

Rainbow Trout — Challenges and Solutions

Gary Fornshell

University of Idaho, Twin Falls, ID 83301, USA. Tel.: +1-208-734-9590. Email: gafornsh@uidaho.edu

ABSTRACT: The U.S. trout industry is a mature, stable industry. Production of market-size rainbow trout, *Oncorhynchus mykiss*, averaged 25,000 metric tons per year between 1988 and 1999, with a range from 23,600 to 27,300 metric tons per year. Trout growers reported total sales in 1999 of \$76.9 million, compared with an average value of \$71.7 million ex-farm between 1988 and 1999. Total sales include food fish, fish for stocking, fingerlings, and eggs. Market-size fish (> 30 cm and 340 g) comprised 84% of total sales in 1999.

The challenge for the trout industry is to at least maintain current production and possibly expand. Where can this growth come from? Additional growth can result from value-added products and increased productivity of existing operations. This paper will discuss the challenges faced by the trout industry, specifically, the market-size sector as it looks to expand, and suggest possible solutions that address these challenges.

Freshwater availability and environmental constraints, including effluent limitations and public concerns about environmental impacts, are the primary obstacles toward industry expansion. Given water quality and quantity requirements for trout, development of new facilities, based on current production techniques, is limited. Therefore, additional production must come from existing operations through greater intensification and increased efficiency. Development of improved strains, high-performance feeds, vaccines for disease control, and new production technologies will provide the potential for increased production.

Value-added products increase revenues without requiring increased production. Product development and marketing will be key to product diversification and sales. Consumers increasingly demand convenient products that are quickly and easily prepared. Marketing efforts will need to focus on perceived value, brand identification, promotion, and service.

KEY WORDS: flowthrough production, raceway, value added, *Oncorhynchus mykiss*.

I. INTRODUCTION

Rainbow trout, *Oncorhynchus mykiss*, are native to North America, extending throughout the eastern North Pacific region, from Mexico through the Aleutian Islands, and extending to the Kamchatka Peninsula. At the end of the last ice age, they were distributed throughout this region, west of the Continental Divide in the U.S. and Canada. Livingston Stone, reportedly one of the foremost trout breeders of his time, established the first rainbow trout spawning station

on the McCloud River in California in 1879 (Gall and Crandell, 1992). Supported by the U.S. Commission of Fish and Fisheries, eggs from this station were shipped throughout the country with subsequent establishment of rainbow trout culture. The first shipment of eggs outside the country is believed to have been to Japan. In 1885, eggs were sent to the National Fish Culture Association in England, which subsequently established a breeding stock. Shortly thereafter, farming of rainbow trout began in Denmark. It is believed most of the rainbow trout cultured worldwide today probably originated from the McCloud River.

In Idaho, the first rainbow trout farm was established at Devil's Corral, just east of Twin Falls, in 1909. Warren Meader of Pocatello established a broodstock station in 1914. This station by 1940 was supplying up to 60 million eggs to private and public hatcheries throughout the country (Brannon and Klontz, 1989).

Today, the U.S. trout industry consists of about 561 farms located in 42 states. Major producing states include Idaho (70 to 75% of domestic production), North Carolina, Pennsylvania, California, and Colorado. Most of the farms are small family-operated businesses with average sales per farm of \$129,473 (USDA, 2000a). Less than 20% of the farms (108), however, account for 86% of the total sales. This dichotomy, that is, farms being located in most states, but with production mainly from one, and most farms being small family businesses, yet fewer than 20% accounting for the majority of sales, is also seen in Idaho, where a few large companies produce 80% of the fish.

Total yearly sales averaged \$71.7 million between 1988 and 1999 (Figure 1). These sales are ex-farm and are the gross value received by the producer. Total sales include the sale of eggs, fingerlings, stockers, and market-size fish. The fluctuation of total sales from year to year reflects varying production (especially influenced by Idaho), market price, and the proportion of sales coming from the different sectors within the industry.

Total sales of market-size trout (> 30 cm and 340 g) averaged \$57 million during this period; followed by stockers (15 to 30 cm and < 340 g) at \$7.7 million; eggs at \$5.27 million; and fingerlings at \$ 1.61 million.

Because the market-size sector dominates the industry, both through production and value of sales, this article concentrates on this sector of the industry. According to the 1998 U.S. Department of Agriculture Census of Aquaculture (USDA, 2000a), nearly 60% of market-size trout were sold to processors (Table 1).

