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Trout Production

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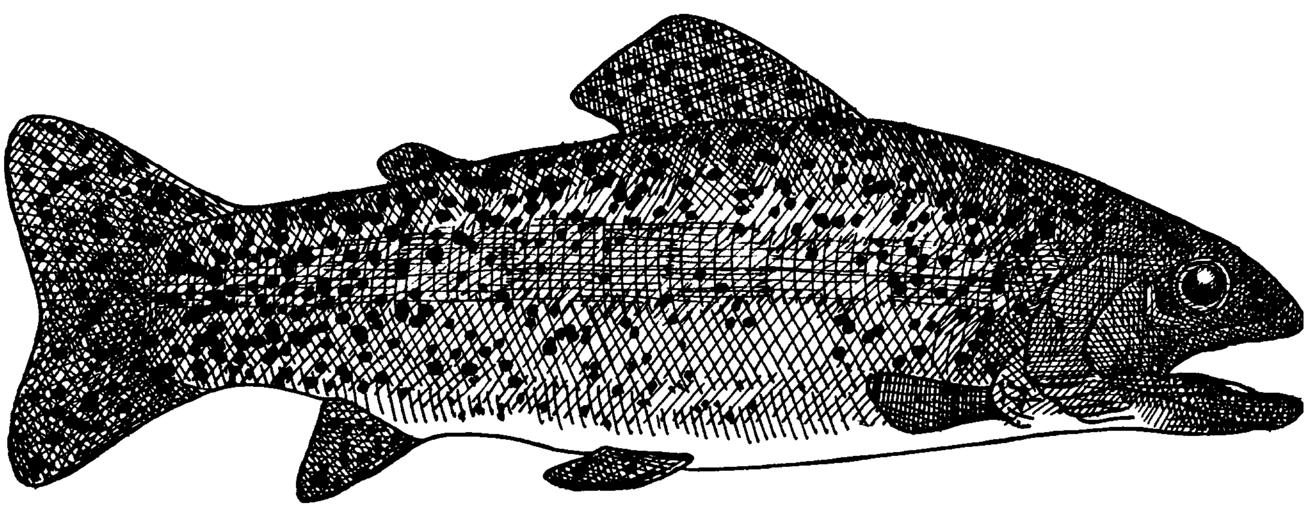

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Trout Production

Trout Farming is the oldest form of commercial fish production in the United States. Trout farming dates back over 400 years in Europe and about 150 years in the United States.

Trout are farmed both for food fish and for stocking recreational fisheries. Rainbow trout *(Oncorhynchus mykiss),* is the most commonly raised species. Brown trout *(Salmo trutta),* and brook trout *(Salvelinus fontinalis),* are also farmed. There are several subspecies and strains of each species. For example, Shasta and Kamloops refer to domestic strains of rainbow trout. Rainbow trout were originally native to North American rivers draining into the Pacific ocean.

Due to their popularity as a sportfish and as a food fish, trout have been widely distributed and are now cultured in waters around the world. The brown trout is a native of European waters. Like the rainbow trout, it has also been widely distributed. Brown trout were first brought to the United States over 100 years ago and are now present throughout North America. Brook trout originally are native to an area that extends from the northeastern coast of North America west to the Great Lakes and south along the Appalachian mountains as far as northern Georgia. There are migratory races of both rainbow trout and brown trout which spawn in freshwater and migrate in the same manner as salmon.

Trout are generally cultured in raceways or ponds supplied with flowing water. However, some are produced in pens, nets and recirculating systems.

CURRENT STATUS

According to USDA's annual survey of trout producers, total sales of trout for 1992 were about $67.0 million (food-size fish, $53.0 million: stockers (6 to 12 inches in length), $6.7 million: fingerlings, $1.4 million and eggs, $5.8 million). While Idaho grows over 70 percent of the total trout production annually, trout farming operations exist throughout the United States (Table 1).

Trout eggs are typically produced on broodfish farms. Trout egg production for the United States is primarily concentrated in the western region (Table 2).

Table 1.1992 Trout Production: Number of Operations and Total Pounds from U.S. Farms.'+

State	Number of Operations	Food-Size	Stockers	Fingerlings
California	23	2.270	266	20
Colorado	33	310	695	23
Idaho	30	41,500	----	
Michigan	54	600	200	61
Missouri	14	578	160	
New York	37	106	89	7
North Carolina	68	3,874	154	7
Oregon	26	400	33	3
Pennsylvania	45	2,470	432	12
Tennessee	13	316	29	
Virginia	26	969	81	12
Washington	32	222	118	15
Wisconsin	48	374	199	6
Other	12[1]	2,255[1]	829[2]	127[3]
Total	461	56,264	3.285	293

[1] Other includes GA and UT
[2] Other includes GA. UT. and ID
[3] Other includes GA, ID. MO. TN. and UT

*Source: Aquaculture Situation and Outlook. Commodity Economics Division. Economic Research Service. U.S. Department of Agriculture. March 1993. AQUA- 10

Table 2. Trout Egg Sales for 1992 by Region.*

Region	Number (1,000's)	$ Value (1,000's)
Northeast	573	7
Central	339	5
West	452.187	8,817
Total	453.099	5,829

*Regions are as follows: North East- PA and NY
Central-MI. WI, GA. MO. NC. TN. VA
West-CO. ID. UT, WA

*Source: Aquaculture Situation and Outlook. Commodity Economic\ Division. Economic Research Service. U.S. Department of Agriculture. March 1993, AQUA-IO

Trout production in the United States has remained relatively constant over the past few years. However. from 1990 to 1992, the number of trout production operations grew in Colorado. Idaho, Michigan, Missouri, Pennsylvania, Tennessee and New York.

