Nelson & Sons, Inc.
118 West 4800 South, Murray, Utah 84107

# A MANUAL FOR RAINBOW TROUT PRODUCTION ON THE FAMILY-OWNED FARM

by

GEORGE W. KLONTZ, M.S., D.V.M.
Professor of Aquaculture
Department of Fish and Wildlife Resources
University of Idaho
Moscow, Idaho 83843



This manual was prepared especially for Nelson and Sons, Inc., 118 West 4800 South, Murray, Utah 84107, the manufacturers of Nelson's Sterling Silver Cup Fish Feeds.

# TABLE OF CONTENTS

APPENDIX I: REFERENCE TABLES

# I. INTRODUCTION

## A. Scope

This presentation is intended for the family-owned and -operated trout farm producing 15-50 tons (30,000-100,000 lbs.) per year. The impetus for my writing this text comes from hearing genuine concerns about rainbow trout in the marketplace. Chefs, restauranteurs, and retailers have stated quite clearly and repeatedly that they expect farmed trout to be of high quality, delivered when needed, and presented in the form required. Stated another way, quality, timeliness, and portion control are the bywords of successful trout production and marketing. Notice that selling price is not among the concerns.

Unfortunately, the trout-producing community has yet to heed these concerns, if, indeed, they were even heard in the first place. This is quite understandable, given the backgrounds of most family trout farmers and the availability of these concerns to them. By and large, the family trout farmers are individuals who decided to produce trout because it sounded like a good life and, in their enthusiasm, they learned how to raise trout. But then came the day of reckoning - What do they do with their fish? Who will buy them? When will they buy them? In what form do they want to buy them? Now the farmer has to become a processor, marketer, salesman, and merchandiser - all skills requiring more knowledge than he/she possesses. At this point, trout farming becomes a whole new ballgame and survival is its name. This treatise is designed to provide some insights on survival skills in trout farming.

The methods and suggestions offered in this text are compiled from methods used by trout farmers in many countries. These farmers exemplify the saying, "Necessity is the mother of invention." The majority of the methods are not published in any journal, and they have not been presented at association meetings. Most fish farmers seem to be reluctant to share their experiences through these media. So, the best way to find out what is going on is to visit fish farms and learn what is being done or not being done.

## B. Overview of the Process

There are five major task groups which must be accomplished to produce a high quality trout product. These are:

1. Establish a product definition.
2. Determine the capability of the farm to produce the product definition.
3. Develop a production plan.
4. Implement and monitor the production plan.
5. Market the fish.

# II. FACTORS AFFECTING PRODUCTIVITY

Every trout farm, no matter how large or small, is composed of five major groups of factors which can, and often do, affect the productivity of the farm. These are (1) the fish, (2) the water, (3) the pond, (4) the feed, and (5) the management practices. Within each of these major groups are several individual factors, each acting in a mutually interdependent fashion with other factors. (See Table 1 and Figure 2) That is, if one factor changes quantitatively, this initiates a series of changes in several other factors. The net result can be beneficial to production or it can be detrimental. It is incumbent upon the fish farmer to evaluate the initial change in terms of its possible end effect(s).

For example, the simple expedient of increasing the feeding rate, i.e., the lbs. of feed per 100 lbs. of fish, a seemingly innocuous act sets into motion a series of quantitative changes within the system, which may or may not result in achieving the desired result of having the fish grow faster. (See Figure 3)

In another example, the increase of water temperature from 9 °C (48 °F) to 15 °C (59 °F) generates the following changes in the environment of a 100 gram rainbow trout:

A. Fish-associated changes
1. A 67.5% increase in metabolic rate (oxygen demand)
2. A 97.8% increase in daily length-gain potential
3. A 66.7% increase in daily weight-gain potential
4. A 98.6% increase in ammonia-generation potential
5. A 33.1% decrease in oxygen-carrying capacity

B. Water-associated changes
1. A 12.8% decrease in oxygen concentration
2. A 58.8% increase in environmental unionized ammonia
3. A 67.5% decrease in dissolved oxygen in the outfall water

Thus, the life support (oxygen-based) carrying capacity of the pond is greatly reduced, possibly to the point where it could be detrimental to the health of the fish, depending upon the initial biomass in the pond. A method frequently employed, where possible, to restore the oxygen-based carrying capacity is to increase the water inflow, which, in turn, generates the following series of changes within the system:

1. The oxygen-based carrying capacity of the pond is increased
2. The water velocity is increased
3. The swimming energy expenditure of the fish is increased
4. The oxygen demand of the fish is increased
5. The oxygen-based carrying capacity of the pond is decreased

The net effect of these two alterations within the system might be mutually counterproductive to the physiological status of the fish. A better solution to the reduction of oxygen-based carrying capacity might have been the reduction of the population within the pond.

At this point, an in-depth examination of the specific factors is warranted:

**A. Fish-Associated Factors**

This group of factors can be termed intrinsic factors, in that they are part and parcel of the nature of the fish. Their function is governed largely by the genetic make-up of the fish.

The major intrinsic factor affecting the well-being of the fish is the stress response. Fish in intensively managed conditions are either continually or irregularly under the stressors of population density and physical manipulations, i.e., grading, inventorying, pond cleaning, etc. The major physiological changes occurring in the stress response that have the greatest impact on the health of the fish are the reduction of circulating ascorbic acid (Vitamin C) and the increase in plasma cortisol. Both actions compromise the ability of the host to resist the activation of a latent systemic bacterial or viral infection. Another aspect of the stress response is the induction of environmental gill disease (EGD), which impedes the uptake of oxygen and the excretion of blood ammonia.

Other fish-associated factors, without regard to degree of significance, are:

1. *Ammonia:* As $NH_4^+$, ammonia is generated in the system as the end-product of protein metabolism. There are two major pathways of generation: endogenous and exogenous. The endogenous pathway is a catabolic function of the body, in which the vital processes of the body are accommodated. The exogenous pathway is anabolic, in which the dietary protein is metabolized for growth and other physiological functions. The fish excretes ammonia, as $NH_4^+$, across the gill membranes. In the aquatic environment the measured ammonia occurs in two forms: dissociated or ionized ($NH_4^+$), which is nontoxic for fish, and undisassociated or unionized ($NH_3$), which is toxic for most fin fish at continuous levels exceeding 0.03 mg/l. The ratio of $NH_4^+$ to $NH_3$ is both temperature- and pH-dependent. (See Appendix 1: Table 10)

2. *Behavior:* Rainbow trout are territorial animals. When in free-living or confined conditions they establish their required amount of space based upon water conditions and food availability. They will defend these areas quite actively. In confined conditions, the defensive acts are mostly in the form of nipping the dorsal fin and/or pectoral fins of the transgressor. This gives rise to the injured areas appearing as a "target" to other aggressive fish in the population. The fin-nipping sometimes becomes so severe that the condition called "soreback" occurs. Thus, it is desirable to have ponds and pond loadings so as to permit the establishment and maintenance of territories. It is then incumbent upon the fish farmer to feed the fish so that a fish does not have to "invade" the territory of another to acquire food.

3. *Nutritional Requirements:* Based upon their food preferences, rainbows are carnivores. Thus, it follows that the dietary formulation must satisfy this need. The current state of knowledge about fish nutrition is such that nutritionally adequate diets are available for most species of salmonids.

The energy ingredients of a trout diet formulation are protein, lipid (fat), and carbohydrate. The protein comes from both animal (fish meal) and plant (wheat, corn, soybean) sources. The lipid comes from fish meal and fish oil. The carbohydrate comes from the ingredients of plant origin.

Rainbow trout require 1600-1650 metabolizable kilocalories (kcal) of energy per lb. of weight gain. They can derive 4.0 kcal per gram of digestible crude protein, 9.0 kcal per gram of digestible lipid, and 1.8 kcal per gram of digestible carbohydrate. The majority of commercial fish feeds are designed energy-wise to provide feed conversions of 1.2-1.4:1. The Silver Cup formulation typically delivers a feed conversion of 1.2:1, if properly fed.

4. *Environmental Requirements:* Rainbow trout are classified as cold-water fish as their Standard Environmental Temperature (SET) is 15 °C (59 °F). For each degree C above or below the SET, there is an 8.5% reduction in metabolic rate, which can be translated into a comparable decrease in weight gain or growth.

Other environmental preferences are dissolved oxygen levels above 60% of saturation and continuous levels of ammonia (as $NH_3$) below 0.03 mg/l. These are "No-Effect Limits" (NEL). The NEL values for other environmental requirements are presented in Table 2.

5. *Product Definition:* This term is a relatively new concept to intensive aquaculture. It implies that the production cycle begins with the size and number of fish to be harvested on or about a specific date. The process then proceeds backwards in time, taking into account the several factors which might influence production, and identifying a starting date and the management processes which must be implemented to achieve the Product Definition.

6. *Growth Rate Potential (GRP):* Growth of rainbow trout can be measured as an increase in length, weight, or both. The GRP is largely under genetic control and influenced by water temperature (Appendix I: Table 5).

The Allowable Growth Rate (AGR), on the other hand, is the growth rate which the system will permit. The major factors which affect the AGR are:

a. Water temperature
b. Oxygen availability
c. Water osmolarity
d. Feed quality
e. Feed quantity
f. Subclinical respiratory disease

Under ideal conditions, the AGR and the GRP are equal; however, in the majority of cases this is not the case. Plus, an aquaculturist should be capable of taking all the factors influencing growth into consideration to establish the AGR of the system. The AGR then becomes the key factor in production forecasting to achieve the Product Definition.

7. *Disease History:* The impacts of clinical and subclinical episodes of infectious and noninfectious diseases on productivity have been documented. However, the documentation relates more to the impact of dead fish rather than those that are clinically ill but do not die. When fish are exposed to environmental conditions that exceed the accepted "No-Effect Limits" for an extended period, there comes a point where

the fish can no longer cope with the situation. Two of the first signs of this are the loss of tissue between the fin rays (the "frayed fin" syndrome) and a generalized melanosis (body darkening).

8. *Length-Weight Relationship:* This factor - called the "condition factor" - is, perhaps, the most misused mathematical term in aquaculture. Typically, populations are inventoried periodically for growth and feed conversion. This process entails the weighing of groups (sample lots) of fish to obtain the number of fish per pound - or a reasonable estimate thereof. This statistic is then used to determine the mean length of the fish using a weight-length table (Appendix I: Table 1). Unfortunately, most tables assume a constant condition factor which is not true - thus, an incorrect length is obtained, which then leads to further complications because the feeding rate models use body length as their basis.

If condition factor is to be used in the production process, as it should be, then individual fish must be weighed and measured at the end of each growth stanza or period and the condition factor calculated from these data.

9. *Cannibalism:* The major impact of this factor is having a progressive loss of small fish in the fish population, which can lead to errors in estimating biomass. The problem can be circumvented by (1) grading and/or (2) feeding regimen. With respect to the latter, if populations are fed in such a fashion, i.e., hand feeding, that the size variance is minimal, then cannibalism is minimized. This, plus judicious grading, will nearly always preclude cannibalism from being a serious problem.

10. *Oxygen Uptake:* The rate of oxygen uptake across the gill lamellar membranes is a function of the differences in partial pressures of dissolved oxygen between the water and the lamellar capillaries. Under ideal conditions, the partial pressure difference should be 15-20 mm Hg. However, if the gill lamellar epithelia become hypertrophic or hyperplastic, the $p0_2$ difference must be greater. If the $p0_2$ difference is insufficient, the oxygen demand of the fish cannot be met and growth suffers accordingly.

11. *Oxygen Demand:* The oxygen demand of fish is regulated by the metabolic rate. The Standard Metabolic Rate (SMR) is influenced by water temperature, primarily, and age (as fish size), secondarily (Appendix I: Table 7). If the oxygen demand cannot be met because of insufficient $_p0_2$ differential between the water and the lamellar capillaries, the metabolic rate is negatively influenced, which, in turn, negatively influences the growth rate and the general well-being of the fish.

12. *Fecal Solids:* The resultant influence of fecal solids on productivity is, if they are left to accumulate, a reduction in growth rate. This can occur via one or more of the following changes in the system, attributable to the presence of fecal solids.

a. Increased Biological Oxygen Demand (BOD)
b. Sestonosis - an accumulation of solids and other detritus on the buccal aspect of the gill rakers
c. Lamellar thickening (hypertrophy or hyperplasia) resulting from the physical irritation due to solids passing over the lamellar tissues
d. Toxic by-products of fecal solid decomposition

13. *Carbon Dioxide:* Fish-generated carbon dioxide is a respiratory by-product. Other than in closed,

recycled water systems, it should have no deleterious effects. On the other hand, plasma carbon dioxide levels can influence the off-loading of oxygen from hemoglobin at the tissue level. This can adversely affect the productivity.

**B. Water-Associated Factors**

The productivity of an aquaculture facility is largely dependent upon the quality and quantity of water available. The container, nutrition, and management factors are subordinate to the water quality and quantity. The factors to be identified and defined all must be considered as equally important to productivity.

1. *Dissolved Oxygen:* To be within the accepted "No-Effect Limits" for most species of salmonids, the dissolved oxygen in the water entering the facility should be >95% of saturation (Appendix I: Table 2). The dissolved oxygen in the water exiting a rearing unit should have a $p0_2$ of >90 mm Hg (Appendix I: Table 3). This is a departure from the traditionally accepted dissolved oxygen limit of 5 mg/l, which under certain circumstances of temperature is less than 90 mm Hg $p0_2$ .

2. *Nitrite:* Nitrite is the oxidation product of ammonia-nitrogen. It is under the influence of *Nitrosomonas sp* . The accepted tolerance level of nitrite is 0.55 mg/l. Levels exceeding this create methemoglobinemia, in which the iron in the heme molecule becomes reduced and cannot transport oxygen, thus inhibiting the satisfaction of the oxygen demand of the fish.

3. *Alkalinity and Hardness:* In freshwater systems, fish are *hypertonic* to their environment. That is, water is attempting to equilibrate the differences in osmolarity; thus the fish must excrete large quantities of urine to maintain its internal physiological balance. Fish in marine environments are *hypotonic* to the environment and must drink water to maintain their physiological balance. Thus, in freshwater situations, fish in hard water (>250 mg/l alkalinity) will spend less metabolic energy on osmoregulation than fish in soft water(<100 mg/l alkalinity), thus providing more metabolic energy for growth.

4. *Contaminants:* Waters used in aquaculture systems must be virtually free of municipal, industrial, and agricultural contaminants. In addition, natural contaminants, such as heavy metals (Cd, Cu, Zn, and Hg) must all be in the <O.l mg/l range. One of the major natural contaminants is nitrogen supersaturation of the water. Excesses above 100% of saturation will create "gas-bubble" disease, a syndrome in which nitrogen comes out of solution in the plasma and creates gas emboli that interfere with blood flow to organs and tissues. Many water sources, especially those from deep wells, are oxygen deficient and supersaturated with nitrogen. In these cases, the best remedy is to pass the water through packed columns for gas stabilization prior to use in a rearing unit.

5. *Solids:* Waters containing high levels of certain types of suspended/settleable solids can create impairment of oxygen uptake by causing an inflammatory response in the gill lamellar tissues. In addition, certain plant pollens (especially pine pollen) can cause similar problems in gill tissues. The net results are often a reduction of growth rate and an increase in feed-conversion ratio.

**C. Container-Associated Factors**

This group of factors which can affect productivity is largely hydraulic in nature. The water replacement time and the water velocity function to provide adequate available dissolved oxygen for the fish and to remove the potentially deleterious metabolic waste products.

### D. Nutrition-Associated Factors

As has been stated, adequate nutrition is a key factor to optimizing growth and product quality. The diets must be formulated and presented with the requirements of the fish in mind. If these requirements are not met, the production goals will be compromised accordingly. It should be reiterated that this aspect of aquaculture technology is the most expensive in terms of production costs. It is also one aspect — if not the main aspect — over which the aquaculturist can exercise control. The other groups of factors — save the management-associated factors — cannot be altered routinely or easily. Their influence constitutes the nature of establishing the Allowable Growth Rate (AGR), i.e., the growth rate that the system will permit.

### E. Management-Associated Factors

This group of factors comprises the discretionary activities that an aquaculturist can exercise during the production cycle. Each must be executed after giving some consideration to the possible effects of such activity on production. For example, increasing the feeding rate to a population of fish would ostensibly result in an increase in growth rate - but only if done within the limits imposed by the system. There are at least three other metabolic pathways that could negatively impact growth rate and offset the anticipated increase in productivity (Figure 2).

# III. CONCEPTS OF PRODUCTION FORECASTING

Production forecasting is the application of techniques to prepare a production schedule for market-size rainbow trout. The process might seem somewhat complicated at first, but, with time and patience, the benefits of this approach should become apparent in terms of numbers and quality of fish produced and reduced production costs.

The process follows a logical sequence of activities. First, the trout farmer must decide on a Product Definition. Next, he or she must determine whether or not the facility can produce that fish in that quantity - thus, the carrying capacities of the farm must be defined. Finally, the production plan is developed, implemented, and evaluated. Each step must be accomplished in sequence if the process is to be beneficial. So, without further ado...

## A. Product Definition

The production-forecasting process begins with establishing the Product Definition. This embodies designating the following product criteria:

1. Species (strain) of fish to be produced
2. The average size of fish to be harvested (g/fish; oz./fish; no./lb.) (round weight or dressed weight)
3. The number of fish to be produced
4. The biomass (lbs.) to be produced
5. The date(s) of harvest

A Product Definition for a rainbow trout should be based upon the nature of the product appearing in the marketplace (Table 3).

An example of an acceptable Product Definition would be:

2,500 rainbow trout (Kamloops) at 1.42-1.19fib. (320-380 g/fish) (round weight), (250-300 g dressed weight) are to be harvested weekly for processing.

## B. Carrying Capacities of Ponds

The concepts of carrying capacities or rearing ponds bring together the interaction of the fish with the aquatic medium, the fish with the rearing unit, and the aquatic medium with the rearing unit. Stated in other terms, the carrying capacity concepts are the balance of the biotic (fish) factors with the abiotic (water and pond) factors. The fish are the key issue in these concepts. For optimum performance (growth, health, and feed conversion), the needs of the fish relative to rearing space, life support (dissolved oxygen), and water quality must be met. There are four fundamental carrying capacity concepts in intensive aquaculture, namely,
(1) density, (2) oxygen, (3) ammonia, and (4) suspended solids.

It should be noted that the fish will (should) not suffer irreparable harm if one or more the carrying capacity values are exceeded, but their performance, i.e., growth rate and feed conversion, will be compromised to a measurable degree. The negative effects on productivity are dose-dependent, i.e., the more one of the carrying capacity limits is exceeded, the greater the effect on the fish.

Each carrying capacity has its unique set of determinant factors (Table 4). As such, each must be defined for each rearing unit and/or system. The lowest value becomes the maximum permissible biomass of a specified species. At this point in time, virtually all of the methods used to estimate carrying capacities are applicable only to salmonids.

1. *Required data:* The process of determining the carrying capacities of each rearing unit begins with collecting and recording the necessary data. The following data must be collected with precision if the concepts of carrying capacities are to be implemented with any degree of reliability:

a. Physical parameters

1) Pond dimensions — total water dimension (ft.)
— total fish rearing dimensions (ft.)

2) Water use — single pass system
— multiple pass
• number of falls between uses
• height of each fall (ft.)

3) Elevation of the farm above sea level (ft. above MSL)

4) Daily mean water temperature (weekly basis) ( °C)

5) Water inflow (gpm, cfs, lps, lpm, or cms)

b. Chemical parameters

| | |
|---|---|
| ph | Calcium hardness (mg/l) |
| Alkalinity (mg/l) | Specific conductance (umos) |
| Dissolved nitrogen (% sat.) | Biological Oxygen Demand (mg/l) |
| Dissolved oxygen (mg/l) | Total ammonia (mg/l) |
| Unionized ammonia (mg/l) | Nitrite (mg/l) |
| Nitrate (mg/l) | Total phosphate (mg/l) |

c. Water discharge permit specifications — ammonia
— solids
• suspended
• settleable
— phosphate

d. Feed quality — metabolizable energy (kcal/lb.)
— protein content (%)
— estimate feed conversion ratio

2. *Density-carrying capacity:* The density-carrying capacity of a pond is based upon the spatial

requirements for the fish in the system (Piper, et al, 1982). The formula is:

Wden = Pvol*Dfac

When: Wden = biomass (lbs.) of fish per unit of body length (in.) per pond

Pvol = pond volume (cu. ft.)

Dfac = density index (lbs. fish per cu. ft. or rearing space per in. of body length)

| Species | lb./in./ft.$^3$ |
|---|---|
| RBT-Shasta | 0.5 |
| RBT-Kamloop | 0.5 |
| Steelhead | 0.25 |
| Chinook salmon | 0.3 |
| Coho salmon | 0.4 |
| Atlantic salmon | 0.3 |

To determine the density-based permissible biomass in the rearing unit, the following formula is applied:

Bio = Wden*L

When: Bio = permissible biomass (lbs.) based upon the density-carrying capacity

Wden = biomass (lbs.) per unit of mean body length (in.) for the rearing unit

L = the mean body length (in.) of the fish in the target population

4. *Oxygen-carrying capacity:* The oxygen-carrying capacity of a rearing unit may be estimated using one of several methods. Each has its unique application and limitations.

a. Single-Pass System

To calculate permissible oxygen-based biomass (lbs.) in a single-pass, open water system, the following formula may be used (Piper, et al, 1982):

W = F*L*I

When: W = permissible biomass (lbs.) of fish at length L

F = lbs. fish/gpm/in. body length (from Appendix I: Table 6)

L = mean body length (in.)

I = water inflow (gpm)

This method is applicable only to single-pass, linear rearing units. The F-value is based upon the temperature and elevation-compensated oxygen requirement of the fish per unit of body length. Implicit within the value is an inflow-dissolved oxygen level of >95% saturation and an outfall-dissolved oxygen level of 5.0 mg/l. Thus, unless there is sufficient oxygen recharge between uses, the fish in successive uses will be in an oxygen-deficient medium.

b. Multiple-Pass Systems Without Supplemental Aeration

Ponds, particularly raceway ponds, arranged for serial passage of water have been one of the more serious constraints to successful fish health management. In systems utilizing 3-5 serial water uses, the status of health in succeeding populations often gets progressively worse. This condition is influenced by at least three major factors within the system: 1. The size of fish. 2. The successive accumulation of waste products (fecal material and ammonia) and uneaten food. 3. The successive depletion of dissolved oxygen. Thus, any successful production in situations such as this must take these three constraints into account.

First, the anticipated dissolved-oxygen depletion must be defined. By way of example, the system to be modeled is a series of five raceways (10' wide, 100' long, 3' water depth) at a 1,000 foot elevation. Between each raceway in the series is a 3' fall, which serves to recharge the water with dissolved oxygen. The water inflow to the first-use pond is 2.0 cfs (56.64 lps). The water temperature is 15 °C (59 °F). The dissolved oxygen content of the water at 95% saturation is 9.71 mg/l (Appendix 1: Table 2). Thus, there is a total of 1,979,907.8 mg dissolved oxygen entering the pond per hour.

There should not be more than a 30% depletion of total dissolved oxygen in the first use. Thus, the water exiting the first-use pond should be 70% of saturation (6.8 mg/l). With the fall from the first-use pond into the second-use pond, there will be an oxygen recharge to 82.59% of saturation (8.02 mg/1) (Appendix I: Table 8). The water leaving the second-use pond should have a partial pressure of oxygen ($pO_2$) of not less than 90 mm Hg or 59.75% of saturation (5.8 mg/1) (Appendix I: Table 3). With the fall between the second-use and the third-use, the oxygen saturation of the water entering the third-use pond will be 76.2% (7.4 mgl). Again, as with the second-use pond, the water exiting the third-use pond should not be less than 59.75% of oxygen saturation. The fourth and successive passages of water will be the same. Now the system has been "stabilized" with respect to available dissolved oxygen.

There will be 2.91 mg/l D.O. available in the first use, 2.2 mg/l D.O. available in the second use, and ca. 1.6 mg/l available in the subsequent uses in the system. Expanding these data to oxygen availability per hour in each pond, the first pond will have 593,972.3 mg, the second pond will have 448,588.8 mg, the third and successive ponds will have ca. 326,246.4 mg.

The next step is to determine the oxygen utilization (mg/hr) by rainbow trout of a specific size. This can be accomplished using the Standard Metabolic Rate table (Appendix I: Table 7).

With the oxygen requirement of the fish known, this value divided into the amount of oxygen available in each pond generates the permissible head-count. The head-count divided by the number of fish per kg or lb. generates the permissible biomass.

### c. Multiple-Pass Systems With Supplemental Aeration

Providing multiple-pass systems with supplemental aeration may be accomplished by providing either pumped air or pure oxygen (as a gas or a liquid) into either the inflow end of each successive raceway or throughout the length of each raceway. In such cases, if the supplemental oxygenation is sufficient to have the dissolved oxygen in the pond outfall water >60% of saturation, the density-carrying capacity becomes limiting.

With any form of supplemental aeration, there is always the risk of supersaturating the environment with nitrogen (in the case of using pumped air) or oxygen (in the case of using gaseous oxygen). The nitrogen supersaturation can cause acute gas-bubble disease at levels exceeding 110% of saturation and chronic gas-bubble disease at levels exceeding 102%. The oxygen supersaturation below 2 atm of pressure is not likely to cause health problems for the fish.

