

## Nutrient Requirements of Fish and Shrimp

The continued growth of the aquatic farming industry depends on the development of nutritious feeds that maximize fish growth and health while minimizing the environmental impacts caused by uneaten feed and animal waste—a challenge that can only be met with updated information on the nutritional requirements of fish and shrimp. This report, the latest in a series of National Research Council reports on the nutritional needs of fish, evaluates the most recent scientific literature on the nutrient requirements of several commercially important species of fish and shrimp. The report also reviews the role of aquaculture feeds in determining the nutritional value of seafood to humans, and identifies critical research needs for better defining fish and shrimp nutrient requirements.

In recent years, the aquaculture industry has grown rapidly to become an internationally important source of food and income. In fact, aquaculture—the farming of fish and shellfish for food—now supplies approximately 50 percent by weight of all the fish and shellfish consumed worldwide. With demand for seafood increasing, the aquaculture industry is predicted to continue to grow in coming years.

Nutrition plays a key role in the aquaculture industry by influencing the growth and health of fish, the quality of the seafood produced, and, because uneaten feed and animal waste can add nutrients to the water, the environmental impacts of aquaculture operations. In addition, feed accounts for a significant portion of the costs of an aquaculture enterprise, and therefore nutrition also influences the economic returns of the industry. The development of cost-effective feeds that provide balanced nutrition to maximize growth, while minimizing environmental effects, depends on knowing the species' nutritional requirements—and meeting those requirements with diet formulations and appropriate feeding practices.



Credit: Stephen Ausmus/USDA

The National Research Council has published a series of reports on the nutrition and feeding of fish. Since the release of the last report in 1993, a wealth of new information on fish and shrimp nutrition has become available. In addition to the updated fish and shrimp nutrient requirements, the report also considers strategies to increase nutrient retention and thus reduce environmental pollution; discusses the benefits and detriments of including marine products in fish feeds; and considers the role of feeds in determining the nutritional value of fish for humans.

### Fish Nutrition and Feeding

Based on recent scientific literature on the nutrient requirements of fish and shrimp at all stages of life, the report provides an extensive discussion of each of the nutrient classes, including proteins, lipids, carbohydrates, vitamins, and minerals and a review of experiments to determine nutrient requirements. This material forms the basis for updated values for the daily requirement intakes of essential nutrients such as lipids, amino acids, minerals, and vitamins. The values given are the minimum dietary concentrations required to

support normal growth and development and represent a comprehensive compilation of data from an expanded list of commercially important fish and crustacean species, including salmon, tilapia and four species of shrimp.

In addition, the report discusses feed additives, substances such as antimicrobial agents, enzymes, and other compounds that are commonly found in, or added to, feeds for fish and shrimp. Information on antinutrients and other undesirable substances found in fish feeds is also presented.

Topics such as the digestive physiology and metabolism of fish are reviewed to provide context for understanding how to use nutritional data in preparing feeds and applying appropriate feeding regimens to support efficient aquaculture production. The report also reviews some of the more applied aspects of fish nutrition and feeding, addressing topics such as feeding during the early life stages, feeding in intensive production systems, and waste management.

### Sustainable Sources of Fish and Shrimp Feed

Traditionally, aquaculture feeds were based on fish oil and meal made from relatively inexpensive fish species such as anchovies, sardines, herrings, and mackerel. However, as aquaculture production increases, demand for these marine resources will

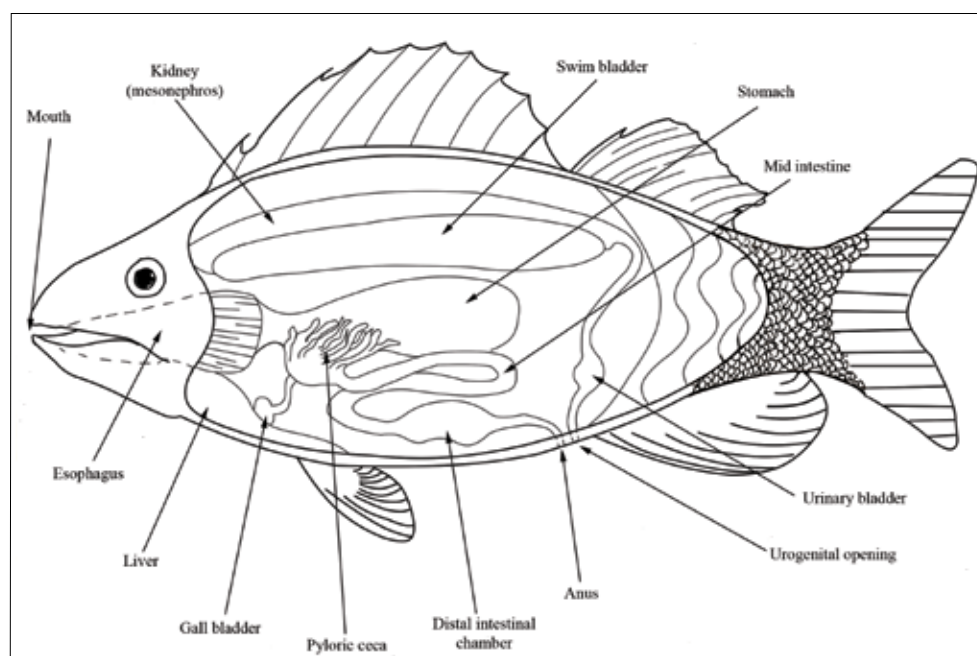
outstrip supply, and consumers and governments are becoming increasingly aware of the environmental consequences of exploiting marine resources to produce animal feeds.

