Feeds for Production of Market-sized Cutthroat Trout

Technical Report

WESTERN REGIONAL AQUACULTURE CENTER

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Introduction: Why Consider Cutthroat Trout?

Cutthroat trout (*Oncorhynchus clarkii*) are popular game fish in the western United States, prized for their brilliant coloration (Figure 1). For commercial fish farmers, these colorful trout potentially represent a valuable high-end specialty product for the recreational stocking market because of their limited supply compared to the more commonly grown rainbow trout (*Oncorhynchus mykiss*). There are a variety of cutthroat trout (*O. clarkii*) subspecies in the western U.S., including at least 11 distinct strains, of which about nine were still present in 1992 (Figure 2) Historical distribution included temperate rainforests of the Pacific Northwest, pluvial lakes within the Great Basin, subalpine areas of the Rocky Mountains, and high deserts of the Southwest. Inland cutthroat trout have adapted to a diverse range of habitats and are found in tiny headwater streams as well as large rivers and large lakes, such as Lake Tahoe on the California–Nevada border and Pyramid Lake in Nevada.

As a result of adapting to diverse habitats, cutthroat trout display a varied set of life history strategies, paralleling those seen in the closely related rainbow trout. Some, like the coastal cutthroat trout are similar to anadromous salmon, rearing in freshwater as juveniles, migrating into the ocean, and returning to freshwater to spawn. Other subspecies of cutthroat trout are adfluvial, living in large lakes and migrating into rivers to spawn, and still others reside in rivers and streams year-round. Cutthroat trout also vary widely in size. One lineage of Lahontan cutthroat trout currently stocked in Pyramid Lake, Nevada, grows to more than 40 pounds, while some varieties found in small headwater streams rarely exceed two pounds.

Despite the wide range of fish sizes and habitats, cutthroat trout subspecies share some key characteristics that should be of interest to fish culturists.

- Cutthroat trout are generally spring spawners, a trait that can increase the likelihood of hybridization with most strains of the closely related rainbow trout.
- Their natural diet consists mostly of aquatic and terrestrial insects and other aquatic invertebrates. Larger individuals will eat fish.
- Because they are closely related to the rainbow trout, cutthroat trout readily interbreed to produce cuttbows, a hybrid cross that can sometimes breed successfully. This propensity to hybridize with rainbow trout is one of the reasons cutthroat trout declined throughout their native range following the introduction of rainbow trout.

Photo credit: Gary Fornshell

Figure 1. Snake River cutthroat trout.

- Cutthroat trout, similar to other salmonids, build and lay their eggs in redds, typically in the gravel of streams, rivers, or the inlets and outlets of ponds and lakes. Egg incubation time varies with water temperature.
- All cutthroat trout subspecies are excellent sportfish, taking flies, lures, and bait. They are often prized by anglers for their coloration and vigorous fighting ability.

Snake River Cutthroat Trout— A Culturable Cutthroat

The Snake River cutthroat trout, a subspecies originally found in the Snake River drainage, is of particular interest to fish culturists. Its distribution is not shown in Figure 2 because it is the most widely introduced subspecies and has been distributed throughout the western states either as a pure cutthroat trout or more commonly, as a cuttbow. The Snake River cutthroat is a popular sportfish, renowned for its willingness to aggressively strike dry flies and small lures. Fisheries management agencies favor the Snake River cutthroat because it can be readily distinguished from other native cutthroat subspecies by its distinct fine-spotted coloration.

