Nutritional Support of Fish

Stacey R. Gore, DVM

Abstract

Proper nutrition is the foundation of any animal's health, but because of the variety of wild fish diets, it is often difficult to provide a balanced diet for these animals in captivity. Although the nutrition of fish species that are important to aquaculture has been extensively researched, there is relatively little information on the dietary requirements of most other captive species. Nutritional support of fish must take into consideration their natural history, foraging behavior, diet, anatomy, and metabolic requirements. This article provides a brief overview of relevant fish anatomy and basic nutritional requirements, and describes techniques used to encourage feeding in anorectic fish. It also addresses the indications, and a possible technique, for tube feeding teleosts. Copyright 2006 Elsevier Inc. All rights reserved.

Key words: **fish; nutrition; tube feeding; captivity; diet**

There are more than 25,000 species of fish, of which 4,000 to 5,000 are kept as pet or aquarium fish worldwide.[1] The number and diversity of fish species present an unusual challenge to veterinarians. When fish are brought into captivity, their natural diet is often unknown or unavailable. As with any animal, fish also succumb to diseases that cause inappetance. A basic understanding of their relevant anatomy and natural diet is necessary to successfully manage patients. This article will focus on teleost (bony) fish.

Anatomy

The location of the mouth and the dentition often provide insight into how the fish forages and the diet it consumes. For instance, syngnathids (seahorses and pipefish) use their long, tubular mouths to suck in small items, piranhas use their triangular teeth to cut prey, and catastomids (suckers) use their subterminal mouth to sift through the sediment for benthic organisms.[2,3] Pharyngeal (throat) teeth (Fig 1) are modifications of the fifth ceratobranchial bones, epibranchial, or pharyngobranchial bones and are a reflection of the diet. For example, parrotfish use their beak (fused teeth) for breaking off coral pieces or algal fronds and then use their pharyngeal teeth to extract the algal cells from the coral.[2]

The esophagus is a short, thick-walled tube leading to the stomach or intestine. The anterior portion contains the taste buds.[4] Upper gastrointestinal obstruction is rare because of the distensibility of the esophagus in most fish, especially carnivorous species, although miscalculation of prey size can still lead to death of the predator.[2] The swim bladder is evolutionarily derived from the digestive system as an outgrowth of the foregut. Physostomous fishes (e.g., salmonids, cyprinids, and characids) maintain active communication between the swim bladder and the esophagus via the pneumatic duct, in con-

From the National Aquarium in Baltimore, Baltimore, MD 21202 USA.

Address correspondence to: Stacey R. Gore, DVM, National Aquarium in Baltimore, Pier 3, 501 East Pratt Street, Baltimore, MD 21202. E-mail: sgore@aqua.org

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Figure 1. Oral cavity of a blue-striped grunt (*Haemulon sciurus*) showing gill rakers and pharyngeal teeth.

trast to physoclistous fishes (e.g., eels), which lack this connection. Physostomous fishes may therefore present a problem to the clinician because it may be possible to pass a tube, or food, into the swim bladder and cause infection. Some pelagic fish (e.g., tuna, mackerel, flounder) lack a swim bladder entirely.[2,5]

The stomach, if present, is usually a simple sac adapted for mechanical grinding of the food before it is passed into the intestines.[6] In some species (e.g., syngnathids), the stomach is difficult to identify because the pyloric region is not demarcated.[5] Cyprinids (carp and goldfish), lungfish, killifish, wrasses, and parrotfish all lack a true stomach.[2] In some species, the stomach has unusual modifications that serve an entirely different function; for example, the stomach of blowfish and porcupinefish is used to take in water or air to cause the body to inflate as a defensive mechanism, while the stomach of plecostomids is used to extract oxygen.[2]

Many species, including scorpionfish, tuna, salmonids, cod, and striped bass have pyloric caeca, blind sacs that attach to the proximal intestine and function in digestion and absorption of sugars, amino acids, and dipeptides.[7]

Intestinal length is variable and is generally correlated with feeding habits. The intestinal tract is not clearly divided into small and large intestines as in mammals, but functional differences do exist between the anterior and posterior sections. Carnivorous species often have shorter intestines than herbivorous fish. The central stoneroller (*Campostoma anomalum*) is an example of an herbivorous fish in which the intestine is very long and is uniquely wrapped around the swim bladder.[2] In addition to pyloric caeca and long intestines, some fish also have thickened intestinal mucosa (e.g., striped bass) or a spiral valve (e.g., sharks, lungfish, gar) to increase the surface area for absorption.[2,7]

Nutritional Requirements

Fish are highly efficient at converting food energy protein. This is because they are poikilotherms and expend less energy to maintain posture and excrete nitrogen compared with mammals and birds.[8] Nutritional studies have been performed primarily on aquaculture species; nutrient requirements have been reviewed and compiled by the National Research Council (NRC).[9] Although there has been little nutritional research on aquarium fish, the NRC found that nutrient requirements among fishes do not vary greatly and so can often be extrapolated to other species. Protein, essential fatty acids, and vitamin and mineral requirements in the major aquaculture species have been published.[1,4,5,8,10] Nutritional deficiencies have also been reported in the literature.[4,5,8,11] The NRC publication on nutrient requirements of fish is available online for free at www.nac.edu.