LIFE HISTORY

Trout belong to the group of fishes known as Salmonids. Salmonids are cold water fishes, and species cultured include Atlantic Salmon *(Salmo*

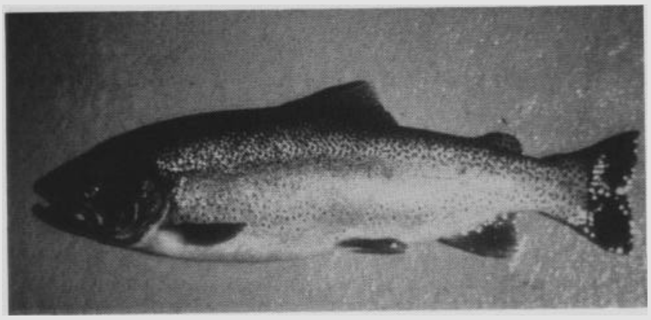

Figure 1. Rainbow Trout

salar), pacific salmon ***(Oncorhynchus spp.),*** rainbow trout, brown trout and brook trout. Salmonids are characterized by the presence of a small, fatty adipose fin on the back between the dorsal fin and tail.

The typical coloration of rainbow trout is blue to olive green above the lateral line, a pink band along the lateral line and silver below the lateral line. The back, sides, head and fins are generally covered with small black spots. Brown trout are generally some shade of brown on the back and side, fading to yellow on the belly. Spots are large and dark (brown or black). Spots are normally surrounded by pale halos. Brook trout are best identified by the heavy vermiculations (wavy or winding lines) on the back. Background color can be anywhere from light blue to dark green. Lighter spots (red and yellow) cover the body, the red spots being surrounded by pale halos. (See Figure 1.) Table 3 gives ranges of temperature for survival, optimum growth and spawning of trout.

Table 3. Ranges of Temperature for Survival, Otimum Growth and Spawning of Trout.*

Species	Survival (°F)	Optimum Spawning (°F)	Optimum Growth (°F)
Rainbow trout	33-78°	50-60°	50-55°
Brook trout	33-72°	45-55°	45-55°
Brown trout	33-78°	48-60°	48-55°

*Source: Fish Hatchery Management, 1982. R.G. Piper, I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler and J.R. Leanard. United States Department of Interior, U.S.F.W., Washington, D.C.

Wild rainbow trout generally spawn from January to May and wild brown and brook trout from October to January. However, considerable variation in spawning season results from climatic and genetic differences. Through many generations of selective breeding, hatchery strains of trout have been developed that spawn throughout the year. This means that dependable year-round supplies of trout eggs are available.

In nature, trout spawn in cold, well oxygenated streams with gravel bottoms (areas typically associated with the headwaters of river systems). Wild trout sexually mature at three years (two years for domestic brood stock). The act of natural spawning often begins with an upstream migration of anywhere from a few hundred feet to over a thousand miles. Once trout arrive at their spawning grounds, females begin digging circular beds in the gravel bottom. During the process, the female will select a mate. The male will then begin guarding the bed and defending the female against other males. At the time of spawning, the female positions her vent at the bottom of the bed and the male darts along side her. The female releases her eggs and simultaneously the male, whose vent is in close proximity to that of the female, releases his milt into the bed. After the milt releases, the sperm must fertilize eggs within less than one minute, or the sperm becomes inactive.

Immediately following spawning, the female sweeps gravel into the bed to cover the eggs. The time required for the eggs to hatch depends mainly on water temperature (Table 4.)

Table 4. Number of Days Required for Trout Eggs to Hatch and the Number of Eggs Produced Per Pound of Female Bodywight.*

		WATER TEMPERATURE					
Species	**Weight**	**35°F**	**40°F**	**45°F**	**50°F**	**55°F**	**60°F**
Rainbow	1000	*	80	48	31	24	19
Brown	1000	156	100	64	41	*	*
Brook	1200	144	103	68	44	35	*

*Source: Trout and Salmon Culture, 1980. E. Leitritz and R.C. Lewis. Division of Agricultural Sciences. University of California.

SITE SELECTION AND DEVELOPMENT

A major factor in determining the chance of success for any aquaculture endeavor is location. The basic characteristics of salmonids outlined in the section on life history indicate that specific criteria must be met by a potential site for commercial trout production. A trout farm must have a dependable year-round supply of high quality water. For this reason, a thorough study of the water supply is the first step in assessing the potential of any site production. A small trout farm capable of producing up to 100,000 pounds of trout per year will require a continuous water flow of at least 500 gallons per minute. The quality of the water, and the topography of the site will be important in determining actual production levels. Table 5 contains some basic water quality criteria for trout hatch ery water supplies.