Compared to the other cutthroat trout subspecies, the Snake River cutthroat trout is are well suited for commercial aquaculture due to faster growth and better feed conversion efficiency. This strain is often approved for private aquaculture production and stocking, unlike many of the other, rarer, cutthroat subspecies (Figure 3). State agencies that regulate aquaculture and the stocking of sport fish vary from state to state, as do the nature of the regulations. Consult your state departments of natural resources or agriculture to determine which species are

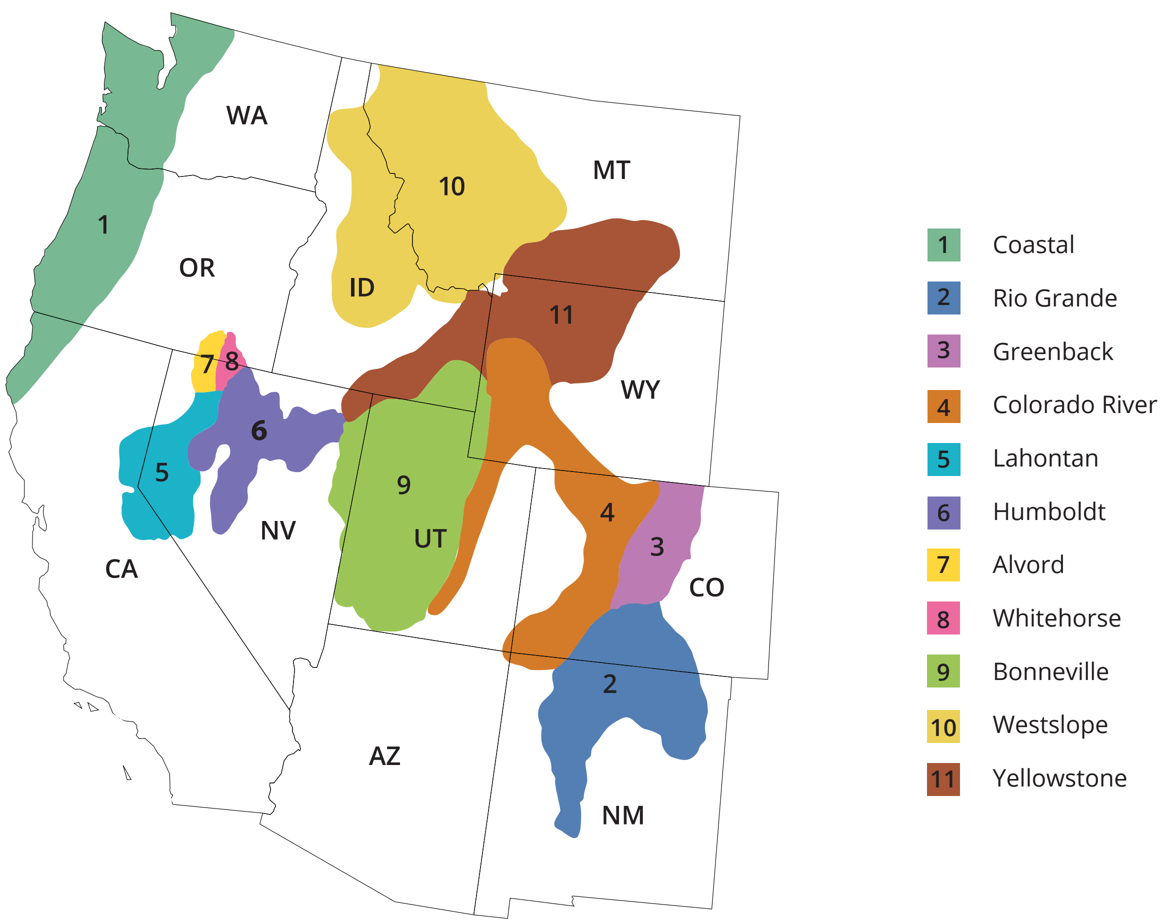

Figure 2. Map showing the distribution of extant cutthroat trout subspecies in the western United States. Data are from Behnke 1992. The Snake River cutthroat has been widely introduced and is not shown on this map.

Photo credit: Gary Fornshell

Figure 3. Juvenile Snake River cutthroat trout ready for stocking.

approved for propagation, particularly when working with cutthroat trout. There are a number of rare subspecies that may be subject to special regulations. Alternatively, contact your state's extension service for assistance and information. Ultimately, any producer needs to consider the unique local regulatory environment and economic situation before electing to raise cutthroat trout for the recreational market.

Is Raising Fish for the Recreational Market Worthwhile?

