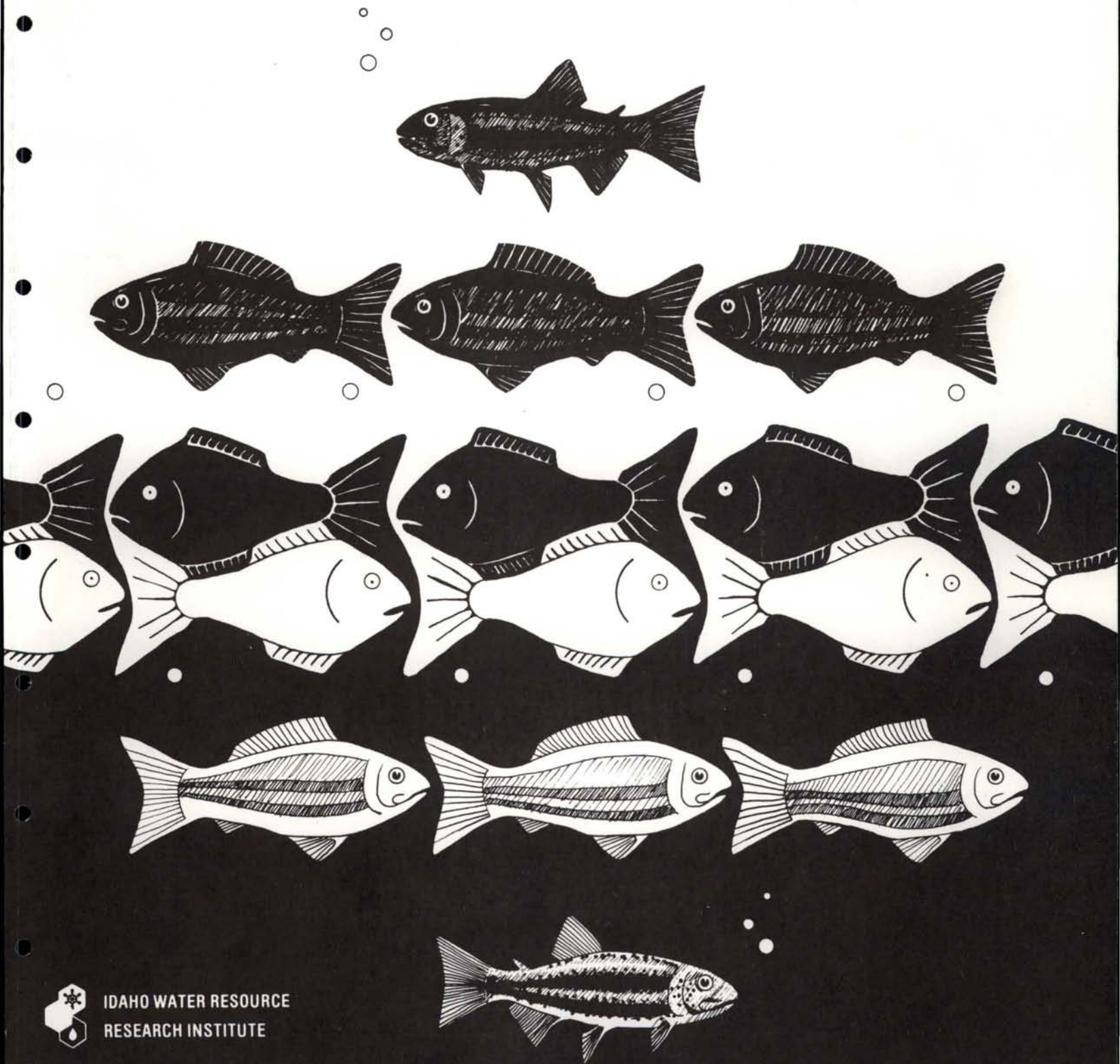# Aquaculture Techniques: A Computer Simulation of an Intensive Fish Culture System (AQUA)

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AQUACULTURE TECHNIQUES: A Computer Simulation of an
Intensive Fish Culture System (AQUA)

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ABSTRACT

AQUA is a computer simulation model used for teaching fish culture concepts. In this model, the student functions as a hatchery manager and must program fish growth, monitor pond loadings, treat diseases and make various calculations concerning the interactions of fish, water, container, nutrition and management using a group of rainbow trout. As the student's objective, a product definition is presented at the beginning of the model and is used as a standard for comparison for feedback comments on how well the student "grew" the fish. A handout containing the necessary equations and information for using AQUA proficiently complements the model to guide inexperienced fish health managers. AQUA is currently being used by students of fish culture and disease at the University of Idaho Department of Fisheries Resources to reinforce and apply concepts taught in the classroom.