Figure 2. Production Raceways

Ground water is an excellent source of water for trout production in areas where it is shallow enough to make pumping economical or where artisan wells occur. Some ground water sources are low in dissolved oxygen and high in hydrogen sulfide and will require aeration before use. Well water can also be supersaturated with dissolved nitrogen which can cause a condition known as gas-bubble disease in fish. This disease results from small gas bubbles forming in the blood of the fish and blocking normal circulation. Aeration will also remove supersaturated nitrogen from water.

In areas where ground water is not available, stream water can be used for trout production. However, temperature and flow fluctuation must be taken into account when estimating production capacity.

The type of production units (concrete raceways versus earthen ponds) and the number of water reuses possible will vary based on the specific characteristics of a site. For example, in areas where water pH is low (6.5 to 7.0), it is possible to reuse water six or more times before unionized ammonia reaches toxic levels. However, in alkaline water where pH values are 8.0 or above, only limited water reuse may be possible. Obviously, land slope is also important in determining the number of raceways or ponds that can be built in series to allow gravity flow from upper ponds to the ones below. (See Figure 2.) A minimum fall of 18 inches is recommended between raceways to provide aeration of water. The greater the fall between units, the more dissolved oxygen available for subsequent water uses.

Trout production units are typically 6 to 10 feet wide, 35 to 100 feet long and 3 to 4 feet deep. The actual dimensions of a facility will depend on available water flow and topography. Where possible, tank construction in pairs with a shared center wall will greatly reduce construction costs.

In planning and developing a trout farm, it is important to consider all local, state and federal laws which may apply to the use of a water source or to water discharge.

Table 5. Water Quality Criteria for Trout Hatchery Water Supplies.

Parameter	Desirable Level
Dissolved oxygen	near saturation
Carbon dioxide	< 2.0 ppm
Temperature	45-65°F
pH	6.5-8.5
Total Alkalinity (as $CaCO_3$)	10-400 ppm
Manganese	<0.01 ppm
Iron	<1.0 ppm
Zinc	<0.05 ppm
copper	<.006 ppm in soft water <0.3 ppm in hard water

PRODUCTION METHODS

Hatchery Production

Hatchery production of trout eggs requires a high degree of skill and is very labor intensive. Egg production requires the maintenance of an adequate number of good quality broodfish at low stocking densities.

SPAWNING

Artificial spawning of trout requires sorting brood fish and selecting only fully mature (ripe) females. Broodfish are normally starved for three or four days prior to stripping. This prevents fecal contamination during fertilization. The eggs of ripe females will flow freely from the vent under gentle pressure. Ripe females should always be held tail down with the head high. This permits the eggs to flow down the oviduct toward the vent.

The use of anesthetics during stripping can simplify handling and minimize stress to broodstock. Stripping of eggs requires two people. One person firmly holds the fish near the head with one hand and just in front of the tail with the other (head up). The fish is held with the belly downward over a collection pan. A towel will help in handling wet, slippery fish. The second person gently dries the belly of the female and then begins to stroke the belly, starting near the pelvic fins and moving back toward the vent. An alternate method of egg removal is air spawning. A rubber hose is used to connect a large diameter hypodermic needle to a low pressure (2 psi) air compressor. The needle is inserted about ½ inch into the body cavity of the female near the pelvic fins. The low

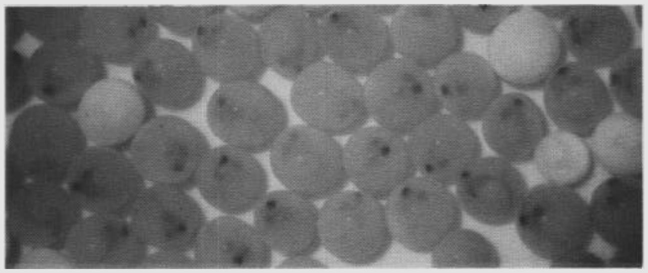

Figure 3. **Eyed Stage-Trout Eggs**

pressure air pushes the ripe eggs out the vent. After stripping, the air must be removed from the body cavity by gently massaging the sides of the fish. Air spawning is reported to be less stressful to broodfish and produces cleaner, healthier eggs.

Once the eggs are collected, milt is added to the bowl. Males are stripped in much the same way as females. Again, the belly of the fish is first dried, placed over the bowl containing eggs or over another container and stroked gently from front to back. Eggs from more than one female can be collected in one container, and more than one male should always be used to insure good fertilization. The eggs and milt are mixed thoroughly, and water is added to activate the sperm. As soon as water is added, the eggs begin to absorb it, swell and become firm. This process generally takes about 20 minutes and is known as water hardening. Eggs increase in size about 20 percent during this process.

Water hardened eggs can be transported for a period of up to 48 hours after fertilization. After the initial 48-hour period, eggs should not be moved until they reach the eyed stage (the eyes become visible through the egg shell.) (See Figure 3). Trout eggs are usually shipped during the eyed stage. Trout eggs must be shielded from direct light during all stages of development.

EGG INCUBATION

Three types of egg incubation systems are commonly used: hatching troughs, vertical flow incubators and hatching jars.

A hatching trough is a horizontal channel with water being piped in at one end and drained out at the other. Wire baskets or screened trays (California trays) are suspended within the trough. A partition is placed between each tray or basket which forces water to flow up through the eggs from below before spilling over into the next compartment.

