PART I

METHODS FOR DIAGNOSING FISH DISEASES

CHAPTER 1

Major Cultured Species

Before discussing methods used for diagnosing fish diseases, it is important to have an understanding of the numerous types of fish species that are cultured, as well as the diversity of culture systems. Understanding the different requirements for maintaining these different groups is essential to both short- and long-term health management.

AQUARIUM (PET) FISH

Aquarium fish constitute an extremely large segment of the pet animal industry (Winfree 1989). The bulk of aquarium fish are kept in the United States, Europe, and Japan (Chapman et al. 1997). In 2008, expenditures for the entire U.S. pet industry (including livestock and all products and services) were valued at over $41 billion, with 63% of U.S. households (an estimated 71 million homes) having pets and 15% of all households owning aquarium fish (APPA 2008). The great majority (nearly 95%) owned freshwater fish, but marine fish have continued to gain in popularity. Worldwide, between 1.5 and 2 million people keep marine aquaria, with 600,000 of those being in the United States (Wabnitz et al. 2003). The global market for marine aquarium products is substantial and growing rapidly, with worldwide trade estimated to exceed $7 billion (Falls et al. 2003). Worldwide trade in live marine animals (exclusive of food animal species) is estimated to be worth $200–330 million annually, with the main markets being the United States, the European Union, and, to a lesser extent, Japan (Wabnitz et al. 2003). According to the United Nations Environmental Program World Conservation Monitoring Centre's report on global trade in marine species, only 1–10% of marine fish are captive bred, with the remainder being collected from coral reefs.

Expensive and highly sophisticated aquaria are becoming increasingly more common, and it is becoming more common for an owner to have several hundred to several thousand dollars invested in fish alone. Thousands of types of pet fish (from the commonplace guppy to the more exotic and often more expensive species) are kept by hobbyists. While some aquarium fish, such as the common goldfish, cost only a few dollars, many fish command high prices, often costing several hundred dollars and some commanding over $100,000. The average freshwater aquarium fish probably costs somewhere between $3 and $10; marine fish are usually considerably more expensive, averaging $20–50. The average cost incurred by owners of fish in the United States is estimated to be about $235 per year, which compares to $200 for a bird, $645 for a guinea pig, $911 for a rabbit, and $1,200 for a dog (www.spca.bc.ca). Some pet fish owners, like owners of other animals, also become emotionally attached to their pets and are willing to spend considerable sums for proper medical care. It is also interesting to note that over 80% of pet fish owners also own other pets.

Many hobbyists specialize in a single group of fish (e.g., African cichlids, bettas, catfish, koi), and there are a number of local, national, and international breed associations for these various groups. The reader should refer to Axelrod et al. (1980), Bower (1983), Moe (1992a, 1992b), Goldstein (1997, 2008), Debelius and Baensch (1998), and other reference texts for specific details on taxonomy, biology, and husbandry. Schmidt (2002) and Axelrod et al. (2007) provide comprehensive photographic compendia of freshwater aquarium fish but nothing on husbandry.

Tropical Freshwater Aquarium Fish

The largest segment of the aquarium fish industry is the freshwater aquarium fish sector. Major groups include the poeciliids and the egg-layers.

- Poeciliids (guppies, mollies, swordtails, platies)—These are also known as livebearers because they are viviparous. (A few other nonpoeciliid fish are also viviparous.) They are prolific, with many line bred strains. These fish are often relatively inexpensive, although certain strains may be high priced.