Protein

Proteins function as enzymes, hormones, antibodies, primary constituents of tissues, and as an energy source. Essential amino acids are those that must be supplied in food. Ten essential amino acids have been identified for fish: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The required amounts for each are only known for some fish species. Most fish require 25% to 55% crude protein in the diet, depending on age and species.[9]

Carbohydrates and Fiber

Most fish do not require carbohydrates in their diets, and carbohydrate digestibility varies among species. In general, warm-water fish are better able to utilize carbohydrates than cold-water and marine fish.[10] Some herbivorous fish (e.g., cyprinids) use the microflora in their hind gut to digest complex carbohydrates.[1]

Fiber is indigestible plant material and provides physical bulk to the feed. Small amounts of dietary fiber have allowed increased growth rates and increased efficiency of protein utilization. Fiber should be limited to less than 8% in a diet.[9]

Lipids

Lipids provide important sources of energy and the essential fatty acids necessary for cell membrane function, enzyme function, and vitellogenesis. They also allow the absorption of fat-soluble vitamins.[12] Fish require omega-3 or omega-6 fatty acids, and sometimes both, in the diet. As a general rule, freshwater fish require either dietary linoleic acid (18:2w6) or linolenic acid (18:3w3), or both, whereas marine fish require dietary eicosapentaenoic acid (20:5w3) and/or docosahexaenoic acid (22:6w3).[1]

Minerals

Minerals are important structural components of tissues (e.g., calcium in bones), constituents of body fluids (e.g., electrolytes), and catalysts in enzyme and hormone systems.[12] Fish can absorb some water-soluble minerals from the water via their gills or, as in marine fish that drink salt water, via the intestinal mucosa. Phosphorous is one of the most important minerals that must be obtained from dietary sources because natural waters are relatively low in dissolved phosphorous.[1,8] Most calcium needs are met via absorption through the gills. The skeleton does not serve as a reservoir of calcium as in mammals, and it is thought that during periods of dietary deficiencies, fish rely entirely on the environment for calcium.[11]

Vitamins

Vitamins are organic elements that can be divided into fat-soluble and water-soluble categories. They serve many diverse functions, including blood hemostasis, free radical scavenging, vision, cell membrane integrity, and DNA synthesis, among others.[12] Most fish species cannot synthesize vitamin C, and therefore must obtain it from their food. Vitamin C is usually destroyed in the processing of feed, and any remaining traces deteriorate with time. A stable source which should be used in all feeds is available in the form of L-ascorbyl-2-phosphate, or ascorbic acid phosphate.[8]

Feeds

There are many commercially available fish feeds and just as many homemade diets published in the scientific and hobbyist literature. Common feedstuffs available include flake food, pelleted feed, gel foods (commercially available as gels or component powder), frozen whole feed, and live feed. Mazuri is a Purina-Mills company (St. Louis, MO USA) that offers multiple gel diets for different types of fish, each supplied in a powder that can be made into a gel or gruel for tubing. Other liquid gruels can be made by mixing flake food and water, soaking pellets in water, or grinding whole fish into a slurry that can then be passed through a tube.

History

As with any animal, a clinician must obtain a complete history, perform a physical examination, and carry out any appropriate diagnostics that would help yield a diagnosis. In aquatic species, important questions to ask relate to water quality, recent additions of new fish to the tank, other species present in the tank, and recent changes in the environment. Water quality analysis, a full physical examination, and an external parasite check should be performed in every case. Other diagnostics that may be of value include radiographs (e.g., identifying rocks in the gastrointestinal tract) and ultrasound (e.g., identifying a hypoechoic liver indicative of fatty liver disease).

Whether a diagnosis has been made, an anorectic fish provides many challenges. One of the biggest challenges relates to husbandry and presentation of feed. Food type, size, texture, density, and palatability are all important characteristics of feed that will affect whether a fish eats. Most aquariums contain mixed fish species that use different levels of the water column; therefore, varied diets must be provided. Floating pellets are not appropriate for bottom-dwelling fish, and sinking food will not allow the mid-column fish enough time to consume the food before it falls.

If a fish is anorexic, there are many techniques aquarists can use to encourage feeding. These include optimizing environmental parameters, pole feeding, providing a variety of food including live prey, covering the outside of a tank to darken it or minimize the view of activity, or moving the fish to a tank with different dimensions related to depth, volume, and water flow. Competition, or lack thereof, and group dynamics in a tank are other factors to consider. Some fish respond to competition, while some will be out-competed and need to be separated for feeding.