Vertical flow incubator systems involve stacking 8 to 16 trays on top of each other in specially designed racks. Water is introduced at one end of the top tray and flows up through the screen bottom, circulating through the eggs. The water then spills over into the tray below and is aerated as it drops.

Hatching jars are available commercially or can be constructed from PVC pipe, five gallon plastic buckets or other materials. The jars are cylindrical and water flows in through a hose or tube at the bottom, upwells through the eggs and spills over the top. The water movement suspends and gently rolls the eggs in the circulating water.

Trout eggs should be placed in baskets or trays no more than two layers deep in order to allow adequate water circulation. Flow rates for vertical or horizontal tray incubators are 4 to 6 gallons per minute (gpm). Hatching jars should contain no more than $^2/_3$ of the total volume in eggs. The flow rate for each jar should be adjusted so that eggs are lifted to 50 percent of the standing depth of eggs when flow is shut off. For example, if a hatching jar is filled with eggs to a depth of 10 inches when the water flow is shut off, the flow rate should be adjusted so that eggs upwell to a depth of 15 inches with water on.

Buying Trout Eggs

Most trout farmers buy eggs rather than producing their own. Trout eggs should be purchased from a supplier whose hatchery is “certified disease free.” Suppliers should disinfect eggs before shipping, but they should be treated again upon arrival. Trout eggs will arrive packed in boxes designed to keep them moist and cool. Eggs should be tempered gradually to the temperature of the hatchery. This is done by transferring eggs to a clean container and adding small amounts of clean hatchery water over a period of 30 minutes to 1 hour. The eggs should be gently stirred a few times during the process to ensure adequate water circulation. Egg shipping containers should be discarded or destroyed to prevent possible contamination of the hatchery with disease causing organisms.

Disinfectants used for treating eyed trout eggs contain iodine. Various brand names and concentrations are available. Treatment should be at a rate of 100 parts per million (ppm) of free iodine for 10 minutes. Label concentrations of iodine are often given as a percent active ingredient.

In soft or acid waters (alkalinity below 30 ppm) egg mortality can result from pH reduction by iodine treatment. Baking soda (sodium bicarbonate) should be added as a buffer at a rate of 20 grams (0.7 ounces) per 10 gallons of water. Eggs and disinfecting solution should be mixed together gently to assure thorough coverage. After 10 minutes pour off the disinfectant and rinse eggs in fresh hatchery water to remove residual iodine before transferring eggs to incubators.

Fungus will grow rapidly on dead trout eggs and can spread to live eggs. During the incubation process. dead eggs should be removed regularly. If fungus becomes so widespread that siphoning off dead eggs becomes too time consuming, formalin can be used. Formalin is added to the water flowing into incubators at a rate of 1 part formalin to 600 parts water for a duration of 1.5 minutes daily. This translates to 95 ml. (3.2 fluid ounces formalin for every gpm of water flow). Do not treat trout eggs with formalin within 24 hours of hatching or high mortalities will likely occur.

Fry Rearing

The number of days required for eggs to hatch depends on water temperature (Table 4). Once hatching begins, eggs and fry should not be treated with any chemicals. Empty egg shells should be removed from incubation units regularly. All eggs in a batch will usually complete hatching within three to four days. Trout emerge from eggs with a reserve of food in a yolk sac. At this stage, they are referred to as sac fry and will continue to feed on their yolks for 2 to 4 weeks, depending on water temperature. If trout eggs were incubated in containers other than rearing troughs, sac fry should be transferred to troughs shortly after hatching is complete. Dead and deformed fry should be removed daily. Troughs for fry rearing are typically 12 to 16 feet long, 12 to 18 inches wide and 9 to 12 inches deep. Fry should be stocked at a rate of 1,000 to 2,000 fry per square foot of trough surface area. The actual stocking density for a system will depend on the flow rate and water temperature. Typically, 10 to 1.5 gpm flow is used for fry trough systems. The water level in the fry trough should be kept quite shallow (3 to 4 inches) until the fry begin to "swim up." Troughs should be screened at the upper end to remove debris from inflow and must be screened at the lower end to prevent fry from being flushed out. "Swim up" refers to the stage when fry have absorbed most of their yolk sac and begin actively searching for food.

When about half of the fry reach the "swim up" stage, begin feeding. Fry feeds should contain 48-50 percent crude protein and 12-5 percent fat. Introduce a small amount of starter granules on the surface three or four times daily at first. When most of the fry are actively feeding, feed should be applied more often (every 15 minutes if possible, but at least hourly). Automatic feeders make frequent feeding of fry much easier. For the first two to three weeks, it is best to feed fry "by eye." In other words, apply enough feed so that all fish have food available to them, but do not overfeed to the point where an abundance of uneaten feed accumulates in the troughs. When fry reach about M-inch length (about 2,500 fry/pound), begin feeding based on published feeding charts (Table 6). Feeding charts are based on fish size and water temperature. Uneaten feed should be either swept out through the screen or siphoned off at least daily, because decomposing feed will consume dissolved oxygen and produce ammonia, which is toxic to fish.

