Fish Calculations (all info excerpted from Soderburg 1995):

Growth Equations (as a function of temperature)

Temperature Range (^oC)	Growth Equation	Regression Coefficients
4 - 19	$\Delta L = -0.040 + 0.505\ T$	$r^2 = 0.886$
7 - 19	$\Delta L = 0.043 + 0.0450\ T$	$r^2 = 0.801$
7 - 16	$\Delta L = -0.167 + 0.066\ T$	$r^2 = 0.971$

The optimum growth range for trout has been reported as 10-15.6^{o}C (Piper *et a*l. 1982) and 13-21^{o}C (Meade 1989); however, the survivable range is much broader at 0.6-25.6 ^{o}C (Piper *et al*. 1982). As demonstrated in the Table, growth rates vary with temperature, the most reliable equation being the one given for temperatures between 7-16^{o}C, where the r^2 value is closest to 1.

Condition Factor

In fish culture, it is often important to quickly switch between weight and length. Condition Factor, K, relates the weight and length of different fish species as follows:

$$K = \frac{W}{L^3}, \text{ where W = weight in pounds and L = length in inches.}$$

For rainbow trout, K was determined to be 4.055×10^{-4} by Haskell in 1959.

Feed Conversion

Feed conversion, FC, is perhaps the most commonly used indication of the performance of a fish rearing facility.

$$FC = \frac{\text{kg food}}{\text{kg gain}}$$

A grower can estimate FC of a given feed by using energy available in a given diet. For instance, feeds are identified by two sources of energy, protein and fat. Typical diets consist of 38% protein and 11% fat, high energy diets may consist of 42% protein, 12% fat, and many, many combinations exist. Typically, high energy diets produce bigger fish faster, less waste from the fish, and corresponding less pollutants; however, they are also more expensive. According to Soderberg, Piper *et al*. (1982) determined that 3.9 calories per gram of protein are available for trout, 8.0 calories per gram of fat are available for trout, and 1.6 calories per gram of carbohydrate are available for trout. They also determined that ~3,850 calories are required per kilogram of trout weight gain.

For example, if a farmer is using feed that is 45% protein, 8% fat, and 10% carbohydrate, then he can estimate his feed conversion as follows:

Protein	450 g/kg * 3.9 C/g = 1,750 C/kg
Fat	80 g/kg * 8.0 C/g = 640 C/kg
Carbohydrate	100 g/kg * 1.6 C/g = 160 C/kg
Total	**2,550 C/kg**

The anticipated feed conversion will then be:

$$\mathrm{FC} = \frac{3{,}850\ \mathrm{C/kg\ fish}}{2{,}550\ \mathrm{C/kg\ feed}} = \frac{1.51\ \mathrm{kg\ food}}{\mathrm{kg\ fish\ weight\ gain}} = 1.51$$

Feeding Rate

Feed conversion can also be used to estimate feeding rates, FR, as follows:

$$\mathrm{FR} = \frac{3 \times \mathrm{FC} \times \Delta\mathrm{L} \times 100}{\mathrm{L}},$$

where FR is % body weight to feed per day, FC is feed conversion, ΔL is change in length, and L is length of fish on a given day.

Raceway Requirements

Length:Width Ratio	10:1
Depth of Water	2 ft
Water Exchange Rate	4 exchanges/hr
Linear Velocity	0.033 m/sec

It is often not possible to satisfy all requirements of a design; thus, the best compromise must be used.

Oxygen Consumption

After treatment of mine water, one can assume the water to be saturated with oxygen; however, as oxygen is one of the most important water quality parameters for fish, it is prudent to calculate oxygen consumption, or use it for design when sizing the system and anticipated size of fish. The following is a useful equation:

$$\mathrm{OC} = \left(\frac{3 \times \mathrm{FC} \times \Delta\mathrm{L}}{\mathrm{L}}\right)(9155.23),$$

where OC = oxygen consumption in mg DO/kg of fish per hour, FC = feed conversion, ΔL = daily increase in fish length, and L = fish length. The minimum DO recommended for fish is 5 mg/L.

Carrying Capacity

Calculated as

$$\mathrm{CC} = \frac{0.5 \times (\mathrm{Ci - Cm})}{\mathrm{OC}},$$

where CC = carrying capacity in lb/gpm, Ci – Cm = the DO available for respiration in mg/L, and OC the oxygen consumption in mg DO/kg of fish per hour.

Rearing Density

While carrying capacity is a measure of fish density in terms of oxygen requirements, rearing density is a measure of fish density in terms of spatial requirements. For trout production, a density index of 0.5 is recommended, and rearing density can be determined as follows:

$$\text{Rearing Density} = L \times 0.5$$

where rearing density is represented as lb/ft^3, and L is the length of fish in inches. Note, much higher density indices have been used by hatcheries with no effect on growth (*i.e.*, 0.8, 1.0, 2.0).

Reaeration Efficiency

Soderberg compiled research from 3 different authors performing studies of reaeration efficiencies of different devices and came up with the following Table. Having an accurate estimate of the fate of dissolved oxygen is crucial for facility managers to maximize their output. Efficiency is calculated as follows:

$$E = 100 \times \frac{Cb - Ca}{Ce - Ca},$$

where Cb = concentration of oxygen (mg/L) below the device, Ca = DO concentration (mg/L) above the device, and Ce = the equilibrium concentration of DO (mg/L).

The equilibrium concentration, Ce, can be determined by the following equations:

$$(1)\quad Ce = 14.161 - 0.3943\,T + 0.0077147\,T^2 - 0.0000646\,T^3$$

$$(2)\quad Ce = \frac{125.9}{T^{0.625}},$$

where T = temperature in ^{o}C in equation (1) and T = temperature in ^{o}F in equation (2), which is slightly less accurate.

Reaeration Efficiencies for Gravity Fed Devices.

Device	Water fall (cm)	Efficiency (%)
Simple Weir	22.9	6.2
	30.5	9.3
	61	12.4
Inclined Corrugated Sheet	30.5	25.3
	61	43
Inclined Corrugated Sheet with Holes	30.5	30.1
	61	50.1
Splashboard	22.9	14.1
	30.5	24.1
	61	38.1
Lattice	30.5	34
	61	56.2
Cascade	25	23
	50	33.4
	75	41.2
	100	52.4

Flow Discussion and Tank Design

Velocity is a vector, it has magnitude and direction. When particles settle out of solution, as in the treatment of mine water or the clarification of fish culture effluent, we picture them as falling from a water surface, down to the bottom of the pond or container. However, in most applications there is also water flowing linearly, or side to side. Thus, in an ideal sedimentation system, particles will move horizontally with the flow of fluid and vertically under the force of gravity.

Illustrated in the Figure below (Tchobanoglous and Schroeder 1987) is a spherical particle suspended in fluid in an idealized rectangular horizontal flow settling tank. The fluid is moving with a horizontal velocity, V_h, and a critical settling velocity, V_{sc}. The particle is moving with a horizontal velocity, V_h, equal to the V_h of the fluid. However, the particle is moving with a settling velocity, V_s, different from the critical settling velocity of the fluid. If a particle enters the inlet zone, at any depth, and has a $V_s > V_{sc}$, that particle will settle in the sludge zone. Particles with a $V_s < V_{sc}$ may or may not settle in the sludge zone and will be removed in the proportion V_s/V_{sc}.