The most efficient and safe method of introducing pumped air into a fish-rearing unit is via gas stabilization chambers, rather than by a venturi or airstones. In any event, the total gas pressure should not exceed 100% of saturation, to preclude any unwanted health problems for the fish.

d. Circulating Water Systems

The oxygen-carrying capacities of circulating water systems, i.e., circular or rectangular circulating ponds, by virtue of their hydraulics, cannot be calculated using the methods described for linear or noncirculating water systems. In circulating water systems, there is a considerable degree of homogenization of the inflow water with the water already in the system.

If there is no supplemental aeration, the most reliable method of estimating the oxygen-carrying capacity in these systems is by monitoring the system as the biomass increases. The outfall-dissolved oxygen level is established at the mg/l or percentage of saturation when the $pO_2$ is 90 mm Hg. Daily dissolved-oxygen levels in the outfall water are measured. When the dissolved-oxygen levels are near or below the set values, the biomass and size of fish are recorded for future pond-loading criteria.

Circulating water systems are becoming more and more frequently employed because they are less consumptive of water than are linear, noncirculating systems. The reduced water use virtually mandates the use of supplemental aeration. Thus, if the system is properly aerated, it removes the dependency of the fish on dissolved oxygen, and the limiting carrying capacity is the density. The supplemental aeration of circulating systems has the same attendant caveats as in the linear, multiple-pass system.

5. *Ammonia-Carrying Capacity:* The ammonia, as $NH_3$, carrying capacity is based upon the Median Tolerance Limit — Chronic (TLMc) of unionized ammonia ($NH_3$) by salmonids. The currently accepted TLMc value for salmonids is constant exposure to <0.03 mg/l $NH_3$ or intermittent exposure to <0.05 mg/l $NH_3$. The pH and temperature of the water directly influences the degree of free ammonia (as $NH_3$) generated (Appendix I: Table 10).

There are several methods of estimating ammonia production in fish-rearing units. The method of Meade (1974) provides a relatively simple and reliable estimate of total ammonia generated by salmonids. The formula is:

$$P_a = R_f * W * N_1 * N_u * N_e$$

When: $P_a$ = total ammonia (kg) generated daily
$R_f$ = daily feeding rate (kg/100 kg biomass)
$W$ = biomass (kg)
$N_1$ = protein content of diet (%)
$N_u$ = protein digestibility (%)=O.9
$N_e$ = nitrogen (%) excreted as ammonia-N=1.0

In properly managed, single-pass linear systems, the ammonia-carrying capacity should not be exceeded. However, in multiple-pass systems, the risk of exceeding the limit of 0.03 mg/l can occur because of the increased accumulations with each successive reuse of the water. The same can occur in circulating systems by virtue of an increased water-retention time. In both cases, the problem can be alleviated by reducing the feeding intensity (rate).

6. *Suspended solids-carrying capacity:* As with the methods of estimating the amount of ammonia generated, the methods of estimating the amounts of fecal solids are quite unreliable. There are at least two major dependencies, namely, the digestibility of the feed (feed conversion ratio) and the feeding techniques. The tolerance limits of salmonids for suspended solids, although quite broad, also depend upon the nature of the solids, i.e., are they gill tissue irritants or not. Most fecal and uneaten feed solids are quite nonirritating to salmonids larger than 40/pound. Smaller fish can accumulate solids on the buccal ("upstream") aspect of their gill rakers. These solids become conducive to the growth of aquatic fungi, which further blocks the water-flow over the giIIs and reduces oxygenation of the fish. This condition is termed *sestonosis* and there is no treatment for it.

**C. Production Plan**

Beginning with the time period for harvesting the fish, the next step is to calculate the time required to have fish of the specified size. That is, the water temperature-dependent growth rate must be established on a growth period basis. The length of a growth period in most instances is 14 days; however, longer periods have been used. One caveat in this is that the longer the period, the greater the error, because of having to use a mean water temperature and a constant condition factor for an extended period. The suggested approach is to use 14-day intervals for the programming segment. Another suggestion is to use a Julian date calendar (Appendix I: Table 11) in conjunction with the usual calendar dating.

The format for generating a production plan contains 8 categories (Figure 3):

1. Date
2. Mean daily water temperature (°C)
3. Number of fish
4. Mean body length (mm)
5. Mean weight per fish (no./lb.)
6. Biomass (lbs.)
7. Weight gain (lbs.) during the period
8. Feed required (lbs.) during the period

The first task is to complete the dating sequences and mean daily water temperatures in 14-day intervals, beginning with the harvest date and working backward in time for what would be estimated as the time required to produce this fish. The second task is to complete the number of fish column, beginning with the harvest number and increasing this number by the anticipated mortality during each 14-day period. The usual daily mortality is calculated at 0.02%. It is not advisable to estimate the mortality expected to occur due to disease episodes.

The temperature-dependent expected body-length increases are estimated using the data in Appendix I: Table 5.

The weight-per-fish data are obtained from either historical data or from the weight-length table (Appendix I: Table 1). The weight-per-fish values are multiplied by the headcount data to calculate the biomass (lbs.).

The feed requirements on a growth-period basis can be calculated, as follows:

dW = Bend-Bbeg

When: dw = weight gain (lbs.) during the growth period
Bend = biomass (lbs.) at the end of the growth period
Bbeg = biomass (lbs.) at the beginning of the growth period

Ffed = dW*FCR

When: Ffed = amount of food required (lbs.) during the growth period
dw = weight gain (lbs.) during the growth period
PCR = estimated food conversion ratio

This sequence is continued backwards in time until the fish are of a size to be well on feed — usually 1000/lb. for the time required to begin the production from either green or eyed eggs, a thermal (temperature) unit chart should be consulted (Piper, et al, 1982).

## IV. CONCEPTS OF PRODUCTION METHODS

### A. Pond Loading

In many of today's fin fish-production facilities, fish are often stocked into rearing ponds quite arbitrarily — sort of by the "seat of the pants" or "it looks about right" method. These fish are fed daily and, perhaps, evaluated for growth and feed conversion on a biweekly or monthly basis. When the pond "looks a bit overloaded," the population is reduced by grading or general transfer to another pond.

An alternative to the foregoing scenario is the practice of "stocking the pond for take-out." This means that the pond is stocked with the number of fish (plus ensuing mortality) that are to be removed some weeks or months from the stocking date. The process is quite simple, namely:

1. Establish the date on which the pond population is to be reduced by grading or random transfer to another pond.
2. Determine the number of growing days between the date of stocking the pond and the date of population reduction.
3. Calculate the temperature-based daily growth rate (mm) of the fish between the pond-stocking date and the population-reduction date (Appendix I: Table 4).
4. Apply the daily length-increase data on a day-by-day fashion throughout the period between pond stocking and population reduction.
5. Using the weight-length table, determine the number of fish per lb. (Appendix I: Table 1).
6. Determine the permissible biomass (lbs.) based upon the lowest carrying capacity parameter.
7. Determine the permissible number of fish by multiplying the biomass by the number of fish per lb.
8. Estimate the "natural" mortality to occur between the dates of stocking and population reduction. A reliable figure to use is 0.02-0.03% per day. DO NOT ANTICIPATE DISEASE EPISODES!
9. The sum of the permissible number at the end of the growing period and the accumulated daily mortality generates the number of fish to be stocked into the pond. This number, divided by the number of fish per lb. on the date of stocking, generates the biomass to be stocked into the pond.

From the point of pond stocking, good husbandry is the watchword. The fish are fed, ponds are cleaned, feeding and inventory records are kept, and all should be well.

### B. Pond Inventorying

Anyone who has dealt with raising fish under intensively managed conditions knows first-hand the frustration of not knowing with any degree of certainty either the exact number or biomass of fish in a given pond population. Most fish farmers would agree that +/- 5% discrepancy between what is actually in the pond and what the record book indicates would be acceptable. However, the discrepancy is quite often in the neighborhood of +/- 15-25%. This makes growth programming quite difficult and frustrating. The sources of the error, most would agree, is in the acquisition of pond inventory data, the unaccountable numbers of fish escaping, eaten by birds and eaten by their pond-mates, and in the recording of the daily mortality. (The prioritization of these sources of error is mine, not the industry's).

The basic purpose of a regularly scheduled population inventory is to determine the following statistics:

1. Growth, as increases in individual length and weight, and in population weight
2. Feed conversion
3. Other factors — costs of production
   mortality (daily rate and total size variations within the population)
   percentage of pond-carrying capacity being used

To determine these statistics, ideally, the following performance indicators should be measured:

1. Mean length increase (mm)
2. Mean body weight increase (lbs.; g; no./lb.)
3. Biomass increase (lbs.)
4. Condition factor change
5. Length variation within the population
   a. Median
   b. Mean
   c. Mid-range
   d. Standard deviation
   e. Coefficient of variance
6. Body weight variation within the population
   a. Median
   b. Mean
   c. Mid-range
   d. Standard deviation
   e. Coefficient of variance
7. Feed conversion ratio
8. Dress-out percentage
9. Depuration weight loss (%)
10. Gross appearance
11. Flesh quality

Obviously, the best method to acquire the data to quantify the listed evaluative criteria would be to count and weigh the entire population. In practice, however, this is not very realistic because of the time and labor requirements. Therefore, the next approach is to have reliable sampling methods, of which there are many.

Basically, there are three methods, each with several variants, by which to sample pond populations. First, a few handfuls of feed are cast out into ponds, and when there is a feeding "boil" a cast net is thrown over it. The collected fish are weighed, usually in the net, and counted back into the pond. The weight, minus the weight of the castnet and number of fish, is recorded. This process is repeated three or four times at different sites in the pond. The data are handled either (1) by totaling the numbers of fish and the sample weights and calculating the mean number of fish per pound or (2) by determining the number of fish per pound for each sample and determining the mean number of fish per pound from that.

The latter method does have the advantage of indicating the variation in fish size, whereas the former does not. But, statistically, it is not sound because it is calculating a mean value from a series of mean values. The main sampling error encountered in this technique is that most often the only "lead" fish in the population are sampled. If the growth program can account for this bias, then the validity of the technique is increased. The main advantage of the technique is that it requires only one person and very little time.

The second and, perhaps, the most common technique is, after 18-24 hours of feed deprivation, to crowd the fish to one end of the pond and to take several samples for weighing and counting. This method does reduce the bias of sampling only a small segment of the population. And, if performed well, the results can be quite illustrative of the actual population composition. The major drawbacks to this procedure are (1) the personnel and time commitments and (2) the stressful nature of the technique. There have been innumerable references to this method being "the best diagnostic tool for ERM or IHN."

The third technique (the "5x5" method) is much like the second in that the 18-24 hour post-prandial (since eating) population is crowded into a small space. The degree of crowding should be such that in a 3-foot water depth the bottom of the crowding screen is not occluded by the fish density. Of course, this presumes that the water clarity is such that it permits this. If it is not, then one will have to make a "judgment call." Just outside the area of crowding is a live box (ca. 3'x3'x3')(Figure 5). Five nets of fish are dipped from the crowded population into the live box. One net of fish is removed, the fish weighed and counted, and returned to the area outside the crowded area. The live box is emptied (tip it over). This process is repeated five times. During the process, one or two of the samples of fish to be weighed and measured are anesthetized. At least 40 of the group are selected at random for individual lengths (mm) and, if possible, weight (g). This entire process requires no more personnel or time than does the second method - but there is greater attention to detail.

The "5-by-5" method does have the following advantages over the other two, namely:

1. The following length-weight characteristics of the population are recorded:
   a. Length frequency
   b. Weight frequency
   c. Mean individual length
   d. Mean individual weight
   e. Range, mid-range and median values for length and weight
   f. Number per unit of biomass
2. From the foregoing, an assessment of the need to grade the population can be made. The usual criterion is at point when the length of the shortest fish in the population is less than 50% of that of the longest fish.

3. By using graphic plots of the length and weight data, the sizes for grading can be determined.

4. The estimations of weight gain, length increase, and feed conversions are made significantly more reliable.

Once again, the decision of which of several methods to use to accomplish some action in fish health management must be made. In my opinion, given the nature of intensively managed fish farms, the best inventory method is a combination of all three of the methods described. Each has its particular place in the scheme of things and, as such, can be quite useful. A typical scenario would be:

1. After determining as accurately as possible the number of fish per unit of weight (preferably n/lb.), weigh the prescribed biomass of fish into the pond.

NB: The following approach to weighing groups of fish into a pond is suggested:
a. Groups of small fish (40-75 mm) should be weighed +/- 1.0 g.
b. Groups of fish 75-150 mm should be weighed +/- 5 g.
c. Fish over 150 mm should be weighed +/- 10 g.

Rationale: 1 g = 1/454th of a pound
10 g = 1.45th of a pound
1 oz. = 1/16th of a pound (28.38g)

Thus,the opportunity for rounding error is much less with the metric system than with the avoirdupois (American) system.

2. The first inventory of a pond population (fish over 100 mm) should be done as follows:
a. Sample as in Method 1 (the castnet method), with the following modification: anesthetize, weigh and measure at least 40 fish in each sample. This will indicate which portion of the population is sampled by this technique.
b. Sample as in Method 2 using the modification listed above for the same reason.
c. Sample as in Method 3 to establish the population-size composition.
d. Evaluate all data in terms of their conformity with each other and with their unique portions of the population sampled.

3. The next series of inventories (4-5) can be done using Method 1. Remember, the growth-programming data for feeding rates must be adjusted accordingly. If in doubt, then the best suggestion is to go back to the pond with Method 3. With a little practice, one should be able to use this approach quite reliably.

4. At intervals, especially prior to grading the population, it is suggested that Method 3 be used in addition to Method 1. At this point, the population-size composition should be as accurate as possible.

The collected length and weight data are recorded (Figure 5) for later comparison with the expected length and weight data. If the feeding program for the previous growth period was effective, there should be very little difference between the inventory (observed) data and the expected growth data. If, however, the differences are greater than 5%, then some adjustments must be made for the upcoming growth period.

**C. Growth Programming**

There are several methods by which feeding rates may be calculated. None is actually better than the other. The best basis for selecting a feeding-rate calculation method is its degree of suitability to the system.

Of all the methods to derive feeding rates for fish, the Haskell method has been used the most widely. The equation is:

Rf = (dL*FCR*3*100)/Ld
When: Rf = lbs. of feed per 100 lbs. of fish daily
dl = daily length increase (in.)
FCR = feed conversion ratio
3 = length-weight-conversion factor
100 = decimal-removing factor
Ld = length (in.) of fish on the day of feeding

The first step applying this model to a group of fish is to establish the length of the growth period. In practice, a 14-day growth period has been found to be most reliable. However, periods of up to 28 days have been used. The major reason for suggesting the 14-day period is to reduce the error created by the increasing condition factor. In the example following, a 14-day feeding period is used (Figure 7). The feeding on Day 1 uses an Ld value derived from an inventory. On Day 2 the Ld value is increased by the dL. On Day 3 the Ldvalue is the original Ld value plus 2 dL values, and so on, for 14 days. The next step is to multiply the Rf values by the respective daily hundredweight increments of the biomass in the pond. An oft-stated axiom in "fish culturedom" is: "Always feed the gain." Thus, the daily gain in biomass must be taken into account. Not doing so has led many a fish culturist to the brink of mental confusion.

**D. Feeding Methods**

There are two fundamental principles which should be incorporated into the practice of feeding a group of trout: 1.Select the proper pellet size based upon the smallest fish in the population (Table 5). 2. Present the feed in such a fashion that all fish in the pond can eat their share.

In a "rule of thumb," the proper size of feed for the smallest fish in the population is one size less than that required for the average-sized fish in the pond. Many farmers have elected to feed no pellet larger than 1/8", even though the feed manufacturer recommends otherwise. The rationale in this case is that there are more 1/8" pellets per pound than there are 5/32" and larger pellets per pound. Thus, more pellets get spread through the population. Farmers feeding in this fashion report less size variations in the population at harvesting. This makes some sense in certain cases.

Feeding the fish daily is more an art than a science. Hand feeding is by far the best method. The feeder has the opportunity to observe the behavior of the fish and to feed the fish where they are in the pond.

Feeding with demand feeders, which seemed to be quite popular until recently, has several advantages and disadvantages. The advantages include (1) having feed available when the fish are hungry, (2) fish are less responsive to people approaching the pond, (3) the oxygen "drain" on the system is spread over hours, rather than having "peaks" and "valleys," and (4) a similar condition exists for ammonia generation.

The disadvantages include (1) increased size variations because of the "hogs" remaining near the feeder so that the smaller fish cannot receive food, (2) difficulty in observing which fish are feeding and which are not, (3) fish wasting feed by "playing" with the trigger or because only a few activate the feeder, which dumps excess feed, (4) the trigger mechanism getting "gummy" due to wind and rain, and (5) the feeders are loaded by the sackful when they are empty, rather than by weight, which precludes having an accurate feed conversion estimate.

If demand feeders are to be used, the following method has the best chance of being economically sound: 1. Install at least six feeders (three per side) on a 10'x100' pond. This reduces the size variation potential. 2. Load the feeders with a weighed amount of feed that the fish are to eat over a 3-4-day period. If they consume it all in 2-3 days, then the feeder sits empty until the stated period. It is common knowledge that trout can eat more than they can use metabolically — thereby reducing the FCR and increasing the feed costs. 3. When loading the feeders, present some feed by hand to observe the behavior. This is the best "early warning" signal for a disease episode. "Sick fish do not eat."

On the small farm, i.e., <50 tons annually, there is no need for a trailer or truck-mounted pneumatic feeder. These are expensive and not all that labor-saving on a small farm.

So, the bottom line is hand feeding. Daily feeding frequencies are based upon the size of fish (Table 6). A novel method being used more often is to feed 7 days of feed in 5 days. The amounts of feed for the 6th and 7th days are added to the feedings for Days 1-5. Thus, the weekends are periods of rest for the fish farmer, as well as for the fish. From the reports, this practice works very well in that no adverse effects have occurred.

## V. PUTTING IT ALL TOGETHER

In this section, the foregoing concepts will be applied. At the outset, it should be stated that the data used are from actual production conditions, so that the inherent utility of the foregoing approaches to production forecasting can be appreciated. If some aspect of this section is not understood, return to the appropriate preceding section for clarification.

The following is an example of developing a production plan:

### A. Product Definition

2,500 rainbow trout (Kamloops strain) at a round weight of 1.42-1.191b. (85% dress-out) to be harvested weekly for processing as boned (pin bone in, head off (56% yield from round weight). Harvesting is to commence 1 July 1992.

The foregoing Product Definition entails twice-weekly harvesting of 1,250 fish with a total annual production of 136,000 fish (100,000 lbs.). Eyed eggs will be purchased twice a year in lots of 100,000 each. Thus, harvesting will occur over a 6-month period. The production plan to be developed entails ensuring that the stated fish size (1.42-1.19/lbs.) will be available throughout the harvest period.

### B. Facility Description

Incubation — fry start — 2 upwelling incubators
2 shallow troughs (1'x10'x0.75')
4 deep tanks (4'xl2'x3')

Ponds — 8 raceways; double pass
— dimensions: 10'x100'x3' (total)
10'x96.7'x3' (rearing)
— single fall of 4.0' between ponds

Water — elevation 1000'
— temperature 13 °C (constant)
— dissolved oxygen 10.15 mg/l
— inflow 1.9 cfs (853 gpm; 54 lps)

Feed — FCR (estimated) 1.45:1
Mortality — eggs purchased at the eyed stage=0%
— eye to hatch =5%
— hatch to swim-up =10%
— swim-up to ponding =3.5%
— daily mortality =0.02%

Density Index — 0.4 lbs./$ft^3$/in. body length

The annual production program calls for purchase of two lots of at least 98,499 eyed eggs no later than 24 September 1991 and 24 March 1992, in order to meet the stated product definition under the stated rearing conditions (Table 5).

**C. Production Plan**

In this scheme, 100,000 eyed eggs are to be received, incubated, hatched, and grown out to provide processable fish over a 6-month period. This necessitates the implementation of a very novel approach to achieve this goal. The approach has been demonstrated to be quite reliable. (Kaiser, et al, 1991)

The entire lot is held in deep tanks and fed for maximum growth (Table 7). After 3 biweekly feeding periods (approximately 29 November 1991), the fish, some 82,500, should be approximately 100/lbs. Actually, they are 82.l/lbs. At this time, 150 lbs. (ca. 12,315 fish) are removed and placed into the upper end of one of the first water-use raceways. These fish are retained in the upper one-third of the pond by a screen, thus facilitating feeding and pond cleaning. As the fish grow, the screen should be moved downstream.

The remaining lot of 70,185 fish are kept in the deep tanks and fed 50% of the maximum ration for 7 days, followed by 7 days of no feeding. This puts the fish on maintenance energy levels, and growth will be virtually nil during the ensuing 5-month period. Each month 12,500-13,000 fish are transferred to a raceway and put on full feeding.

The 12,315 fish in the raceway are fed for maximum growth to reach harvest size by 30 June 1992 (Table 8). If this group is fed properly, little or no grading should be necessary, other than at harvest time, to obtain the proper size(s) for processing.

**D. Pond Stocking**

1. Density-carrying capacity of each raceway is 1161 lbs./in of body length.
2. Oxygen-carrying capacity of the ponds can be calculated as follows:

Upper (first-use) ponds:

| | |
|---|---|
| Water inflow | — 1.9 cfs (54 lps) |
| | — 193,709 lph |
| D.O. at saturation | — 10.15 mg/l |
| D.O. at outfall | — 7.10 mg/l (70% sat.) |
| D.O. available | — 590,812 mg/hr |

Lower (second-use) ponds:

| | |
|---|---|
| Water inflow | — 1.9 cfs (54 lps) |
| | — 193,709 lph |
| D.O. at inflow | — 83.0% of saturation |
| | (From Appendix I: Table 8) |

Outfall at 70% of saturation with a fall of 4.0' yields a recharge to 83% of saturation

| | |
|---|---|
| D.O. at outfall | — 6.04 mg/l |
| | (From Appendix I: Table 3) |
| | ($pO_2$ = 90 mm Hg) |
| D.O. available | — 461,899 mg/hr |

Standard Metabolic Rate of 1.3/lbs. (350 g) rainbow trout in 13 °C water is 60.53 mg

$0_2$/hour (Appendix I: Table 7)

Thus, the permissable headcount in the first-use pond is 9,761 (7,508 lbs.) 1.3/lb. fish. The permissable headcount in the second-use pond is 7,631 (5,870 lbs.) 1.3/lb. fish.

One upper pond would be stocked with fish at the beginning of growth period No. 4 (11/29/91). The fish would remain there until they are 1.9-2.0/lb. At that time, the population would be reduced by transferring one-third of the population into a second-use pond.

Each month, another raceway will be stocked with 138 lbs. (13,750) fish from the "master" lot being fed at maintenance levels. In this scenario, there could be a slight logistics problem, in that there are only eight raceways and six lots of fish on full feed, which will occupy two raceways during the last two months of the production cycle. Thus, at least two raceways will contain two monthly lots of fish separated by a screen. The smaller fish should be upstream from the larger fish. As a raceway becomes available, it is cleaned well and stocked with fish from a pond holding two lots.

**E. Feeding Program**

Basically, there are two methods by which 14-day feeding rates for a pond of fish can be estimated. The first, and more simple, is to use a feed chart supplied by the feed manufacturer (Appendix I: Table 9). Using this method entails knowing the number of fish/lb. at the beginning of the feeding period and knowing the biomass of fish in the pond. The former is much more accurate than the latter.

For example, at the beginning of the fourth feeding period the fish are 82 to the pound. By using the weight-length table (Appendix I: Table 1), the length is estimated to be 3.12" (79 mm). The biomass in the pond is 150 lbs. The daily feeding rate from the feed chart is 4.0%, which means that on Day 1 the fish will receive six pounds of feed. On Day 2, the biomass will be 154 lbs, (6 lbs. of feed) /1.45 = 4.1 pounds of gain; 1.45 = FCR). Each subsequent daily feeding is calculated in the same fashion.

The second method is to use one of the mathematical approaches to calculating daily feeding rates. This method is quite time-consuming and requires much more data.

In this example, the following input inventory data are used:

| | |
|---|---|
| a. Date | 29 November 1991 |
| b. Head count | 12,315 |
| c. Biomass | 150 lbs. |
| d. Length | 3.12 in. (79.5 mm) |
| e. No./lb. | 82.1 |
| f. Condition factor | 0.000401 |
| g. Elevation | 1000 feet |
| h. Water temperature | 13 °C (constant) |
| i. Density index | 0.5 lb./ft.$^3$/in. |
| j. Life Support Index | 1,358 lbs./gpm.in. |
| k. Daily increase in length | 1.0 mm |

| | |
|---|---|
| l. Water inflow | 1.94 cfs (551ps) |
| m. Feed conversion | 1.45:1 |
| n. Daily mortality (0.02%) | 3 fish |

There is an obvious difference between the Projected Production Schedule date (Table 7) and the data for the feed programming. The average body length is somewhat in agreement (3.0" vs. 3.12"), but the nos./lbs. are quite different (97.68 vs. 82.1). The reason for this is the condition factors (0.00037785 vs. 0.000401)—a difference of 6.1%, which gave rise to a similar difference in predicted and actual biomass. This is but one of the problems to be dealt with from time to time. The best axiom to follow is: "Believe what is seen and do not see what is believed."