The committee concluded that more sustainable alternatives to fish meal and oil are needed for aquaculture production to continue to expand as it has in recent years. However, fish meal and fish oil constitute important sources of nutrition in aquatic feeds, conferring desirable characteristics to the diet and health of the cultured organism, and ultimately to the consumer. For example, fish meal contains high levels of most essential amino acids and other important nutrients such as minerals. Fish oil contains long-chain, polyunsaturated fatty acids, such as omega-3 fatty acids, and therefore fish fed with fish oils are a rich source of these important components of the human diet. The report reviews efforts to identify sustainable alternatives to fish oil and meal that still offer similar desirable qualities.

### Alternatives to Fish Meal

Potential alternative sources of protein include products from land animals, single-cell proteins, and plant protein sources such as meals made from oilseeds, grains, or legumes. However, most of these sources do not have amino acid profiles that satisfy essential nutritional requirements of fish and shrimp as well as fish meal does.

Fish meal is also a source of essential nutrients such as phosphorus and trace minerals. Some studies have shown significantly reduced growth rates in fish fed diets with little or no fish meal, despite the fact that the diets seemed to be nutritionally adequate. It is likely that nutrient deficiencies, differences in the digestible nutrient content of diets, and possibly reduced feed intake associated with altered palatability can



Organization of internal organs in a generalized fish.

Illustration courtesy of Victoria Blondin, University of Guelph, Ontario



Atlantic salmon, one of the major species grown in aquaculture.  
Credit: Troutlodge, Inc./USDA

explain the reduced performance of fish fed low fish meal diets in many studies.

### ***Alternatives to Fish Oil***

Fish fed diets that contain fish oil are a rich source of omega-3 fatty acids in the human diet. However, when fish are cultivated using alternative feeds that do not contain fish oil, their omega-3 fatty acid content is reduced. Currently, there are no ideal substitutes for fish oil as a source of long-chain polyunsaturated fatty acids.

One possibility is obtaining fatty acids from sectors of the marine ecosystem other than fish. Significant quantities of fish oil (and meal) could be recovered from seafood processing waste, and this source could extend the period before supplies of fish oil become limiting to aquaculture production.

Another option that is currently being employed is to extract fatty acids from land plants, specifically the oilseed plants that produce vegetable oil. However, vegetable oil differs from fish oil in its fatty acid composition, as higher plants do not produce long-chain fatty acids. Irrespective of fish species, fish given feed that contains vegetable oil instead of fish oil will contain less of the fatty acids that are beneficial to human health. Despite this limitation, the committee found that vegetable oils are currently the only readily available, sustainable, and cost-effective alternative lipid source for aquaculture diets. The report reviews strategies for minimizing the impact of substituting vegetable oil in place of fish oil, which include blending different vegetable oils to reach optimal combinations of

fatty acids, or using feeds that do contain fish oil for a period of time before the fish are harvested, to restore levels of omega-3 fatty acids before the fish are consumed.

### **Minimizing Potential Environmental Impacts of Aquaculture**

Feeds constitute the major source of environmental pollution resulting from aquaculture, either directly, in the form of uneaten feed, or indirectly, through solid waste and dissolved waste products. These pollutants contribute to the nutrient loading of the culture system, and the environment, if the pollutant-containing water is discharged.

The main concern is the release of nitrogen, phosphorus, and solid organic matter wastes. Nitrogen and phosphorus are limiting nutrients for algae growth in marine and freshwater ecosystems, respectively; therefore the release of these nutrients can boost the growth of algae and cause environmental harm.

Reducing the waste outputs of aquaculture operations is considered a key element for the long-term sustainability of aquaculture in many parts of the world.

One strategy is to minimize the generation of waste by selecting highly digestible ingredients, reducing indigestible components from the feed and minimizing nitrogen and phosphorus levels in the diet. The amount of nitrogen in waste can be lowered by formulating the amino acid balance and the digestible energy to protein ratio to minimize the catabolism of proteins and promote the retention of amino acids. Applying similar concepts to phosphorus, the trout industry has been able to formulate diets that contain less phosphorus, resulting in 70 percent less urinary and 50 percent less fecal loss of phosphorus compared to diets in the 1980s. Reaching these outcomes for other species depends on detailed information on nutrient requirements and on the digestibility of feed ingredients.

In addition to selecting the proper feed, appropriate feed management is critical to obtaining efficient aquaculture production and minimizing pollution. Small errors in overfeeding, or delivering feed that the animal cannot consume, leads to increased nutrient loading of the culture system

and a direct loss of profits. Steps toward the proper delivery of daily nutrients includes determining the proper feed ration for the potential growth of the species, and providing the correct form of the feed—flakes, pellets, or liquid.

### Needs for Future Research

Significant gaps in knowledge of fish and shrimp nutrition still exist, in part because limited effort has been directed toward refining previously published estimates of nutrient requirements of the most well-established species of farmed fish and shrimp.

The committee identified several topic areas that represent critical needs for future research. These include the requirements, delivery, and interaction of nutrients; alternatives to fish meal and oil; diet formulation and processing; and the effects of nutrition on gene expression and metabolism. As these research needs are addressed, the results will help improve the health and welfare of fish, the nutritional quality and safety of farmed fish for consumers, and the economic aspects of aquaculture production. In addition, this research will help ensure high standards of environmental stewardship, by supporting the efficient and effective use of marine resources with minimum impacts on the aquatic environment.



Young rainbow trout.

Credit: Stephen Ausmus/USDA

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The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Department of Agriculture's Agricultural Research Service, the National Oceanic and Atmospheric Administration, and the United Soybean Board. Additional support came from internal National Research Council funds. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.



For more information, contact the Board on Agriculture and Natural Resources at (202) 334-3062 or visit <http://dels.nas.edu/banr>. Copies of *Nutrient Requirements of Fish and Shrimp* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; [www.nap.edu](http://www.nap.edu).

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