INTRODUCTION

A computer teaching model lets the student assume an active learning role dealing with simulated reality. Modeling promotes decision-making skills for natural resource managment without any of the detrimental effects which might occur from a real-world decision. Feedback is immediate, unlike the long-term effects on an aquatic ecosystem. Computer models have many attributes: they are very quick, can be accessed by many people, are relatively easy to operate, are quantitative and can be complex with respect to interactions.

Models present different learning situations and increase one's exposure to more experiences. Often, the same mistakes made while using the model are made by beginning managers in real life. If the novice had been exposed to commonly occurring problems and their solutions via models, many on-the-job problems might be averted. Experience can be pooled from many managers to be shared with newcomers into the field.

Over the past 10 to 15 years, great strides have been made in teaching natural resource subjects by computer modeling (Lackey, 1975; Patten, 1969). Areas of forestry, water resources and wildlife management have developed useful models to aid in their particular resource goals. Three of these models, DAM, SCRAP, and FARMS aid in training natural resource managers. The teaching model DAM combines many disciplinary aspects in examining a reservoir situation, where students take several different professional points of view; such as fishery biologist, recreationist, town mayor, etc. Students can trade roles to see other manager's points of view (Titlow and Lackey, 1974). FARMS was developed to evaluate land use and big game populations in British Columbia (Walters and Bunnell, 1971).

The field of fishery management also has developed several teaching models which are resource management oriented. CATS, or catchable trout stocking simulation, simulates the effects of varied stocking techniques on fishing response (Hammond and Lackey, 1976). TROUT simulates the management of a trout fishery by demonstrating the effects of various management strategies implemented on a lake fishery (Titlow and Lackey, 1973). SALMON is a fairly simple model based on stock-recruitment theory. Students manage a theoretical salmon fishery for either catch or escapement (Li and Adams, 1976).

Students of fish culture have had little opportunity to use teaching models. An optimization model, HATCH, was developed to maximize a hatchery's productivity, but was not designed for instructional purposes (Bergman and Matthews, 1970).

AQUA, a teaching model, will help students understand modeling in fish culture. The model presents problems requiring mathematical and verbal solutions and is deterministic with probabilistic aspects. It can be used to help hatchery personnel and university students become knowledgeable of the various concepts in intensive fish culture. New hatchery workers have few training aids other than experience. Trainees are not usually exposed to managerial experiences because of the nature of their work. Courses in continuing education are often too expensive, in both time and money.

AQUA was designed as a teaching aid for students of fish culture and disease at the University of Idaho. AQUA simulates many aspects of a trout hatchery operation through a one-year growing season. The student assumes the role of hatchery manager and has a goal of "growing" a certain poundage and size of trout in a definite period of tiem. A Users Manual (Appendix Number 1) is available as a handout, which explains the model and provides

necessary equations. The student manager must face problems and make calculations and decisions during the ongoing culture process in a similar manner to a real hatchery manager. At the end of the management year, he/she is evaluated on production and general fish health.

AQUA is run on remote terminals which have eliminated much of the inconvenience in teaching models. To get on to the computer, the operator types in a coded password on a remote terminal. The terminals may be permenantly located in buildings or a portable terminal may be used. A portable terminal, which needs only a standard telephone and a power outlet to function, can connect with the University of Idaho computer from anywhere in the United States.

PROGRAM DESIGN

AQUA is written in FORTRAN IV, but the operator needs no knowledge of this computer language. The model consists of 614 lines, including seven subroutines and a random number generator. The subroutines are used for repetitious or seldom used operations. The repeating operations common throughout the model are for inventories, splitting fish into new ponds, low densities caused from using too many ponds, as a check against very incorrect calculations (including guessing) and for random disease occurrences. The random number generator determines the product at the start of the model and varies the possible diseases that can occur, thus reducing the model's predictability. A basic flow chart was made before the model was programmed to help clarify thought and logic.