Table 6. Recommended Feeding Rates for Small Trout as Percent Body Weight. Numbers represent total feed/day (divided evenly among the number of feedings/day).*

	Number of Fish per Pound				
	2500+	2500-800	800-300	300-100	100-30
Water Temp.	Approximate Length (inches)				
(°F)	%-I	l-1.5	1.5-2	2-3	3-4
* 55	6.1	5.2	5.1	4.2	3.2
60	7.5	6.3	6.1	5.1	3.9
65	9.0	1.5	1.2	6.1	4.9
Feed Sizes	Starter granule	No. 1 granule	No. 2 granule	No. 3 granule	No. 4 granule
No. Feedings/ day	8	8	6	4	3

*Source: Trout and Salmon Culture, 1980. E. Leitritz and R.C. Lewis. Division of Agricultural Sciences. University of California.

When all fry in a trough have been actively feeding for two weeks, begin taking a sample count every week in order to adjust feeding rate, feeding frequency and feed size (Table 9). If fry are being fed properly, grading is not necessary; but fry may need to be "thinned out" as they grow in order to prevent overcrowding. Spread feed over the upper $^2/_3$ of the water surface area so that all fry have a chance to obtain sufficient food. If dissolved oxygen levels fall below 6 ppm at the lower end of a trough, reduce the weight of fish in the trough.

When fry reach 200 to 250 per pound (about 2 inches), they are ready for transfer to larger, deeper fingerling tanks. Tanks for fingerling growout are constructed of a variety of materials (fiberglass, aluminum, concrete blocks, etc.) and are either circular or rectangular.

FOOD FISH PRODUCTION

Fish are generally held and fed in fingerling tanks until they reach about 3 inches in length (about 100 fish per pound.) At this time fish are moved to outdoor raceways or earthen ponds for final growout.

The maximum amount of fish that can be held in a rearing unit (tank, raceway or pond) is referred to as carrying capacity. The actual carrying capacity of a culture unit depends on water flow rate, water volume, water temperature, dissolved oxygen concentration, pH and fish size. Carrying capacity is expressed in terms of weight of fish per unit water volume (pounds fish per cubic foot or pounds fish per gallon) or in terms of weight of fish per unit water flow (pounds fish per gpm or pounds fish per cubic foot per second (cfs)).

A common method for estimating maximum carrying capacity in a tank or raceway is the Density Index (D). The Density Index is a factor which, when multiplied by rearing unit volume in cubic feet (V) and by fish length in inches (L) will give the maximum allowable weight of fish (W):

$$W = D \times V \times L$$

As a rule of thumb, D for trout should be from 0.4 to 1. In other words, fish densities (pounds of fish per cubic foot of tank space) should be no greater than 0.5 to 1 times their length in inches (Table 7). For example, if a D factor of 0.5 is used, 2-inch fish could be held at a density of 1 pound per cubic foot (0.5 x 2). If a D factor of 1 is used, 2-inch fish could be held at a density of 2 pounds per cubic foot (1x2).

Table 7. Maximum Density (pounds per cubic feet) of Trout of Various Lengths Based on Density Index (D) Factors of 0.5, 0.75, and 1.0 That Can be Held in a Given Rearing unit.

D factor	Fish length (inches)				
	2	4	6	8	12
0.50	1.0	2.0	3.0	4.0	6.0
0.75	1.5	3.0	4.5	6.0	9.0
1.00	2.0	4.0	6.0	8.0	12.0

While the D is useful in estimating carrying capacity, it considers only space (pounds of fish per unit volume). Another very important consideration in establishing carrying capacity is flow rate. The flow rate determines how rapidly fresh water will replace "used" water (water in which fish have reduced dissolved oxygen concentrations and excreted waste products).

The Flow Index (F) takes flow rate into consideration when estimating maximum allowable weight of fish that a culture unit can hold:

$$W = F \times L \times I$$

Where W = maximum allowable weight of fish (pounds)

F= Flow Index
L= Length of fish in inches
I= Water inflow (gallons per minute)

As a rule of thumb, F values for trout raceways range from 0.5 to 1.5. Actual F values will depend on several factors, especially the dissolved oxygen concentration of the inflowing water. To estimate the Flow Index for a specific culture unit, fish are added while water flow is held constant. When enough fish have been placed in the system so that the dissolved oxygen level of the outflowing water has been reduced below 6 ppm, the unit is at maximum. F will then be equal to this value in pounds divided by the average fish length in inches times flow rate in gpm:

$$F = \frac{W}{L \times I}$$

Once the F value has been established for a culture system, the previous equation can be used to determine carrying capacity for various flow rates and various sizes of fish.

Example: 600 pounds of 4-inch trout held in a raceway with a flow rate of 150 gpm cause the dissolved oxygen concentration of the outflow to decline below 6.0 ppm. Calculate the F and use it to determine (a) how many pounds of 6-inch fish can be held and (b) what (I) would be required in order to hold 400 pounds of 4-inch trout.

Solution: The Flow Index is calculated using the equation given above:

$$F = \frac{W}{L \times I} - \frac{\mathbf{600}}{4 \times 150} = 1.0$$

(a) We can determine carrying capacity (W) for the system using 6-inch fish:

$$W = F \times L \times I = 1.0 \times 6 \times 150 = 900 \text{ pounds}$$

(b) Next we can determine water flow rate (I) needed to hold 600 pounds of 4-inch fish:

$$I = \frac{W}{F \times L} = \frac{400}{1.0 \times 4} = 100 \text{ gpm}$$

It is important to remember that the Flow Index concept operates on the assumption that inflowing water is saturated with dissolved oxygen. If the inflowing water is below saturation, carrying capacity will be reduced proportionally. When trout production facilities are designed for optimal use of space and water flow, Flow Index and Density Index values for a unit should be quite similar.