Market outlets vary throughout the country. Idaho trout growers rely on processors for nearly all their sales (96%), while Colorado growers sell most of their fish to live haulers and fee-fishing operations (38 and 55%, respectively). California trout growers sell nearly all their fish (96%) to fee fishing outlets. In the eastern half of the U.S., direct sales and fee-fishing operations are important market outlets; however, in North Carolina 43% of the trout are sold to processors.

The production of market-size trout has remained relatively stable between 1988 and 1999, averaging 25,000 metric tons per year (Figure 2). Fluctuations in production are probably due to a variety of reasons, including varying losses to disease and predators from year to year, fluctuating spring flows, droughts, floods, and the accuracy of the production reports.

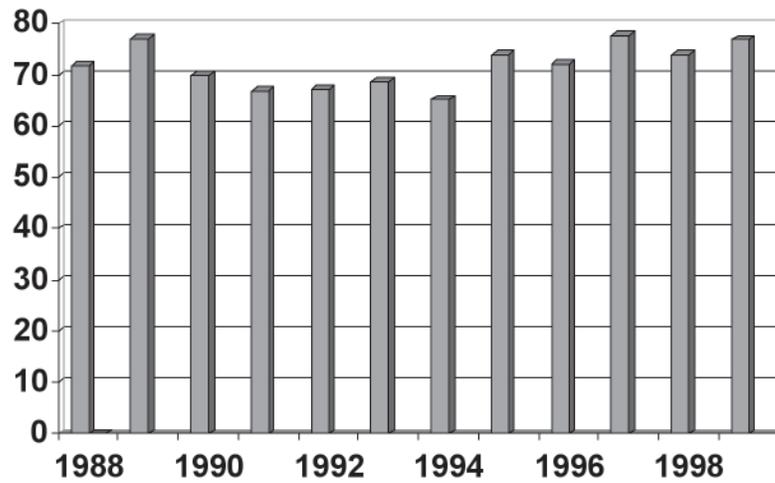


FIGURE 1. Yearly total sales (\$ Million) ex-farm.

TABLE 1
Percent Sale of Market-Size Trout by Point of First Sale.

Outlet	%
Processor	59.7
Fee Fishing	18.2
Retail	8.3
Direct	4.2
Live Haul	3.6
Other	6.0

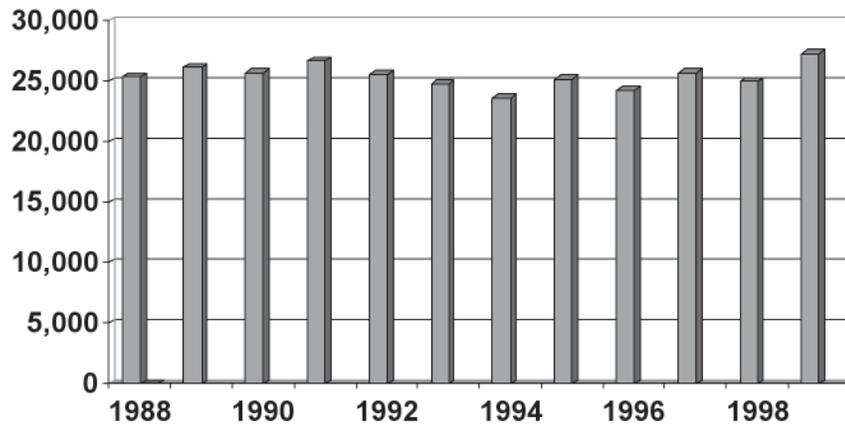


FIGURE 2. U.S. Trout production (metric tons) of market-size fish.

II. TECHNOLOGICAL ADVANCES

Although trout farming began in the early 1900s in Idaho, significant expansion did not occur until the 1970s and 1980s. A number of factors contributed to the growth of the trout industry in Idaho. One of the most significant advances was the development of pelleted feeds in the early 1950s. The U.S. Fish and Wildlife Service was primarily responsible for identifying the nutritional requirements of rainbow trout. Pelleted feeds reduced the cost of production by eliminating the need to prepare feeds onsite. Tremendous effort and time was required to procure feedstuffs, such as carp and horses, and then to grind the carcasses into small enough pieces to enable the fish to eat. Feed conversion ratios were high as a result of the use of these feedstuffs and water quality suffered as well.