**F. Inventory Data and Analysis**

Using the "5-by-5" inventory method, the following inventory data were obtained:

a. Total mortality: 22 fish

b. Total feed fed: 145 lbs.

c. Length data (mm)

| | | | |
|---|---|---|---|
| 100 | 102 | 86 | 91 |
| 88 | 76 | 97 | 89 |
| 96 | 86 | 83 | 83 |
| 99 | 100 | 104 | 90 |
| 92 | 104 | 99 | 93 |
| 90 | 92 | 89 | 87 |
| 103 | 93 | 96 | 102 |
| 102 | 99 | 101 | 87 |
| 96 | 90 | 93 | 91 |
| 105 | 98 | 89 | 103 |

d. Weight data (g/fish)

| | | | |
|---|---|---|---|
| 13.7 | 14.5 | 7.8 | 11.2 |
| 9.2 | 5.2 | 8.6 | 6.5 |
| 11.6 | 8.0 | 7.1 | 14.6 |
| 11.7 | 12.7 | 8.5 | 12.0 |
| 9.5 | 13.0 | 9.1 | 8.9 |
| 9.6 | 10.0 | 7.4 | 11.2 |
| 14.6 | 13.5 | 12.7 | 13.0 |
| 12.5 | 11.3 | 8.6 | 9.5 |
| 9.3 | 13.5 | 9.2 | 8.7 |
| 11.6 | 8.0 | 15.4 | 9.9 |

From the foregoing inventory data, the following data can be generated for the next growth period feeding program:

| Parameter | Expected | Observed |
|---|---|---|

| | | |
|---|---|---|
| Mean body length (mm) | 94.0 | 94.1 |
| Range of body lengths (mm) | | 76-105 |
| Median body length (mm) | | 93.0 |
| Average body weight (g) | 9.23 | 10.58 |
| Standard deviation of weights | | 2.49 |
| Median body weight (g) | | 10.0 |
| Number per lb. | 49.05 | 42.93 |
| Daily length increase (mm) | 1.0 | 1.045 |
| Biomass (lbs.) | 249.9 | 286.3 |
| Condition factor | 0.000401 | 0.000463 |
| Mortality | 42 | 22 |
| Weight gain | 99.1 | 136.3 |
| Feed conversion | 1.45 | 1.06 |

Observed/expected biomass . . . . . . . . . . . . 1.146
Observed/expected length . . . . . . . . . . . . . 1.001

**G. Conclusions**

At this point, one of the most difficult and confusing aspects of intensive aquaculture hopefully has been "conquered." The disparity between the expected biomass and the observed (calculated) biomass in the pond, i.e., 12.7%, is nothing to be concerned about — unless one is concerned about the rather high condition factor, which is, plus the rounding error between the entered condition factor, i.e., 0.000401, versus the calculated condition factor, i.e., 0.000463, the main cause for the difference. Another cause is the lower-than-predicted mortality.

This example does point up the need for starting a feeding program with precise data. The initial biomass was estimated from the headcount and number of fish per pound. The condition factor was estimated from the mean body length and number-per-pound data. However, it was not carried out to a sufficient number of digits. Nonetheless, these fish had an unusually high condition factor for their size. Under practical conditions, it should be reduced by either (1) irregular feedings or (2) increasing the water velocity.

The increase in water velocity is best accomplished by removing half of the dam boards (or reducing the standpipe height) by 50% about two hours after the last feeding of the day and restoring the water height the next morning. The fish will literally have to "swim their tails off" during the night, which is not going to hurt them one bit. The condition factor will decrease, but the feed conversion will also decrease, i.e., get worse, because of the increased metabolic demand.

In situations of rearing fish in large (>O.25 A) ponds where it is inconvenient to have a reasonably accurate estimate of biomass, feed conversion or unaccounted loss through escape, bird predation or mortality, the following method of evaluating inventory data is suggested. The collected length, weight, and condition factor data are compared with the comparable data prepared for the growth of the lot. If the fish are smaller than the predicted size, increase the amount of daily feeding during the upcoming growth period, and vice versa, if the fish are larger than the predicted size. This method does not have, obviously, the sensitivity of the method described for populations being raised in raceways, circulating ponds, or floating cages. It does, however, provide the fish culturist with a reasonable estimate of where the fish will be size-wise at a future point in time.

## VI. COPING WITH DISEASE PROBLEMS

Perhaps the most troublesome occurrence on a trout farm is losing fish to this or that disease. On the average, the total loss of fish from eyed egg to processing ranges between 45 and 55%. The diseases causing these losses are classified as (1) noninfectious or (2) infectious. Noninfectious diseases are caused mostly by environmental problems with which the fish cannot cope. Infectious diseases are caused by microbial pathogens, i.e., viruses, bacteria, fungi, protozoa, and metazoa. It is a generalized consensus that infectious disease episodes are usually preceded by either a subclinical or clinical episode of a noninfectious process. However, most farmers, and pathologists as well, seem to be more concerned about the infectious diseases. Perhaps this presentation will serve to change some opinions.

### A. Noninfectious Diseases

#### 1. Physiological Diseases

*Stress* is a complex physiological response to an environmental condition. Its effects, both directly and indirectly, affect the fish (Wedemeyer, 1981; Wedemeyer, et al, 1984).

Causal factors in the acute (short-term) stress response are the day-to-day husbandry activities such as population, inventorying, pond cleaning, transportation, and administration of chemotherapeutants for an infectious process. Common causal factors in the chronic (long-term) stress response are population density and water quality, i.e., ammonia-nitrogen, low-level toxic contaminants, and hypoxia.

The main clinical feature of the acute stress response is hyperactivity. Physiologically, there are many alterations. Chief among them are the rapid depletion of intrarenal ascorbic acid, an increase in circulating cortisol, cessation of renal and intestinal activity, hemoconcentration, leukocytosis, and an increase in blood ammonia. This response is the Alarm Reaction. With the removal of the stressor from the system, the physiological activities return to their original state.

If the stressor persists in the system, the stage of Adaptation ensues. In this stage of the stress response, the fish "adjusts" its physiological activities to cope with the situation. For the most part, all physiological parameters are within baseline values. However, the longer the fish must accommodate the stressor, the more pronounced are the deleterious effects. Growth rates begin to decline measurably and a generalized melanosis becomes apparent. Concomitant with this is the loss of tissue integrity between the fin rays, especially the caudal, anal, and pectoral fins.

The physiological explanation for this is that these tissues have become ischemic, resulting in necrosis ("frayed fin" syndrome). In this stage of the stress response, if an acute stressor is applied, the fish may die rather unexplainedly. This is the stage of Exhaustion, in that the fish is no longer capable of mounting another Alarm Reaction. This aspect of the stress syndrome is seen quite often as Post-Transportation Mortality. One of the clinical features of this occurrence is that the "fish is the healthiest dead fish seen," i.e., there are no significant postmortem lesions.

Another significant effect of the stress response, particularly of a severe acute stressor, is the activation of a latent bacterial or viral infection. In far too many cases, the act of size grading or population inventorying has been followed within 2-3 days by a severe episode of a systemic bacterial or viral disease. Some aquaculturists chalk this up to the "risks of doing business." This is unfortunate because there are means to prevent such occurrences, were the aquaculturist aware of the processes "triggering" the event.

To prevent adverse effects of the acute stress response, the following regimen is recommended:

1. If there is a history of latent systemic bacterial infection, activation following the activity, i.e., size grading, etc., the method to preclude or, at best, lessen the severity of the ensuing episode, is to "prime" the fish with an appropriate antibacterial. Ilis is accomplished by three days of feeding the appropriate antibacterial 4-7 days prior to the stressful event. This is followed by 1-2 days of unmedicated feeding.

2. Withhold food for 24-48 hours prior to the stressful situation.

3. Following the stressor, administer a 1-2% salt flush to the system, In this case, the volume of the pond is calculated and the appropriate amount of salt deposited at the water inlet of the pond and permitted to dissipate (usually 1-2 hours are required). The major effect of this act is to reduce the blood ammonia levels via the increased sodium levels being taken up across the lamellar membrane.

4. Resume regular feeding within 24 hours after the event.

*Environmental Gill Disease (END)* of salmonids under confined, i.e., farm ponds or raceways, and freeliving conditions, is very complex and, in many cases, not well understood from epidemiological and etiological standpoints. This disease, in the opinion of many, is one of the major production-limiting factors in farmed fishes. Subclinical episodes are often quite difficult to detect due to their insidious onset. Clinical episodes, especially those complicated by secondary, opportunistic pathogens, are frequently dramatic in terms of the mortality involved, which has a rapid onset and often an exponential daily increase.

The END syndrome is considered to be, first, stress-mediated, and, second, environmentally mediated. By itself, i.e., uncomplicated by pathogens or other noninfectious factors, it is more a debilitating process than it is lethal. This aspect is, perhaps, what makes it such an economically significant disease process. There is no specific recommended treatment regimen, largely because the causal factors are often quite obscure, if evident at all.

One of the major cost-incurring factors in this disease is the chemotherapeutic regimen, which could best be described as "categorical." That is, fish with the clinical signs of rapid, shallow respiratory movements, grossly enlarged gill tissues, and incomplete opercular closure are treated with one of the many medicants added to the pond water. The results have ranged from "rewarding" to "Well, we guessed wrong." The latter cases could have been prevented, perhaps, by elucidating the nature of the problem prior to treatment.

With proper chemotherapy and management practices, the foregoing responses can be healed. The repair process in the more severe cases requires 2-3 weeks, provided there are no further insults to the physiological respiratory process.

There are several approaches to preventing and controlling environmental gill disease episodes. The first *is avoidance* of the conditions which are conducive to the occurrence of subclinical and clinical episodes. This is best accomplished by maintaining the fish within the environmental "no-effect" limits with respect to settleable and suspended solids, ammonia-nitrogen, dissolved oxygen, and population density. However, since these limits were not established for all systems, the unique limits for the facility must be established. To accomplish this, measuring the environmental parameters and their effects on growth and gill tissues begins with sac fry and continues throughout the production cycle. One caveat is that the process is time-consuming and often frustrating, but always rewarding in the long run.

If and when a clinical episode of gill disease occurs, then an accurate diagnosis must be made prior to initiating any therapeutic regimen. The sequence of changes occurring in the gill tissues is the best indicator of the nature of the causal factors involved. The presence of bacteria and the so-called gill parasites is often a reflection of an underlying environmental problem, the most common of which is "poor housekeeping." At this juncture, it might be apropos to present an oft-quoted saying by Frederick Fish, a fish pathologist of the 1930s, to wit: "In fish culture, cleanliness is not next to godliness - it supersedes it."

Once the problem is defined, i.e., the major causal factors identified, the next step is to "re-balance" the system. This is best accomplished by first withholding feed for 3-4 days, if the fish are of sufficient size to permit this. This will (1) reduce the oxygen demand of the fish, (2) reduce the ammonia-nitrogen generated by the fish, and (3) reduce the fecal and uneaten solids in the system. Second, administer sufficient salt (as granulated NACI) to the system to obtain a 1-2% solution. This will (1) reduce the blood ammonianitrogen levels, (2) stimulate mucus secretion, (3) and have an astringent effect on the gill tissues. Third, reduce the population density to approximately one-half the oxygen-related carrying capacity of the system. This should be accomplished without unduly stressing the fish.

*Nephrolithiasis* is a chronic inflammatory condition in which calcium and other minerals precipitate within the distal renal and collecting tubules. This condition is commonly seen in waters high in carbon dioxide and phosphates. Some speculate the presence of a dietary mediating factor. It is more debilitating than lethal. Most cases are diagnosed coincidentally to examining a fish for other causal factors. In severe cases, the only sign usually seen is bilateral exophthalmia. 'Mere is no known treatment.

*Strawberry Disease* is a nondebilitating disease of rainbow trout. It is characterized by circumscribed reddened areas in the skin. These occur primarily below the lateral line posterior to the dorsal fin. The morbidity is usually 10-15%

The condition is most frequently seen during the processing of the fish for market. Such fish are discarded as being unsuited for the marketplace. Thus, there is some concern from an economic standpoint.

For years, the causal factor was thought to be infectious, because treating affected fish with an antibacterial reduced the lesions within a few days. Another theory of causation was that it is an atopy an allergic response to an unidentified allergin, presumably a substance released by a saprophytic bacterium. This theory had its basis in the observation that affected fish were in an environment that was conducive for high populations of saprophytic bacteria, i.e., the benthos was quite organic from uneaten feed and fecal material. The GI tracts of the resident fish contained many of the saprophytes, which were reduced with the feeding of antibacterial, thus reducing the allergin. This theory has yet to be proven conclusively, although subcutaneous injections of antihistamine into the reddened areas did reduce the lesions considerably.

2. Psychological Diseases

*Fin-nipping* is a condition precipitated by overcrowding. It is commonly a problem in concrete raceways and is uncommon in earthen ponds. Rainbow trout are especially territorial, and defend their territory by acts of aggression - primarily nipping the dorsal fin or pectoral fins of an intruder. Following the initial trauma, the affected fin(s) become discolored and a target for further traumatization. The end result of this is "soreback" or "hamburger pectoral." The condition is seen far too commonly by anglers catching released hatchery-raised trout. It is also quite common in farmed trout destined for the marketplace. Such fish are also usually in the adaptive phase of the chronic stress response and, as such, are quite melanotic.

The suggested treatment regimen is to reduce the population by grading out the larger, more aggressive fish. Other methods have included increasing the water velocity, so as to "give the fish something else to think about." Sometimes it works - but not always.

*Soreback* is a sequel to dorsal fin-nipping, especially in rainbow trout populations raised in concrete raceways. In this condition, the initially traumatized dorsal fin is a target for further aggression, to the point that the skin and the underlying musculature are literally eaten away. Some cases are so severe that the dorsal vertebral spines are exposed. Such cases are seldom secondarily infected with *Saprolegnia, an* opportunistic pathogenic aquatic fungus, due to the continual nipping by the fish.

The condition is probably quite painful, but nonlethal. The morbidity can be 5-10% in highly crowded ponds.

The recommended therapy is to move affected fish from the population to a pond by themselves and to reduce the general population by size grading. The lesions on affected fish will heal within a matter of weeks, depending upon the water temperature. If the environmental conditions permit, there should be no secondary problems.

3. Physical Diseases

*Electrocution* in salmonid-rearing facilities should be termed an "extra-environmental" disease. It is caused by electrical shock, usually from two sources: lightning and faulty electrical devices coming in contact with the water. In either case, the mortality is virtually 100%. The most common postmortem lesion is intramuscular hemorrhage. Of all the environmental and extra-environmental diseases of salmonid, it also presents the greatest health hazard to the aquaculturist. It is general policy in recent hatchery construction to either eliminate all electrically operated equipment from the facility or to convert the necessary equipment to direct current, thereby reducing the hazards to both the fish and the human populations.

*Traumatic diseases,* if they can be called such, are the result of mishandling the fish. The morbidity and mortality are very low and are often "written off" as part of doing business. During pond cleaning, fish get stepped upon. While being size-graded, they get "gilled" in the grader. During crowding for population inventory, they get impinged between the crowding screen and the pond wall or bottom. Furthermore, any of these acts, in addition to being lethal to a few fish, are quite stressful to the remainder, which can result in many of the aforementioned syndromes.

*Sestonosis* is the accumulation of organic material, i.e., uneaten food and fecal materials, and aquatic fungi, along the buccal aspect of the gill rakers. The problem is quite common to sac fry, which spend their time on the bottom of the rearing units. The result is a very high morbidity (>50%) and a high mortality (>90%). The problem is untreatable by current technology. The best therapy is prophylaxis, i.e., virtually constant siphoning of the debris from the rearing units.

*Sunbum,* or "back-peel," is not uncommon during mid-summer in the northern latitudes. The complete etiological picture has not been demonstrated (Warren, 1971; Roberts, 1978). Some workers think there is a contributory nutritional imbalance, and others think there is a genotype contribution.

Sunburn is usually seen in populations of small (ca. 2-3-inch) fish within days of their being moved from the inside rearing units to small outside rearing units containing very clear water. The morbidity can be >50%, but the mortality is quite low in cases not complicated by aquatic bacteria, e.g., one of the myxobacteria. In this case the mortality can be very high. The suggested treatment regimen is to provide shade for the rearing units and to keep the fish on a high plane of nutrition fortified with extra vitamins - especially the B-complex and C vitamins. Recovery is usually uneventful and quite rapid. Prevention is easily accomplished by not stocking unshaded outside rearing units.

4. Chemical Diseases

*Botulism* is a problem associated with deep earthen ponds from which the sediments have not been removed for a number of years. The benthos becomes quite anaerobic and covered with a thin layer of aquatic fungi. This provides an excellent medium for the production of anaerobic bacteria. One of these is *Clostridium botulinum,* Type E or Type C. Intoxieations of the resident fish occur when the sediments are disturbed and the fish ingest the sediments. This condition is seen most commonly in mid-summer, although it could presumably occur at any time during the year if the water temperatures are above 12-15'C.

The clinical signs are initially disorientation exhibited by erratic swimming behavior, followed by complete ataxia, flaccid paralysis, and death. The postmortem lesions are not distinctive. The investigator must assemble the associated factors of (1) earthen ponds, (2) accumulated sediments, (3) history of disturbing the sediments, and (4) analysis of sediments and fish tissues for Type E toxin.

There is no known treatment for botulism in fish. It is best prevented by removing accumulated sediments annually or by keeping the benthos well aerated. The latter does have the undesirable effect of suspending the benthic materials and perhaps causing gill problems.

Heavy metal toxicities in aquaculture systems are quite rare. The rarity notwithstanding, there is always the potential for them to occur, especially as the traditional sources of water are being replaced with "water replenishment" systems. In these systems, copper and/or zinc plumbing fixtures can provide sufficient levels to be toxic for the fish. Other metals are cadmium, chromium, lead, selenium, and silver.

Death from chronic low-level heavy metal intoxication occurs due to the failure of either the kidneys or liver. These two organs bio-accumulate the metal to the point of its becoming pathological. Thus, diagnosis is based largely on analyzing tissues for levels of a suspect metal. The next step is to identify the source and remove it from the system.

*Brown blood disease* is the common name for clinical methemoglobinemia. The major causal factor is nitrite, the oxidation product of ammonia-nitrogen in the environment. Continuous levels >0.55 mg/l are sufficient to start the process of oxidizing the ferrous iron (Fe++) in heme to ferric iron (Fe... ),thereby inhibiting the oxygen-transport capabilities of hemoglobin. A secondary causal factor is the use of pure oxygen in the transport of fish.

The primary clinical sign is, as the common name implies, brown blood. The gill tissues are quite brown, rather than their rich, red color. A blood sample is also quite brown. Methemoglobin levels exceeding 25% are considered clinical, with lethal levels exceeding 50%.

The suggested treatment is 1-2% sodium chloride, followed by high dietary levels of ascorbic acid.

*Hypoxia* is the clinical term for a reduction of the partial pressure of dissolved oxygen below 90 mm He. At this point, the pressure differential between the water and the lamellar blood is insufficient to fully oxygenate the blood.

The usual causal factors are (1) exceeding the oxygen-carrying capacity of the rearing unit, (2) nighttime or cloudy weather oxygen demands by phytoplankton/zooplankton populations in the rearing unit, and (3) the biological oxygen demand of the rearing unit. The morbidity is usually 100% and the mortality slightly elevated above baseline. However, an increased mortality ensues as the condition persists.

The primary clinical sign is a reduction of growth rate, followed by labored respiration as the condition worsens.

*Anoxia* is caused by either of two factors: 1. When the dissolved oxygen in the aquatic environment decreases to the point where there is insufficient dissolved oxygen to support life. The primary causes of this are a cessation of inflowing water to the rearing unit or the loss of water in the rearing unit. 2. When the lamellar epithelium is altered so as to not permit oxygen uptake. The primary causes of this are sestonosis or complete interlamellar occlusion from the epithelial hyperplasia associated with environmental gill disease.

Fish having died of anoxia exhibit a typical posture. The mouth is agape, the opercula are extended, and the body is in rigor immediately at the time of death.

The suggested method of prevention is to constantly monitor the dissolved oxygen levels in the rearing units and to be watchful of clinical signs of hypoxia. Also, cleanliness of the rearing units and proper attention to chronic stressors will prevent the gill lamellar changes.

*Herbicidelpesticide and other organic compound toxicities* are the most difficult to define. In many cases, the investigator makes a tentative diagnosis of a chemical toxicity when all the other possibilities have been excluded. By this time, the offending chemical, if w aterborne, has long since left the system, thus making a definitive diagnosis quite difficult.

The effects range from mild paralytic signs at low level exposures to death in high level exposures. One of the main effects in low-grade toxicities in immunosuppression, which leaves the fish vulnerable to infectious agents. Neoplasia is another effect of long-term, low-grade exposure to certain organic toxicants.

Diagnosis is based, in main, on a history of toxicant release(s), paralytic signs in the fish, and histopathological and chemical analyses of the tissues.

*Gas bubble disease* is caused by N2 supersaturation of the water in the rearing unit. The factors giving rise to this condition are varied. The water passing pinhole leaks in pipes creates a vacuum, thus drawing in atmospheric air. Water flowing into a plunge-pool entrains air and the pressure of the depth creates the supersaturation. Water being pumped in a closed system from a deep well (>300 feet) is usually supersaturated with nitrogen and deficient in oxygen. The excess solubilized nitrogen in the water passes the lamellar epithelium and endothelium, only to come out of solution in the blood vascular system and creating emboli, which lead to death.

Nitrogen saturation levels of 101-105% affect sac fry. Levels >110% affect juvenile fish (>100/kg). Levels >125% affect adult fish.

Characteristic clinical signs in peracute cases are few. In acute cases, there is depression and bilateral exophthalmia. In chronic cases, the effects are not well documented and are of some concern to aquaculturists. Sac fry having died of gas bubble disease usually float upside down due to gas in the yolk sac.

Diagnosis is based largely upon observing air emboli in the vessels of the fins and periorbital tissues. In addition, total gas pressures are markedly increased.

Prevention of nitrogen supersaturation is accomplished easily by installing gas stabilization chambers through which the inflowing water passes into the rearing unit. Other methods of gas reduction and oxygenation, such as cascading the inflow water over a series of boards or screens, have been reported as successful.

*Cyanide toxicity* occurs during the mid-summer months when the water temperatures are at maximum. This condition enhances the growth of cyanogenic blue-green algae, which, when killed, release cyanide, This is very rare in conditions of intensive management, but can be an annual problem in fish being raised in net pens (cages) in large impoundments (reservoirs).

The antemortem signs are indistinct, as are the postmortem signs. The diagnosis is based largely upon recording a massive fish-kill in a eutrophic condition, supporting the production of blue-green algae.

Prevention is best accomplished by preventing the environment from becoming eutrophic (minimizing the organic load) and by applying one of the commercial "shade" chemicals, thereby restricting the sunlight energy needed by the algae.

*Oxygen supersaturation* causes a massive distension of the swim bladder of fish in waters coming from highly vegetated streams on bright, sunny days. The vegetation in this environment produces copious quantities of oxygen that are not dissipated and that overfills the swim bladder in the fish.

The morbidity is often low to moderate. The affected fish swim distressedly on their side at the surface of the water. At sundown and on cloudy days the condition disappears. The mortality is virtually none, unless the fish is unable to cope with the internal pressure and "anxiety" response.

The suggested means of prevention is to provide a means of gas reduction in the inflowing water and/or to reduce the vegetation in the source stream.

*Therapeutant toxicities*, unfortunately, are quite common. The majority of causes are, as the name of the syndrome implies, an overdose of a chemical intended to treat a clinical condition. The most common chemicals involved are formalin and malachite green (which is no longer permitted for use in food or game fish). It has been said by several wags that therapeutants have killed more fish than the diseases they were intended to treat. There is probably more truth than poetry in this statement. One of the more common maladies attributed to the exuberant use of malachite green on embryonating eggs is "white spot" disease." The syndrome appears at the sac fry stage, in which the yolk material contains particles of cream-colored coagulated yolk. As the clinical course progresses, the fins become extended rigidly and covered with a whitish film. Death ensues within days. There is no known treatment.

The recommended approach to prevent this situation is to establish a rigid facility policy that no fish will be treated with water-borne chemicals until a bioassay for dose and efficacy have been completed. The dosages recommended in many texts and extension leaflets should be considered as guides only. The toxic levels of all water-administered chemotherapeutants are affected by exposure time, pH, temperature, hardness, fish species, and fish age.

B. Infectious Diseases

*1. Viral Diseases*

There are three major viral diseases of trout, namely, infectious pancreatic necrosis (IPN), infectious hematopoietic necrosis (IHN), and viral hemorrhagic septicemia (VHS). All severely affect young trout. Mortalities can be as high as 90% in a single clinical episode. In addition, IHN and VHS affect older trout, although not as severely as young trout. All can be transmitted by contaminated eggs, although only IPN virus is truly vertically transmitting, i.e., within the egg. The others are egg-transmitted as contaminants.

There are no effective treatment regimens for these viral diseases. The most effective "treatment" is avoidance. Most states in America and most European countries have rigid conditions under which trout eggs may be imported.

A recommended method of preventing introduction of any of the three viruses is (1) rigid certification of the broodstock, (2) water-hardening the eggs in an iodophore, (3) disinfection of the eggs with an iodophore at the eyed stage, (4) incubating and hatching the eggs in upwelling incubators under strict quarantine, (5) removal of the egg shells from the sac fry soon after hatching, (6) getting the fry on feed under "ideal" environmental conditions, and (7) certifying that the fry are free from viruses before they leave the quarantine facility for the rearing ponds on the premises or elsewhere. Unfortunately, not many trout farmers in America fulfill all seven criteria. Thus, clinical episodes of these diseases are still severe problems.