Overloading trout production units can result in decreased dissolved oxygen and increased ammonia levels. These conditions can reduce growth rates and stress fish. The loading rates for culture units and the number of water uses possible for raceway systems will be set based on the allowable levels for these two water quality parameters. Dissolved oxygen levels should not be allowed to drop below 4 ppm. Dissolved oxygen levels should be monitored regularly. The quickest method of making these measurements is with a dissolved oxygen meter. Smaller farms may use an oxygen test kit which is less expensive but much more time consuming than a meter. Ammonia occurs in two forms in water, ionized and unionized. The ionized form (NH_4^+) is much less toxic. The relative proportion of the two forms de-pends on the pH of the water. At relatively low pH (6.5 to 7.0), most of the ammonia present will be in the ionized (nontoxic) form. A more alkaline pH (>7.5) means that most of the ammonia present will be in the unionized (toxic) form. Total ammonia concentrations can easily be measured using a water quality test kit. However, the percent of the total present in the toxic form will depend on the pH (Table 8).

Continuous exposure to unionized ammonia (NH_3) concentration above 0.03 ppm can reduce growth rates. The more times water is reused, the more likely it is that this level will be exceeded. The number of water uses possible in multiple-pass systems varies from 3 to 10 times or more.

Table 8. Percent of Total Ammonia in the Unionized (NH_3) Form in Freshwater at Varying pH and Water Temperatures.

	TEMPERATURE		
pH	60°F	50°F	68°F
7.0	0.19	0.27	0.4
7.5	0.59	0.85	1.24
8.0	1.83	2.65	3.83
8.5	5.55	7.98	11.18

Grading and Inventory

From the time fingerlings are stocked in raceways (about 3 inches) until they reach marketable size (12 to 16 inches), they must be graded periodically. Grading allows fish to be sorted into similar size groups and improves feeding efficiency. Trout are typically graded four times during a production cycle, but this will vary depending on the specific conditions of each culture unit. Some farmers grade when the length of the shortest fish in a tank is less than 50 percent of the length of the longest fish.

Graders consist of a rectangular frame with evenly spaced bars (aluminum tubing, PVC pipe or wooden dowels) across it. The grader should be as long as the raceway is wide, and slightly taller than the water is deep. The grader is placed in the inflow end of the raceway and moved toward the outflow end. This crowds the larger fish in the outflow end so they can be removed and stocked in another raceway with fish of similar size. Fish should be graded whenever the loading rate for a culture unit is approached and density needs to be reduced.

Keeping track of the quantity and size of fish in each culture unit on a farm is important because it allows a farmer to estimate growth rates, feed conversions, production costs and how near each unit is to carrying capacity. Sampling should be done at least once, and preferably twice, per month. In sampling raceways, fish are generally crowded starting at a distance from the outflow equal to one-third the total length of the tank and moving toward the inflow. This is done to avoid sampling the smaller, weaker fish which tend to school near the outflow. When the fish are concentrated near the inflow end of the tank, a sample is taken with a dip net and either weighed in the net or transferred to a bucket of water (of known weight) and weighed. As the fish are poured back into the raceway they are counted and the weights and counts recorded. Three or four samples of at least 40 fish each should be taken from different areas of each tank.

Dividing the number of fish in each sample by the weight of the sample will give fish size expressed as number of fish per pound. This value can then be multiplied by the original number of fish stocked in the raceway, less any mortalities, to give the total weight of fish in a unit. Table 9 shows the relationship between weights and lengths for rainbow trout of various sizes. It is important to remember that these numbers are averages and the actual relationship between length and weight will vary depending on the condition of the fish.

Table 9. Length - Weight Relationships for Trout.*

Length (inches)	No./pounds	weight/l ,000 fish (pounds)
3	98.0	10.2
4	39.8	25.5
5	19.8	50.4
6	11.2	X9.2
7	6.9	144.9
8	4.5	222.2
9	3.1	322.1
10	2.2	454.6
11	1.6	625.1
12	1.2	833.3

*These numbers are averages

It is more difficult to keep track of fish quantity and size of fish in earthen ponds. Some farmers use earthen ponds only to grow out stockers (4 fish/pound) to marketable size with no grading. Other farmers sample count fish in earthen ponds by throwing a few handfuls of feed into ponds and throwing a cast net over the feeding fish. Fish are then weighed, usually in the net, and counted back into the pond. This method typically yields biased results since the larger, more aggressive fish will come to feed first.

Feeding Practices

The cost of feed is the major variable cost in producing trout. Growout diets for trout should contain about 40 percent protein and 10 percent fat. Several brands of high quality trout feed are available commercially. While the obvious goal in feeding is to get fish to marketable size as quickly as possible, feeding efficiency is critical in determining overall farm profits. Efficient feeding means always giving fish slightly less than the maximum amount they will eat. This will result in an optimum rate of fish growth, uniform fish size and maintenance of good water quality.

The best guide to determining the correct size and amount of feed needed is a published feeding chart provided by feed manufacturers. Using this chart as a reference, a farmer should adjust actual feeding rates based on specific conditions on the farm. Feeding charts give the approximate amount of feed (pounds of feed per 100 pounds of fish or as a percentage of the total weight of fish) for a specific size fish at a specific water temperature.