Technique

Once it has been determined that intervention is necessary and the feeding habits and anatomy have been identified, orogastric tube feeding may be indicated. The aquatic environment limits the application of esophagostomy, gastrostomy, or enterostomy tubes; therefore, the fish must be caught each time the animal is tube fed. Force-feeding is not usually

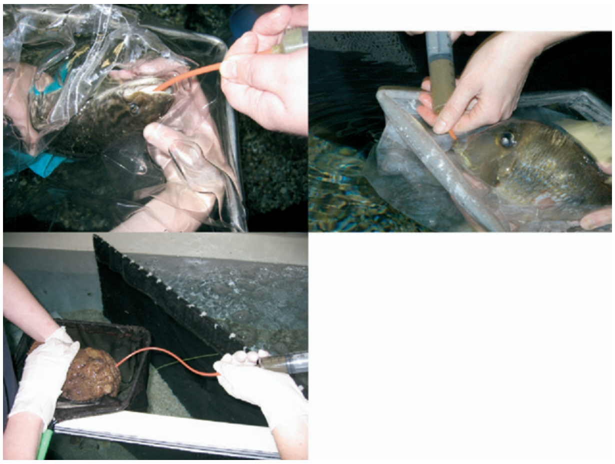

Figure 2. Examples of tube feeding a bowfin (top left), eartheater (top right), and toadfish (bottom left) tank side with a red rubber catheter without using anesthesia.

Figure 4. Feeding tube exiting from the opercular cavity of a blue-striped grunt.

applicable to fish as it is in many other animals, because they will usually release food placed directly into their oral cavity. The tube size must be based on the size of the fish, mouth type, and length from the mouth to the stomach or intestines. Red rubber catheters (Fig 2) with larger bore sizes are appropriate for medium to large fish, whereas intravenous catheters (Fig 3) are appropriate for fish <50 g. The end of the tube can be cut off if the gruel is too thick. Mouth guards should be used if there is a risk the animal could bite down during the procedure and swallow the tube. Anesthesia may or may not be indicated depending on the overall health of the fish and the ease of handling. The author recommends that anesthesia be used when a fish is excitable and when more damage is caused by catching and restraint, or if the fish poses a threat to human safety (e.g., venomous fish). If using manual restraint, the handler must have good control of the fish because many species have dorsal spines, sharp operculums, or peduncle blades.

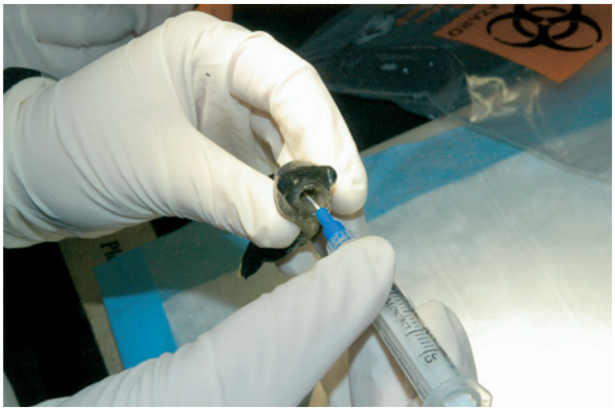

Figure 3. Tube feeding a smaller fish, mummichog, using an intravenous catheter as a feeding tube.

An estimate of the length from mouth to stomach or intestines should be done before tube feeding. Because of the variations in fish anatomy, identifying an absolute external landmark for the distance to pass a tube is not possible. A good rule of thumb for most teleosts is to estimate between the caudal edge of the operculum and the base of the pectoral fin. The fish is then manually or chemically restrained, and the tube is inserted through the pharynx. Both gill cavities should be checked to ensure that the tube has gone past the pharynx and is not located at the level of the gills (Fig 4). There is minimal risk for aspiration, but care should be taken to avoid coating the gills in food material because this can interfere with proper function of the gill lamellae. Some fish species (e.g., seahorses) have closed opercular cavities with only a small hole to allow for water flow; care should also be taken to prevent food from accidentally entering this cavity and filling it. Once placement of the tube is confirmed, the food should be given at a slow but steady rate. The fish should be monitored for food coming up from the gastrointestinal tract into the mouth or gill cavities; if this is observed, the procedure should be discontinued. The fish can then be returned to its tank or recovered from anesthesia. The fish should be monitored because some will regurgitate many minutes after the procedure or on recovery.

Gastrointestinal rupture is a potential complication of tube feeding, but can be minimized by using a soft-edged tube of appropriate length, advancing the tube gently, and using an amount of food that is appropriate for the anatomy and the health of the fish.

The amount and frequency of food given will vary depending on the health of fish, anorectic period, and anatomy of the gastrointestinal tract. Fish should be fed based on a percentage of body weight, approximately 0.5% to 1% body weight per day for maintenance.[13] Normal feeding protocol dictates that a fish should be fed at least 5 days per week, but often the clinician must balance the stress of capture with providing adequate nutrition. If a fish has a stomach, this indicates that the species eats intermittently rather than continuously.[6] For species that lack a stomach, the clinician will need to consider offering more frequent, smaller meals.

The clinician is faced with many challenges when presented with an anorexic fish. An understanding of the natural history, anatomy, and feeding habits of the fish is essential. When used appropriately, tube feeding can provide nutritional support during periods of illness and inappetance.

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