The first processing plant in Idaho was constructed during the mid-1950s by the Snake River Trout Company (Brannon and Klontz, 1989). This allowed for product diversification and greater distribution. Soon thereafter, automated processing equipment was developed. Development of automatic feeders, graders, and fish pumps followed.

A rather simple change from earthen ponds to concrete raceways increased production significantly. Concrete raceways are easier to keep clean, thereby increasing production. It is also much easier to work the fish in concrete raceways, whether the fish are sampled, graded, moved, or harvested. Depending on the individual site, the switch from earthen ponds to concrete raceways may increase production by 25 to 40% on the same quantity of water. Although there remain today numerous earthen ponds, over 90% of production is estimated to come from concrete raceways.

A characteristic of rainbow trout that contributed to their success as a farmed fish was the availability of eggs year-round (Hardy, *et al.*, 2000). Rainbow trout are naturally spring spawners, but spawning time can be manipulated through genetic selection and photoperiod adjustment. Selection for early winter spawning on a particular strain in California began during the 1930s. The median time of spawning

for this strain shifted from March in 1880 to October by 1940, and further work decades later moved the median time to August in 1980.

By 1970, year-round eggs were available, and one observed in Idaho an almost fivefold increase in production from 1970 to 1976, in large part due to year-round egg availability, which allowed continuous production to supply constant market demand.

Another technological advance that many trout growers adopted was the use of all female stocks. The use of all female stocks eliminates the occurrence of sexually precocious males, which are economically undesirable because of poor flesh quality. In general, females are considered more valuable due to the high value of the eggs and the production of offspring.

III. TROUT FARMING

As with other successful aquaculture species, rainbow trout possess desirable characteristics that contribute to their culture. Rainbow trout are easy to spawn and the fry are large compared with most other aquaculture species. They readily accept prepared feeds from their first feeding on. They grow rapidly, a little over 2.54 cm per month at the ideal water temperature of 15°C, and reach market size (400 to 650 g) from 10 to 13 months of age. Rainbow trout can tolerate water temperatures from 0 to 28°C and spawn successfully at temperatures between 2 to 12°C.

The production systems for rainbow trout are similar throughout the U.S. Fish are cultured in flow-through systems, consisting of earthen ponds, concrete raceways, or tanks. Water quantity and quality determine the carrying capacity and production of flowthrough systems. The incoming water supplies oxygen and flushes away toxic metabolic wastes. Loading rate (kg/l flow) is a more accurate and practical indicator of the carrying capacity of the system than density (kg/m³). Loading rate depends on water flow rate, turnover rate, temperature, oxygen content, metabolic product accumulation, and the size and species of fish being cultured. Density refers to the relationship of fish weight and size to water volume, and the spatial relationship of one fish with another (Piper *et al.*, 1982). In most situations, loading rate becomes limiting before density. A common misperception is that poor performance, as indicated by reductions in growth rate, poor feed conversion ratios, and disease problems, is due to high densities, when, in fact, the problem is usually related to insufficient flow to sustain the biomass.

Trout growers in Idaho use gravity to move spring water through their raceway production systems. Raceways range from 18 to 40 m long, 2.5 to 6 m wide, and have water depths of 0.6 to 1.2 m. Usually, four to six raceways receive water in series before oxygen and then ammonia becomes limiting. In areas with soft water and low pH, such as North Carolina, up to 20 uses are possible with oxygen supplementation before ammonia becomes limiting. Carrying capacity in Idaho averages 1.8 kg per liter/minute (kg/lpm), while production averages 5.3 kg/lpm and may reach levels as high as 9.6 kg/lpm when all raceways in a series are combined (Brannon and Klontz, 1989). Water velocities usually range from 2 to 4 cm/s, and the turnover rate is usually four per hour, that is, the volume of water in the raceway is exchanged four times in an hour.

Most growers purchase eyed-eggs rather than produce their own eggs. After arrival, the eggs are tempered to the ambient water temperature and disinfected with an iodine solution prior to placement in upwelling incubators. After hatching, the sac-fry are removed from the incubator into a trough, where they remain until the yolk-sac is absorbed (about 10 days) and first feeding begins. As the fish grow, they are moved to larger troughs and/or divided into other troughs. Fish are stocked outdoors in first-use water when they are between 1 to 4.5 g in weight. Similar to the situation in the hatch house, as the fish grow, they are moved to other raceways in a downward procession, until the market-size fish are in the last-use raceway.