While the scale of operations that produce trout for the recreational market is small compared to that of the fish farms that produce trout for the food market, the economic contribution of the recreational-based aquaculture sector in the western U.S. is substantial. In 2010, about 173 producers of fish for the recreational market generated $53.2 million in direct annual sales and over 1200 jobs. Their customers included private pond owners, dude ranches, fishing clubs, homeowners' associations, fee-fishing operations, and public waters. The average angler spent $150 per day at these businesses. In the western U.S., the total annual economic contribution of the recreational-based aquaculture industry was estimated to be $1.9 billion. Accounting for both forward and backward linkages, every dollar of recreation-based aquaculture industry sales generates $36 in economic activity, and every million dollars of sales generates 500 jobs.

Overcoming Challenges to Raising Cutthroat Trout

A previous Western Regional Aquaculture Center (WRAC) research project evaluated factors limiting consistent growth, survival, and quality from year to year of fry and fingerling cutthroat trout production. That project focused on evaluating commercial rainbow trout feeds and open-formula experimental feeds, determining optimum water temperature and fish rearing density for the best growth. One finding from that study was that cutthroat trout were more sensitive to feed ingredients and required different ingredient combinations than the closely related rainbow trout.

Fish Nutrition 101— A Primer on Feed Formulation

Fish feed typically represents 50% or more of production costs. Selecting the correct feed is essential for producing aquatic animals economically. Developing cost-effective, nutritious diets for fish requires incorporating knowledge of species-specific nutritional requirements into balanced nutrient-based feeds that are delivered using appropriate feeding methods and rates. The basic building blocks of a feed consist of proteins (amino acids), lipids (fats), carbohydrates (sugars and starches), vitamins, and minerals. Fish metabolize proteins, lipids, and carbohydrates to produce energy required for numerous physiological processes and physical activities, and they require certain vitamins and minerals in small quantities to maintain good health.

Proteins consist of various amino acids. Although over 200 amino acids are found in nature, only about 20 are common. Amino acids are grouped into essential (indispensable) and nonessential (dispensable) amino acids (Table 1). Fish require the same 10 essential amino acids that other vertebrates, including humans, require. It is important to meet a fish's minimum dietary requirement for protein, with a balanced mixture of amino acids, to ensure adequate growth and health of the fish. Fish fed diets deficient in any one of the essential amino acids become inactive and lose both appetite and weight. However, feeding dietary protein to excess is wasteful because protein is the most expensive dietary component. Additionally, excess dietary protein increases excretion of nitrogenous waste, leading to water quality issues. Protein requirements for herbivorous and omnivorous fish typically range from 25 to 35 percent crude protein. Trout and other carnivorous species may require 40 to 50 percent crude protein, depending upon species and life stage.

Table 1. The two major groups of amino acids.

ESSENTIAL	NON-ESSENTIAL
Arginine	Alanine
Histidine	Asparagine
Isoleucine	Aspartic acid
Leucine	Cystine
Lysine	Glutamic acid
Methionine	Glutamine
Phenylalanine	Glycine
Threonine	Proline
Tryptophan	Serine
Valine	Tyrosine

Lipids are organic substances that include fats and oils. They are the most concentrated energy source of the nutrient groups, containing about twice as much energy per unit weight as protein or carbohydrates. Dietary lipids also supply essential fatty acids and serve as transporters for fat-soluble vitamins. Fatty acids include saturated fatty acids (no double bonds), polyunsaturated fatty acids (> 2 double bonds), and highly unsaturated fatty acids (> 4 double bonds). Fatty acids of the linolenic acid (omega-3) family are considered more essential than those of the linoleic acid (omega-6) family. Marine fish oil is high in omega-3 unsaturated fatty acids and is a good source of lipids for fish feeds. The trend in recent years is to use higher levels of lipids in feeds for salmon and trout. Increasing dietary lipid levels can help reduce the cost of feed by sparing protein; however, too high a level can result in excessive fat deposition in the liver, decreasing fish health, product quality, and product shelf life.