Once fish are stocked in raceways or earthen ponds, hand-feeding alone is usually not practical, except when administering medicated feed to sick fish. Trout should be fed seven days per week under normal circumstances. A variety of automatic feeders are available, including electric, water and solar powered units. These feeders deliver feed at preset intervals. Feed wagons are also available which use a blower to deliver a large amount of feed as they are pulled around the farm by a truck or tractor.

Many farms use demand feeders for the majority of feeding. (See Figure 4). A demand feeder consists of a conical hopper with a small opening at the bottom. The small opening is covered by a movable disc attached to a rod which extends into the water. The lower end of the rod acts as a trigger, and trout learn that striking the target causes feed to fall from the hopper. Demand feeders reduce labor costs and allow feeding activity to be spread over several hours. This helps to insure efficient feed utilization and prevents the rapid decline in dissolved oxygen and rise in ammonia which can occur when a large quantity of feed is applied at once. Demand feeders must be adjusted periodically to prevent overfeeding. It is recommended that some feed be applied by hand each day so that overall fish behavior can be observed. This can be done when checking or loading demand feeders. Since demand feeders can hold enough feed for several days, careful records should be kept so that the amount of feed going to each culture unit is known. In loading demand feeders, remember that trout can eat more than they can metabolize. Therefore, it is important to add feed based on the amount of feed trout should be eating daily based on fish size, water temperature and personal experience. Just filling the feeders when they are empty can result in poor feed conversion ratios.

Sampling records are used to adjust feeding rates and check feed conversion rates. Feed conversion rates for trout are generally between 1.2 and 2.0 pounds of food per pound of weight gain. Remember to include daily weight gain when calculating daily

Figure 4. Demand Feeder

feeding rates.

Because trout are cold-blooded animals, their metabolic rate depends on water temperature. The minimum temperature for growth in trout is about 38°F. At or below this temperature, only a maintenance feeding level is needed (0.5 to 1.8 percent body weight per day, depending on fish size.) At these water temperatures, no feed for a day or two will not harm fish. Optimum growth for trout occurs between 55° to 65°F. When water temperature exceeds 65°F, feeding time, feeding frequency and amount of food per feeding should be adjusted based on dissolved oxygen levels. At water temperatures above 68°F, a trout's digestive system becomes inefficient and much of the nutrient content of the feed ends up as waste in the water.

Certain markets for trout require diet modifications to produce salmon-colored flesh. Carotenoid pigments (canthaxanthin) added to feed impart a pink or red coloration to flesh when used for 3 to 6 months (depending on water temperature) before harvest.

In order to minimize stress, fish should not be fed for a period prior to handling or transport. For routine handling, such as grading, 24 hours without food is sufficient. For long distance transport or processing, feed should be withheld for 3-4 days.

FISH HEALTH

Diseases can be divided into two categories; noninfectious and infectious. Noninfectious diseases include nutritional disorders, contaminant exposure (pesticides or heavy metals) and exposure to toxic metabolites (ammonia and nitrite.) Infectious diseases include parasitic, bacterial and viral infections.

Noninfectious Diseases

Nutritional disorders like anemia can result from improper storage of feed and feeding old, moldy feed. Fish feed should always be stored in a cool, dry place and purchased in quantities small enough to be used quickly.

Chronic exposure to ammonia can result in poor growth. When fish densities and feeding rates are heavy, ammonia levels should be monitored regularly with a water test kit. Remember that water pH will determine the toxicity of ammonia. While ammonia exposure doesn't usually kill fish directly, it is a source of stress.

Stress plays an extremely important role in the onset of a disease problem. Under normal conditions, the immune system of a fish is able to fight off most infectious disease agents. However, when a fish becomes stressed. the effectiveness of the immune response is diminished. Sources of stress include improper or excessive handling. sudden changes in water temperature, low dissolved oxygen, high ammonia levels, poor nutrition and overcrowding. Most infectious disease outbreaks occur after fish have been exposed to one or more of these stressors.

Infectious Diseases

Diagnosis of infectious diseases in trout should be performed by a trained fish diagnostician. Accurate identification of causative agents usually involves the use of sophisticated equipment not readily available on most fish farms. A farmer should be familiar with the procedure for quickly getting sick or dead fish to the nearest diagnostician.

There are three main viral diseases of trout: infectious pancreatic necrosis (IPN), infectious hematopoietic necrosis (IHN) and viral hemorrhagic septicemia (VHS). All these are most harmful to young trout, and moralities can be very high. Infectious hematopoietic necrosis and VHS can affect older trout, but moralities are much lower than with young fish. All three disease can be transmitted by contaminated eggs. There are no effective treatments for theses viral diseases. Prevention involves purchasing only certified disease-free eggs (or using only certified broodstock) and disinfecting eggs at the eyed stage.

There are three categories of bacterial infections which affect trout; acute systemic. chronic systemic and acute external. Because diseases within each category exhibit similar symptoms, laboratory diagnosis is essential.

Acute systemic bacterial infections include enteric redmouth (ERM), furunculosis and bacterial hemorrhagic septicemia. The recommended treatment for these diseases involves feeding one of the FDA-approved antibacterial drugs according to label directions. In areas where ERM has been reported, fingerlings should be vaccinated 7 to 10 days before moving fish into raceways.