Usually, the first limiting factor in aquaculture production systems is oxygen, and this holds true for rainbow trout in raceways and ponds. Although rainbow trout survive levels as low as 3 mg/l, it is recommended to keep minimum dissolved oxygen levels above 5 mg/l, and ideally above 7 mg/l. Drops between raceways are used to passively aerate the water. Splashboards of various designs are used to increase oxygen transfer from the atmosphere into the water. This works quite well; however, saturation levels are never reached and eventually oxygen levels drop below levels tolerable to rainbow trout.

The second limiting factor is ammonia. Ammonia is a metabolic excretory product associated with catabolism of protein (amino acids). When ammonia is dissolved in water, an equilibrium is established between ammonia and ammonium ions: $\text{NH}_3 + \text{H}_2\text{O} = \text{NH}_4^+ + \text{OH}^-$. As pH and water temperature increase, the proportion of unionized ammonia increases, which is the form most toxic to fish. Fortunately, unionized ammonia rarely approaches toxic levels in flow-through systems.

The use of either concrete raceways or earthen ponds in trout farming has an effect on the final product. As previously mentioned, most production occurs in concrete raceways; however, growers whose markets include recreation and fee-fishing ponds prefer earthen ponds because fish grown therein usually have brighter skin color and better fin quality.

IV. OUTLOOK FOR TROUT

The challenge for the U.S. trout industry is to at least maintain current production levels and to possibly expand. There are several factors, however, that will influence the future of the industry. Some of the more important factors include freshwater availability, environmental regulations, competition from other protein sources (notably, chicken and pork), and perhaps the most important factor of all, the response of the industry to these challenges. The industry, collectively and individually, has little control over the above-mentioned factors, but it does have control over how it responds to these factors.

Aquaculture producers tend to think of other aquaculture/seafood products as their primary competition, and given the wide array of seafood products, it is easy to understand their reasoning. It is, in fact, the other animal protein sources that rainbow trout and other aquaculture products must compete against. This is particularly true with chicken and pork. In 1998, U.S. per capita consumption of seafood, poultry, and red meat was 6.76, 29.5, and 52.5 kg, respectively (Johnson

& Associates, 1999). Seafood consumption represents only 7.6% of the total amount of animal protein consumed.

Poultry is relatively inexpensive to produce, and the poultry industry has excelled in developing and marketing value-added products, making poultry the most formidable competitor of aquaculture. The pork industry has followed the example set by the poultry industry and has moved toward vertical integration and value-added product development. Now and in the future, rainbow trout will have to compete with relatively inexpensive poultry and pork for the center of the plate.

Although most forms of trout farming are not consumptive users of water, flowthrough raceway production systems require large quantities of water, and that water must be of high quality. Complete utilization of available freshwater in most trout rearing areas in the U.S. is limiting expansion of new production facilities. This is particularly true in south-central Idaho, where almost the entire Idaho aquaculture industry is located. Essentially all available water is allocated for irrigation, aquaculture, drinking water, hydropower, and industrial uses. In addition, the aquifers that supply the trout growers with approximately 62 m³/s water flow have declining groundwater levels, which are causing reduced spring flows. Increased groundwater pumping for irrigation, conversion from furrow to sprinkler irrigation, changes in water management, and drought are the causes for declining groundwater levels. Expansion of the industry will not come from additional water resources.

New sites with sufficient water quantity and quality for trout farming are rare. Development of new water is being explored in West Virginia, where large quantities of water are available from abandoned coal mines. However, questions remain about the feasibility of utilizing these water resources and potential water quality problems with low pH and heavy metal contamination.

In general, a minimum of 1900 lpm water flow is recommended in order to start a trout growing business. Usually, but not always, most small facilities grow trout for stocking or direct sale because the profit margins are higher than selling to a processor. In Idaho, most of the trout farms have flows above 17,000 lpm and the largest farm has a flow of 510,000 lpm.

Concern over environmental impacts of aquaculture has increased substantially during the past 10 to 15 years. In 1997, the Environmental Defense Fund released their report, "Murky Waters: Environmental Effects of Aquaculture in the United States" (Goldburg and Triplett, 1997). The report, which contained unsubstantiated claims and inaccuracies, succeeded in getting the attention of the U.S. Environmental Protection Agency (EPA), environmental groups, and the media. The result is that environmental scrutiny of aquaculture is here to stay and will continue to increase.