AQUA was originally designed to be stored in CALL/VS, a time-sharing system in an IBM 370 at the University of Idaho. CALL/VS was designed for the rapid response needed in interactive models and is far superior to using punched cards in a batch system. CALL/VS has subsequently been removed from the Idaho computer system and replaced by CMS. AQUA has since been adapted to be run on CMS.

The cost to run AQUA is minimal and AQUA can be adapted to any time-sharing system. Another important aspect is that the computer will wait while the student calculates an answer, then continues the program once the answer is received. In this way, the student gets immediate response to his/her answers.

The model is programmed to ask the operator (student) questions and to wait for the answer. The student types in an answer and gets instant feedback. If the question requires a numerical answer, erroneous guesses

will be rejected. A subroutine compares the response with the correct answer. If the answer given is greater or less than 20% of the correct answer, the computer asks for a recalculation.

A User's Manual is to accompany the use of the model. It contains the necessary equations and concepts and is written for a novice who has been exposed only briefly to hatchery situations. More experienced students may need only the equations found in the manual. Students also need a hand-held calculator to facilitate calculations of answers needed by the computer.

Logistically, the movement of fish through a hatchery is as follows: eggs are taken from brood-stock, fertilized and hatched in incubators. The yolk-sac fry are then put into troughs until the yolk is absorbed and all the fry are on feed. The fry are reared in deep tanks until they are approximately 2 inches long. Up to this point, the rearing has been done indoors. The fish are moved to outdoor raceways where the majority of growth occurs. When the distribution truck comes, the fish are pumped from the raceways into the truck and then transported to the stream.

Units are in English, not metric because English units are used by most fish culturists. In AQUA, principles of fish culture are emphasized; units can easily be converted to metric at a later time if deemed necessary.

The six components of intensive fish culture are: fish, water, container, nutrition, disease and management (Klontz, et al., 1978). All of these components are considered in AQUA. The interactions of these components are exhibited throughout the model.

For simplicity, the only species raised in the model is rainbow trout, Salmo gairdneri. When the fish are ready to have their grown programmed, the average length (L) is assumed to be 1.00 inch. The fish are to be reared for approximately 6 to 7 months and then planted into a put-and-take

fishery. It is assumed the trout will be caught soon after entering the receiving waters.

The model hatchery water is plentiful, of good quality, and, at 56°F, is very near the Standard Environmental Temperature of trout or the optimum temperature for growth.

Basic water-container interactions are accented by asking for calculations at various times throughout the model. Pond changeovers/hour (RΔ), average water velocity (Rv) in the pond, water inflow (Rw) in cubic feet/second and in gallons per minute are all to be determined, emphasizing the need for awareness about the supporting medium.

Containers used in AQUA are egg incubators, deep start tanks and raceways, all commonly used in trout hatcheries. The available rearing facilities are 12 deep tanks and 20 raceways. Deep tanks are 5' x 20' x 3' indoor concrete containers. Raceways are 10' x 100' x 3', made from concrete with vertical sides. Both types of ponds have a single-pass water use.

Feed and nutrition receive the least attention in the model, as commercial trout feeds are assumed to be of high quality. However, feeding rates using the method of Haskell (1955) are to be calculated at least once during each run of the model. Feed is also used as a carrier for an antibacterial treatment of a disease outbreak.

Most decisions facing the student relate to fish and management. The desired quantity and size of the trout are predetermined and presented to the manager as a "product definition". The manger's job is to grow the product as close to the definition as possible. To do this, he must plan the growth, programming the fish to grow as desired. A growth increment, expressed as ΔL (the daily increase in average length in inches) is determined from the established growing period length and the starting and

ending body length. The ΔL is a simple concept but critical to arrive at the production goals.

Fish mortalities are derived from an accepted mortality rate of 0.03% daily (Klontz, 1977). That is, 0.03% of the fish population will die each day from natural attrition.

IMPLEMENTATION OF AQUA

To begin AQUA, the student uses the appropriate code word to log on to the computer via a remote terminal. An introduction is printed:

> "This model simulates a fish hatchery. You are the
> manager and must make several calculations and
> decisions to produce your product. Type in a number
> from 1 to 32."