*2. Bacterial Diseases*

The bacterial diseases of rainbow trout are classified as (1) acute systemic, (2) chronic systemic, and (3) acute cutaneous. Diseases within each group share common clinical signs and, as such, require some degree of laboratory work to specifically identify the pathogen. Diseases within each group also share common methods of treatment and prevention, thus reducing the necessity of specifically identifying the pathogen.

a. Acute systemic bacterial diseases

1) Furunculosis
2) Enteric redmouth disease
3) Bacterial hemorrhagic septicemia
4) Vibriosis
5) Streptococcosis

The clinical signs of acute systemic bacterial disease episodes in rainbow trout are:

Antemortem: Depression, inappetence, dark coloration, and reddened fin bases.

Postmortem: Enlarged, dark spleen; reddened viscera, empty GI tract, "pulpy" kidney, and reddish abdominal fluid.

The recommended treatment approach is to feed one of the FDA-approved antibacterials at the recommended level for 7-10 days. It is often advisable to request that the minimal inhibitory concentration of the antibacterial be determined. After the antibacterial feeding there must be at least a 28-day holding period before the fish can be processed for the market.

b. Acute cutaneous bacterial diseases

1) Columnaris
2) Myxobacteriosis

The clinical signs of these diseases can be confused with infections of several external parasitisms, e.g., *Gyrodactylus*, or a fungus, e.g., *Saprolegnia*.

Antemortem: Circumscribed, reddened areas of the skin; loosely defined, grayish mat over the back, and depression

Postmortem: Microscopic examination of skin scrapings reveal the typical column formation of organisms from skin and gill lesions.

The recommended treatment approach is to administer a suitable chemical via the water. Among the recommended chemicals are salt, formalin, or one of the quaternary ammonium compounds. It is advisable to conduct a bioassay of the selected chemical for efficacy and safety before treating the entire population. In addition, the ponds should be cleaned more frequently so as to reduce further infections.

c. Chronic systemic bacterial diseases

1) Bacterial kidney disease (BKD)
2) Mycobacteriosis (fish tuberculosis)

The clinical signs of these diseases are often not too apparent. The mortality is often quite low but persistent, despite appropriate therapy.

Antemortem: Depression and enlarged abdominal region.

Postmortem: Abcessation in the "soft" tissues, such as the liver, kidney, and spleen; clear to reddish abdominal fluid, and empty GI tracts.

The recommended treatment regimen for BKD is erythromycin thiocyanate in the feed for 21 days. However, this antibacterial is not yet FDA-approved for use in food fish. Instead, combinations of tetracycline and sulfamerazine are fed with varying degrees of success.

There is no effective treatment regimen for mycobacteriosis. It is, perhaps, very fortunate that this disease is quite rare.

The pathogens for these diseases are transmitted by susceptible fish ingesting flesh contaminated with the pathogen. In addition, the primary means of transmitting the BKD pathogen, *Renibacterium salmoninarum*, is via the egg from infected females. At present, the method to prevent this is to inject erythromycin phosphate subcutaneously into the females at 30-day intervals some 3-4 months before spawning. This permits the antibacterial to become deposited in the yolk material of the maturing ovum. At spawning, the just-fertilized eggs are water hardened in erythromycin phosphate. Incubation and hatching are done in upswelling incubators. The egg shells are flushed from the system as soon as possible after hatching. This precludes the fry from becoming infected after "nibbling" on the possibly contaminated shells.

3. Mycotic (Fungal) Diseases

There are two major mycotic diseases of rainbow trout: 1. Saprolegniosis, a cutaneous disease. 2. Ichthyophonus, a systemic disease. Both causal agents are saprophytic, i.e., can live free in nature.

Saprolegniosis, the more common of the two, is initiated by infection of a wound by the pathogen, *Saprolegnia*, with the resultant spread of the lesion over the body surface. Treatment is the water administration of a suitable chemical. Until recently, malachite green was the chemical of choice, but that is no longer the case. Currently, formalin seems to be quite effective.

Ichthyophonus is initiated by the fish ingesting the spores of *Ichthyophonus hofeii,* a free-living organism of dirt-bottom ponds or ponds in which the fecal solids have accumulated over a period of months. The organism was most likely introduced into the ponds through feeding infected scrap fish. This practice is rare, but in view of increasing feed costs, might become more common. The morbidity and mortality are quite low. The main clinical signs are lordoscoliosis, i.e., spinal curvature and erratic swimming behavior. The organism can be seen in brain and spinal cord tissues, where it becomes sequestered. There is no treatment. The suggested method of prevention is converting dirt-bottom ponds to concrete or some other suitable material, and practicing rigid sanitation.

4. Protozoan Diseases

There are several genera of protozoa capable of affecting rainbow trout. The majority are external opportunists, i.e., not parasitic, per se. These do cause the host some discomfort, with the resultant loss of growth potential. The ensuing stress response often "paves the way" for secondary systemic bacterial disease episodes.

The major parasitic external protozoan affecting rainbow trout is *Ichthyophthilius mulliftliis.* Episodes caused by this organism must be treated repeatedly with water-administered formalin to fully reduce the pathogen population.

There are also several systemic pathogenic protozoa. However, the majority do not cause clinical episodes of disease as much as they create physical and physiological changes that are conducive to the establishment of other pathogens, especially the systemic bacteria. Such is the organism that causes proliferative kidney disease (PKD). The infective stage is not known, nor is the means of transmission or the intermediate host, if there is one. There is no known effective treatment, at present. The primary damage attributable to this organism is a complete taking over of the immune response. This permits a secondary viral or bacterial pathogen to exert its pathological influences, virtually unhindered by the host defensive mechanism.

5. Metazoan Diseases

As with the protozoan diseases, there are many genera of metazoans affecting the well-being of trout. The majority of them live on the skin and gills of the host. There are some which live in the tissues (trematodes and nematodes) and in the intestinal tract (cestodes and nematodes). However, these are very rare in farm-raised trout.

The most common trematodal problems in trout are *Gyrodactylus and Dactylogyrus*, both monogenetic trematodes. The condition clinically is termed "blue-slime disease" - a misnomer, as there are many causes of this condition. Treatment of this infestation is by water-administered chemicals. Formalin is the most common. With *Gyrodaciylus*, only one treatment is necessary because it is a live-bearer. Cases of *Dactylogyrus* must be treated repeatedly, because this organism is an egg-layer.

Since the fish-infecting protozoa and metazoa are largely saprophytic and, as such, are opportunists in the disease process, pond cleanliness is the most effective method of preventing clinical episodes.

# VI. ECONOMICS AND MARKETING

This section discusses the costs of producing a table fish and explores methods by which the small volume trout producer can reduce production costs or, at least, keep them from rising at the same rate as other costs, through better management of feeding practices. In this day and age, this is necessary because pondside and processed trout selling price increases are not keeping pace with increases in production costs - thus, profit margins are slowly decreasing.

The fundamental question which must be asked and then answered is, "Am I producing the best fish I can?" It is unlikely that many could respond to that in the affirmative. In some cases, the person who would is fooling himself or herself and is destined for a life of prolonged disillusionment. So, the response is "No." Now what? What is the problem? Notice the use of the term "problem," rather than "problems." We can all identify problems -but when they are all lined up one behind the other in some array of causes and effects, one problem should stand out as being the one to be dealt with above all others, namely, the one which is seen every morning in the mirror - the BIG ME.

If that premise is accepted, then the next set of questions should be posed in a positive, rather than negative, mode. For example, "What should I be doing better?" rather than "What am I doing wrong?" The place to start is with the financial balance sheet. "What are my production costs?" is usually the first question, as well it should be. But, let's look at it a little differently. Let's itemize the production costs. For example:

What are the costs of:
eggs/fish
feed
utilities (heat, lights, telephone, fuel)
labor (including yours)
benefits (health insurance, holiday time, Social Security, etc.)
taxes (federal, state, and local)
insurance
mortality
chemicals
memberships and meetings
maintenance (vehicles, miscellaneous equipment)
advertising
debt service
legal fees
consultant fees

accountancy fees

These costs could be assembled on a personal computer spreadsheet so that they are readily available for examination, evaluation, and updating on a regular basis.

Under most circumstances, the total of the individual costs are in the neighborhood of $ 0.80-$l.l0/lb. In a few circumstances, especially under exquisitely managed conditions, the costs are in the neighborhood of $0.55-$O.86/lb. The usual breakdown for a typical "mom 'n' pop" trout farm is as follows:

| Item | % of costs |
|---|---|
| Eggs | 3.21 |
| Feed | 57.05 |
| Labor | 11.11 |
| Treatment | 4.70 |
| Mortality | 6.41 |
| Overhead | 17.52 |

Feed costs constitute the majority of production costs and they are not static. In this day and age of changing world politics and economics, no feed manufacturer is going to emulate President Bush by stating, "Read my lips - No increase in feed prices!" Fish feed prices will increase and maybe decrease, in some cases for a short time. This is due to various costs of feed ingredients, labor, packaging, distribution, and overhead.

If feed costs $0.23/lb. and is 57.05% of the total costs, by extrapolation of the other items, the total production costs would be $0.69/lb. Not too shabby on the surface of it, but what are trout selling for at pondside?. The usual range of prices is $0.70 (pond-runs) - $1.00 (prime fish)/lb. That does not leave much for net profit. So, what to do? Where can costs be cut? How can the selling price be better? How can more fish be produced on the farm? After all, doesn't volume increase profitability? How can I compete better with the "big boys" when they undercut my prices? These are questions frequently asked by troubled trout farmers.

Dealing with each of these questions individually, and collectively, is an interesting introspective exercise. First, "What to do?" The best approach is to completely evaluate your position. Identify problem areas and contact an expert. Now, this brings up another problem - who are the experts? It has been said that there are a lot of folks who claim to be experts and consultants, but who are not quite there yet. To reduce the risk of retaining someone unsuitable, ask other farmers for names of individuals whom they have called upon and have been satisfied with their service. Also, feed suppliers can provide some names.

When initially contacting the expert, ask for a copy of his or her credentials, references, and fee schedule. The client has this right and responsibility - his or her livelihood depends upon it. Above all, do not be in a hurry. In fact, a good thing to do is to start looking about long before this person is actually needed. It must be realized that calling in an expert is a costly proposition - in the range of $25-$50 an hour, plus travel, meals, and lodging expenses. So, it behooves one to have one's "ducks in line" to reduce the number of hours. A reputable consultant will request that a detailed description of the farm and the problems and concerns be available some weeks in advance of the site visit. Some clients put the expert on a small monthly retainer for a stated period of time. This gives the client the privilege of talking with him or her by phone now and again. Remember, the more the expert knows about the situation, the better the advice and the less it will cost.

Next, "Where can costs be cut?" Here, the topic of what not to do should be addressed. One of the many things trout farmers do to cut costs is to purchase "labor-saving" devices, most of which are initially very expensive, expensive to maintain, often difficult to operate, and frequently unreliable. If purchase of such a piece of equipment is contemplated, request a complete brochure from the manufacturer and a list of other purchasers to contact for opinions. Then request a site visit by a company representative. Finally, before making a decision to purchase the equipment, ask the consultant for his or her advice.

Reducing production costs is not easy, because the majority of the routine activities is just that -routine and difficult to change. The best approach is to completely evaluate the production process. Feed costs can be cut only if (1) the biomass and size(s) of fish in the ponds are known, (2) the carrying capacities are within the "no-effect" limits, (3) the anticipated growth rates are realistic, (4) the feed is weighed and presented properly, (5) the periodic pond inventories are precisely carried out, and (6) the production records are meticulously kept.

Next, "How to increase the selling price?" The best method to accomplish this is to produce a quality fish. A quality fish can be defined as one having all its fins in good condition, a bright body color, a high dress-out (> 80%), a high pin-boned fillet yield (> 50%), no off-flavors, and in the quantity and time period the purchaser needs it. The process of producing a quality fish begins with the desire to do so. A producer has to "have the fire" to get the job done.

Producing a quality fish leads into the next question, "How can more fish be produced on the farm?" Every trout farmer asks this question at one time or another. The best method to determine whether the farm could produce more fish is to initiate, with the assistance of a consultant, an in-depth evaluation of the facility from the standpoints of ponds (number, dimensions, and arrangements); water quality, quantity, and use; production schedule, and market potential. The next step is to design a production program beginning with the time eggs or fish are received and ending with the market-sized fish leaving the farm. This is not an easy task for the beginner - or the-not-so-beginner, for that matter. There are commercially available computer programs to assist in this task.

The last question is a very touchy one: "How can I compete better with the big boys when they undercut my prices?" The question, whether true or not, has been expressed on numerous occasions by many low volume trout farmers. Perhaps the best response is, "Market a product which is noncompetitive with those of the large growers." There are several potential products and market outlets that can satisfy this suggestion. They all require a lot of effort on the part of the concerned segment of the industry.

The key to the new product development is a market survey. An in-depth survey can be quite expensive. An informal, owner-conducted survey is quite simple, often quite educational, and tax deductible. It is simple in that potential outlets are visited personally to inquire about volume and price. But when conducting such a survey, one must ask questions in the proper manner. For example, at a restaurant, one does not inquire about how many pounds of trout are sold each week. One asks how many servings of what sized trout are presented each week and what is the cost per serving. In a fish market one asks how many fish and of what size are sold each week. Then, keeping in mind that fresh trout are quite perishable (the average shelf life is 48-72 hours on ice before it "tasteth peculiar"), one must decide if these markets can be serviced directly twice a week.

Direct service takes advantage of one of the problems faced by the large distributors' industry, namely, quality control after the product leaves the processing plant. When a diner is presented with a poor quality trout, who gets blamed? The producer/processor, of course. But the blame should rest with the distributor or whoever else has had custody of these fish in the time (often months) between their leaving the processing plant and arriving on a diner's plate.

Coming full circle, the bottom line in trout production is producing the right fish for the right market at the right time. Therein lies the crux of the problem for the small trout producer. This individual is primarily a farmer - a producer who got into the business because it sounded like a nice easy way, and a fun way, to make a living. Usually, after one year in the business, it became apparent that it wasn't all that it was touted to be. The farmer had to do things he or she had no experience in doing, namely, marketing his or her product. As a result, much time and wheel-spinning was spent between the two tasks, and frustration ensued.

There is need for an arrangement to lessen the frustration. Such an arrangement is practiced in Europe. It is quite straightforward. A centralized processor contracts with the growers to deliver fish of an agreed upon size and number during an agreed-upon time period at an agreed-upon price. The catfish people are already doing this. The problem to overcome is how to entice a processor and distributor to establish a reasonably located facility. A method which has been successful is for the interested producers collectively to identify and to sell the concept to potential firms. One caveat attendant to this scheme is that the processor must not also be a producer. This can lead to some frightfully bad feelings, especially when the market slumps. One does not have to have a Ph.D. to envision whose fish will go to market and whose will not in this situation.

## VII. BIBLIOGRAPHY AND SUGGESTED READINGS

### General Aquaculture

Bardach, J. E., H. Ryther and W. 0. McLarney, *Aquaculture - The Farming and Husbandry of Fresh Water and Marine Organisms.* Wile-Interscience, New York, 1974.

Bell, M. C., *Fisheries Handbook of Engineering Requirements and Biological Criteria.* U.S. Army Corps of Engineers, Portland, OR, 1986.

Brown, E. E., *World Fish Farming.- Cultivation and Economics,* second ed. AVI Publishing Co., Westport, CT, 1983.

Brown, E. E., and J. B. Gratzek, *Fish Farming Handbook* AVI Publishing Co., Westport, CT, 1980.

Cairns, V.W., P.V. Hodson and P.O. Nriagu, eds., *Contaminant Effects on Fisheries.* John Wile and Sons, New York, 1984.

Davis, H. S., *Culture and Diseases of Game Fishes.* University of California Press, Berkeley, 1967.

Huet, M., *Textbook of Fish Culture - Breeding and Cultivation of Fish,* second ed., revised by J. Timmermans. Fishing News Books, Ltd., Farnham, UK, 1986.

Jensen, G., *Handbook for Common Calculations in Finfl'sh Aquaculture.* Louisiana State University Ag. Center, LSU, 1988, 59 pages.

Klontz, G. W., *Concepts and Methods of Intensive Aquaculture.* Forestry, Wildlife and Range Experiment Station, University of Idaho, 1990, 198 pages.

Klontz, G. W., P. C. Downey and R. L. Focht, *A Manual for Trout and Salmon Production,* 1989 revision. Sterling R. Nelson and Sons, Murray, UT, 1985.

Klontz, G. W., and J. G. King, *Aquaculture in Idaho and Nationwide.* Res. Tech. Compl. Rept.. Idaho Department of Water Resources, Boise, ID, 1975.

Lannan, J. E., R. 0. Smitherman and G. Tchobanogious, eds., *Principles and Practices of Pond Aquaculture.* Oregon State University, Corvallis, OR, 1986.

Leitritz, E., and R. C. Lewis, *Trout and Salmon Culture (Hatchery Methods).* State of California Department of Fish and Game, Sacramento, CA, 1976.

Piper, R. G., ed., *Fish Hatchery Management.* U.S. Fish and Wildlife Service, Washington, DC, 1982.

Schaeperelaus, W., Textbook of Pond Culture (Rearing and Keeping of Carp, Trout and Allied Fishes). Paul Harey, Berlin, 1933.

Sedgewick, S. D., *Trout Farming Handbook,* fourth ed. Andre Deutsch, London. 1985.

Sedgewick, S. D., *The Salmon Handbook* Andre Deutsch, London, 1982.

Stevenson, J. P., *Trout Farming Manual.* Fishing News Books, Ltd., Farnham, UK, 1980.

Wheaton, F. W., *Aquaculture Engineering.* John Wile and Sons, New York, 1977, 708 pages.

Commercial Fish Farming

Chaston, I., *Marketing in Fisheries and Aquaculture.* Fishing News Books, Ltd., Farnham, UV, 1985.

Chaston, *I., Managerial Effectiveness in Fisheries and Aquaculture.* Fishing News Books, Ltd., Farnham, UK, 1988.

Christopher, M., **S.** H. Kennedy, M. McDonald and G. Wills, *Effective Marketing Management*. Gower Publishing Co., Ltd., Westmeat, UK, 1980.

In gram, M., *Wellies and Wallets: Investment in Intensive Aquaculture.* Clearwater Publ., Ltd., Isle of Man, 1985, 991 pages,

Laird, L. M., and T. Needham, eds., *Salmon and Trout Farming.* John Wile and Sons, New York, 1988.

Thompson, C. K., "Analyzing the Fish Farm." *The Appraisel Joumal,* April 1979, pp. 195-203.

Finfish in Aquaculture Systems

Haskell, D. C., "Graphical Method for Presenting Data on the Growth of Trout. *Prog.*

*Fish-Cult, 10:59-61* (1948).

Haskell, D. C., "Trout Growth in Hatcheries," *N. Y Fish and Game Joumal*, 6(2):204-237 (1959).

Pickering, A., ed., *Stress and Fish.* Academic Press, New York, 1981.

Tave, D., *Genetics for Fish Hatchery Managers.* AVI Publishing Co., Westport, CT, 1986.

Water in Aquaculture Systems

Ellis. M. M., B. A. Westfall, and M.D. Ellis, *Determination of Water Quality, Research Rupiah No. 9.* U.S. Fish and Wildlife Service, 1948.

Soderberg, R. W., "Aeration of Water Supplies for Fish Culture in Flowing Water." Prog. Fish-Cult., 44(2):89-93 (1982).

Rearing Ponds

Beveridge, M. C. M., *Cage Aquaculture.* Fishing News Books, Ltd., Farnham, U& 1987.

Burrows, R. E., and H. H. Chenowith, *Evaluation of Three Types of Fish Rearing Ponds, Research Report No.* 39, Bureau of Sport Fisheries and Wildlife, 1985.

Burrows, R. E., and H. H. Chenowith, "The Rectangular Circulating Rearing Pond," *Prog. Fish-Cult.*, 32(2):67 (1970).

Haskell, D. C., "Factors in Hatchery Pond Design." *N. Y Fish and Game Joumal*, 7(2):112-129 (1960).

Larmoyeux, J. D., H. Chenowith and R. G. Piper, "Evaluation of Circular Tanks for Salmonid Production," *Prog. Fish-Cult.*, 35(3):122 (1973).

Moody, T. M., and R. N. *McClesky, Veilical Raceways for Production of Rainbow Trout, Bulletin No.* 17. New Mexico Department of Fish and Game, 1978, 37 pages.

U.S. Soil Conservation Service, *Ponds - Planning, Design, Construction. Agricultural Handbook No.590.* U.S. Department of Agriculture, 1982, 51 pages.

Westers, H., and K. M. Pratt, "Rational Design of Hatcheries for Intensive Salmonid Culture Based on Metabolic Characteristics." *Prog. Fish-Cult.,* 39(4):157-165 (1977).

Carrying Capacities

Klontz, G. W., "Carrying Capacities in Single and Multiple-Use Systems." *Salmonid,* 14(l):14-18 (1990).

Piper, R. G., "Know the Carrying Capacities of Your Farm." *American Fishes and U.S. Trout News,* 15(l):4 (1970).

Piper, R. G., "Managing Hatcheries by the Numbers." *American Fishes and US. Trout News,* 17(3):10 (1972).

Westers, H., "Carrying Capacity of Salmonid Hatcheries." *Prog. Fish-Cult.,* 32(l):43-46 (1970).

Willoughby, H., "A Method for Calculating Carrying Capacities of Hatchery Troughs and Ponds." *Prog. FishCult.,* 30(3)173-174 (1968).

Feeds and Feeding

Cowie, C., A. Mackie and J. Bell, eds., *Nutrition and Feeding in Fish.* Academic Press, New York, 1985.

Halver, J. E., ed., *Fish Nutrition,* second ed. Academic Press, 1989.

Haskell, D. C., "Trout Growth in Hatcheries." *N.Y. Fish and Game Joumal*, 6(2):204-237 (1959).

Kaiser, H., J. de la Garza and G.W. Klontz, "Evaluation of Feeding Rate Models for Salmonids." *Journal of Applied Aquaculture* (in press 1991).

Kindschi, G. A., "Effect of Intermittent Feeding on Growth of Rainbow Trout, *Salmo gairdneri* Richardson." *Aquacult. Fish. Management.* 19:213-215 (1988).

Klontz, G. W., "Some Thoughts on How Pollutants Discharged from Fish Hatcheries are Generated." *Salmonid,* 1(3):8 (1979).

Klontz, G. W., M. H. Maskill and H. Kaiser, "The Effects of Reduced Continuous Versus Intermittent Feeding of Steelhead Trout." *Prog. Fish-Cult, (in press 1990).*

O'Keefe, T., "Demand Feeding Cuts Cost," *Salmonid,* 10(l):7 (1986).

Subcommittee on Fish Nutrition, *Nutrient Requirements of Trout, Salmon and Catfish.* National Academy of Sciences, Washington, DC, 1973.

Subcommittee on Fish Nutrition, *Nutrient Requirements of Coldwater Fishes.* National Academy of Sciences, Washington, DC, 1981.

Willoughby, H., N. Larson and J. T. Bowen, "The Pollutional Effects of Fish Hatcheries, *American Fish and U.S. Trout News,* 17(3):6,7,20,21 (1972).

Production Forecasting

Klontz, G. W., and D. I. Klontz, *AQUASYST.- A Production Program for Trout and Salmon Farmers*. Sterling H. Nelson and Sons, Murray, Utah, 1986, 62 pages.

Spawning and Egg Incubation

Gordon, M. R., K. C. Klotins, V. M. Campbell and M. M. Coper, *Fanned Salmon Broodstock Management.* B.C. Research, Vancouver, BC, 1987.

Disease Prevention and Control

Herwig, N., *Handbook of Drugs and Chemicals Used in the Treatment of Fish Diseases*. C.C. Thomas, Springfield, II, 1979.

Klontz, G. W., B. C. Stewart and D.W. Eib, "On the Etiology and Pathophysiology of Environmental Gill Disease in Juvenile Salmonids." *Fish and Shellfish Pathology,* A.E. Ellis, ed., Academic Press, 1985, pp. 199-210.

Roberts, R. J., and C. J. Shepherd, *Handbook of Trout and Salmon Diseases,* second Ed. Fishing News Books, Ltd, Farnham, UK, 1986.

Wood, J. W., *Diseases of Pacific Salmon: Their Prevention and Treatment*. State of Washington Department of Fisheries, Olympia, WA, 1970.