Environmental regulations in Idaho have essentially prohibited construction of new facilities along the mid-Snake River. The Idaho Division of Environmental Quality (DEQ) declared the mid-Snake River water quality limited in 1990 because beneficial uses were not being met (Idaho Division of Environmental Quality, 1996). Specifically, conditions in the river violated two narrative standards that concerned aquatic nuisance weeds and floating, suspended, or submerged matter. Once a state declares a water body water quality limited, the state is required by the Clean Water Act to prepare a water quality management plan to mitigate for those impacts impairing state water quality standards. As part of the plan, a total maximum daily loading (TMDL) is required. A TMDL establishes allowable pollution loadings, based

on a variety of factors that include background levels, assimilative capacity of the water body, and a margin of safety.

Shortly after declaring the mid-Snake River water quality limited, the DEQ implemented a no net increase policy that prohibited any new aquaculture facilities unless the discharge did not contribute any pollutants to the mid-Snake River. The nature of flowthrough production systems is such that there is a continuous discharge during production and that discharge will contain solids and nutrients as a result of production. The trout growers were regulated by a National Pollutant Discharge Elimination System (NPDES) permit administered by the EPA that limited the net discharge of total suspended solids to 5 mg/l. However, there were concerns that nutrients, primarily phosphorous, were contributing to the growth of aquatic weeds. Therefore, a TMDL was developed to allocate phosphorous among the contributors along the mid-Snake River, including point sources (aquaculture, food processors, sewage treatment plants) and nonpoint sources (irrigated agriculture, grazing). Aquaculture received an allocation of 440 kg total phosphorous per day, a 40% reduction from the estimated baseline level. A new NPDES permit was issued that incorporated the phosphorous TMDL and maintained the limits on solids. The 440 kg total phosphorous per day will be divided among the approximately 75 farms that are required to have a discharge permit. Estimated net concentrations of total phosphorous, as a result of the TMDL, range from 0.06 to 0.09 mg/l. The consequence of the TMDL is that any increase in production cannot result in an increase of phosphorous above the allocated amount of 440 kg per day. This will be a most difficult challenge to overcome.

Nationally, EPA is developing effluent guidelines and limitations for all aquaculture production systems. The current effort to develop proposed rules is a result of a suit filed by the Natural Resources Defense Council (NRDC) in 1989 against the EPA for lack of enforcement of the Clean Water Act (NRDC, *et al.* v. Reilly, Civ. No. 89-2980, D.C. Cir.). The EPA, under a Consent Decree reached as part of the settlement, was ordered by the court to develop effluent guidelines and limitations for aquaculture (Federal Register, 1998).

The proposed rules for effluent guidelines and limitations will be technology-based rather than water-quality-based, such as the TMDL in Idaho. Technology-based standards seek to determine the "Best Available Technology" or "Best Management Practices" that are economically achievable and protect the environment. Possible outcomes of the proposed rule include no regulation with or without voluntary guidance or regulation with numeric limits, best management practices, or both. The proposed rule may apply to all aquaculture production systems, certain subcategories, or certain size facilities. Currently, many trout growers use a combination of settling basins and feed management to reduce, capture, and remove solids and nutrients from their effluent.

V. GREATER INTENSIFICATION

Additional production will have to come from existing operations, because freshwater availability and environmental constraints limit the development of new farms. Trout growers will have to produce more fish in the same amount of water through greater intensification and increased efficiency. Greater intensification will require

continued research in the following areas: improved strains, high-performance feeds, vaccines, and technologies designed to increase production and efficiency.

Rainbow trout are highly adaptable, as is evidenced by their worldwide distribution, within one hundred years, from a relatively narrow range on the Pacific coast of North America. Hershberger (1992), in a review of the literature, found that most (92%) genetic variation occurred within populations, which may offer an explanation to the successful introduction of rainbow trout to a variety of environments worldwide. Rainbow trout growers, however, are not fully utilizing the genetic potential of rainbow trout. The more important economic traits include growth rate, feed efficiency, disease resistance, and flesh quality. Individual and family selection appear to be the most promising selection methods of improving these traits. Previous studies have shown positive gains through selection, including a 67% increase in body weight over three generations of selection, for body weight at 147 d, and a gain of 4.3% per year for body weight at 2.5 years of age after two generations of selection (Gjedrem, 1992). Selection programs within the industry have also found success for body weight improvement, realizing a 7 to 10% increase each generation at a given age. Marker assisted selection has the potential to improve traditional breeding programs. Given the great number of rainbow trout strains, performance differences among them, and the surprisingly little work done thus far at improving economic traits of importance to the trout industry, great potential exists for the development of improved strains.