Fish do not have a specific dietary requirement for carbohydrates, but because carbohydrates are the least expensive source of energy for fish feeds, they are included in fish feeds to reduce feed costs and to provide pellet integrity and stability. Carnivorous fish, such as trout, utilize dietary carbohydrate for energy less efficiently than herbivorous and omnivorous fish such as tilapia. Dietary carbohydrate is stored as glycogen in liver and muscle, where it is readily available to meet energy demands. Some dietary carbohydrate is also converted to fat and stored in the body for energy.

Vitamins are organic compounds required in relatively small concentrations in the diet to support normal fish growth and health. Vitamins can be classified as water-soluble and fat-soluble. Water-soluble vitamins include B vitamins, choline, inositol, and ascorbic acid (vitamin C). Vitamin C is an antioxidant, and it boosts the immune system of fish. Fat-soluble vitamins include vitamins A, D, E, and K. Water-soluble vitamins are not stored in large amounts in the body. Signs of deficiency occur much sooner than with fat-soluble vitamins, which are metabolized and stored with body lipids. Vitamin deficiencies are seldom observed in commercial aquaculture production because relatively inexpensive vitamin premixes are added to the feed. Excess vitamins are added to the feed to ensure adequate nutrition and mitigate potential losses of vitamins during feed manufacture and storage.

Minerals are inorganic elements required in the diet for normal body functions. Fish require the same minerals as other vertebrates. Minerals can be classified as macro or micro, based on the quantities required in the diet and stored in the body. Fish can also absorb dissolved minerals from the water, allowing them to meet some of their metabolic requirements in case of mineral deficiencies in their diet. Common dietary macrominerals are calcium, phosphorus, magnesium, chloride, sodium, potassium, and sulfur. These minerals are involved with osmo-regulation, acid-base balance, and bone formation and integrity. Microminerals (or trace minerals) include iron, copper, chromium, cobalt, iodine, manganese, zinc, and selenium. Microminerals are required in small amounts as components in enzyme and hormone systems.

Previous work with cutthroat trout identified the lack of specific feeds as one factor limiting growth of fry and fingerlings. There is also a need to develop or identify suitable feeds (e.g., those being produced for other salmon or trout species) for production of market-sized cutthroat trout.

Feed Pellet Texture Matters

Feed characteristics such as buoyancy and texture affect feed acceptance in some fish, including cutthroat trout. There were no differences in growth rate, feed conversion ratio, feed intake, and survival when Snake River cutthroat trout were fed the same feed formulation either as floating or sinking extruded pellets. However, when fed the same formulation manufactured as a semi-moist pellet, Snake River cutthroat trout gained more weight compared to those fed sinking and floating pellets. It has yet to be determined if the benefit in weight gain by Snake River cutthroat fed semi-moist pellets is enough to justify the use of this more expensive feed, which requires special temperature-controlled storage and adds to production and transportation costs.

Cutthroat Trout Growth—Does It Match Rainbow Trout?

Empirical observations of growth rates indicate that cutthroat trout do not grow as fast as commercial stocks of rainbow trout and that there is considerable variation in growth rate among different cutthroat trout subspecies and strains.

Thermal Growth Coefficient

The thermal growth coefficient (TGC) is a growth rate formula based on a presumption of body weight as approximately equal to the cube of the fish's length ($W \sim L^3$) that incorporates time and water temperature. This formula allows for a better comparison of growth rates for salmonids than other growth rate formulas over time and between different farms because it takes into account water temperature. Experimentally, the thermal growth coefficient formula has closely followed the actual growth curves of rainbow trout, brown trout, Atlantic salmon, Chinook salmon, and lake trout. However, as with any growth-rate formula, one should be aware of the assumptions the formula is based upon and that uncritical use can lead to mistaken growth projections. The assumptions of the TGC formula are:

- growth increases in a steady and predictable manner with increasing water temperature
- growth in length (for any temperature) is constant over time
- the weight to length relationship is $W \sim L^3$

Growth does not show a steady increase with increasing water temperature, but instead shows the classic bell-shaped curve (Figure 4), where growth rates are lower with lower water temperatures, increase as water temperature approaches the growth optimum, and then decline as water temperature exceeds the optimum. A TGC calculated for a specific water temperature should not be used for growth projections over the entire range of temperatures included on the growth-temperature curve. The use of TGC to predict growth works best for water temperatures that are on the ascending curve of the growth-temperature curve. Fish growth in length is not constant under the full range of conditions over which farmed fish may be reared; however, in general, salmonid growth in length is constant between water temperatures of 5 and 15°C.

