Stress and Fish Disease

Stress and the immune response of fish to disease-causing organisms.

By Beverly Dixon

Over the past several years our awareness of stress and the problems it can cause has been increasing. In fact, stress has been so popularized by the press that it is blamed for nearly every malady afflicting man and beast.

Stress is also used to explain diseases that are either undiagnosed or misdiagnosed. For those of us who are involved in the aquarium hobby, however, relatively little emphasis has been placed on the role of stress in the health of fish. Although it is understood that stress is the most important factor in the occurrence of fish health problems, very little is written in the hobbyist literature describing how fish stress is able to produce such widespread undesirable effects in fish.

Much of our knowledge of how stress affects the body comes from research done in recent years. Scientists have looked at a variety of stresses, with particular interest in how the immune system responds. The immune system, the body's defense mechanism against disease, is very sensitive to the environmental changes that we call stress. It is the response of the immune system to these changes that ultimately determines whether we, or our fish, will survive an encounter with stress.

Although exquisitely complicated, much is known about the immune response. The immune system in fish has long been studied because it is less complex than in higher animals and therefore easier to unravel. As a result of the worldwide increase in fish farming and aquaculture, the need for more effective disease treatments has created increased interest in research on the immune system in fish. The results of this research can be found in studies published in scientific journals.

Stress affects the immune response in fish in much the same way it does in higher animals. The cause of stress, whatever it may be, is referred to as the stressor. Stress stimulates a part of the brain called the hypothalamus. The hypothalamus is one of the oldest parts of the brain (in evolutionary terms) and is responsible for controlling the most basic functions: hunger, thirst, sex drive and, in mammals, body temperature.

Once stimulated, the hypothalamus releases chemical signals that begin a chain of events eventually resulting in the release of hormones from the adrenal glands. In mammals, the adrenal glands are walnut-shaped and sit on top of each kidney. In fish, the adrenal tissue is mixed in with the kidney tissue.

Two important hormones are released by this tissue. The first, epinephrine, is responsible for what is called the "fight or flight" reaction. This hormone produces a number of physiological changes that prepare the animal to stand its ground and fight or beat a hasty retreat. Numerous reactions occur, such as an increase in heart rate, that result in increased blood pressure and respiration. The liver's store of glucose — in the form of glycogen — is mobilized to provide a quick energy source. Blood flow to the brain is increased for fast thinking and to the limbs to provide muscles with extra oxygen. In combination, these reactions prepare the animal to contend with the immediate stress. However, if these changes are prolonged, they can exhaust the body and in themselves become stressors.

Cortisol is the other hormone released by the adrenal tissue in response to stress. Studies on various fish indicate that cortisol levels increase rapidly and dramatically when fish are crowded together or handled. Cortisol, like epinephrine, can also produce many physiological changes. If prolonged, these changes can lead to metabolic imbalances, such as increases in protein breakdown and elevated thyroid hormones, which can further increase the demands on the body, leading to biochemical exhaustion.

It is the effect of cortisol on the immune system that is central to our discussion of the immune system. Cortisol can directly interfere with the normal functioning of the immune system. It is this disruption of the system that leads to the diseases associated with stress, particularly bacterial infections. Specifically, cortisol is known to interfere with the immune process known as phagocytosis.

Phagocytosis, which actually means "cell eating," refers to the actions of certain white blood cells that "consume" bacteria or other foreign materials that enter the body. This process is often the first line of defense when bacteria break through the skin and mucous membranes or through wounds. These white blood cells, called macrophages (meaning big eaters), are mobilized by chemical signals to move into the area where bacteria have managed to penetrate the body. These cells

are remarkably similar to single-cell amoeba, and move in exactly the same manner of cell-flowing. Some scientists even speculate that these phagocytic cells may have originally evolved from amoeba living in the tissues of primitive animals, such as sponges and jellyfish. Over billions of years of evolution these amoebae lost their independence and eventually became a part of the immune system.

Once these phagocytic cells arrive at the scene, they surround the invading bacteria and engulf them. Within the cell are membrane-bound "bags of enzymes" called lysosomes. Lysosomes fuse with the bacteria contained within the phagocytic cells and release their digestive enzymes, which break down the bacterial cells. Some phagocytic cells also make sodium hypochlorite — what we know as household bleach — to kill the engulfed bacteria. Once the bacteria are digested, the residual material is excreted from the cell into the bloodstream for processing by the kidney into urine.

Cortisol interferes with this important process of phagocytosis. It chemically changes the lysosomal membranes and prevents their fusion within the bacterial-containing cells. The digestive enzymes cannot be released and the bacteria are able to remain alive in the cells and spread throughout the body.

Some recent evidence in the area of nutritional immunology suggests that vitamin C may prevent this chemical change of lysosomal membranes by cortisol, allowing enzyme release and phagocytosis. It is also known that vitamin C can increase resistance to bacterial infection with Edwardsiella, a deadly bacterial infection in channel catfish. Other vitamins such as A and E are also known to enhance the immune response.

Trace metals also participate in this immune function. Selenium, for example, is an immune helper involved in the phagocytic process in a manner similar to vitamin E. Other metals, such as cadmium and zinc, interfere in this process. Research in the area of heavy metal involvement in the immune response of fish is expanding and should eventually provide much needed information on fish nutrition. It is certain that fish maintained on high-quality diets are less susceptible to parasitic infections. A reduction in parasite load may be an important factor, because parasites can spread bacterial infections by acting as carriers and creating wounds that allow bacteria easy access into the body.

There are other aspects of the immune system affected by stress. For example, the humoral response is the part of the system that produces antibodies. Antibodies are proteins that specifically bind to foreign materials, such as bacteria, that enter the body. Antibodies function in a variety of ways. They can neutralize circulating viruses, neutralize bacterial components, such as toxins, and coat bacterial cells, making them "sticky" and easier to phagocytize. Studies on both coldwater and warmwater fish show that antibody production is lowered in periods of stress — the exact time when the animal needs these proteins for defense. Research has shown that dietary supplements of vitamins E and A can increase antibody levels.

Should the immune system fail and the fish become infected, the standard procedure is to treat with antibiotics. The unwitting hobbyist, or wholesaler or retailer for that matter, in an effort to help diseased fish, may, in actuality, depress the immune response even more by administering antibiotics. For example, we now know that oxytetracycline can suppress the immune response in carp and rainbow trout. Another favorite medication for treating fish, tetracycline, should also be limited in it's use because it increases bacterial resistance to treatment and interferes with the immune response.

In the face of all the stresses that aquarium fish are forced to endure, and despite the havoc that these stresses reek on the immune response, it is truly amazing that so many fish manage to survive. This is testimony to the excellence of the immune system. Even so, a reported 30 to 50 percent of new aquarists leave the hobby each year out of frustration because their fish die.

It is important to the health of the fish, and therefore to the hobbyist, not only to minimize stress but also to be able to deal with it once it occurs. Clean water and proper nutritional balance are undoubtedly needed as preventative measures to maintain good health in fish. However, much more study is required to determine how to help the immune response once it is challenged. Perhaps this help will be forthcoming in the form of more effective treatments for stress-related diseases.