Trout feed formulations have changed dramatically over the last 40 years. One of the reasons for this is in response to environmental concerns. Dietary protein levels have increased from 35% to 45% and dietary lipid levels from 5% to over 22% in high-energy feeds. These feeds are more nutrient dense, that is, they contain more calories per kilogram and result in greater growth with less feed. The quality of feed ingredients has also improved, resulting in improved digestibility. In the 1960s, typical feed conversion ratios were around 2.0:1.0. Today, the best nutrient-dense feeds can yield feed conversion ratios of 1.2:1.0 to less than 1, under optimum conditions combined with good feeding practices.

Another change that has occurred is the use of extruded pellets. Once dry pellets became available in the 1950s, growers used sinking stream-pelleted feeds. To make the switch to higher-energy feeds, however, it is necessary to use extrusion manufacturing because stream-pelleted feeds cannot contain the lipid levels necessary for a high-energy feed. The advantages of extruded pellets include fewer fines, resulting in better water quality and the option to use floating, slow sink, or sinking pellets.

Trout feeds contain fish meal, fish oil, grains, and other by-products derived from food and food oils production. Fish meal is a finite resource and it can also be relatively expensive, particularly when supplies decrease because of El Niño weather conditions or shifts in market demand. Efforts have been made to reduce the amount of fish meal used in rainbow trout feeds by substituting other protein sources (Stickney *et al.*, 1996). Alternate protein sources for fish meal include wheat and corn gluten, oilseed meals, protein concentrates, rendered products, recovered fisheries by-catch, and seafood processing byproduct. The use of alternate protein sources has decreased the amount of fish meal in trout feeds by approximately 33%. For essentially the same reasons, alternate sources of oils are sought to reduce the use of fish oils.

Phase feeding, that is, the use of different feeds, to influence product quality and alter effluent water quality will increasingly become an important tool for the trout grower. Growout feeds, which account for 90% of feed usage during production, impact farm profitability and environmental compliance. Some trout growers use feeds containing astaxanthin, a carotenoid pigment found in natural foods of trout, to give the flesh a red color. These feeds are usually fed during the last 2 to 3 months of production. Other types of phase feeding may include the use of low phosphorous feeds during the latter half of production to reduce effluent phosphorous discharge, and varying lipid levels throughout production to influence product flavor and fat content.

The development of high-performance feeds has resulted in improved feed conversion ratios, reduced fish meal usage, and improved water quality. Research to further improve high-performance feeds and to refine innovative feeding practices must continue to allow rainbow trout growers to comply with environmental discharge regulations while maintaining production efficiency.

Disease losses can be substantial. As a general rule of thumb, it takes three eggs to produce one market fish. Disease losses were about 73% of total losses in 1999 (USDA, 2000b). There are just two approved antibiotics for all of aquaculture in the U.S. Additionally, the use of antibiotics is restricted to specific aquaculture species and pathogens. This, in combination with their limited effectiveness against several trout diseases and high cost, has limited their use. Integrated fish health management that relies upon prevention and good husbandry practices is a more cost-effective approach that results in fewer disease losses. Sanitation, good water quality, high-quality feed, reduction of stress, elimination of disease vectors, and vaccination are all part of integrated fish health management.

Vaccination has proven successful against some important bacterial diseases in rainbow trout. Enteric redmouth disease, *Yersinia ruckeri*, is the first fish disease for which a commercially available vaccine was developed. The single most effective management tool for control of mortality due to enteric redmouth disease is vaccination. Vaccination has also proven effective for the Atlantic salmon industry, reducing both disease losses and antibiotic use. Vaccine development is critical for trout growers, as several other diseases for which treatments are limited or nonexistent, including coldwater disease (*Flavobacterium psychrophilium*), infectious hematopoietic necrosis, and infectious pancreatic necrosis, cause severe losses.

Technologies that increase efficiency and production will become necessary as trout growers seek to intensify production. Key will be improved methods of inventory assessment. Production and harvest scheduling, grading, egg orders, and feeding are based on inventory. Errors in estimating inventory, which is used to determine growth, biomass, feed conversion ratios, and other variables, such as mortality and pond carrying capacity, may cause several problems that ultimately impact profitability. Fish farmers in general agree that a +/- 5% discrepancy between estimated inventory and what is actually in the ponds is acceptable; however, the reality is usually closer to +/- 15 to 25%. Technologies that accurately count and weigh the fish in a pond are being developed.