The so-called egg-layers encompass all other freshwater aquarium fish. Major groups include the following:

- Characins (tetras)—These are active, schooling fish that usually stay in the upper water column. Some species may be a bit aggressive and nip fins or chase tankmates. Most make good members of a community aquarium. This group also includes the piranhas,

which are not good for the community aquarium (see oddball fish).
- Tropical Cyprinids (barbs, danios)—These are active, schooling fish that usually stay in the upper water column. Like the characins, they may be a bit aggressive and nip fins or chase tankmates. Most make good members of a community aquarium.
- Anabantids (bettas, gouramies, paradise fish, etc.)—These are generally peaceful fish that are good candidates for a community aquarium, except for the popular Siamese fighting fish, which, although aggressive toward conspecifics, are shy toward unrelated species. Anabantids breathe air by using an accessory organ modified from gill tissue (labyrinth organ).
- Cyprinodonts (killifishes, topminnows)—These are generally small, often brilliantly colored fish, many of which have short natural life spans (e.g., annual fish). They are often shy among other types of fish and do best in a separate aquarium. There is usually marked sexual dimorphism.
- Catfish (*Corydoras*, *Pimelodella*, *Plecostomus*, etc.) and Loaches (clown loach, kuhli loach, etc.)—These are generally peaceful, bottom-feeding fish that are useful as scavengers to keep the gravel clean. Most make good members of a community aquarium.
- Cichlids (freshwater angelfish, discus, oscar, African rift lake cichlids, etc.)—These are a popular group of fish that include a wide range of species having diverse behaviors. Some make excellent members for a community aquarium (e.g., angelfish), while others are extremely territorial and can only be kept with equally aggressive species (e.g., oscar). Some species have marked sexual dimorphism.
- Oddball fish (archerfish, piranha, freshwater butterfly fish, etc.)—These are species that are occasionally kept by aquarists as novelties. They include a diverse array of species.

Cool Freshwater Aquarium Fish

This includes the cool water cyprinids (goldfish and koi). These are hardy fish that are popular for both aquarium and pond culture. They are not tropical fish and can thrive in a wide range of temperatures. They do best in slightly cooler water. Koi culture has been one of the most rapidly growing areas of the pet fish industry and owners often spend large sums of money on both the fish and their culture environment. Details about koi husbandry and diseases peculiar to this species can be found in Stoskopf (1993), Saint-Erne (2002), and Johnson (2006).

Tropical Marine Aquarium Fish

Marine fish are becoming an increasingly larger component of the pet fish industry. At least part of this growth is because of the recent strides that have been made in successfully keeping these fish in captivity. Better tank design and its integration with more reliable and efficient pumps, filters, and other apparatus have helped to greatly improve water quality, which is essential for marine fish health. Although proper veterinary care is still sorely lacking in many situations, owners and retailers also have a better awareness of diseases and the proper means of treating them compared to years past. Another factor that may contribute to the surge in marine aquarium keeping relates to the greater amount of disposable income in many households, which has allowed more people to afford these beautiful but expensive creatures. Many marine hobbyists have reef tanks, which are elaborate and usually expensive setups that are used for the display of live invertebrates (corals, anemones, etc.) as well as fish. When a dozen or more such animals are kept in a single tank, this can become a sizable economic investment.

The majority of marine fish come from Indo-Pacific reefs (Indonesia, Philippines, Pacific Islands), with some from the Florida Keys, the Bahamas, the Caribbean, and the Red Sea (Lewbart 1992; M. Weiss, personal communication). Despite some significant advances in captive propagation, the great majority of marine aquarium fish are wild caught. A striking example of the dramatic difference in adaptation to culture between wild-caught and captive-raised marine fish is the clownfish: The relative survival rate of this group of 28 species as wild-caught individuals is markedly less than that of captive-produced stocks. Brooklynellosis (PROBLEM 24), relatively rare in captive-bred clownfish, is often called "clownfish disease" because of its common presence on wild-caught fish (Fenner 1998).

Important ecological differences between marine and freshwater fish have a direct bearing on their health in captivity (Table I-1). Compared with freshwater ecosystems, the tropical marine environment has little natural fluctuation in temperature, oxygen, or other water-quality conditions. Thus, marine reef fish are not adapted to withstand the poor water conditions to which they are often exposed in captivity; this is exacerbated by the fact that most marine aquarium fish are wild caught

Table I-1. Differences between tropical freshwater and marine aquarium fish (from Noga 1992).