The formula for thermal growth coefficient is:

- $TGC = [(W_F^{1/3} - W_I^{1/3}) / \Sigma(t \times °C] \times 100$

where W_F and W_I are the final and initial fish weights (g), respectively; t is time in days from initial to final fish weights, and °C is water temperature degrees Celsius. Once TGC is known, growth can be predicted by the following;

- $W_F = \{W_I^{1/3} + \Sigma[(TGC/100)(°C)(days)]\}^3$

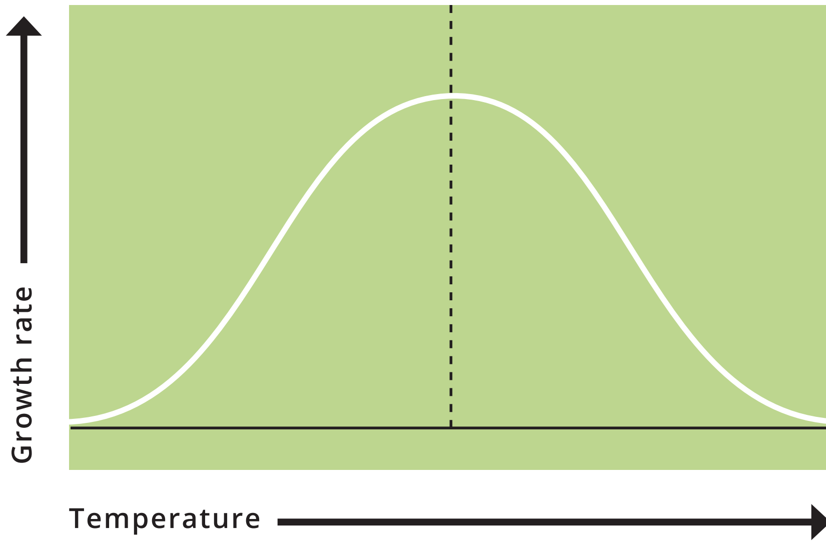

Figure 4. Classic bell-shaped growth-temperature curve.

Thermal growth coefficient values and growth rate are dependent on species, strain, nutrition, husbandry, and other factors. It is necessary to determine the specific TGC value for a given production system using previous growth and water temperature records.

Comparing Rainbow and Cutthroat Trout Performance

The mean TGC calculated for rainbow trout grown in North Carolina, Idaho, and Pennsylvania from a yield verification study conducted during 2004–2005 was 0.16 and is comparable to previously reported values of 0.15 and 0.17. In contrast, a good performing strain of Snake River cutthroat trout grown under variable water temperatures at a salmonid farm had an average TGC of 0.132. Fish grew from 33 g (13.7 fish per pound) to 359 g (1.3 fish per pound) in 251 days. Under laboratory conditions and a constant water temperature of 14°C, the same strain of Snake River cutthroat had a TGC of 0.152. This experiment was 63 days in length and the fish grew from 20 g (22.7 fish per pound) to 66 g (6.9 fish per pound). In general, smaller cutthroat trout have a higher potential for growth than larger cutthroat trout proportionate to their size. Fish growth during early rearing can be characterized as exponential (Figure 5).

