of good stock, handled properly, stocked disease-free in ponds with good water quality, and fed properly with nutritionally complete feed are very unlikely to become diseased. However, disease epizootics in pond 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 with drugs and chemicals may be necessary, but they should not be routinely used. They may be the chosen alternative for use on specific occasions but then only a specific drug or chemical treatment should be used for a specifically identified disease.