This number, called a 'seed number', is needed by the random number generator to provide variation. After the student types in the seed number, the model asks if he wants the rules for running AQUA. A student familiar with the rules may skip this part and begin the model. If the rules are desired, the student types 1, which means yes to the computer.

The rules are as follows:

> "1) You will need a calculator and some scratch paper.
>   Refer to the handout for the necessary equations.
> 2) You will take a lot of fish from egg to planting
>   truck.
> 3) A preliminary program is available if needed.
> 4) When splitting ponds, all ponds are to be equally
>   loaded with the same number of fish.
> 5) To answer questions, type in 1 for yes and 2 for no.
> 6) Separate input numbers by commas.
> 7) Units are in English, such as inches and pounds."

Depending on the seed number entered, one of three products will be chosen by the computer and used throughout the first run. A product in this model is the student's objective, a combination of parameters of the fish being produced. The ending weight, ending length, K-factor and number of growing days are all part of the product definition informing the student what is to be grown and under what restraints. This product is the reference to which the studen'ts lot of fish is compared for evaluation purposes at the end of the final growing period. An example of this product definition is as follows:

> "Your product is 140,000 pounds of 7.00 inch
>
> rainbow trout with a K-factor of 0.00041 for
>
> planting in a put-and-take fishery. The truck
>
> comes August 1st, which gives you 182 growing
>
> days."

The underlined numbers are the variables of the product. The product of the next run will contain one of the two remaining combinations of numbers and might have 200,000 pounds of 8.00 inch trout with a K-factor of 0.00043 to be grown in 200 days. With three separate products available, the model run three times in succession displays completely different variables each time, necessitating new calculations of answers to repeating questions.

Also included with the product are some aspects pertinent to the culture of trout. These are the number of temperature units needed for the eggs to hatch, the number of water turnovers per hour of the deep tanks, and the amount of water entering the raceways. Each of these variables is used in an individual problem, such as:

> "Each raceway has an inflow of 2.25 CFS of water.
>
> Type in the pond turnovers/hour."

AQUA then provides the student a programming tool called a preliminary growth program which uses established mortality and growth rates to make a schedule of the overall trends of growth. The preliminary program contains much useful information by predicting the ultimate fish size and biomass. The preliminary program is a means of planning the production schedule before actually raising the fish. It previews the growth of the fish over the time allotted and aids in growth predictions, pond loadings and decisions about the amount of feed needed for the coming growing season. On the first day of each period, the length, number/pound, number of fish and total fish biomass are shown.

Only the starting number of fish, the number of 14-day growing periods and the ΔL (daily length increase in inches) are needed as input for the preliminary program. If one were to grow a fish from a 1.0 inch starting length to 3.5 inches ending length in 100 days, the ΔL would be $\frac{3.5" - 1.0"}{100 \text{ days}}$ or 0.0250 inches growth/day. This figure should probably keep four decimal places.

The number of 14-day growing periods is found by dividing the total number of growing days by 14. If the growing season was exactly 10 periods long, the fish would leave the hatchery on the first day of the eleventh period.

The starting number of fish is found by first determining the ending number of fish comprising the final product. This is done by finding the ending number/pound and multiplying this by the ending number of pounds of fish. The number of fish/pound is another measure of fish size and is the inverse of the average weight. Fish weight is derived from the equation $W=KL^3$, where W is the average weight of a fish in pounds, L is the average

length of the fish in inches and K is the length-weight conversion constant. K is also called the K-factor and is a measure of how deep-bodied a fish is.

The average daily mortality rate is assumed to be a constant 0.0003, or 0.03% of the population die each day. The mortality rate for a 14 day period is rounded to 14 times 0.0003, or 0.0042. By multiplying the number of fish at the end of a 14 day period by 1.0042, the number of fish at the start of that period can be found. This starting number then becomes the ending number for the previous period. This process is repeated for the necessary number of growth periods until the original number of 1.00 fish fry is determined.