## Table 1
## FACTORS AFFECTING THE PRODUCTION OF FARM-RAISED RAINBOW TROUT

A. Fish-Associated

1. Ammonia
2. Behavior
3. Nutritional requirements
4. Environmental requirements
   a. Physical
   b. Chemical
5. Product definition
6. Growth-rate potential
7. Disease history
8. Condition factor
9. Cannabilism
10. Oxygen uptake
11. Oxygen demand
12. Fecal solids
13. C02
14. Stress response

B.Water-Associated

1. Dissolved oxygen
2. Nitrite
3. Alkalinity
4. pH
5. Inflow rate
6. Suspended solids
7. Settleable solids
8. Temperature
9. Carrying capacity
10. Agricultural contaminants
11. Industrial contaminants
12. Municipal contaminants
13. Natural contaminants
    a. $N_2$
    b. $C0_2$
    c. $H_2S$
    d. Fe
14. Utilization
15. Salinity
16. Hardness (Ca++)
17. B.O.D.
18. Viscosity

C. Container-Associated

1. Water volume
2. Water velocity
3. Composition
4. Water-flow pattern
5. Water replacement time
6. Outfall design
7. Shape

D. Nutrition-Associated

1. Feeding rate
2. Feed efficiency
3. Feed style
4. Nutritional quality
   a. Proximate analysis
   b. Energy content
5. Feed storage

E. Management-Associated

1. Fish sampling techniques
2. Feeding frequency

3. Feeding techniques
4. Record keeping
5. Pond cleaning
6. Fish-size grading
7. Management planning
8. Management objectives
9. Production economics

**Table 2**
**THE "NO-EFFECT" PHYSICAL AND CHEMICAL LIMITS OF WATER SUPPORTING MOST FINFISHES**

| PARAMETER | VALUE |
|---|---|
| Dissolved oxygen | >90 mm Hg $pO_2$ |
| | ca. 60% of saturation |
| pH | 6.7-8.5 |
| Alkalinity | 30-200 mg/l as $CaCO_3$ |
| Carbon dioxide | <2.0 mg/l |
| Calcium | >50 mg/l |
| Zinc | <0.04 mg/l at pH 7.5 |
| Copper | <0.006 mg/l in soft water |
| | <0.3 mg/l in hard water |
| Iron | <1.0 mg/l |
| Ammonia-N (as $NH_3$) | <0.03 mg/l constant |
| | <0.05 mg/l intermittent |
| Nitrite-N | <0.55 mg/l |
| Nitrogen | <100% of saturation |
| Suspended solids | <80 mg/l |
| Dissolved solids | 50-200 mg/l |
| Temperature | SET for species |

**Table 3**

**PROCESSED PRODUCTS OF RAINBOW TROUT AVAILABLE IN THE MARKETPLACE IN AMERICA AND WESTERN EUROPE**

| | |
|---|---|
| TRADITIONAL | |
| Iced—round | Frozen—dressed |
| dressed | boned |
| boned fillets | boned and breaded |
| | boned and stuffed |
| | boned fillets |
| VALUE-ADDED | |
| Smoked—dressed | paté |
| boned | quiche |
| fillets | paste |
| sausage | crêpes |
| roll | mousse |
| Kippered—dressed | kedgeree |
| fillets | "burger" |
| boned | hoagie |
| Soup—creamed | goulash |
| Vol-au-vents | pancakes |
| Toast toppers | pickled fillets |
| Canned—minced | pet food |
| whole | |

**Table 4**
**CARRYING CAPACITY DETERMINANT FACTORS**

| CARRYING CAPACITY | DETERMINANT FACTORS |
|---|---|
| Density | Rearing Space<br>Fish length |
| Oxygen | Water temperature<br>Elevation<br>Water inflow to pond<br>Standard Metabolic Rate |
| Ammonia | Water temperature<br>Water pH<br>Feeding rate<br>Protein content<br>Protein digestibility |
| Solids | Feeding rate<br>Feed digestibility<br>Water-retention time<br>Water velocity |

**Table 5**
**RECOMMENDED SIZES OF FEED FOR RAINBOW TROUT**
(Source: Klontz, et al, 1989)

| No./lb. | Feed Size |
|---|---|
| 3600-1000 | Starter |
| 1000-400 | No. 1 fry |
| 400-200 | No. 2 fry |
| 200-100 | No. 3 fine crumble |
| 100-40 | No. 4 course crumble |
| 40-20 | 3/32" pellet |
| 20-8 | 1/8" pellet |
| 8-5 | 5/32" pellet |
| 5-1 | 3/16" pellet |
| >1 | 1/4" pellet |

**Table 6**

**DAILY FEEDING FREQUENCIES BASED UPON FISH SIZE**

| Fish Size | No. Feedings Per Day |
|---|---|
| Fry to 300/lb. | 1. Mechanical feeder set for 15-minute intervals |
| | 2. Hand feeding at 30-60-minute |
| intervals | |
| 300-40 lb. | Hourly feedings by hand |
| 40-20 lb. | Feedings at 1-2-hour intervals |
| >20/lb. | 1. Feedings at 2-4 hour intervals |
| | 2. Demand feeders |

**Table 7**
**A PROJECTED PRODUCTION SCHEDULE FROM FIRST-FEEDING FRY TO 100/LBS. FISH**

| Date | Period No. | Fish (n) | Length (in.) | No./lb. | Biomass (lbs.) | Feed (lbs.) | Feed Size |
|---|---|---|---|---|---|---|---|
| 10/18/91 | 1 | 82397 | 1.25 | 1517 | 54 | 151 | Starter |
| 11/01/91 | 2 | 82166 | 1.83 | 457 | 180 | 296 | #1 |
| 11/15/91 | 3 | 81937 | 2.42 | 192 | 426 | 574 | #2 |
| 11/29/91 | 4 | 81707 | 3.00 | 97.7 | 836 | — | — |

Number of eggs required . . . . . . . . . . . . . . . . . . . 98,499
Date by which eggs must be taken . . . . . . . . . . . 09/24/91
Feed required for the 42 days of feeding . . . . . 1,021 lbs.

**Table 8**
**A PRODUCTION SCHEDULE FOR FISH FROM IOO/LB. TO 1.3/LB.**

| Date | Period No. | Fish (n) | Length (in.) | No./lb. | Biomass (lbs.) | Feed (lbs.) | Feed Size |
|---|---|---|---|---|---|---|---|
| 11/29/91 | 4 | 13750 | 3.0 | 99.8 | 138 | 144 | #3 |
| 12/13/91 | 5 | 13712 | 3.6 | 57.0 | 241 | 203 | #4 |
| 12/27/91 | 6 | 13673 | 4.2 | 35.5 | 386 | 293 | 3/32 |
| 01/10/92 | 7 | 13635 | 4.7 | 23.5 | 581 | 379 | 3/32 |
| 01/24/92 | 8 | 13597 | 5.3 | 16.3 | 833 | 477 | 3/32 |
| 02/07/92 | 9 | 13559 | 5.9 | 11.8 | 1151 | 587 | 1/8 |
| 02/21/92 | 10 | 13521 | 6.5 | 8.8 | 1542 | 708 | 1/8 |
| 03/07/92 | 11 | 13483 | 7.1 | 6.7 | 2014 | 841 | 1/8 |
| 03/21/92 | 12 | 13445 | 7.7 | 5.2 | 2575 | 986 | 5/32 |
| 04/04/92 | 13 | 13408 | 8.2 | 4.1 | 3232 | 1142 | 5/32 |
| 04/18/92 | 14 | 13370 | 8.8 | 3.3 | 3994 | 1310 | 5/32 |
| 05/02/92 | 15 | 13333 | 9.4 | 2.7 | 4867 | 1490 | 5/32 |
| 05/16/92 | 16 | 13296 | 10.0 | 2.3 | 5860 | 1681 | 5/32 |
| 05/30/92 | 17 | 13258 | 10.6 | 1.9 | 6981 | 1884 | 5/32 |
| 06/13/92 | 18 | 13221 | 11.2 | 1.6 | 8236 | 2098 | 5/32 |
| 06/27/92 | 19 | 13184 | 11.8 | 1.4 | 9635 | 479 | 5/32 |
| 06/30/92 | 20 | 13176 | 11.9 | 1.3 | 9954 | — | — |

**Table 9**
**A DAILY 14-DAY PROGRAM FOR GROWTH PERIOD NO. 4**
**(Prepared using the COMPACT programs)**

| Date | Fish (n) | Lenght (mm) | Biomass (lbs.) | Gain (%) | Feed (lbs.) |
|---|---|---|---|---|---|
| 11/29 | 12,315 | 79 | 150 | 4.07 | 8.8 |
| 11/30 | 12,312 | 80 | 156 | 4.01 | 9.1 |
| 12/01 | 12,309 | 81 | 162 | 3.96 | 9.3 |
| 12/02 | 12,306 | 82 | 169 | 3.91 | 9.6 |
| 12/03 | 12,303 | 83 | 175 | 3.86 | 9.8 |
| 12/04 | 12,300 | 84 | 182 | 3.81 | 10.1 |
| 12/05 | 12,297 | 85 | 189 | 3.76 | 10.3 |
| 12/06 | 12,294 | 86 | 196 | 3.72 | 10.6 |
| 12/07 | 12,291 | 87 | 203 | 3.67 | 10.8 |
| 12/08 | 12,288 | 88 | 211 | 3.63 | 11.1 |
| 12/09 | 12,285 | 89 | 218 | 3.58 | 11.3 |
| 12/10 | 12,282 | 90 | 226 | 3.54 | 11.6 |
| 12/11 | 12,279 | 91 | 234 | 3.50 | 11.9 |
| 12/12 | 12,276 | 92 | 242 | 3.46 | 12.1 |

Total feed to be fed . . . . . . . . . . . . . . . . . . . . . . 143.6 lbs.
Expecting ending length . . . . . . . . . . . . . . . . . . . . 93.0 mm (3.7")
Expected n/lb . . . . . . . . . . . . . . . . . . . . . . . . . . . 49.05
Expected biomass . . . . . . . . . . . . . . . . . . . . . . . 250.0 lbs.

APPENDIX I

REFERENCE TABLES
FOR PRODUCTION OF RAINBOW TROUT

| Table 1<br>WEIGHT/LENGTH VALUES FOR RAINBOW TROUT<br>UNDER PRODUCTION CONDITIONS | | | |
|---|---|---|---|
| Length (inch) | Weight (lb) | Number/lb | Condition factor |
| 1.250 | 0.000659 | 1516.97705 | 0.00033751 |
| 1.500 | 0.001166 | 857.50684 | 0.00034553 |
| 1.750 | 0.001889 | 529.38892 | 0.00035246 |
| 2.000 | 0.002869 | 348.60229 | 0.00035857 |
| 2.250 | 0.004147 | 241.14874 | 0.00036406 |
| 2.500 | 0.005766 | 173.42807 | 0.00036903 |
| 2.750 | 0.007769 | 128.70959 | 0.00037359 |
| 3.000 | 0.010201 | 98.03439 | 0.00037780 |
| 3.250 | 0.013103 | 76.31587 | 0.00038171 |
| 3.500 | 0.016523 | 60.52229 | 0.00038537 |
| 3.750 | 0.020504 | 48.77162 | 0.00038881 |
| 4.000 | 0.025092 | 39.85387 | 0.00039206 |
| 4.250 | 0.030332 | 32.96808 | 0.00039513 |
| 4.500 | 0.036372 | 27.56931 | 0.00039805 |
| 4.750 | 0.042958 | 23.27866 | 0.00040083 |
| 5.000 | 0.050436 | 19.82712 | 0.00040349 |
| 5.250 | 0.058754 | 17.02013 | 0.00040603 |
| 5.500 | 0.067959 | 14.71467 | 0.00040847 |
| 5.750 | 0.078100 | 12.80409 | 0.00041082 |
| 6.000 | 0.089224 | 11.20775 | 0.00041307 |
| 6.250 | 0.101380 | 9.86390 | 0.00041525 |
| 6.500 | 0.114616 | 8.72482 | 0.00041735 |

| Table 1<br>WEIGHT/LENGTH VALUES FOR RAINBOW TROUT<br>UNDER PRODUCTION CONDITIONS | | | |
|---|---|---|---|
| Length (inch) | Weight (lb) | Number/lb | Condition factor |
| 6.750 | 0.128981 | 7.75307 | 0.00041939 |
| 7.000 | 0.144525 | 6.91922 | 0.00042136 |
| 7.250 | 0.161297 | 6.19975 | 0.00042327 |
| 7.500 | 0.179347 | 5.57580 | 0.00042512 |
| 7.750 | 0.198723 | 5.03214 | 0.00042692 |
| 8.000 | 0.219476 | 4.55630 | 0.00042867 |
| 8.250 | 0.241659 | 4.13807 | 0.00043037 |
| 8.500 | 0.265318 | 3.76906 | 0.00043203 |
| 8.750 | 0.290506 | 3.44228 | 0.00043364 |
| 9.000 | 0.317274 | 3.15185 | 0.00043522 |
| 9.250 | 0.345672 | 2.89291 | 0.00043676 |
| 9.500 | 0.375752 | 2.66133 | 0.00043826 |
| 9.750 | 0.407566 | 2.45359 | 0.00043973 |
| 10.000 | 0.441163 | 2.26673 | 0.00044116 |
| 10.250 | 0.476597 | 2.09821 | 0.00044257 |
| 10.500 | 0.513920 | 1.94583 | 0.00044394 |
| 10.750 | 0.553184 | 1.80772 | 0.00044529 |
| 11.000 | 0.594440 | 1.68200 | 0.00044661 |
| 11.250 | 0.637743 | 1.56803 | 0.00044791 |
| 11.500 | 0.683140 | 1.46383 | 0.00044918 |
| 11.750 | 0.730690 | 1.36857 | 0.00045042 |
| 12.000 | 0.780442 | 1.28132 | 0.00045165 |

**Table 2**
**DISSOLVED OXYGEN (MG/L) CONTENT AT 100% SATURATION**
**(Compensated for Temperature (° C) and Elevation (ft.))**

| Water Temp | Elevation (feet) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (°C) | 0 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| 0 | 14.60 | 14.34 | 14.09 | 13.84 | 13.59 | 13.35 | 13.11 | 12.88 | 12.65 | 12.43 |
| 1 | 14.20 | 13.95 | 13.70 | 13.46 | 13.22 | 12.98 | 12.75 | 12.53 | 12.30 | 12.08 |
| 2 | 13.81 | 13.57 | 13.33 | 13.09 | 12.86 | 12.63 | 12.41 | 12.19 | 11.97 | 11.76 |
| 3 | 13.45 | 13.21 | 12.97 | 12.74 | 12.52 | 12.29 | 12.07 | 11.86 | 11.65 | 11.44 |
| 4 | 13.09 | 12.86 | 12.63 | 12.41 | 12.19 | 11.97 | 11.76 | 11.55 | 11.34 | 11.14 |
| 5 | 12.76 | 12.53 | 12.31 | 12.09 | 11.87 | 11.66 | 11.46 | 11.25 | 11.05 | 10.85 |
| 6 | 12.44 | 12.21 | 12.00 | 11.78 | 11.57 | 11.37 | 11.17 | 10.97 | 10.77 | 10.58 |
| 7 | 12.13 | 11.91 | 11.70 | 11.49 | 11.29 | 11.09 | 10.89 | 10.69 | 10.50 | 10.32 |
| 8 | 11.83 | 11.62 | 11.41 | 11.21 | 11.01 | 10.81 | 10.62 | 10.43 | 10.25 | 10.06 |
| 9 | 11.55 | 11.34 | 11.14 | 10.94 | 10.75 | 10.55 | 10.37 | 10.18 | 10.00 | 9.82 |
| 10 | 11.28 | 11.08 | 10.88 | 10.68 | 10.49 | 10.31 | 10.12 | 9.94 | 9.76 | 9.59 |
| 11 | 11.02 | 10.82 | 10.63 | 10.44 | 10.25 | 10.07 | 9.89 | 9.71 | 9.54 | 9.37 |
| 12 | 10.77 | 10.57 | 10.38 | 10.20 | 10.02 | 9.84 | 9.66 | 9.49 | 9.32 | 9.15 |
| 13 | 10.53 | 10.34 | 10.15 | 9.97 | 9.79 | 9.62 | 9.44 | 9.27 | 9.11 | 8.95 |
| 14 | 10.29 | 10.11 | 9.93 | 9.75 | 9.58 | 9.40 | 9.24 | 9.07 | 8.91 | 8.75 |
| 15 | 10.07 | 9.89 | 9.71 | 9.54 | 9.37 | 9.20 | 9.02 | 8.87 | 8.71 | 8.56 |
| 16 | 9.86 | 9.68 | 9.51 | 9.34 | 9.17 | 9.00 | 8.84 | 8.68 | 8.53 | 8.37 |
| 17 | 9.65 | 9.48 | 9.31 | 9.14 | 8.98 | 8.81 | 8.66 | 8.50 | 8.35 | 8.20 |
| 18 | 9.45 | 9.28 | 9.12 | 8.95 | 8.79 | 8.63 | 8.48 | 8.32 | 8.17 | 8.03 |
| 19 | 9.26 | 9.09 | 8.93 | 8.77 | 8.61 | 8.46 | 8.30 | 8.15 | 8.01 | 7.86 |

**Table 2**
**DISSOLVED OXYGEN (MG/L) CONTENT AT 100% SATURATION**
**(Compensated for Temperature (° C) and Elevation (ft.))**

| Water Temp | Elevation (feet) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| (°C) | 0 | 500 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| 20 | 9.08 | 8.91 | 8.75 | 8.59 | 8.44 | 8.29 | 8.14 | 7.99 | 7.84 | 7.70 |
| 21 | 8.90 | 8.74 | 8.58 | 8.42 | 8.27 | 8.12 | 7.98 | 7.83 | 7.69 | 7.55 |
| 22 | 8.73 | 8.57 | 8.41 | 8.26 | 8.11 | 7.96 | 7.82 | 7.68 | 7.54 | 7.40 |
| 23 | 8.56 | 8.40 | 8.25 | 8.10 | 7.96 | 7.81 | 7.67 | 7.53 | 7.39 | 7.26 |
| 24 | 8.40 | 8.25 | 8.10 | 7.95 | 7.81 | 7.66 | 7.52 | 7.39 | 7.25 | 7.12 |
| 25 | 8.24 | 8.09 | 7.95 | 7.80 | 7.64 | 7.52 | 7.38 | 7.25 | 7.12 | 6.99 |
| 26 | 8.09 | 7.95 | 7.80 | 7.66 | 7.52 | 7.38 | 7.25 | 7.11 | 6.98 | 6.86 |
| 27 | 7.95 | 7.80 | 7.66 | 7.52 | 7.38 | 7.25 | 7.11 | 6.98 | 6.86 | 6.73 |
| 28 | 7.81 | 7.66 | 7.52 | 7.39 | 7.25 | 7.12 | 6.99 | 6.86 | 6.73 | 6.61 |
| 29 | 7.67 | 7.53 | 7.39 | 7.26 | 7.12 | 6.99 | 6.86 | 6.74 | 6.61 | 6.49 |
| 30 | 7.54 | 7.40 | 7.26 | 7.13 | 7.00 | 6.87 | 6.74 | 6.62 | 6.50 | 6.38 |

**Table 3**
**DISSOLVED OXYGEN CONCENTRATION (mg/l)**
**WHEN THE $pO_2$ IS 90 mm Hg**

| Water Temperature °C | Dissolved Oxygen mg/l |
|---|---|
| 0 | 8.32 |
| 1 | 8.10 |
| 2 | 7.88 |
| 3 | 7.66 |
| 4 | 7.45 |
| 5 | 7.28 |
| 6 | 7.10 |
| 7 | 6.92 |
| 8 | 6.76 |
| 9 | 6.60 |
| 10 | 6.45 |
| 11 | 6.31 |
| 12 | 6.17 |
| 13 | 6.04 |
| 14 | 5.91 |
| 15 | 5.79 |
| 16 | 5.67 |
| 17 | 5.57 |
| 18 | 5.46 |
| 19 | 5.35 |
| 20 | 5.25 |

| Table 4<br>**DISSOLVED OXYGEN CONTENT**<br>**(% SATURATION AT A $pO_2$ OF 90 MM Hg)**<br>**(Compensated for tempature and elevation)** | | | | | | |
|---|---|---|---|---|---|---|
| Water temp | | | Elevation (in feet above msl) | | | |
| °C | 0 | 1000 | 2000 | 3000 | 4000 | 5000 |
| 0 | 0.5687 | 0.5909 | 0.6140 | 0.6380 | 0.6619 | 0.6876 |
| 1 | 0.5692 | 0.5917 | 0.6150 | 0.6388 | 0.6628 | 0.6882 |
| 2 | 0.5694 | 0.5915 | 0.6151 | 0.6391 | 0.6627 | 0.6888 |
| 3 | 0.5691 | 0.5915 | 0.6148 | 0.6387 | 0.6626 | 0.6882 |
| 4 | 0.5698 | 0.5924 | 0.6153 | 0.6396 | 0.6634 | 0.6891 |
| 5 | 0.5701 | 0.5924 | 0.6159 | 0.6397 | 0.6636 | 0.6900 |
| 6 | 0.5703 | 0.5927 | 0.6163 | 0.6402 | 0.6642 | 0.6900 |
| 7 | 0.5705 | 0.5930 | 0.6162 | 0.6407 | 0.6647 | 0.6906 |
| 8 | 0.5709 | 0.5935 | 0.6168 | 0.6408 | 0.6654 | 0.6912 |
| 9 | 0.5714 | 0.5941 | 0.6174 | 0.6414 | 0.6660 | 0.6918 |
| 10 | 0.5718 | 0.5945 | 0.6178 | 0.6418 | 0.6663 | 0.6921 |
| 11 | 0.5726 | 0.5953 | 0.6186 | 0.6432 | 0.6670 | 0.6934 |
| 12 | 0.5729 | 0.5956 | 0.6189 | 0.6434 | 0.6677 | 0.6940 |
| 13 | 0.5736 | 0.5962 | 0.6201 | 0.6446 | 0.6689 | 0.6951 |
| 14 | 0.5743 | 0.5970 | 0.6208 | 0.6452 | 0.6693 | 0.6961 |
| 15 | 0.5748 | 0.5975 | 0.6212 | 0.6462 | 0.6907 | 0.6968 |
| 16 | 0.5751 | 0.5981 | 0.6217 | 0.6465 | 0.6710 | 0.6974 |
| 17 | 0.5762 | 0.5991 | 0.6226 | 0.6473 | 0.6723 | 0.6985 |
| 18 | 0.5772 | 0.6000 | 0.6240 | 0.6485 | 0.6732 | 0.7000 |
| 19 | 0.5771 | 0.6004 | 0.6243 | 0.6485 | 0.6238 | 0.7003 |

| **Table 4**<br>**DISSOLVED OXYGEN CONTENT**<br>**(% SATURATION AT A $pO_2$ OF 90 MM Hg)**<br>**(Compensated for tempature and elevation)** | | | | | | |
|---|---|---|---|---|---|---|
| Water temp | | | Elevation (in feet above msl) | | | |
| °C | 0 | 1000 | 2000 | 3000 | 4000 | 5000 |
| 20 | 0.5782 | 0.6014 | 0.6250 | 0.6506 | 0.6748 | 0.7019 |

| **Table 5**<br>**TEMPERATURE-RELATED**<br>**GROWTH RATE POTENTAL FOR SALMONIDS**<br>**SPECIES/STRAIN** | | | | |
|---|---|---|---|---|
| Tempature (C) | Rainbow Trout-Shasta | Rainbow Trout-Kamloops | Brook Trout | Brown Trout |
| S.E.T. | 15° | 14° | 15° | 15° |
| 25 | 0.193 | 0.222 | 0.088 | 0.140 |
| 24 | 0.283 | 0.327 | 0.166 | 0.206 |
| 23 | 0.374 | 0.432 | 0.245 | 0.272 |
| 22 | 0.465 | 0.537 | 0.323 | 0.338 |
| 21 | 0.556 | 0.641 | 0.401 | 0.404 |
| 20 | 0.646 | 0.746 | 0.480 | 0.470 |
| 19 | 0.737 | 0.851 | 0.558 | 0.536 |
| 18 | 0.828 | 0.956 | 0.637 | 0.602 |
| 17 | 0.919 | 1.060 | 0.715 | 0.668 |
| 16 | 1.009 | 1.165 | 0.793 | 0.734 |
| 15 | 1.100 | 1.270 | 0.872 | 0.800 |
| 14 | 1.009 | 1.165 | 0.950 | 0.734 |
| 13 | 0.919 | 1.060 | 0.872 | 0.668 |
| 12 | 0.828 | 0.956 | 0.793 | 0.602 |
| 11 | 0.737 | 0.851 | 0.715 | 0.536 |
| 10 | 0.646 | 0.746 | 0.637 | 0.470 |
| 9 | 0.556 | 0.641 | 0.558 | 0.404 |
| 8 | 0.465 | 0.537 | 0.480 | 0.338 |
| 7 | 0.374 | 0.432 | 0.401 | 0.272 |
| 6 | 0.283 | 0.327 | 0.323 | 0.206 |

| Table 5<br>**TEMPERATURE-RELATED<br>GROWTH RATE POTENTAL FOR SALMONIDS<br>SPECIES/STRAIN** | | | | |
|---|---|---|---|---|
| Tempature (C) | Rainbow Trout-Shasta | Rainbow Trout-Kamloops | Brook Trout | Brown Trout |
| 5 | 0.193 | 0.222 | 0.245 | 0.140 |
| 4 | 0.102 | 0.117 | 0.166 | 0.074 |
| 3 | 0.011 | 0.013 | 0.088 | 0.008 |
| 2 | 0.000 | 0.000 | 0.010 | 0.000 |

| Table 6<br>LIFE SUPPORT INDICES (LBS. FISH/INCHES OF LENGTH/GPM)<br>FOR TROUT AND SALMON<br>AS RELATED TO WATER TEMPERATURE AND ELEVATION | | | | | | |
|---|---|---|---|---|---|---|
| Temp | Elevation(feet) | | | | | |
| °F | 0 | 1000 | 2000 | 3000 | 4000 | 5000 |
| 33 | 4.183 | 4.022 | 3.867 | 3.719 | 3.576 | 3.438 |
| 34 | 3.984 | 3.83 | 3.683 | 3.541 | 3.405 | 3.274 |
| 35 | 3.794 | 3.648 | 3.508 | 3.373 | 3.243 | 3.118 |
| 36 | 3.613 | 3.474 | 3.341 | 3.212 | 3.089 | 2.97 |
| 37 | 3.441 | 3.309 | 3.182 | 3.059 | 2.942 | 2.828 |
| 38 | 3.277 | 3.151 | 3.03 | 2.914 | 2.802 | 2.694 |
| 39 | 3.121 | 3.001 | 2.886 | 2.775 | 2.668 | 2.556 |
| 40 | 2.972 | 2.858 | 2.748 | 2.643 | 2.541 | 2.443 |
| 41 | 2.831 | 2.772 | 2.618 | 2.517 | 2.42 | 2.327 |
| 42 | 2.696 | 2.593 | 2.493 | 2.397 | 2.305 | 2.216 |
| 43 | 2.568 | 2.469 | 2.374 | 2.283 | 2.195 | 2.111 |
| 44 | 2.446 | 2.352 | 2.261 | 2.174 | 2.091 | 2.01 |
| 45 | 2.329 | 2.24 | 2.153 | 2.071 | 1.991 | 1.914 |
| 46 | 2.1218 | 2.133 | 2.051 | 1.972 | 1.896 | 1.823 |
| 47 | 2.113 | 2.031 | 1.953 | 1.878 | 1.806 | 1.736 |
| 48 | 2.012 | 1.935 | 1.86 | 1.789 | 1.72 | 1.654 |
| 49 | 1.916 | 1.843 | 1.772 | 1.704 | 1.638 | 1.575 |
| 50 | 1.825 | 1.755 | 1.687 | 1.622 | 1.56 | 1.5 |
| 51 | 1.734 | 1.667 | 1.603 | 1.541 | 1.482 | 1.425 |
| 52 | 1.647 | 1.584 | 1.523 | 1.464 | 1.408 | 1.354 |
| 53 | 1.565 | 1.505 | 1.447 | 1.391 | 1.338 | 1.286 |

| **Table 6**<br>**LIFE SUPPORT INDICES (LBS. FISH/INCHES OF LENGTH/GPM)**<br>**FOR TROUT AND SALMON**<br>**AS RELATED TO WATER TEMPERATURE AND ELEVATION** | | | | | | |
|---|---|---|---|---|---|---|
| Temp | Elevation(feet) | | | | | |
| °F | 0 | 1000 | 2000 | 3000 | 4000 | 5000 |
| 54 | 1.486 | 1.429 | 1.374 | 1.321 | 1.271 | 1.222 |
| 55 | 1.412 | 1.358 | 1.306 | 1.255 | 1.207 | 1.161 |
| 56 | 1.342 | 1.29 | 1.24 | 1.193 | 1.147 | 1.103 |
| 57 | 1.274 | 1.225 | 1.178 | 1.133 | 1.089 | 1.048 |
| 58 | 1.211 | 1.164 | 1.119 | 1.076 | 1.035 | 0.995 |
| 59 | 1.15 | 1.106 | 1.063 | 1.023 | 0.983 | 0.945 |
| 60 | 1.093 | 1.051 | 1.01 | 0.971 | 0.934 | 0.898 |
| 61 | 1.038 | 0.998 | 0.96 | 0.923 | 0.887 | 0.853 |
| 62 | 0.986 | 0.948 | 0.912 | 0.877 | 0.843 | 0.811 |
| 63 | 0.937 | 0.901 | 0.866 | 0.833 | 0.801 | 0.77 |
| 64 | 0.89 | 0.856 | 0.823 | 0.791 | 0.761 | 0.732 |
| 65 | 0.845 | 0.813 | 0.782 | 0.752 | 0.723 | 0.695 |
| 66 | 0.803 | 0.772 | 0.743 | 0.714 | 0.687 | 0.66 |
| 67 | 0.763 | 0.734 | 0.705 | 0.678 | 0.652 | 0.627 |
| 68 | 0.725 | 0.697 | 0.67 | 0.644 | 0.62 | 0.596 |
| 69 | 0.689 | 0.662 | 0.637 | 0.612 | 0.589 | 0.566 |