Oxygen supplementation is another area that requires additional research, especially to determine the cost effectiveness of using oxygen. Oxygen supplementation is used to a limited extent by U.S. trout growers, primarily in the eastern half of the U.S. Low-head oxygenators (LHO) are used in North Carolina. As production

intensifies, a balance will need to be struck between carrying capacity and effluent water quality.

Cost-effective and practical water treatments that remove soluble nutrients from the effluent are needed. High volumes of water with minute concentrations of nutrients characterize typical raceway effluents, making treatment difficult and expensive. An active area of research involves the use of iron ore reactors to precipitate phosphorous out of solution.

VI. VALUE-ADDED PRODUCTS

Value-added products can increase revenues without requiring increased production. Where constraints prohibit expansion through production, value-added products allow the industry to grow through increased market share. As mentioned above, the poultry and pork industries may attribute much of their success to vertical integration and value-added product development. Vertical integration and value-added products are not new to the U.S. trout industry. The degree of integration varies from total control of all operations involving production, processing, marketing, and distribution to limited control, but several companies combine production, processing, and marketing, which allow them to become more market oriented than production oriented. Trout are still sold as head-on gutted fish, but the proportion sold as fillets (often boneless) and other value-added products such as smoked trout, trout jerky, pate, and oven-ready products has increased over the last decade.

Overall, there has been a slight downward trend in per capita seafood consumption from the mid-1980s (Johnson & Associates, 1999). Total consumption, however, has remained relatively stable over this period due to an increase in population. A number of factors are cited as to why per capita seafood consumption has not increased. Insufficient supply to satisfy consumer demand is probably the number one reason limiting consumption. Other factors include lack of convenient products, high prices, lack of perceived value, demographics, and lack of generic promotion campaigns. Only about half of all American adults eat seafood regularly, and of these, the heaviest consumers tend to be older (45 to 54), well-to-do, and well educated. Consumers are also willing to pay a higher price for convenience. Most consumers do not have the time or the desire to gut, skin, and fillet the fish they are about to eat. Perceived value, the price a consumer finds acceptable for the desired benefits of a product, also influences seafood sales. If a product has a high perceived value, price becomes less of an issue. In many instances, high priced products sell well because of a high perceived value.

Two separate University of Idaho studies surveyed rainbow trout buyers and consumers to determine marketing attributes and perceptions. The objective of the first study, a survey of wholesale and retail distributors of rainbow trout, was to better understand how intermediaries perceive rainbow trout as a product line (McCain and Guenther, 1991). Distributors rated consistent quality as the most important attribute, followed by competitive price, and consistent supply. Retailers responded similarly, rating consistent quality as the top attribute, followed by competitive price, but ranked shelf life third. Appearance and shelf life are more important attributes for retailers than for wholesalers. Both wholesalers and retailers conduct little consumer research,

and the attributes they most value relate to product quality, while they consistently rated attributes related to marketing activities such as sales and advertising support lower, which indicates that the trout industry cannot depend upon them for promoting the industry. The second study investigated consumer perceptions of trout as a food item (Foltz, 1997). Some of the key findings were taste and freshness are two key qualities involved in the purchasing decision; product form is important, boneless fillets being especially desirable; trout are perceived to be more expensive than other meats, but relative to other fish survey respondents felt that trout was about the same price, and trout appears to be an impulse item for most shoppers. This last item has important implications for increasing sales through the use of eye catching slogans, in-store advertising, recipes, coupons, and other methods to attract shoppers within the store to purchase trout or to get them to add trout to their shopping lists through coupons and newspaper advertising.

Rainbow trout is a unique product that has the attributes, that is, consistent quality and supply, competitive pricing, taste and freshness, convenient products forms, and healthfulness, which consumers, be they wholesalers, retailers, or shoppers, desire. Without marketing programs to enhance the sale and consumption of rainbow trout, however, the U.S. trout industry will be unable to expand sales.

One of the trends predicted for the new millennium is the elimination of the seafood service counter in grocery stores (Johnson & Associates, 1999). Seafood departments are usually one of the lowest returning departments in a grocery store, and one way to reduce costs and to increase profit margins is to switch to self-service. The meat and poultry industries have moved toward case-ready packages delivered directly to the store and the reduction of in-store cutting and packaging. Self-service counters can perhaps offer more opportunity for branding, packaging, and consumer education. The perceived value of a product can increase due to good packaging and promotion.