Chronic systemic bacterial infections include bacterial kidney disease (BKD), which is slow to develop. Once established, it may be impossible to cure. There is no FDA-approved treatment for infected food fish. Strict quarantine and careful disposal of infected fish are recommended.

Acute external bacterial infections include columnaris disease which typically affects stressed fish. especially at high water temperatures. The recommended treatment involves applying an FDA-approved chemical to the water according to label directions.

Hatchery Sanitation

Great care should be taken to prevent the introduction of disease-causing agents into hatchery facilities. The best way to do this is to restrict movement of nonessential personnel. A disinfectant footbath should be placed inside the entrance at all times. Under no circumstances should equipment used in the hatchery, such as nets or buckets, be removed. The hatchery building and all equipment should be periodically cleaned and disinfected using a chlorine bleach solution.

MARKETING

The time to investigate marketing strategies for trout is well before construction of facilities begins. Potential markets for farm-raised trout include live haulers, fee-fishing operations, sales to other producers, direct sales to customers, processors, restaurants and retail outlets. Table 10 shows the relative importance of each of these outlets for the United States in 1992. Percentages may vary greatly from state to state. For example, 98 percent of all trout produced in Idaho during 1992 were marketed through processors, while in Michigan 26 percent went to fee-fishing, 23 percent to processors and 15 percent to restaurants and retail outlets.

Table 10. Percentage of Food-Size Trout Sold by Outlet Type

Outlet	%
Live Haulers	4
Fee Fishing	16
Other producers	3
Direct to consumer	2
Processors	71
Restaurant and retail	3
Other	1

Developing a marketing strategy will require careful investigation of the local feasibility of each of these alternatives. A producer must determine:

1. who is buying trout and at what price
2. how much of a demand exists
3. what are the product form and size preferences
4. is there room for growth

ECONOMICS

If a suitable site for trout production can be identified, it is reasonable to develop a financial budget. Most lending institutions will require a detailed economic feasibility study. Development costs and production costs vary greatly from site to site. Tables 11 and 12 may be useful in estimating development costs for a trout raceway system.

Table 11. Worksheet for Estimating the Cost to Develop a Trout Raceway System.

Category	Units	Price	Quantity	Value
Site preparation				
Concrete floor				
Reinforcement				
Drain pipe				
Screening				
Tank forms				
Labor				
Miscellaneous				
Total				

Production costs of $0.60 to $1.10 per pound have been reported for trout production facilities. Table 12 may be useful in estimating the operating costs of a trout farm.

Table 12. Worksheet for Estimating Annual Operating Budget of a Trout Raceway System.

Category	Units	Price	Quantity	Value
Gross Receipts (Trout)				
Operation inputs				
Eggs or Fingerlings				
Standard feed				
Medicated feed				
Chemicals				
Electricity				
Equipment repairs				
Total Variable Cost				
Capita1 Costs				
Annual operating capita1				
Development investment				
TOTAL INTEREST CHARGE				
Ownership Costs (depreciation, taxes, insurance)				
Labor Costs				
Returns to Land, overhead and management				

REFERENCES AND ADDITIONAL INFORMATION

If you are a new or prospective trout farmer, not only will you need information concerning production management techniques, you may also need information concerning processing, marketing, economics, financial assistance, disease diagnostic services, water quality analyses, aquatic weed control, local and state laws and regulations, site selection and development, etc. In some areas, locating this information can be difficult. The following are possible sources of information or assistance.

1. The county Cooperative Extension Service office, usually listed under "County Government" in the telephone directory, can provide assistance. County Extension agents are employees of land grant universities. The county agent may assist you directly or draw upon the experience and training of a university expert or refer you to some other state or federal agency who can provide you with the information or service you need.

2. In the coastal and Great Lake states, land grant universities also have Sea Grant programs. In many of these states, marine advisory service specialists can provide needed information.

3. State game and fish agencies may also be a source of information on laws and regulations, production technology and diseases.

4. The United States Department of Agriculture Soil Conservation Service can assist in site selection and facility development. This agency is usually listed in the telephone directory under "federal" or "United States Government."

5. The United States Department of Agriculture's five Regional Aquaculture Centers can also refer you to state specialists for other resources specific to your needs.

Center for Tropical and
Subtropical Aquaculture
The Oceanic Institute
Makapu'i Point
Waimanalo, HI 96795

Southern Regional
Aquaculture Center
Delta Branch Experiment Station
P.O. Box 197
Stoneville. MS 38776

North Central Regional
Aquaculture Center
Room 13 Nat. Res. Bldg.
Michigan State University
East Lansing, MI 48824- 1222

Western Regional
Aquaculture Consortium
School of Fisheries. WH- 10
University of Washington
Seattle, WA 98195

Northeast Regional
Aquaculture Center
University of Massachusetts-Dartmouth
Research 20 I
North Dartmouth, MA 02747

6. The United States Department of Agriculture National Agriculture Library is the National Aquaculture Information Center. It provides informational services on aquaculture. The address is:

U.S. Department of Agriculture
Aquaculture Information Center
Room 304 National Agriculture Library
10301 Baltimore Boulevard
Beltsville. MD 20705

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1785

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