Once these calculations are entered, the computer prints out a preliminary program such as:

START OF PERIOD	LENGTH	#/LB	NO. OF FISH	FISH WT.	MORTS/PERIOD
1	1.000	2439.03	734514.	301.2	3085.
2	1.420	851.83	731429.	858.7	3072.
3	1.840	391.53	728357.	1860.3	3059.
4	2.260	211.30	725298.	3432.6	3046.
5	2.682	126.71	722252.	5700.0	3033.
6	3.100	81.87	719218.	8784.7	3021.
7	3.520	55.92	716197.	12806.8	3008.
8	3.940	39.88	713189.	17884.4	2995.
9	4.360	29.43	710194.	24133.4	2983.
10	4.780	22.33	707211.	31667.5	2970.
11	5.200	17.35	704241.	40598.7	2958.
12	5.620	13.74	701283.	51036.8	2946.
13	6.040	11.07	698338.	63089.5	2933.
14	6.460	9.05	695404.	76862.7	2921.
15	6.880	7.49	692384.	92460.4	2908.
16	7.300	6.27	689575.	109984.4	2896.

The preliminary program can be a check on the student's calculations, for the fish weight and length at the last period; in this example, 6.27 fish/pound (0.16 pounds) and 7.3 inches long should be defined by the product. If a discrepancy occurs, the student can recalculate before moving on.

Given the necessary temperature units for the species and constant 47°F. water for incubation, the model asks the student to calculate the number of days for the eggs to hatch. This temperature unit number varies

slightly, depending on the product, to provide three different possible correct answers in three runs.

The egg incubation period, measured in temperature units, depends on the water temperature and the fish species. A temperature unit, sometimes called a degree day, is one day's worth of water passing through the incubator when the water is one degree Fahrenheit above 32°F. For every degree Fahrenheit above 32°F., a thermal unit accrues. If the water temperature is a constant 50°F., each day yields 50 - 32 = 18 temperature units.

The student is then asked to compute the number of eggs needed to be taken which will eventually produce the product; a simple calculation if the student has used the preliminary program. The number of eggs is critical to the outcome of that year's program and cannot be changed once it is entered.

The number of eggs to be taken from the brood stock are back-calculated from the starting number of fry based on predetermined or historical mortality rates. The mortality rate from fertilization to eye-up (when the eyes are visible in the egg) is 10%. From eye-up to hatch, the loss is 5%; as is the loss from hatch to swim-up (when the yolk sac is absorbed and the fry are on feed). The number of eggs necessary for incubation would be the number of fry on feed x 1.05 x 1.05 x 1.10.

A subroutine, called GOOF, checks against gross errors or guessing on simple calculations, such as determining the number of incubating days. If the calculated answer entered into the computer is in error greater ± 20% of the correct number, then an error message is printed:

"Your answer is way off. Recalculate and type

in the correct number."

A correct response will then continue the model. A second incorrect answer causes another error message to be printed:

"Your answer is still off. Please try again."

If the student misses the third time, the error message

"You blew it!",

is printed and the model continues.

To denote time passage, the model prints:

"The eggs have hatched. The number of fry on

feed is _____."

The blank is filled by the computer using a proportion of the number of eggs just calculated by the student. This number of fry is the number of eggs compensated for mortalities in the early life stages.

More time appears to pass as the computer prints:

"The fry are 1.0 inch long and ready for the deep

tanks."

The student is then asked for the number of tanks to be loaded with fry and the loading weight for each tank. When choosing the number of ponds to load, the student should allow for rapid growth and keep the density at the end of the two week growing period below 0.4 pounds/cubic foot/inch of body length.

If the student were to pick a large number of ponds to load the fry into, causing the loading Density Index (Piper, 1972) to be less than 0.1 pounds/cubic foot/inch, a message would be written:

"You have used too many ponds. The fish are too

scattered and are not feeding well. Please

consolidate your fish. Type in the new number

of ponds to be used."

The student must reduce the number of ponds he has loaded fry into, for fry often exhibit poor feeding response if loaded too loosely.

Next, the computer prints the actual loading density as a Density Index so the student can compare his calculations with what he theoretically put into the ponds.

A more difficult question follows, asking the student to calculate the amount of food in pounds to be fed the fish in each tank on the fourth day of the first growth period, given a food conversion of 1.4 pounds of feed fed to get 1.0 pounds of fish weight gain. To calculate the amount of food to be fed, the length of the fish on day 4 must be known. Initially, 1.00 inch long, the fish grow by the daily ΔL increment. Three day's growth is found by multiplying the ΔL by three, then adding this growth to the starting length.