**Table 7**
**STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)**
**FOR RAINBOW TROUT**
**(Compensated for Fish Size and Water Temperature)**

| Fish Weight | Water Temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| (G) | 1 | 3 | 5 | 7 | 9 | 11 | 13 |
| 5 | 0.6010 | 0.7138 | 0.8477 | 1.0067 | 1.1955 | 1.4197 | 1.6861 |
| 10 | 2.0780 | 1.2802 | 1.5203 | 1.8055 | 2.1442 | 2.5464 | 3.0240 |
| 15 | 1.5171 | 1.8017 | 2.1397 | 2.5410 | 3.0177 | 3.5837 | 4.2559 |
| 20 | 1.9334 | 2.2961 | 2.7268 | 3.1382 | 3.8457 | 4.5670 | 5.4237 |
| 25 | 2.3335 | 2.7712 | 3.2910 | 3.9083 | 4.6414 | 5.5120 | 6.5459 |
| 30 | 2.7211 | 3.2315 | 3.8376 | 4.5575 | 5.4123 | 6.4276 | 7.6442 |
| 35 | 3.0986 | 3.6798 | 4.3700 | 5.1897 | 6.1632 | 7.3193 | 8.6922 |
| 40 | 3.4766 | 4.1181 | 4.8906 | 5.8079 | 6.8074 | 8.1912 | 9.7276 |
| 50 | 4.1852 | 4.9702 | 5.9025 | 7.0097 | 8.3246 | 9.8861 | 11.7404 |
| 55 | 4.5353 | 5.3860 | 6.3962 | 7.5960 | 9.0209 | 10.7130 | 12.7224 |
| 60 | 4.8803 | 5.7958 | 6.8829 | 8.1740 | 9.7072 | 11.5281 | 13.6904 |
| 65 | 5.2209 | 6.2003 | 7.3633 | 8.7445 | 10.3847 | 12.3326 | 14.6459 |
| 70 | 5.5574 | 6.5999 | 7.8378 | 9.3080 | 11.0540 | 13.1257 | 15.5899 |
| 75 | 5.8902 | 6.9950 | 8.3071 | 9.8654 | 11.7159 | 13.9135 | 16.5233 |
| 80 | 6.2194 | 7.3860 | 8.7715 | 10.4168 | 12.3708 | 14.6912 | 17.4469 |
| 85 | 6.5455 | 7.7732 | 9.2313 | 10.9629 | 13.0193 | 15.4614 | 18.3616 |
| 90 | 6.8685 | 8.1569 | 9.6869 | 11.5039 | 13.6618 | 16.2244 | 19.2677 |
| 95 | 7.1887 | 8.5372 | 10.1385 | 12.0403 | 14.2988 | 16.9809 | 20.1661 |
| 100 | 7.5063 | 8.9143 | 10.5865 | 12.5722 | 14.9305 | 17.7311 | 21.0570 |
| 105 | 7.8214 | 9.2886 | 11.0309 | 13.1000 | 15.5572 | 18.4754 | 21.9409 |

**Table 7**
**STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)**
**FOR RAINBOW TROUT**
**(Compensated for Fish Size and Water Temperature)**

| Fish Weight | Water Temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| (G) | 1 | 3 | 5 | 7 | 9 | 11 | 13 |
| 110 | 8.1342 | 9.6600 | 11.4719 | 13.6238 | 16.1793 | 19.2142 | 22.8113 |
| 115 | 8.4447 | 10.0287 | 11.9099 | 14.1439 | 16.7970 | 19.9477 | 23.6894 |
| 120 | 8.7531 | 10.3950 | 12.3448 | 14.6604 | 17.4104 | 20.6761 | 24.5545 |
| 125 | 9.0595 | 10.7589 | 12.7769 | 15.1736 | 18.0198 | 21.3999 | 25.4140 |
| 130 | 9.3640 | 11.1205 | 13.2064 | 15.6836 | 18.6255 | 22.1192 | 26.2682 |
| 135 | 9.6666 | 11.4798 | 13.6332 | 16.1904 | 19.2274 | 22.8340 | 27.1171 |
| 140 | 9.9675 | 11.8372 | 14.0575 | 16.6944 | 19.8259 | 23.5447 | 27.9612 |
| 145 | 10.2667 | 12.1925 | 14.4795 | 17.1955 | 20.4210 | 24.2515 | 28.8005 |
| 150 | 10.5643 | 12.5459 | 14.8992 | 17.6939 | 21.0129 | 24.9545 | 29.6353 |
| 155 | 10.8603 | 12.8974 | 15.3167 | 18.1897 | 21.6017 | 25.6537 | 30.4657 |
| 160 | 11.1548 | 13.2472 | 15.7320 | 18.6830 | 22.1875 | 26.3493 | 31.2919 |
| 165 | 11.4479 | 13.5952 | 16.1454 | 19.1739 | 22.7704 | 27.0416 | 32.1140 |
| 170 | 11.7396 | 13.9416 | 16.5567 | 19.6624 | 23.3506 | 27.7306 | 32.9323 |
| 175 | 12.0299 | 14.2865 | 16.9662 | 20.1487 | 23.9281 | 28.4165 | 33.7468 |
| 180 | 12.3190 | 14.6297 | 17.3739 | 20.6328 | 24.5031 | 29.0992 | 34.5576 |
| 185 | 12.6068 | 14.9715 | 17.7798 | 21.1149 | 25.0755 | 29.7791 | 35.3650 |
| 190 | 12.8933 | 15.3118 | 18.1839 | 21.5948 | 25.6455 | 30.4559 | 36.1688 |
| 195 | 13.1787 | 15.6507 | 18.5864 | 22.0728 | 26.2131 | 31.1300 | 36.9693 |
| 200 | 13.4629 | 15.9882 | 18.9872 | 22.5488 | 26.7784 | 31.8014 | 37.7666 |
| 205 | 13.7460 | 16.3245 | 19.3866 | 23.0230 | 27.3416 | 32.4702 | 38.5609 |

| Table 7<br>STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)<br>FOR RAINBOW TROUT<br>(Compensated for Fish Size and Water Temperature) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fish Weight | Water Temperature (°C) | | | | | | |
| (G) | 1 | 3 | 5 | 7 | 9 | 11 | 13 |
| 210 | 14.0281 | 16.6594 | 19.7843 | 23.4954 | 27.9026 | 33.1364 | 39.3521 |
| 215 | 14.3091 | 16.9931 | 20.1806 | 23.9960 | 28.4615 | 33.8001 | 40.1403 |
| 220 | 14.5890 | 17.3256 | 20.5754 | 24.4349 | 29.0183 | 34.4614 | 40.9257 |
| 225 | 14.8680 | 17.6568 | 20.9688 | 24.9021 | 29.5732 | 35.1204 | 41.7082 |
| 230 | 15.1460 | 17.9870 | 21.3609 | 25.3677 | 30.1261 | 35.7770 | 42.4880 |
| 235 | 15.4230 | 18.3159 | 21.7515 | 25.8317 | 30.6770 | 36.4313 | 43.2650 |
| 240 | 15.6991 | 18.6438 | 22.1410 | 26.2941 | 31.2263 | 37.0836 | 44.0369 |
| 245 | 15.9743 | 18.9707 | 22.5291 | 26.7551 | 31.7737 | 37.7337 | 44.8117 |
| 250 | 16.2486 | 19.2965 | 22.9160 | 27.2146 | 32.3193 | 38.3817 | 45.5812 |
| 255 | 16.5221 | 19.6212 | 23.3017 | 27.6726 | 32.8633 | 39.0277 | 46.3484 |
| 260 | 16.7947 | 19.9450 | 23.6862 | 28.1292 | 33.4056 | 39.6716 | 47.1132 |
| 265 | 17.0665 | 20.2677 | 24.0695 | 28.5844 | 33.9461 | 40.3136 | 47.8755 |
| 270 | 17.3375 | 20.5896 | 24.4517 | 29.0383 | 34.4851 | 40.9537 | 48.6357 |
| 275 | 17.6077 | 20.9105 | 24.8328 | 29.4909 | 35.0226 | 41.5920 | 49.3938 |
| 280 | 17.8772 | 21.2305 | 25.2128 | 29.9422 | 35.5586 | 42.2285 | 50.1496 |
| 285 | 18.1458 | 21.5495 | 25.5917 | 30.3922 | 36.0930 | 42.8631 | 50.9033 |
| 290 | 18.4138 | 21.8677 | 25.9696 | 30.8409 | 36.6259 | 43.4960 | 51.6549 |
| 295 | 18.6810 | 22.1851 | 26.3456 | 31.2885 | 37.1575 | 44.1273 | 52.4047 |
| 300 | 18.9475 | 22.5016 | 26.7223 | 31.7348 | 37.6875 | 44.7568 | 53.1522 |
| 305 | 19.2133 | 22.8172 | 27.0972 | 32.1800 | 38.2162 | 45.3846 | 53.8978 |

| Table 7<br>STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)<br>FOR RAINBOW TROUT<br>(Compensated for Fish Size and Water Temperature) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fish Weight | Water Temperature ( °C) | | | | | | |
| (G) | 1 | 3 | 5 | 7 | 9 | 11 | 13 |
| 310 | 19.4784 | 23.1321 | 27.4711 | 32.6241 | 38.7436 | 46.0109 | 54.6416 |
| 315 | 19.7429 | 23.4461 | 27.8441 | 33.0670 | 39.2696 | 46.6356 | 55.3814 |
| 320 | 20.0067 | 23.7594 | 28.2161 | 33.5089 | 39.7943 | 47.2588 | 56.1235 |
| 325 | 20.2698 | 24.0719 | 28.5872 | 33.9496 | 40.3177 | 47.8803 | 56.8616 |
| 330 | 20.5323 | 24.3837 | 28.9575 | 34.3893 | 40.8398 | 48.5004 | 57.5980 |
| 335 | 20.7942 | 24.6947 | 29.3268 | 34.8279 | 41.3608 | 49.1190 | 58.3327 |
| 340 | 21.0555 | 25.0050 | 29.6953 | 35.2655 | 41.8804 | 49.7362 | 59.0656 |
| 345 | 21.3161 | 25.3145 | 30.7021 | 35.7021 | 42.3989 | 50.3519 | 59.7968 |
| 350 | 21.5762 | 25.6234 | 30.4297 | 36.1376 | 42.9162 | 50.9662 | 60.5263 |
| 355 | 21.8357 | 25.9316 | 30.7957 | 36.5723 | 43.4324 | 51.5792 | 61.2544 |
| 360 | 22.0946 | 26.2391 | 31.1609 | 37.0060 | 43.9474 | 51.1908 | 61.9807 |
| 365 | 22.3530 | 26.5459 | 31.5252 | 37.4387 | 44.4612 | 52.8011 | 62.7054 |
| 370 | 22.6108 | 26.8520 | 31.8888 | 37.8705 | 44.9740 | 53.4100 | 63.4286 |
| 375 | 22.8680 | 27.1575 | 32.2516 | 38.3013 | 45.4857 | 54.0177 | 64.1503 |
| 380 | 23.1248 | 27.4624 | 32.6137 | 38.7313 | 45.9964 | 54.6242 | 64.8705 |
| 385 | 23.3810 | 27.7666 | 32.9750 | 39.1604 | 46.5059 | 55.2293 | 65.5891 |
| 390 | 23.6366 | 28.0702 | 33.3355 | 39.5885 | 47.0144 | 55.8311 | 66.3062 |
| 395 | 23.8917 | 28.3732 | 33.6953 | 40.0158 | 47.5218 | 56.4358 | 67.0219 |
| 400 | 24.1464 | 28.6756 | 34.0545 | 40.4423 | 48.0283 | 57.0373 | 67.7362 |
| 405 | 24.4006 | 28.9775 | 34.4130 | 40.8681 | 48.5340 | 57.6377 | 68.4493 |

| Table 7<br>STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)<br>FOR RAINBOW TROUT<br>(Compensated for Fish Size and Water Temperature) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fish Weight | Water Temperature (°C) | | | | | | |
| (G) | 1 | 3 | 5 | 7 | 9 | 11 | 13 |
| 410 | 24.6542 | 29.2787 | 34.7707 | 41.2929 | 49.0384 | 58.2368 | 69.1608 |
| 415 | 24.9073 | 29.5793 | 35.1277 | 41.7169 | 49.5419 | 58.8348 | 69.8709 |
| 420 | 25.1600 | 29.8794 | 35.4841 | 42.1401 | 50.0446 | 59.4317 | 70.5798 |
| 425 | 25.4122 | 30.1789 | 35.8398 | 42.5625 | 50.5462 | 60.0275 | 71.2873 |
| 430 | 25.6640 | 30.4779 | 36.1948 | 42.9842 | 51.0469 | 60.6221 | 71.9935 |
| 435 | 25.9152 | 30.7763 | 36.5492 | 43.4050 | 51.5467 | 61.2156 | 72.6983 |
| 440 | 26.1661 | 31.0742 | 36.9030 | 43.8252 | 52.0457 | 61.8082 | 73.4021 |
| 445 | 26.4164 | 31.3715 | 37.2560 | 44.2444 | 52.5436 | 62.3995 | 74.1043 |
| 450 | 26.6664 | 31.6684 | 37.6086 | 44.6611 | 53.0408 | 62.9900 | 74.8055 |

| **Table 7**<br>**STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)**<br>**FOR RAINBOW TROUT**<br>**(Compensated for Fish Size and Water Temperature)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fish Weight | Water Temperature (°C) | | | | | | |
| (G) | 15 | 17 | 19 | 21 | 22 | 23 | 24 |
| 5 | 2.0023 | 2.3779 | 2.8239 | 3.3515 | 3.6547 | 3.9827 | 4.3402 |
| 10 | 3.5912 | 4.2649 | 5.0649 | 6.0149 | 6.5548 | 7.1432 | 7.7843 |
| 15 | 5.0542 | 6.0023 | 7.1281 | 8.4653 | 9.2251 | 10.0532 | 10.9555 |
| 20 | 6.4410 | 7.6492 | 9.0840 | 10.7880 | 11.7564 | 12.8116 | 13.9616 |
| 25 | 7.7738 | 9.2320 | 10.9637 | 13.0202 | 14.1889 | 15.4625 | 16.8504 |
| 30 | 9.0650 | 10.7654 | 12.7847 | 15.1828 | 16.5457 | 18.0308 | 19.6493 |
| 35 | 10.3227 | 12.2590 | 14.5584 | 17.2892 | 18.8412 | 20.5324 | 22.3754 |
| 40 | 11.5523 | 13.7192 | 16.2026 | 19.3487 | 21.0856 | 22.9782 | 25.0407 |
| 45 | 12.7580 | 15.1511 | 17.9930 | 21.3681 | 23.2861 | 25.3763 | 27.6541 |
| 50 | 13.9427 | 16.5580 | 19.6639 | 23.3523 | 25.4485 | 27.7328 | 30.2221 |
| 55 | 15.1089 | 17.9429 | 21.3086 | 25.3056 | 27.5771 | 30.0524 | 32.7499 |
| 60 | 16.2585 | 19.3082 | 22.9299 | 27.2310 | 29.6755 | 32.3391 | 35.2419 |
| 65 | 17.3932 | 20.6557 | 24.5102 | 29.1115 | 31.7465 | 34.5960 | 37.7104 |
| 70 | 18.5142 | 21.9870 | 26.1112 | 31.0090 | 33.7926 | 36.8258 | 40.1313 |
| 75 | 19.6227 | 23.3035 | 27.6746 | 32.8657 | 35.8158 | 39.0306 | 42.5340 |
| 80 | 20.7196 | 24.6061 | 29.2216 | 34.7029 | 37.8179 | 41.2125 | 44.9117 |
| 85 | 21.8058 | 25.8960 | 30.7535 | 36.5221 | 39.8005 | 43.3729 | 47.2661 |
| 90 | 22.8820 | 27.1741 | 32.2713 | 38.3245 | 41.6747 | 45.5135 | 49.5988 |
| 95 | 23.9488 | 28.4410 | 33.7759 | 40.1114 | 43.7119 | 47.6355 | 51.9113 |
| 100 | 25.0069 | 29.6975 | 35.2681 | 41.8835 | 45.6431 | 49.7400 | 54.2046 |

**Table 7**
**STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)**
**FOR RAINBOW TROUT**
**(Compensated for Fish Size and Water Temperature)**

| Fish Weight | Water Temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| (G) | 15 | 17 | 19 | 21 | 22 | 23 | 24 |
| 105 | 26.0566 | 30.9442 | 36.7485 | 43.6416 | 47.5591 | 51.8280 | 56.4801 |
| 110 | 27.0985 | 32.1815 | 38.2180 | 45.3867 | 49.4608 | 53.9004 | 59.7385 |
| 115 | 28.1330 | 33.4100 | 37.6770 | 47.1194 | 51.3490 | 55.9581 | 60.9809 |
| 120 | 29.1604 | 34.6302 | 41.1259 | 48.8401 | 53.2243 | 58.0017 | 63.2079 |
| 125 | 30.1811 | 35.8424 | 42.5655 | 50.5498 | 55.0874 | 60.0320 | 65.4202 |
| 130 | 31.1955 | 37.0470 | 43.9961 | 52.2487 | 56.9388 | 60.0496 | 67.6191 |
| 135 | 32.2036 | 38.2443 | 45.4180 | 53.9372 | 58.7790 | 64.0550 | 69.8045 |
| 140 | 33.2061 | 39.4347 | 46.8317 | 55.6162 | 60.6085 | 66.0487 | 71.9773 |
| 145 | 34.2029 | 40.6185 | 48.2375 | 57.2857 | 62.4278 | 68.0313 | 74.1378 |
| 150 | 35.1942 | 41.7958 | 49.6357 | 58.9461 | 64.2372 | 70.0030 | 76.2867 |
| 155 | 36.1803 | 42.9669 | 51.0264 | 60.5977 | 66.0373 | 71.9648 | 78.4243 |
| 160 | 37.1615 | 44.1321 | 52.4103 | 62.2412 | 67.8282 | 73.9164 | 80.5512 |
| 165 | 38.1378 | 45.2916 | 53.7873 | 63.8764 | 69.6103 | 75.8585 | 82.6676 |
| 170 | 39.1096 | 46.4456 | 55.1578 | 65.5040 | 71.3840 | 77.7914 | 84.7739 |
| 175 | 40.0769 | 47.5943 | 56.5220 | 67.1241 | 73.1494 | 79.7153 | 86.8705 |
| 180 | 41.0398 | 48.7378 | 57.8800 | 68.7369 | 74.9070 | 81.6306 | 88.9578 |
| 185 | 41.9986 | 49.8765 | 59.2323 | 70.3428 | 76.6569 | 83.5376 | 91.0359 |
| 190 | 42.9532 | 51.0102 | 60.5786 | 71.9416 | 78.3994 | 85.4365 | 93.1052 |
| 195 | 43.9039 | 52.1392 | 61.9193 | 73.5339 | 80.1347 | 87.3275 | 95.1660 |

| Table 7<br>STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)<br>FOR RAINBOW TROUT<br>(Compensated for Fish Size and Water Temperature) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fish Weight | Water Temperature (°C) | | | | | | |
| (G) | 15 | 17 | 19 | 21 | 22 | 23 | 24 |
| 200 | 44.8507 | 53.2636 | 63.2547 | 75.1198 | 81.8630 | 89.2110 | 97.2185 |
| 205 | 45.7940 | 54.3838 | 64.5851 | 76.6996 | 83.5845 | 91.0870 | 99.2630 |
| 210 | 46.7336 | 55.4997 | 65.9102 | 78.2733 | 85.2994 | 92.9559 | 101.2996 |
| 215 | 47.6696 | 56.6113 | 67.2303 | 79.8411 | 87.0080 | 94.8178 | 103.3286 |
| 220 | 48.6023 | 57.7189 | 68.5457 | 81.4032 | 88.7102 | 96.6729 | 105.3502 |
| 225 | 49.5316 | 58.8225 | 69.8563 | 82.9597 | 90.4065 | 98.5213 | 107.3646 |
| 230 | 50.4577 | 59.9223 | 71.1625 | 84.5108 | 92.0968 | 100.3634 | 109.3720 |
| 235 | 51.3805 | 61.0182 | 72.4639 | 86.0564 | 93.7813 | 102.1991 | 111.3725 |
| 240 | 52.3004 | 62.1107 | 73.7613 | 87.5971 | 95.4602 | 104.0287 | 113.3663 |
| 245 | 53.2172 | 63.1995 | 75.0543 | 89.1327 | 97.1337 | 105.8524 | 115.3537 |
| 250 | 54.1311 | 64.2848 | 76.3432 | 90.6634 | 98.8017 | 107.6702 | 117.3346 |
| 255 | 55.0422 | 65.3668 | 77.6282 | 92.1893 | 100.4646 | 109.4823 | 119.3094 |
| 260 | 55.9505 | 66.4454 | 78.9090 | 93.7105 | 102.1223 | 111.2888 | 121.2780 |
| 265 | 56.8558 | 67.5206 | 80.1860 | 95.2269 | 103.7750 | 113.0898 | 123.2402 |
| 270 | 57.7586 | 68.5927 | 81.4592 | 96.7390 | 105.4228 | 114.8856 | 125.1977 |
| 275 | 58.6588 | 69.6618 | 82.7288 | 98.2467 | 107.0659 | 116.6761 | 127.1489 |
| 280 | 59.5565 | 70.7278 | 83.9948 | 99.7502 | 108.7042 | 118.4615 | 129.0945 |
| 285 | 60.4515 | 71.7908 | 85.2572 | 101.2493 | 110.3379 | 120.2418 | 131.0347 |
| 290 | 61.3441 | 72.8508 | 86.5160 | 102.7443 | 111.9672 | 122.0173 | 132.9696 |

| Table 7<br>STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)<br>FOR RAINBOW TROUT<br>(Compensated for Fish Size and Water Temperature) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fish Weight | Water Temperature (°C) | | | | | | |
| (G) | 15 | 17 | 19 | 21 | 22 | 23 | 24 |
| 295 | 62.2345 | 73.9082 | 87.7717 | 104.2355 | 113.5920 | 123.7780 | 134.8992 |
| 300 | 63.1222 | 74.9624 | 89.0237 | 105.7224 | 115.2125 | 125.5540 | 136.8237 |
| 305 | 64.0070 | 76.0140 | 90.2726 | 107.2055 | 116.8288 | 127.3153 | 138.7431 |
| 310 | 67.8910 | 77.0629 | 91.5183 | 108.6849 | 118.4409 | 129.0722 | 140.6576 |
| 315 | 65.7720 | 78.1092 | 92.7608 | 110.1604 | 120.0490 | 130.8245 | 142.5673 |
| 320 | 66.6509 | 79.1529 | 94.0008 | 111.6325 | 121.6530 | 132.5725 | 144.4722 |
| 325 | 67.5274 | 80.1919 | 95.2365 | 113.1006 | 123.2531 | 134.3162 | 146.3724 |
| 330 | 68.4020 | 81.2325 | 96.4699 | 114.5654 | 124.8493 | 136.0557 | 148.2681 |
| 335 | 69.2745 | 82.2687 | 97.7005 | 116.0267 | 126.4417 | 137.7911 | 150.1592 |
| 340 | 70.1449 | 83.3023 | 98.9280 | 117.4845 | 128.0304 | 139.5224 | 152.0459 |
| 345 | 71.0132 | 84.3336 | 100.1527 | 118.1527 | 129.6154 | 141.2497 | 153.9282 |
| 350 | 71.8796 | 85.1624 | 101.3746 | 120.3900 | 131.1969 | 142.9731 | 155.8063 |
| 355 | 72.7442 | 86.3892 | 102.5939 | 121.8381 | 132.7747 | 144.6926 | 157.6802 |
| 360 | 73.6068 | 87.4136 | 103.8105 | 123.2828 | 134.3491 | 146.4083 | 159.5499 |
| 365 | 74.4674 | 88.4357 | 105.0243 | 124.7243 | 135.9201 | 148.1202 | 161.4155 |
| 370 | 75.3263 | 89.4556 | 106.2356 | 126.1628 | 137.4877 | 149.8285 | 163.2771 |
| 375 | 76.1833 | 90.4734 | 107.4443 | 127.5982 | 139.0519 | 151.5332 | 165.1348 |
| 380 | 77.0386 | 91.4891 | 108.6505 | 129.0307 | 140.6129 | 153.2342 | 166.9885 |
| 385 | 77.8920 | 92.5026 | 109.8541 | 130.4601 | 142.1706 | 154.9318 | 168.8385 |