Previous work with fry and fingerling cutthroat trout demonstrated that premium formulations of trout or steelhead feeds with high protein-to-lipid ratios provided the greatest growth. This is also true for Snake River cutthroat trout grown to market size (Figure 6). An on-farm demonstration trial (June 2017–March 2018) compared the performance of Snake River cutthroat trout fed either a commercial steelhead feed or an experimental feed (Table 2) based on cutthroat trout performance in laboratory experiments evaluating dietary protein to dietary lipid ratios, lysine requirement, and vitamin and mineral supplementation (Table 3). Snake River cutthroat trout fed the experimental feed grew significantly larger than fish fed commercial steelhead feed (Figure 7). The thermal growth coefficient for fish fed experimental feed was 0.137 and 0.127 for fish fed commercial steelhead feed. The experimental feed had higher levels of crude protein and lipid than the commercial steelhead feed (Table 4). Over the 251-day grow-out period, water temperatures ranged from 9.5 to 14°C (49 – 57°F).

Average weight of the Snake River cutthroat trout at harvest was 343 g (1.3 fish/lb.) and 374 g (1.2 fish/lb.) for fish fed the commercial steelhead and experimental feeds, respectively. Fish size at harvest for all fish ranged from 92 g (4.9 fish/lb.) to 699 g (0.65 fish/lb.). About 5 months after the fish were stocked, precocious males with flowing milt were observed during all subsequent sampling events. The precocious males were smaller relative to the sample population and much darker in coloration, with fewer spots. The percentage of precocious males that were sampled monthly from December 2017 through March 2018 ranged from 5.5 to 17%. The use of all-female (Figure 8) or triploid cutthroat trout may be warranted if precocious males become too numerous or interfere with production and marketing goals.

A challenge facing growers of commercial cutthroat trout for the recreational fish stocking market and for feed producers in the western U.S. is the lack of information for specific feeds for cutthroat trout. Use of regular salmonid production feeds may result in lower growth rates and higher feed conversion ratios. To improve the efficiency of cutthroat trout production, the effects of diet type (including pellet type and commercial vs. experimental feeds) and diet formulation (including lysine, digestible protein and energy, and vitamin/mineral levels) on the performance of

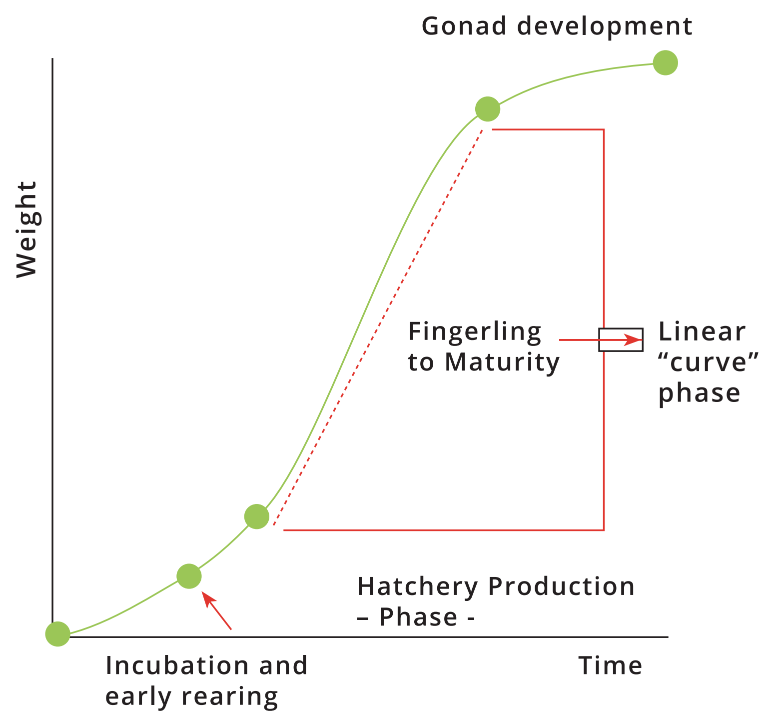

Figure 5. Sigmoid growth curve. Based on Fish Hatchery Management, Second Edition, Gary Wedemeyer, editor.

BOX 1. CALCULATING THERMAL GROWTH COEFFICIENT

This example uses data collected from a commercial farm. Snake River cutthroat trout averaged 33 g when stocked and averaged 359 g when harvested 251 days later.