Seafood products may also be directed to specific market segments. Seafood as "medicine" may be one approach to target health-conscious consumers. Eco-friendly or green labels will become more common as the debate continues over the impact of aquaculture upon the environment. Marketing strategies will continue to promote the safety and wholesomeness of seafood products, especially aquaculture products.

VII. CONCLUSION

Freshwater availability and environmental constraints will limit industry expansion of new facilities, at least as trout are currently produced. Additional growth will have to come from increased productivity of existing operations and from continued development of value-added products. Research in the areas of strain improvement, feeds, vaccines and production technologies is needed to enable trout growers to increase production efficiency and intensification. Marketing programs, developed at the producer/processor level, will be necessary to increase sales and consumption of rainbow trout.

REFERENCES

- Brannon, E. and G. Klontz. The Idaho aquaculture industry. *Northwest Environ. J.*, **5**:23–35 (1989).
- Federal Register. Effluent guideline plans [FR Doc. 98-23891]. Environmental Protection Agency. September 4, 1998, Vol. 63, No. 172. National Archives and Records Administration. Washington, D.C. pp. 47285–47288 (1998).
- Foltz, J. Consumer perceptions of trout as a food item. A.E. Research Series No. 97–5. Departmental Working Paper Series. Department of Agricultural Economics and Rural Sociology. University of Idaho, Moscow, ID (1997).
- Gall, G. A. E. and P. A. Crandell. The rainbow trout. pp. 1–10. **In:** *The Rainbow Trout: Proceedings of the First Aquaculture-sponsored Symposium held at the Institute of Aquaculture, University of Sterling, Scotland.* (G. A. E. Gall, Ed.). *Aquaculture* **100** (1992).
- Gjedrem, T. Breeding plans for rainbow trout. pp. 73–83. **In:** *The Rainbow Trout: Proceedings of the First Aquaculture-sponsored Symposium held at the Institute of Aquaculture, University of Sterling, Scotland.* (G. A. E. Gall, Ed.). *Aquaculture* **100** (1992).
- Goldburg, R. and T. Triplett. *Murky Waters: Environmental Effects of Aquaculture in the United States.* Washington, D.C.: Environmental Defense Fund Publications. (1997).
- Hardy, R.W., G. C. G. Fornshell and E. L. Brannon. Rainbow trout culture. pp. 716–722. **In:** *Encyclopedia of Aquaculture.* (R. R. Stickney, Ed.). New York: John Wiley & Sons (2000).
- Hershberger, W. K. Genetic variability in rainbow trout populations. pp. 51–71. **In:** *The Rainbow Trout: Proceedings of the First Aquaculture-sponsored Symposium held at the Institute of Aquaculture, University of Sterling, Scotland.* (G. A. E. Gall, Ed.). *Aquaculture* **100** (1992).
- IDEQ (Idaho Division of Environmental Quality). The Middle Snake River Watershed Management Plan — Phase 1 TMDL: Total Phosphorous. IDEQ, Twin Falls, ID (1996).
- Johnson, H. M. & Associates. 1999 annual report on the United States seafood industry. H.M. Johnson & Associates, Jacksonville, OR (1999).
- McCain, G. and J. F. Guenther. U.S. trout markets. Extension Bulletin No. 750. College of Agriculture. University of Idaho, Moscow, ID (1991).
- NRDC (Natural Resources Defense Council), *et al.* v. Reilly, Civ. No. 89-2980 (D.C. Cir.) (1989).
- Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler and J. R. Leonard. *Fish Hatchery Management.* U.S. Department of the Interior. Fish and Wildlife Service. Washington, D. C. (1982).
- Stickney, R. R., R. W. Hardy, K. Kock, R. Harrold, D. Seawright and K.C. Masse. The effects of substituting selected oilseed protein concentrates for fish meal in rainbow trout diets. *J. World Aquacul. Soc.*, **27**:57–63 (1996).
- USDA (United States Department of Agriculture). *Census of Aquaculture (1998).* Volume 3, Special Studies Part 3. U.S. Department of Agriculture. Washington, D.C. (2000a).
- USDA. *Catfish and Trout Production.* National Agricultural Statistics Service. Washington, D.C. (2000b).