	Freshwater	Marine
Many inbred strains	Yes	No
Many bred in captivity	Yes	No
Specialized feeding habits or nutritional requirements	Relatively few	Relatively many
Sensitivity to environmental changes	Relatively small	Relatively great
Territorial	Many	Almost all

and must also acclimate to the confines of culture. Reef fish are highly territorial, adding to the stress of capture. They can carry latent infections, which recrudesce under captive conditions. Parasites are especially common. Many reef fish have specialized diets, such as feeding on sponges or corals. Many cannot adapt to standard aquarium food and starve to death in captivity. Unfortunately, certain reef fish are imported and sold in stores with little regard for whether they will ever accept food. All of these factors add up to an increased susceptibility to disease and the marine fish' deserved reputation for being more difficult to keep than their freshwater counterparts. This emphasizes the need for competent health care.

Fish chosen for a marine aquarium should be species with histories of successful maintenance in captivity, and the fish should be eating well. To avoid aggression problems, a good rule of thumb is to have only one fish of any color, color pattern, or shape. Extreme range in size should also be avoided. Bower (1983) and Moe (1992a, 1992b) provide an excellent discussion on choosing fish and proper management of the marine aquarium. In general the best families for the home aquarium are, in descending order, the following: anemonefish, damselfish, angelfish, gobies, wrasses, parrotfish, and butterflyfish. Note that there are many exceptions to this rule of thumb.

Making poor choices of fish for an aquarium not only increases the likelihood of disease and other problems but also might have serious negative impacts on the natural reef environments from where the fish were collected (Helfman 2007). For example, some marine fish are captured using cyanide to temporarily stun them to ease collection. The survivors that make it to the pet store may be seriously weakened by such treatment and of even greater concern is the indiscriminate damage that this collection method does to the other reef inhabitants, including the corals (see PROBLEM 94). Organizations such as the nonprofit Marine Aquarium Council (www.aquariumcouncil.org) are promoting environmentally responsible marine aquarium keeping via certification of wholesalers and pet shops to encourage responsible collection and husbandry. The Reef Fish Guide published by Reef Protection International (www.reefprotect.org) provides a list of fish species that are either recommended or should be avoided.

It is becoming extremely popular for invertebrates to be kept with marine fish in reef tanks or other less elaborate setups. Hard and soft corals, anemones, sea urchins, starfish, shrimps, and crabs are commonly sold in aquarium stores and online. A number of excellent books on biology and husbandry of reef fish and invertebrates are available, including Goldstein (1997), Debelius and Baensch (1998), Fossa and Nilsen (1996, 2000, 2002), Tullock (2001), and Fenner (1998).

Aquarium fish include a diverse array of species from many different habitats, and while they can often withstand a wide range of environments, they do best under more defined conditions (see PROBLEMS 2 and 7 through 10).

BAIT FISH

Several species comprise an important industry that produces bait fish for sport fishermen. Included in this group are various minnow species (Cyprinidae, Cyprinodontidae), such as the fathead minnow and golden shiner. In the United States, farms are concentrated in the Southeast, especially Arkansas. Fish are typically raised in small ponds.

FOOD FISH

According to the Food and Agricultural Organization (FAO), aquaculture is the fastest growing agri-industry worldwide, with an average compounded growth rate of 8.8% per year from 1950 to 2004, compared with only 1.4% for capture fisheries and 2.8% for terrestrial farmed meat production systems (FAO 2000, 2006). This is not just one industry but actually an amalgamation of many different industries that culture many different species of aquatic animals (Pillay 1993). Among the most commonly cultured fish are carp (family Cyprinidae), trout and salmon (Salmonidae), catfish (Ictaluridae, Clariidae, Pangasidae, Siluridae), eel (Anguillidae), tilapia (Cichlidae), mullet (Mugilidae), milkfish (Channidae), yellowtail (Carangidae), flounder (Pleuronectiformes), sea bass/grouper (Serranidae, Centropomidae), and sea bream (Sparidae). Pillay (1993) provides a good introduction to culture of various groups. With such a diverse enterprise, only generalizations can be made about the types of fish and culture systems. Representative species, mainly exemplified by those cultured in the United States, are covered below. Detailed coverage of diseases of salmonids and carp can be found in Bruno and Poppe (1996), Kent and Poppe (1998), and Hoole et al. (2001).