**Table 7**
**STANDARD METABOLIC RATE (MG $O_2$ CONSUMED PER HOUR)**
**FOR RAINBOW TROUT**
**(Compensated for Fish Size and Water Temperature)**

| Fish Weight | Water Temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| (G) | 15 | 17 | 19 | 21 | 22 | 23 | 24 |
| 390 | 78.7436 | 93.5140 | 111.0552 | 131.8864 | 143.7252 | 156.6259 | 170.6846 |
| 395 | 79.5936 | 94.5234 | 112.2539 | 133.3100 | 145.2766 | 158.3166 | 172.5271 |
| 400 | 80.4419 | 95.5308 | 113.4503 | 134.7308 | 146.8250 | 160.0040 | 174.3659 |
| 405 | 81.2887 | 96.5365 | 114.6447 | 136.1492 | 148.3703 | 161.6880 | 176.2011 |
| 410 | 82.1337 | 97.5399 | 115.8363 | 137.5644 | 149.9126 | 163.3687 | 178.0327 |
| 415 | 82.9770 | 98.5415 | 117.0257 | 138.9768 | 151.4520 | 165.0463 | 179.8608 |
| 420 | 83.8189 | 99.5412 | 118.2130 | 140.3869 | 152.9884 | 166.7206 | 181.6855 |
| 425 | 84.6590 | 100.5390 | 119.3979 | 141.7441 | 154.5220 | 168.3919 | 183.5067 |
| 430 | 85.4978 | 101.5351 | 120.5807 | 143.1987 | 156.0528 | 170.0600 | 185.3246 |
| 435 | 86.3348 | 102.5291 | 121.7613 | 144.6008 | 157.5807 | 171.7251 | 187.1391 |
| 440 | 87.1705 | 103.5216 | 122.9400 | 146.0005 | 159.1059 | 173.3872 | 188.9504 |
| 445 | 88.0045 | 104.5120 | 124.1161 | 147.3973 | 160.6284 | 175.0463 | 190.7585 |
| 450 | 88.8172 | 105.5009 | 125.2906 | 148.7921 | 162.1482 | 176.7025 | 192.5633 |

| Table 8<br>OXYGEN RE-CHARGE ($\%X10^{-2}$) OF WATER FALLING FROM VARIOUS HEIGHTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Percent Saturation at Outfall of Upper Reuse | Height of fall (ft.) | | | | | | | |
| Pond | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |
| 32 | .45549 | .50337 | .53724 | .56399 | .58627 | .60543 | .62227 | .63729 |
| 33 | .46350 | .51067 | .54404 | .57040 | .59235 | .61123 | .67782 | .64263 |
| 34 | .47151 | .51798 | .55085 | .57681 | .59844 | .61704 | .63338 | .64796 |
| 35 | .47951 | .52528 | .55765 | .58322 | .60452 | .62284 | .63893 | .63330 |
| 36 | .48752 | .53528 | .56445 | .58963 | .61060 | .62864 | .64449 | .65863 |
| 37 | .49553 | .53989 | .57126 | .59605 | .61669 | .63444 | .65004 | .66396 |
| 38 | .50354 | .54719 | .57807 | .60246 | .62277 | .64025 | .65560 | .66930 |
| 39 | .51154 | .55449 | .58487 | .60887 | .62886 | .64605 | .66115 | .67463 |
| 40 | .51955 | .56180 | .59168 | .61528 | .63494 | .65185 | .66671 | .67997 |
| 41 | .52756 | .56910 | .59848 | .62169 | .64103 | .65665 | .67226 | .68530 |
| 42 | .53557 | .57640 | .60529 | .62810 | .64711 | .66346 | .67782 | .69063 |
| 43 | .54357 | .58371 | .61210 | .63452 | .64319 | .66926 | .68337 | .69597 |
| 44 | .55185 | .59101 | .61890 | .64093 | .65928 | .67506 | .68893 | .70130 |
| 45 | .55959 | .59832 | .62571 | .64734 | .66536 | .68086 | .69448 | .70663 |
| 46 | .56760 | .60562 | .63251 | .64375 | .67145 | .68667 | .70004 | .71197 |
| 47 | .57560 | .61292 | .63932 | .66016 | .67753 | .69247 | .70559 | .71730 |
| 48 | .58361 | .62023 | .64612 | .66658 | .68362 | .69827 | .71115 | .72264 |
| 49 | .59162 | .62753 | .65293 | .67229 | .68790 | .70407 | .71670 | .72797 |
| 50 | .59963 | .63483 | .65973 | .67940 | .67940 | .70988 | .72226 | .73330 |

| Table 8<br>OXYGEN RE-CHARGE (%X10$^{-2}$) OF WATER FALLING FROM VARIOUS HEIGHTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Percent Saturation at Outfall of Upper Reuse | Height of fall (ft.) | | | | | | | |
| Pond | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |
| 51 | .60763 | .64214 | .66654 | .68581 | .70187 | .71568 | .72781 | .73864 |
| 52 | .61564 | .64944 | .67334 | .69222 | .70795 | .72148 | .73337 | .74397 |
| 53 | .62365 | .65674 | .68015 | .69864 | .71404 | .72728 | .73982 | .74931 |
| 54 | .63166 | .66405 | .68695 | .70505 | .72012 | .73309 | .74448 | .75464 |
| 55 | .63966 | .67135 | .69376 | .71146 | .72621 | .73889 | .75003 | .75997 |
| 56 | .64767 | .67865 | .70056 | .71787 | .73229 | .74469 | .75559 | .76531 |
| 57 | .65568 | .68596 | .70737 | .72428 | .73838 | .75049 | .76114 | .77064 |
| 58 | .66369 | .69326 | .71418 | .73070 | .74446 | .75630 | .76669 | .77598 |
| 59 | .67169 | .70056 | .72098 | .73711 | .75054 | .76210 | .77225 | .78131 |
| 60 | .67970 | .70787 | .72779 | .74352 | .75663 | .76790 | .77780 | .78664 |
| 61 | .68771 | .71517 | .73459 | .74993 | .76271 | .77370 | .78336 | .79198 |
| 62 | .69572 | .72247 | .74140 | .75634 | .76880 | .77951 | .78891 | .79731 |
| 63 | .70372 | .72978 | .74820 | .76276 | .77488 | .78531 | .79447 | .80365 |
| 64 | .71173 | .73708 | .75501 | .76917 | .78097 | .79111 | .80002 | .80798 |
| 65 | .71974 | .74438 | .76181 | .77558 | .78705 | .79691 | .80558 | .81331 |
| 66 | .72775 | .75169 | .76862 | .78199 | .79313 | .80272 | .81113 | .81865 |
| 67 | .73575 | .75899 | .77542 | .78840 | .79922 | .80852 | .81669 | .82398 |
| 68 | .74376 | .76629 | .78223 | .79482 | .80530 | .81432 | .82224 | .82931 |
| 69 | .75177 | .77360 | .78903 | .80123 | .81139 | .82012 | .82780 | .83456 |

**Table 8**
**OXYGEN RE-CHARGE (%X10$^{-2}$) OF WATER FALLING FROM VARIOUS HEIGHTS**

| Percent Saturation at Outfall of Upper Reuse | Height of fall (ft.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pond | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |
| 70 | .75978 | .78090 | .79584 | .80764 | .81747 | .82583 | .83335 | .82998 |
| 71 | .76778 | .78820 | .80264 | .81405 | .82356 | .83173 | .83891 | .84532 |
| 72 | .77579 | .79551 | .80945 | .82046 | .92964 | .83753 | .84446 | .85065 |
| 73 | .78380 | .80281 | .81626 | .82688 | .83572 | .84333 | .85002 | .85598 |
| 74 | .79181 | .81011 | .82306 | .83329 | .84181 | .84914 | .85557 | .86132 |
| 75 | .79981 | .81742 | .82987 | .83970 | .84789 | .85494 | .86113 | .86665 |
| 76 | .80782 | .82472 | .83667 | .84611 | .85398 | .86074 | .86668 | .87199 |
| 77 | .81583 | .83202 | .84348 | .85252 | .86006 | .86654 | .87224 | .87732 |
| 78 | .82384 | .83933 | .85028 | .85894 | .86615 | .87235 | .87779 | .88265 |
| 79 | .83184 | .84663 | .85709 | .86535 | .87223 | .87815 | .88335 | .88799 |
| 80 | .83985 | .85939 | .86389 | .87176 | .87831 | .88395 | .88890 | .89332 |
| 81 | .84786 | .86124 | .87070 | .87817 | .88440 | .88975 | .89446 | .89866 |
| 82 | .85587 | .86854 | .87750 | .88458 | .89048 | .89556 | .90001 | .90399 |
| 83 | .86837 | .87584 | .88431 | .89100 | .89657 | .90136 | .90557 | .90932 |
| 84 | .87188 | .88315 | .89111 | .89741 | .90265 | .90716 | .91112 | .91466 |
| 85 | .87989 | .89045 | .89792 | .90382 | .90874 | .91296 | .91668 | .91999 |
| 86 | .88790 | .89775 | .90473 | .91023 | .91482 | .91877 | .92223 | .92533 |
| 87 | .89590 | .90506 | .91153 | .91664 | .92090 | .92457 | .92779 | .93066 |
| 88 | .90391 | .91236 | .91834 | .92306 | .92699 | .93037 | .93334 | .93599 |

**Table 8**
**OXYGEN RE-CHARGE (%X10$^{-2}$) OF WATER FALLING FROM VARIOUS HEIGHTS**

| Percent Saturation at Outfall of Upper Reuse | Height of fall (ft.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pond | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |
| 89 | .91192 | .91966 | .92514 | .92947 | .93307 | .93617 | .93890 | .94133 |
| 90 | .91993 | .92697 | .93195 | .93588 | .93916 | .94198 | .94445 | .94666 |
| 91 | .92793 | .93427 | .93875 | .94229 | .94524 | .94778 | .95001 | .95199 |
| 92 | .93594 | .94157 | .94556 | .94870 | .95133 | .95358 | .95556 | .95733 |
| 93 | .94395 | .94888 | .95236 | .95512 | .95741 | .95938 | .96112 | .96266 |
| 94 | .95196 | .95618 | .95917 | .96153 | .96349 | .96519 | .96667 | .96800 |
| 95 | .95996 | .96348 | .96597 | .96794 | .96958 | .97099 | .97223 | .97333 |
| 96 | .96797 | .97079 | .97278 | .97435 | .97566 | .97679 | .97778 | .97886 |
| 97 | .97598 | .97809 | .97958 | .98076 | .98175 | .98259 | .98334 | .98400 |
| 98 | .98399 | .98539 | .98639 | .98718 | .98783 | .98840 | .98889 | .98933 |

**TABLE 9 (4-12° C)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (kg feed/100 kg fish) multiply the appropiate chart value by expected Feed Conversion.

| LENGTH (mm) | N/Kg | WATER TEMPATURE (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 40 | 1623.0 | 0.76 | 1.44 | 2.12 | 2.80 | 3.49 | 4.17 | 4.85 | 5.53 | 6.21 |
| 50 | 807.7 | 0.61 | 1.15 | 1.70 | 2.24 | 2.79 | 3.33 | 3.88 | 4.42 | 4.97 |
| 60 | 456.5 | 0.51 | 0.96 | 1.42 | 1.87 | 2.32 | 2.78 | 3.23 | 3.68 | 4.14 |
| 70 | 281.9 | 0.44 | 0.82 | 1.12 | 1.60 | 1.99 | 2.38 | 2.77 | 3.16 | 3.55 |
| 80 | 185.6 | 0.38 | 0.72 | 1.06 | 1.40 | 1.74 | 2.08 | 2.42 | 2.76 | 3.10 |
| 90 | 128.4 | 0.34 | 0.64 | 0.94 | 1.25 | 1.55 | 1.85 | 2.15 | 2.46 | 2.76 |
| 100 | 92.3 | 0.31 | 0.58 | 0.85 | 1.12 | 1.39 | 1.67 | 1.94 | 2.21 | 2.48 |
| 110 | 68.5 | 0.28 | 0.52 | 0.77 | 1.02 | 1.27 | 1.51 | 1.78 | 2.01 | 2.26 |
| 120 | 52.2 | 0.25 | 0.48 | 0.71 | 0.93 | 1.16 | 1.39 | 1.62 | 1.84 | 2.07 |
| 130 | 40.6 | 0.23 | 0.44 | 0.65 | 0.86 | 1.07 | 1.28 | 1.49 | 1.70 | 1.91 |
| 140 | 32.2 | 0.22 | 0.41 | 0.61 | 0.80 | 1.00 | 1.19 | 1.38 | 1.58 | 1.77 |
| 150 | 26.0 | 0.20 | 0.38 | 0.57 | 0.75 | 0.93 | 1.11 | 1.29 | 1.47 | 1.66 |
| 160 | 21.2 | 0.19 | 0.36 | 0.53 | 0.70 | 0.87 | 1.04 | 1.21 | 1.38 | 1.55 |
| 170 | 17.6 | 0.18 | 0.34 | 0.50 | 0.66 | 0.82 | 0.98 | 1.14 | 1.30 | 1.46 |
| 180 | 14.7 | 0.17 | 0.32 | 0.47 | 0.62 | 0.77 | 0.93 | 1.08 | 1.23 | 1.38 |
| 190 | 12.4 | 0.16 | 0.30 | 0.45 | 0.59 | 0.73 | 0.88 | 1.02 | 1.16 | 1.31 |
| 200 | 10.6 | 0.16 | 0.29 | 0.42 | 0.56 | 0.70 | 0.83 | 0.97 | 1.11 | 1.24 |
| 210 | 9.1 | 0.15 | 0.27 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.05 | 1.18 |
| 220 | 7.8 | 0.14 | 0.26 | 0.39 | 0.51 | 0.63 | 0.76 | 0.88 | 1.00 | 1.13 |
| 230 | 6.8 | 0.13 | 0.25 | 0.37 | 0.49 | 0.61 | 0.72 | 0.84 | 0.96 | 1.08 |
| 240 | 6.0 | 0.13 | 0.24 | 0.36 | 0.47 | 0.58 | 0.69 | 0.81 | 0.92 | 1.03 |

**TABLE 9 (4-12° C)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (kg feed/100 kg fish) multiply the appropiate chart value by expected Feed Conversion.

| LENGTH (mm) | N/Kg | WATER TEMPATURE (°C) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 250 | 5.3 | 0.12 | 0.23 | 0.34 | 0.45 | 0.56 | 0.67 | 0.78 | 0.88 | 0.99 |
| 260 | 4.6 | 0.12 | 0.22 | 0.33 | 0.43 | 0.54 | 0.64 | 0.75 | 0.85 | 0.96 |
| 270 | 4.1 | 0.11 | 0.21 | 0.31 | 0.42 | 0.52 | 0.62 | 0.72 | 0.82 | 0.92 |
| 280 | 3.6 | 0.11 | 0.21 | 0.30 | 0.40 | 0.50 | 0.60 | 0.69 | 0.79 | 0.89 |
| 290 | 3.3 | 0.11 | 0.20 | 0.29 | 0.39 | 0.48 | 0.57 | 0.67 | 0.76 | 0.86 |
| 300 | 3.0 | 0.10 | 0.19 | 0.28 | 0.37 | 0.46 | 0.56 | 0.65 | 0.74 | 0.83 |
| 310 | 2.7 | 0.10 | 0.19 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.71 | 0.80 |
| 320 | 2.4 | 0.10 | 0.18 | 0.27 | 0.35 | 0.44 | 0.52 | 0.61 | 0.69 | 0.78 |
| 330 | 2.2 | 0.09 | 0.17 | 0.26 | 0.34 | 0.42 | 0.50 | 0.59 | 0.67 | 0.75 |
| 340 | 2.0 | 0.09 | 0.17 | 0.25 | 0.33 | 0.41 | 0.49 | 0.57 | 0.65 | 0.73 |
| 350 | 1.8 | 0.09 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.55 | 0.63 | 0.71 |
| 360 | 1.7 | 0.08 | 0.16 | 0.24 | 0.31 | 0.39 | 0.46 | 0.54 | 0.61 | 0.69 |
| 370 | 1.5 | 0.08 | 0.16 | 0.23 | 0.30 | 0.38 | 0.45 | 0.52 | 0.60 | 0.67 |
| 380 | 1.4 | 0.08 | 0.15 | 0.22 | 0.30 | 0.37 | 0.44 | 0.51 | 0.58 | 0.65 |
| 390 | 1.3 | 0.08 | 0.15 | 0.22 | 0.29 | 0.36 | 0.43 | 0.50 | 0.57 | 0.64 |
| 400 | 1.2 | 0.08 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.48 | 0.55 | 0.62 |
| 410 | 1.1 | 0.07 | 0.14 | 0.21 | 0.27 | 0.34 | 0.41 | 0.47 | 0.54 | 0.61 |

**TABLE 9 (13-20° C)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (kg feed/100 kg fish) multiply the appropiate chart value by expected Feed Conversion.

| LENGTH (mm) | N/Kg | WATER TEMPATURE (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 40 | 1623.0 | 6.89 | 7.57 | 8.25 | 7.57 | 6.89 | 6.21 | 5.53 | 4.85 |
| 50 | 807.7 | 5.51 | 6.06 | 6.60 | 6.06 | 5.51 | 4.97 | 4.42 | 3.88 |
| 60 | 456.5 | 4.59 | 5.05 | 6.50 | 5.05 | 4.59 | 4.14 | 3.68 | 3.23 |
| 70 | 281.9 | 3.94 | 4.33 | 4.71 | 4.33 | 3.94 | 3.55 | 3.16 | 2.77 |
| 80 | 185.6 | 3.44 | 3.78 | 4.12 | 3.78 | 3.44 | 3.10 | 2.76 | 2.42 |
| 90 | 128.4 | 3.06 | 3.36 | 3.67 | 3.36 | 3.06 | 2.70 | 2.46 | 2.15 |
| 100 | 92.3 | 2.76 | 3.03 | 3.30 | 3.03 | 2.76 | 2.48 | 2.21 | 1.94 |
| 110 | 68.5 | 2.51 | 2.75 | 3.00 | 2.75 | 2.51 | 2.26 | 2.01 | 1.76 |
| 120 | 52.2 | 2.30 | 2.52 | 2.75 | 2.52 | 2.30 | 2.07 | 1.84 | 1.62 |
| 130 | 40.6 | 2.12 | 2.33 | 2.54 | 2.33 | 2.12 | 1.91 | 1.70 | 1.49 |
| 140 | 32.2 | 1.97 | 2.16 | 2.36 | 2.16 | 1.97 | 1.77 | 1.58 | 1.38 |
| 150 | 26.0 | 1.84 | 2.02 | 2.20 | 2.02 | 1.84 | 1.66 | 1.47 | 1.29 |
| 160 | 21.2 | 1.72 | 1.89 | 2.06 | 1.89 | 1.72 | 1.55 | 1.38 | 1.21 |
| 170 | 17.6 | 1.62 | 1.78 | 1.94 | 1.78 | 1.62 | 1.46 | 1.30 | 1.14 |
| 180 | 14.7 | 1.53 | 1.68 | 1.83 | 1.68 | 1.53 | 1.38 | 1.23 | 1.08 |
| 190 | 12.4 | 1.45 | 1.59 | 1.74 | 1.59 | 1.45 | 1.31 | 1.16 | 1.02 |
| 200 | 10.6 | 1.38 | 1.51 | 1.65 | 1.51 | 1.38 | 1.24 | 1.11 | 0.97 |
| 210 | 9.1 | 1.31 | 1.44 | 1.57 | 1.44 | 1.31 | 1.18 | 1.05 | 0.92 |
| 220 | 7.8 | 1.25 | 1.38 | 1.50 | 1.38 | 1.25 | 1.13 | 1.00 | 0.88 |
| 230 | 6.8 | 1.20 | 1.32 | 1.43 | 1.32 | 1.20 | 1.08 | 0.86 | 0.84 |
| 240 | 6.0 | 1.15 | 1.26 | 1.37 | 1.26 | 1.15 | 1.03 | 0.92 | 0.81 |

**TABLE 9 (13-20° C)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (kg feed/100 kg fish) multiply the appropiate chart value by expected Feed Conversion.

| LENGTH (mm) | N/Kg | WATER TEMPATURE (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 250 | 5.3 | 1.10 | 1.21 | 1.32 | 1.21 | 1.10 | 0.99 | 0.88 | 0.78 |
| 260 | 4.6 | 1.06 | 1.16 | 1.27 | 1.16 | 1.06 | 0.96 | 0.85 | 0.75 |
| 270 | 4.1 | 1.02 | 1.12 | 1.22 | 1.12 | 1.02 | 0.92 | 0.82 | 0.72 |
| 280 | 3.6 | 0.98 | 1.08 | 1.18 | 1.08 | 0.98 | 0.89 | 0.79 | 0.69 |
| 290 | 3.3 | 0.95 | 1.04 | 1.14 | 1.04 | 0.95 | 0.86 | 0.76 | 0.67 |
| 300 | 3.0 | 0.92 | 1.01 | 1.10 | 1.01 | 0.92 | 0.83 | 0.74 | 0.65 |
| 310 | 2.7 | 0.89 | 0.98 | 1.06 | 0.98 | 0.89 | 0.80 | 0.71 | 0.63 |
| 320 | 2.4 | 0.86 | 0.95 | 1.03 | 0.95 | 0.86 | 0.78 | 0.69 | 0.61 |
| 330 | 2.2 | 0.84 | 0.92 | 1.00 | 0.92 | 0.84 | 0.75 | 0.67 | 0.59 |
| 340 | 2.0 | 0.81 | 0.89 | 0.97 | 0.89 | 0.81 | 0.73 | 0.65 | 0.57 |
| 350 | 1.8 | 0.79 | 0.87 | 0.94 | 0.87 | 0.79 | 0.71 | 0.63 | 0.55 |
| 360 | 1.7 | 0.77 | 0.84 | 0.92 | 0.84 | 0.77 | 0.69 | 0.61 | 0.54 |
| 370 | 1.5 | 0.74 | 0.82 | 0.89 | 0.82 | 0.74 | 0.67 | 0.60 | 0.52 |
| 380 | 1.4 | 0.73 | 0.80 | 0.87 | 0.80 | 0.73 | 0.65 | 0.58 | 0.51 |
| 390 | 1.3 | 0.71 | 0.78 | 0.85 | 0.78 | 0.71 | 0.64 | 0.57 | 0.50 |
| 400 | 1.2 | 0.69 | 0.76 | 0.83 | 0.76 | 0.69 | 0.62 | 0.55 | 0.48 |
| 410 | 1.1 | 0.67 | 0.74 | 0.80 | 0.74 | 0.67 | 0.61 | 0.54 | 0.47 |

**TABLE 9(39-55° F)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (lb feed/100 lb fish) multiply the appropiate chart value by expected Feed Conversion.