Water temperatures varied over the 251 days: 58 days at 9.5°C; 33 days at 10.1°C; 34 days at 12°C; 65 days at 12.5°C; 28 days at 13.6°C and 33 days at 14°C.

$\mathrm{TGC} = (359\ \mathrm{g}^{1/3} - 33\ \mathrm{g}^{1/3}) \div [(58\times9.5)+(33\times10.1)+(34\times12)+(65\times12.5)+(28\times13.6)+(33\times14)] \times 100 = 0.132$

Photo credit: Gary Fornshell

Figure 6. Market-size Snake River cutthroat trout.

juvenile cutthroat trout under laboratory and production conditions were evaluated. In summary:

- Empirical observations of cutthroat trout growth rates indicate that cutthroat trout do not grow as fast as commercial stocks of rainbow trout.
- Previous research and this study indicate Snake River cutthroat grow much faster than Yellowstone and Westslope strains, and there are growth differences amongst Snake River cutthroat trout strains. Growers should carefully select the strains of cutthroat trout to optimize performance.
- When fed the same formulation, cutthroat trout perform equally well on floating or sinking pelleted feeds.
- Cutthroat trout growth rates are highest and feed conversion ratios lowest when the trout are fed feeds with high protein-to-lipid ratios. Cutthroat fed commercial salmonid feeds such as premium trout and steelhead feeds performed well. The experimental feed formulation (Tables 2 and 3) is an open-formula.
- Given the limited supply of cutthroat trout relative to the more common rainbow trout, and their coloration, cutthroat trout, when viewed as a "boutique species", are potentially more valuable for the recreational stocking market than rainbow trout.

Table 2. Experimental cutthroat trout feed formulation (as-fed basis).

INGREDIENTS (%)	TEST DIET
Fish meal, sardine	32.00
Poultry byproduct meal, hi-pro	12.00
Blood meal spray dried	3.00
Squid meal	2.00
Corn protein concentrate, 75% CP	6.70
Soy protein concentrate, Profine VF	3.37
Soybean meal, dehulled and solvent extracted	2.00
Wheat gluten meal	1.25
Wheat flour	23.00
DL-methionine	0.29
L-Lysine HCl	0.67
Dicalcium phosphate	0.30
Trace mineral mix, Trout Nutrition	0.10
Vitamin Premix, ARS 702	1.00
Choline chloride (60%)	0.60
Stay C (Vitamin C, 35%)	0.20
Fish oil	11.52
Total	100.00

Table 3. Calculated constituent values of experimental feed formulation.

	CALCULATED VALUES		CALCULATED VALUES
Dry Matter (%)	92.12	Valine (%)	2.32
Protein (%)	45.33	Taurine (%)	0.24
Fat (%)	16.52	Calcium (%)	2.03
Crude fiber (%)	0.95	Phosphorus (%)	1.35
Ash (%)	8.90	Sodium (%)	0.16
Gross energy (kcal/kg)	4843	Chlorine (%)	0.16
Digestible protein (%)	**39.80**	Potassium (%)	0.37
Digestible energy (kcal/kg)	**4080**	Magnesium (%)	0.09
Arginine (%)	2.56	Sulfur (%)	0.33
Histidine (%)	1.19	Copper (mg/kg)	11.60
Isoleucine (%)	1.80	Iron (mg/kg)	219
Leucine (%)	3.82	Manganese (mg/kg)	19.85
Lysine (%)	**3.40**	Selenium (mg/kg)	0.78
Methionine (%)	**1.28**	Zinc (mg/kg)	100
Cystine (%)	0.55	**Digestible phosphorus (%)**	**0.70**
Phenylalanine (%)	2.03	Sum n3 (%)	2.75
Tyrosine (%)	1.30	Sum n3 LC- PUFA (%)	2.40
Threonine (%)	**1.69**	Sum n6 (%)	0.35
Tryptophan (%)	0.48		