Warm Water Food Fish

This category includes fish that thrive at temperatures generally greater than about 20°C (about 68°F). In the United States, the most important member of the warm water food fish is the channel catfish (Ictaluridae). Annual U.S. production is over 225 million kg (500 million lb), having a farm value of about $400 million. This translates into over half of all aquaculture production in the United States. Major producing states are concentrated in the Southeast, especially in the southern Mississippi River floodplain, because of an ample clean water supply

and a long growing season. However, significant catfish production also exists in other areas, ranging from California to North Carolina and Missouri to Florida.

Most channel catfish are less demanding of water-quality conditions than cold water species and are usually raised in earthen ponds. Channel catfish are typically spawned in late spring or summer, with the young fish being kept in small ponds or other small facilities until they reach an adequate size (usually 13–20 cm or 5–8 inches) to fend for themselves in larger ponds, where they remain until they are harvested.

Many channel catfish farms are vertically integrated, with broodstock for spawning, hatchery and nursery facilities, and grow-out operations on the same farm. Some farms specialize in supplying fingerlings to other producers. Commercial channel catfish farms typically raise fish in 2–8 ha (5–20 ac) ponds. Annual yields average 6,500 kg/ha (5,800 lb/ac). This represents an annual harvest income of $9,750–$11,375/ha ($4,060–$4,640/ac) at farm gate price of catfish of $1.50–1.75/kg (= $0.70–0.80/lb). With such a substantial investment at stake, proper medical care is a worthwhile expenditure.

Tilapias are also raised in the U.S. on a limited basis where high tropical temperatures can be maintained (far southern states or areas having geothermal well water) or in intensive, closed culture systems. Redfish (Sciaenidae) is a marine species that is cultured extensively in states that border the Gulf of Mexico (mainly to replenish natural stocks).

Cold Water Food Fish

This category includes fish that thrive at temperatures generally below about 20°C (about 68°F). The principal members of this group in the United States and worldwide are the salmonids (salmon and trout). Rainbow trout production currently exceeds 500,000 tons worldwide, having an estimated value in excess of $1 billion, and Atlantic salmon has a similar market value. Rainbow trout is the most important cultured species in the United States, but others (e.g., Atlantic salmon, brown trout) are also valuable. Annual farm value of U.S.-produced trout and salmon is over $70 million.

Salmonids are anadromous (spawn in freshwater and then migrate to the sea to mature) and can be grown in both freshwater and seawater. Because they are demanding in their water-quality requirements, most salmonids are raised in open or semi-open systems. Most commercial salmonid production in the United States is in freshwater raceways, but increasing numbers of salmon are being raised in marine net-pens, and marine Atlantic salmon and freshwater cyprinid production are the most valuable fish aquaculture industries worldwide.

Other species of importance in the United States include sturgeon (Acipenseridae), flatfish (Pleuronectidae), and hybrid striped bass, especially striped bass × white bass hybrids (Percichthyidae). Hybrid striped bass and some flatfish species are more appropriately considered cool water groups, since they can tolerate much higher temperatures than salmonids.

LABORATORY FISH

Fish are now widely used as animal models in biomedical research (Ostrander 2000). While several larger fish species are used as animal models, including salmonids, the most important are smaller aquarium species, especially medaka and zebrafish. Zebrafish has become the most important aquatic model for comparative medicine research. Many different inbred and transgenic lines have been developed to study various biological processes and diseases. Consequently, many stocks are maintained for very long periods and thus chronic diseases (e.g., mycobacteriosis [PROBLEM 55]) can be a serious problem. An online manual of common zebrafish diseases is available at http://zfin.org/cgi-bin/webdriver?MIval=aa-ZDB_home.apg.