| Length (in.) | N/Lb | WATER TEMPATURE (°F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 39 | 41 | 43 | 45 | 47 | 49 | 51 | 53 | 55 |
| 1.5 | 857.5 | 0.72 | 1.52 | 2.31 | 3.10 | 3.50 | 4.29 | 5.09 | 5.88 | 7.07 |
| 2.0 | 348.6 | 0.54 | 1.14 | 1.73 | 2.33 | 2.63 | 3.22 | 3.82 | 4.41 | 5.30 |
| 2.5 | 173.4 | 0.43 | 0.91 | 1.39 | 1.86 | 2.10 | 2.58 | 3.05 | 3.53 | 4.24 |
| 3.0 | 98.0 | 0.36 | 0.76 | 1.15 | 1.55 | 1.75 | 2.15 | 2.54 | 2.94 | 3.54 |
| 3.5 | 60.5 | 0.31 | 0.65 | 0.99 | 1.33 | 1.50 | 1.84 | 2.18 | 2.52 | 3.03 |
| 4.0 | 39.9 | 0.27 | 0.57 | 0.87 | 1.16 | 1.31 | 1.61 | 1.91 | 2.21 | 2.65 |
| 4.5 | 27.6 | 0.24 | 0.51 | 0.77 | 1.03 | 1.17 | 1.43 | 1.70 | 1.96 | 2.36 |
| 5.0 | 19.8 | 0.22 | 0.45 | 0.69 | 0.93 | 1.05 | 1.29 | 1.53 | 1.76 | 2.00 |
| 5.5 | 14.7 | 0.20 | 0.41 | 0.63 | 0.85 | 0.95 | 1.17 | 1.39 | 1.60 | 1.93 |
| 6.0 | 11.2 | 0.18 | 0.38 | 0.58 | 0.78 | 0.88 | 1.07 | 1.27 | 1.47 | 1.67 |
| 6.5 | 8.7 | 0.17 | 0.35 | 0.53 | 0.72 | 0.81 | 0.99 | 1.17 | 1.36 | 1.63 |
| 7.0 | 6.9 | 0.15 | 0.32 | 0.49 | 0.66 | 0.75 | 0.92 | 1.09 | 1.26 | 1.52 |
| 7.5 | 5.6 | 0.14 | 0.30 | 0.46 | 0.62 | 0.70 | 0.86 | 1.02 | 1.18 | 1.34 |
| 8.0 | 4.6 | 0.14 | 0.28 | 0.43 | 0.58 | 0.66 | 0.81 | 0.95 | 1.10 | 1.33 |
| 8.5 | 3.8 | 0.13 | 0.27 | 0.41 | 0.55 | 0.62 | 0.76 | 0.90 | 1.04 | 1.25 |
| 9.0 | 3.2 | 0.12 | 0.25 | 0.38 | 0.52 | 0.58 | 0.72 | 0.85 | 0.98 | 1.18 |
| 9.5 | 2.7 | 0.11 | 0.24 | 0.36 | 0.49 | 0.55 | 0.68 | 0.80 | 0.93 | 1.12 |
| 10.0 | 2.3 | 0.11 | 0.23 | 0.35 | 0.47 | 0.53 | 0.64 | 0.76 | 0.88 | 1.06 |
| 10.5 | 1.9 | 0.10 | 0.22 | 0.33 | 0.44 | 0.50 | 0.61 | 0.73 | 0.84 | 1.01 |
| 11.0 | 1.7 | 0.10 | 0.21 | 0.31 | 0.42 | 0.48 | 0.59 | 0.69 | 0.80 | 0.96 |
| 11.5 | 1.5 | 0.09 | 0.20 | 0.30 | 0.40 | 0.46 | 0.56 | 0.66 | 0.77 | 0.92 |

**TABLE 9(39-55° F)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (lb feed/100 lb fish) multiply the appropiate chart value by expected Feed Conversion.

| Length (in.) | N/Lb | WATER TEMPATURE (°F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 39 | 41 | 43 | 45 | 47 | 49 | 51 | 53 | 55 |
| 12.0 | 1.3 | 0.09 | 0.19 | 0.29 | 0.39 | 0.44 | 0.54 | 0.64 | 0.74 | 0.88 |
| 12.5 | 1.2 | 0.09 | 0.18 | 0.28 | 0.37 | 0.42 | 0.52 | 0.61 | 0.71 | 0.85 |
| 13.0 | 1.1 | 0.08 | 0.17 | 0.27 | 0.36 | 0.40 | 0.50 | 0.59 | 0.68 | 0.82 |
| 13.5 | 1.0 | 0.08 | 0.17 | 0.26 | 0.34 | 0.39 | 0.48 | 0.57 | 0.65 | 0.79 |
| 14.0 | 0.9 | 0.08 | 0.16 | 0.25 | 0.33 | 0.38 | 0.46 | 0.55 | 0.63 | 0.76 |
| 14.5 | 0.8 | 0.07 | 0.16 | 0.24 | 0.32 | 0.36 | 0.44 | 0.53 | 0.61 | 0.73 |
| 15.0 | 0.7 | 0.07 | 0.15 | 0.23 | 0.31 | 0.35 | 0.43 | 0.51 | 0.59 | 0.71 |
| 15.5 | 0.6 | 0.07 | 0.15 | 0.22 | 0.30 | 0.34 | 0.42 | 0.49 | 0.57 | 0.68 |
| 16.0 | 0.5 | 0.07 | 0.14 | 0.22 | 0.29 | 0.33 | 0.40 | 0.48 | 0.55 | 0.66 |

**TABLE 9 (57-69° F)**
**SILVER CUP FEEDING CHART**

To calculate the feeding rate (lb feed/100 lb fish) multiply the appropiate chart value by expected Feed Conversion.

| Length (in.) | N/Lb | WATER TEMPATURE (°F) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 57 | 59 | 61 | 63 | 65 | 67 | 69 |
| 1.5 | 857.5 | 7.87 | 8.66 | 7.87 | 7.07 | 6.68 | 5.88 | 5.09 |
| 2.0 | 348.6 | 5.90 | 6.49 | 5.90 | 5.30 | 5.01 | 4.41 | 3.82 |
| 2.5 | 173.4 | 4.72 | 5.20 | 4.72 | 4.24 | 4.01 | 3.53 | 3.05 |
| 3.0 | 98.0 | 3.93 | 3.93 | 4.33 | 3.93 | 3.54 | 3.34 | 2.94 |
| 3.5 | 60.5 | 3.37 | 3.71 | 3.37 | 3.03 | 2.86 | 2.52 | 2.18 |
| 4.0 | 39.9 | 2.95 | 3.25 | 2.95 | 2.65 | 2.50 | 2.21 | 1.91 |
| 4.5 | 27.6 | 2.62 | 2.89 | 2.62 | 2.36 | 2.23 | 1.96 | 1.70 |
| 5.0 | 19.8 | 2.36 | 2.60 | 2.36 | 2.12 | 2.00 | 1.76 | 1.53 |
| 5.5 | 14.7 | 2.15 | 2.36 | 2.15 | 1.93 | 1.82 | 1.60 | 1.39 |
| 6.0 | 11.2 | 1.97 | 2.16 | 1.97 | 1.77 | 1.67 | 1.47 | 1.27 |
| 6.5 | 8.7 | 1.82 | 2.00 | 1.82 | 1.63 | 1.54 | 1.36 | 1.17 |
| 7.0 | 6.9 | 1.69 | 1.86 | 1.69 | 1.52 | 1.43 | 1.26 | 1.09 |
| 7.5 | 5.6 | 1.57 | 1.73 | 1.57 | 1.41 | 1.34 | 1.18 | 1.02 |
| 8.0 | 4.6 | 1.47 | 1.62 | 1.47 | 1.33 | 1.25 | 1.10 | 0.95 |
| 8.5 | 3.8 | 1.39 | 1.53 | 1.39 | 1.25 | 1.18 | 1.04 | 0.90 |
| 9.0 | 3.2 | 1.31 | 1.44 | 1.31 | 1.18 | 1.11 | 0.98 | 0.85 |
| 9.5 | 2.7 | 1.24 | 1.37 | 1.24 | 1.12 | 1.05 | 0.93 | 0.80 |
| 10.0 | 2.3 | 1.18 | 1.30 | 1.18 | 1.06 | 1.00 | 0.88 | 0.76 |
| 10.5 | 1.9 | 1.12 | 1.24 | 1.12 | 1.01 | 0.95 | 0.84 | 0.73 |
| 11.0 | 1.7 | 1.07 | 1.18 | 1.07 | 0.96 | 0.91 | 0.80 | 0.69 |
| 11.5 | 1.5 | 1.03 | 1.13 | 1.03 | 0.92 | 0.87 | 0.77 | 0.66 |

| TABLE 9 (57-69° F)<br>SILVER CUP FEEDING CHART<br>To calculate the feeding rate (lb feed/100 lb fish) multiply the appropiate chart value by expected Feed Conversion. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Length (in.) | N/Lb | WATER TEMPATURE (°F) | | | | | | |
| | | 57 | 59 | 61 | 63 | 65 | 67 | 69 |
| 12.0 | 1.3 | 0.98 | 1.08 | 0.98 | 0.88 | 0.83 | 0.74 | 0.64 |
| 12.5 | 1.2 | 0.94 | 1.04 | 0.94 | 0.85 | 0.80 | 0.71 | 0.61 |
| 13.0 | 1.1 | 0.91 | 1.00 | 0.91 | 0.82 | 0.77 | 0.68 | 0.59 |
| 13.5 | 1.0 | 0.87 | 0.96 | 0.87 | 0.79 | 0.74 | 0.65 | 0.57 |
| 14.0 | 0.9 | 0.84 | 0.93 | 0.84 | 0.76 | 0.72 | 0.63 | 0.55 |
| 14.5 | 0.8 | 0.81 | 0.90 | 0.81 | 0.73 | 0.69 | 0.61 | 0.53 |
| 15.0 | 0.7 | 0.79 | 0.87 | 0.79 | 0.71 | 0.67 | 0.59 | 0.51 |
| 15.5 | 0.6 | 0.76 | 0.84 | 0.76 | 0.68 | 0.65 | 0.50 | 0.49 |
| 16.0 | 0.5 | 0.74 | 0.81 | 0.74 | 0.66 | 0.63 | 0.55 | 0.48 |

| Table 10 (5 - 15 Centigrade, 41 - 59 Fahrenheit)<br>UNIONIZED AMMONIA (% $NH_3$) IN AQUEOUS SOLUTIONS<br>(Compensated for tempature and pH) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 °C | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| pH | 41.0 °F | 42.8 | 44.6 | 46.4 | 48.2 | 50.0 | 51.8 | 53.6 | 55.4 | 57.2 | 59.0 |
| 6.5 | .04 | .04 | .05 | .05 | .06 | .06 | .06 | .07 | .07 | .08 | .09 |
| 6.6 | .05 | .05 | .06 | .06 | .07 | .07 | .08 | .09 | .09 | .10 | .10 |
| 6.7 | .06 | .07 | .07 | .08 | .09 | .09 | .10 | .11 | .12 | .13 | .14 |
| 6.8 | .08 | .09 | .09 | .10 | .11 | .12 | .13 | .14 | .15 | .16 | .17 |
| 6.9 | .10 | .11 | .12 | .13 | .14 | .15 | .16 | .17 | .19 | .20 | .22 |
| 7.0 | .12 | .14 | .15 | .16 | .17 | .19 | .20 | .21 | .24 | .25 | .27 |
| 7.1 | .16 | .17 | .19 | .20 | .22 | .23 | .26 | .27 | .30 | .32 | .34 |
| 7.2 | .20 | .22 | .23 | .25 | .27 | .29 | .32 | .34 | .37 | .40 | .43 |
| 7.3 | .25 | .27 | .30 | .32 | .34 | .37 | .40 | .43 | .47 | .51 | .54 |
| 7.4 | .31 | .34 | .37 | .40 | .43 | .47 | .51 | .54 | .59 | .64 | .68 |
| 7.5 | .39 | .43 | .47 | .50 | .54 | .59 | .64 | .68 | .74 | .80 | .85 |
| 7.6 | .49 | .54 | .59 | .63 | .68 | .74 | .80 | .85 | .93 | 1.00 | 1.07 |
| 7.7 | .62 | .68 | .74 | .80 | .86 | .92 | 1.01 | 1.07 | 1.17 | 1.26 | 1.35 |
| 7.8 | .78 | .85 | .93 | 1.00 | 1.08 | 1.16 | 1.27 | 1.35 | 1.46 | 1.58 | 1.69 |
| 7.9 | .98 | 1.07 | 1.16 | 1.25 | 1.35 | 1.46 | 1.59 | 1.69 | 1.83 | 1.98 | 2.12 |
| 8.0 | 1.22 | 1.34 | 1.46 | 1.58 | 1.70 | 1.83 | 2.01 | 2.12 | 2.30 | 2.48 | 2.65 |
| 8.1 | 1.54 | 1.68 | 1.83 | 1.98 | 2.13 | 2.29 | 2.50 | 2.65 | 2.88 | 3.11 | 3.32 |
| 8.2 | 1.93 | 2.11 | 2.29 | 2.48 | 2.67 | 2.86 | 3.12 | 3.32 | 3.59 | 3.88 | 4.14 |
| 8.3 | 2.41 | 2.64 | 2.87 | 3.10 | 3.33 | 3.58 | 3.90 | 4.14 | 4.48 | 4.84 | 5.16 |
| 8.4 | 3.02 | 3.30 | 3.59 | 3.87 | 4.16 | 4.46 | 4.87 | 5.15 | 5.58 | 6.01 | 6.41 |
| 8.5 | 3.77 | 4.12 | 4.47 | 4.82 | 5.18 | 5.55 | 6.05 | 6.40 | 6.92 | 7.45 | 7.98 |

| Table 10 (5 - 15 Centigrade, 41 - 59 Fahrenheit)<br>UNIONIZED AMMONIA (% $NH_3$) IN AQUEOUS SOLUTIONS<br>(Compensated for tempature and pH) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 °C | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| pH | 41.0 °F | 42.8 | 44.6 | 46.4 | 48.2 | 50.0 | 51.8 | 53.6 | 55.4 | 57.2 | 59.0 |
| 8.6 | 4.70 | 5.13 | 5.57 | 5.99 | 6.44 | 6.89 | 7.50 | 7.93 | 8.56 | 9.21 | 9.79 |
| 8.7 | 5.85 | 6.38 | 6.91 | 7.43 | 7.97 | 8.53 | 9.26 | 9.78 | 10.54 | 11.32 | 12.02 |
| 8.8 | 7.25 | 7.90 | 8.54 | 9.18 | 9.84 | 10.50 | 11.38 | 12.01 | 12.92 | 13.84 | 14.68 |
| 8.9 | 8.96 | 9.74 | 10.52 | 11.28 | 12.07 | 12.87 | 13.92 | 14.66 | 15.74 | 16.82 | 17.80 |
| 9.0 | 11.02 | 11.96 | 12.89 | 13.80 | 14.74 | 15.68 | 16.91 | 17.78 | 19.04 | 20.30 | 21.42 |

| Table 10 (16 - 25 Centigrade, 60 - 77 Fahrenheit)<br>UNIONIZED AMMONIA (% $NH_3$) IN AQUEOUS SOLUTIONS<br>(Compensated for tempature and pH) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 °C | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| pH | 60.8 °F | 62.6 | 64.4 | 66.2 | 68.0 | 69.8 | 71.6 | 73.4 | 75.2 | 77.0 |
| 6.5 | .09 | .10 | .10 | .12 | .13 | .13 | .14 | .16 | .17 | .18 |
| 6.6 | .12 | .13 | .13 | .15 | .16 | .17 | .18 | .20 | .21 | .22 |
| 6.7 | .15 | .16 | .17 | .18 | .20 | .21 | .23 | .25 | .26 | .28 |
| 6.8 | .19 | .20 | .21 | .23 | .25 | .27 | .29 | .31 | .33 | .35 |
| 6.9 | .23 | .25 | .27 | .29 | .32 | .34 | .36 | .39 | .42 | .44 |
| 7.0 | .29 | .31 | .34 | .37 | .40 | .42 | .45 | .49 | .52 | .55 |
| 7.1 | .37 | .39 | .42 | .46 | .50 | .53 | .57 | .62 | .66 | .70 |
| 7.2 | .46 | .50 | .53 | .58 | .63 | .67 | .71 | .77 | .83 | .88 |
| 7.3 | .58 | .62 | .67 | .73 | .79 | .84 | .90 | .97 | 1.04 | 1.10 |
| 7.4 | .73 | .78 | .84 | .91 | .99 | 1.05 | 1.13 | 1.22 | 1.30 | 1.38 |
| 7.5 | .92 | .98 | 1.06 | 1.15 | 1.24 | 1.32 | 1.42 | 1.53 | 1.63 | 1.73 |
| 7.6 | 1.16 | 1.24 | 1.33 | 1.44 | 1.56 | 1.66 | 1.78 | .192 | 2.05 | 2.17 |
| 7.7 | 1.45 | 1.55 | 1.67 | 1.81 | 1.96 | 2.08 | 2.23 | 2.41 | 2.57 | 2.72 |
| 7.8 | 1.82 | 1.95 | 2.09 | 2.26 | 2.45 | 2.61 | 2.79 | 3.01 | 3.21 | 3.39 |
| 7.9 | 2.29 | 2.44 | 2.62 | 2.83 | 3.06 | 3.26 | 3.48 | 3.76 | 4.01 | 4.24 |
| 8.0 | 2.86 | 3.05 | 3.28 | 3.54 | 3.83 | 4.07 | 4.35 | 4.69 | 4.99 | 5.28 |
| 8.1 | 3.58 | 3.81 | 4.09 | 4.42 | 4.77 | 5.07 | 5.41 | 5.83 | 6.21 | 6.55 |
| 8.2 | 4.46 | 4.75 | 5.10 | 5.50 | 5.94 | 6.30 | 6.72 | 7.23 | 7.69 | 8.11 |
| 8.3 | 5.55 | 5.90 | 6.33 | 6.82 | 7.36 | 7.80 | 8.31 | 8.94 | 9.49 | 10.00 |
| 8.4 | 6.89 | 7.32 | 7.84 | 8.44 | 9.09 | 9.62 | 10.24 | 10.99 | 11.66 | 12.27 |
| 8.5 | 8.52 | 9.04 | 9.68 | 10.40 | 11.18 | 11.82 | 12.56 | 13.45 | 14.25 | 14.97 |

| Table 10 (16 - 25 Centigrade, 60 - 77 Fahrenheit)<br>UNIONIZED AMMONIA (% $NH_3$) IN AQUEOUS SOLUTIONS<br>(Compensated for tempature and pH) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 °C | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| pH | 60.8 °F | 62.6 | 64.4 | 66.2 | 68.0 | 69.8 | 71.6 | 73.4 | 75.2 | 77.0 |
| 8.6 | 10.49 | 11.12 | 11.88 | 12.74 | 13.68 | 14.44 | 15.31 | 16.37 | 17.30 | 18.14 |
| 8.7 | 12.86 | 13.61 | 14.51 | 15.53 | 16.63 | 17.53 | 18.54 | 19.77 | 20.84 | 21.82 |
| 8.8 | 15.67 | 16.55 | 17.61 | 18.30 | 20.07 | 21.11 | 22.27 | 23.68 | 24.90 | 26.00 |
| 8.9 | 18.96 | 19.98 | 21.20 | 22.57 | 24.02 | 25.19 | 26.51 | 28.09 | 29.44 | 30.66 |
| 9.0 | 22.75 | 23.91 | 25.30 | 26.85 | 28.47 | 29.78 | 31.23 | 32.96 | 34.44 | 35.76 |

**Table 1 1**
**JULIAN CALENDAR**

| 00 | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 001 | 032 | 060 | 091 | 121 | 152 | 182 | 213 | 244 | 274 | 305 | 335 |
| 02 | 002 | 033 | 061 | 092 | 122 | 153 | 183 | 214 | 245 | 275 | 306 | 336 |
| 03 | 003 | 034 | 062 | 093 | 123 | 154 | 184 | 215 | 246 | 276 | 307 | 337 |
| 04 | 004 | 035 | 063 | 094 | 124 | 155 | 185 | 216 | 247 | 277 | 308 | 338 |
| 05 | 005 | 036 | 064 | 095 | 125 | 156 | 186 | 217 | 248 | 278 | 309 | 339 |
| 06 | 006 | 037 | 065 | 096 | 126 | 157 | 187 | 218 | 249 | 279 | 310 | 340 |
| 07 | 007 | 038 | 066 | 097 | 127 | 158 | 188 | 219 | 250 | 280 | 311 | 341 |
| 08 | 008 | 039 | 067 | 098 | 128 | 159 | 189 | 220 | 251 | 281 | 312 | 342 |
| 09 | 009 | 040 | 068 | 099 | 129 | 160 | 190 | 221 | 252 | 282 | 313 | 343 |
| 10 | 010 | 041 | 069 | 100 | 130 | 161 | 191 | 222 | 253 | 283 | 314 | 344 |
| 11 | 011 | 042 | 070 | 101 | 131 | 162 | 192 | 223 | 254 | 284 | 315 | 345 |
| 12 | 012 | 043 | 071 | 102 | 132 | 163 | 193 | 224 | 255 | 285 | 316 | 346 |
| 13 | 013 | 044 | 072 | 103 | 133 | 164 | 194 | 225 | 256 | 286 | 317 | 347 |
| 14 | 014 | 045 | 073 | 104 | 134 | 165 | 195 | 226 | 257 | 287 | 318 | 348 |
| 15 | 015 | 046 | 074 | 105 | 135 | 166 | 196 | 227 | 258 | 288 | 319 | 349 |
| 16 | 016 | 047 | 075 | 106 | 136 | 167 | 197 | 228 | 259 | 289 | 320 | 350 |
| 17 | 017 | 048 | 076 | 107 | 137 | 168 | 198 | 229 | 260 | 290 | 321 | 351 |
| 18 | 018 | 049 | 077 | 108 | 138 | 169 | 199 | 230 | 261 | 291 | 322 | 352 |
| 19 | 019 | 050 | 078 | 109 | 139 | 170 | 200 | 231 | 262 | 292 | 323 | 353 |
| 20 | 020 | 051 | 079 | 110 | 140 | 171 | 201 | 232 | 263 | 293 | 324 | 354 |
| 21 | 021 | 052 | 080 | 111 | 141 | 172 | 202 | 233 | 264 | 294 | 325 | 355 |
| 22 | 022 | 053 | 081 | 112 | 142 | 173 | 203 | 234 | 265 | 295 | 326 | 356 |
| 23 | 023 | 054 | 082 | 113 | 143 | 174 | 204 | 235 | 266 | 296 | 327 | 357 |
| 24 | 024 | 055 | 083 | 114 | 144 | 175 | 205 | 236 | 267 | 297 | 328 | 358 |
| 25 | 025 | 056 | 084 | 115 | 145 | 176 | 206 | 237 | 268 | 298 | 329 | 359 |
| 26 | 026 | 057 | 085 | 116 | 146 | 177 | 207 | 238 | 269 | 299 | 330 | 360 |
| 27 | 027 | 058 | 086 | 117 | 147 | 178 | 208 | 239 | 270 | 300 | 331 | 361 |
| 28 | 028 | 059 | 087 | 118 | 148 | 179 | 209 | 240 | 271 | 301 | 332 | 362 |
| 29 | 029 | | 088 | 119 | 149 | 180 | 210 | 241 | 272 | 302 | 333 | 363 |
| 30 | 030 | | 089 | 120 | 150 | 181 | 211 | 242 | 273 | 303 | 334 | 364 |
| 31 | 031 | | 090 | | 151 | | 212 | 243 | | 304 | | 365 |

**Table 12**

**WEIGHT AND MEASURE CONVERSIONS**

Multiply > > > > > >

<<<<<< Divide

| | |
|---|---|
| Acre | 43560.0 ft$^2$ |
| | 4046.8 m$^2$ |
| | 0.4049 ha |
| | |
| Acre-Foot | 43560.0 ft$^3$ |
| | 325851.0 gals(US) |
| Condition Factor(metric) | Condition Factor(English)/36.12729 |
| Cubic Foot | 28.321 |
| | 7.48 gals(US) |
| | 62.43 lbs |
| Cubic Foot Per Second | 28.32 lps |
| | 448.80 gpm |
| Foot | 30.48 cm |
| | 0.305 m |
| Gallon | 3.785 l |
| | 128.00 fl oz |
| | 8.35 lbs |
| Gallons Per Minute | 3.785 lpm |
| Inch | 25.4 mm |
| Kilogram | 2.205 lbs |
| | 35.274 oz |
| Liter | 33.82 fl oz |
| | 1.057 qt |
| | 0.264 gal |
| Meter | 39.370 in |
| | 3.281 ft |
| | 1.094 yd |
| Ounce (weight) | 28.35 g |
| Ounce (liquid) | 29.57 ml |
| Quart | 946.34 ml |
| | 32.00 fl oz |
| Tablespoon | 14.79 ml |
| | 3.00 tsp |

Figure 1

Figure 2

**Figure 3**
**Example of a format for production planning**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | Water Temp. (°C) | Number of Fish | Mean Length (mm) | Mean Weight (n/lb.) | Total Weight (lbs.) | Weight Gain (lbs.) | Feed Req'd. (lbs.) |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Figure 4
Schematic of activities for the "5-by-5" method of pond inventorying

**Figure 5**
**Example of an inventory data recording form**

**Pond No.:___________**

**Date:___________**

| Sample Number | Weight (g) | (lb.) | Number |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**Length: Weight - Individual Fish**

| | mm | g |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

| | mm | g |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

| | mm | g |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |

| | | |
|---|---|---|
| 8 | | |
| 9 | | |
| 10 | | |

| | mm | g |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |

| | | |
|---|---|---|
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

**Figure 6**
**Example of a form used to establish the daily feeding program for a pond of fish**

Pond NO.____________

Dates of feeding period:____________ to ____________

| Date | Length | Biomass | Feed |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Expected Data on Day 15: n/lb. ____________________________
Lbs

. ____________________________
Length____________________________