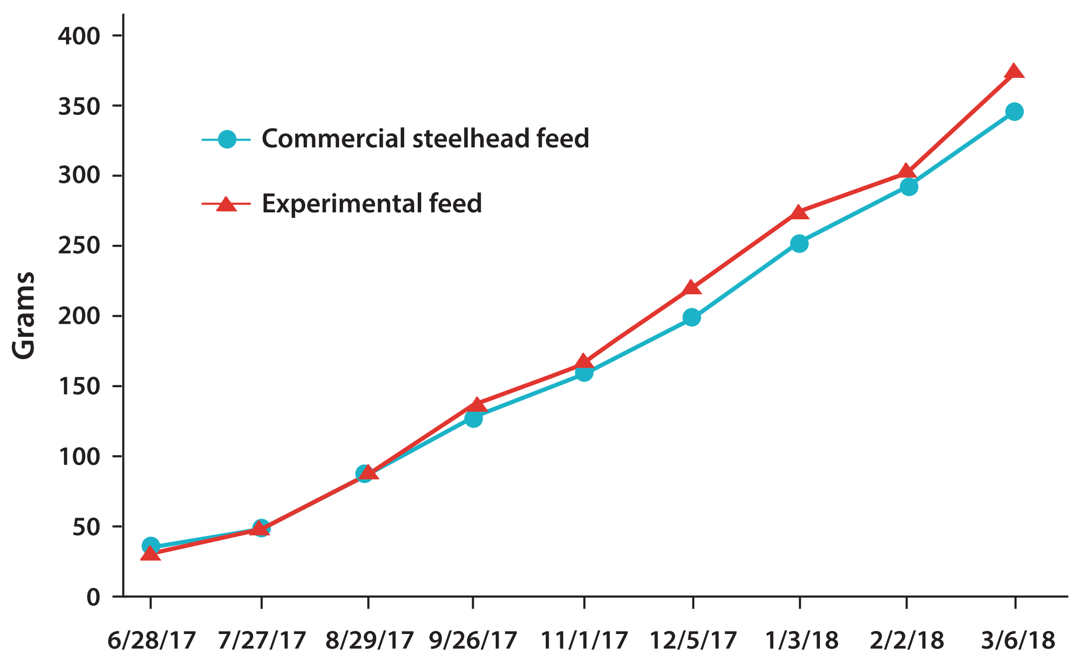

Figure 7. Growth of Snake River cutthroat trout under production conditions fed two diets. Data points indicate sampling dates.

Table 4. Proximate composition of the diets.

PERCENT WET WEIGHT	EXPERIMENTAL	COMMERCIAL STEELHEAD
Moisture	3.9	8.0
Crude Protein	49.4	46.4
Crude Fat	17.3	14.7
Ash	9.6	6.6
Gross Energy (MJ/kg)	22.0	21.5

Photo credit: Gary Fornshell

Figure 8. Female Snake River cutthroat trout.

Suggested Readings

Deisenroth, DB, CA Bond and JB Loomis. 2012. The economic contribution of the private, recreation-based aquaculture industry in the Western United States. Aquaculture Economics & Management. 16 (1):1–21.

Fornshell, G and C Myrick. 2014. Early rearing of cutthroat trout. Western Regional Aquaculture Center Publication, University of Washington, Seattle, Washington.

Gatlin, DM, III. Principles of fish nutrition. Southern Regional Aquaculture Center publication 5003, July 2010.

Ham, BR, CA Myrick, FT Barrows, CJ Yeoman, GC Duff, MG Maskill, and WM Sealey. 2015. Feed characteristics alter growth efficiency of cutthroat trout. Journal of Fish and Wildlife Management. 6(1):83–91.

Owens, CE, WM Sealey, ZB Conley, G Fornshell, and CA Myrick. 2017. Evaluating dietary impacts of commercial-type diets on the growth of Snake River cutthroat trout (*Oncorhynchus clarkii behnkei*). Aquaculture 480:77–82.

Piper, RG and coauthors. 1982. Fish hatchery management, 1st edition. U.S. Fish and Wildlife Service, Washington, DC, USA.

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To learn more about WRAC, go to the website at depts.washington.edu/wracuw.

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