The number of "morts" or fish which die during the three previous days are found by multiplying the daily mortality rate (0.0003 or 0.03%) by 3 and then multiplying the starting number of fish by this three-day mortality rate of 0.0009. The morts are then subtracted from the original number of fish, yielding the number of fish alive on day 4.

The biomass in each pond is calculated next. The average weight of a fish is determined from the equation $W=KL^3$ explained earlier. The number of fish times this average weight will give the biomass on day 4. This total biomass is divided by the number of ponds being used to get the biomass in each pond, since the ponds are loaded equally.

Next, the percent body weight to be fed each day is calculated from Haskell's formula:

$$\% \text{ body weight fed} = \frac{\text{conversion} \times \Delta L \times 3 \times 100}{\text{length}}$$

where: conversion is the pounds of feed needed to produce one pound of
fish;

ΔL is a daily increase in length;

3 is a length-weight relationship constant; and

100 removes the decimal to make the number a percentage
(Haskell, 1955).

The numerator, conversion x ΔL x 3 x 100, is also called the Hatchery

Constant (Buterbaugh and Willoughby, 1967). Length in the denominator is

the average length of the fish on the day to be fed. The next day, the

length increases by ΔL. This equation, when used with body weight,

calculates the amount of feed needed for a fish any length to grow the

prescribed ΔL in one day.

To find the amount of feed to be fed on day 4, multiply the % body

weight to be fed times the pond biomass. If the biomass is in pounds, the

feed will be in pounds. A large error will call the GOOF subroutine.

Once the fry have been loaded into the deep tanks and are being fed, a

message is typed indicated time passage. This message is repeated

throughout the model:

"Two weeks have passed. Do you want an inventory?"

This gives the student fish culturist an option of taking an inventory of

the hatchery every two weeks. As with the preliminary program, no penalty

occurs for taking inventory and much useful information is gained.

With an inventory, the manager can tell if the fish are growing at the

prescribed rate and are "on program". Pond loadings also are monitored

with an inventory. Hopefully, this helps the fish culturist realize the

value of inventories.

An example of an inventory from AQUA FOLLOWS:

Inventory data for period 1

Length = 1.462 inches

No/lb = 820.5

Number of fish = 1,033,830

Pond weight = 2.0.0 pounds

Number of tanks used = 6

PLI * length = 254.4 pounds/pond

MDI * length = 219.3 pounds/pond

The last two lines of the inventory example provide two methods of determining a pond's carrying capacity which consider different limiting factors. The Pond Loading Index (PLI) is the carrying capacity of the pond in pounds per inch of body length and is based upon life support, i.e., dissolved oxygen. The Maximum Density Index (MDI) is the carrying capacity of the pond in pounds of fish per inch of body length and is based upon the space requirements for the species being raised (Klontz, 1981).

The PLI uses a loading index obtained from an elevation and water temperature correctec chart. This index (Wi) is in pounds of fish per cubic foot of rearing space per hourly water turnover rate per inch of body length. The index is multiplied by the pond volume and then by the number of water turnovers per hour (Rw), yielding pounds of fish per pond per inch of body length (Klontz, 1981).

The MDI is determined by multiplying the Density Index for rainbow trout (0.5 pounds/ft^3/inch) by the volume (ft^3) of rearing space. This result is also expressed as pounds of fish per pond per inch of body length (Piper, 1972).

The limiting carrying capacity is the lesser of the two, either PLI or MDI. This number is called the Maximum Pounds per Inch (MPI) for the pond (Klontz, 1981). In the example, the MPI is the MDI found by multiplying the 300 ft^3 pond volume times the Density Index of 0.5 pounds/ft^3/inch. The MPI times the 1.462 inches of fish length yields 219.3 pounds per pond, only slightly above the pond biomass. When pond loadings approach the MPI, as in the example, the pond biomass should be divided equally into another pond or "split".

If a pond biomass exceeds the MPI, a warning message is written:

"The fish appear very crowded."

This statement is printed because crowding can cause many detrimental effects. When fish become crowded, territoriality is broken down, nipping occurs, oxygen levels decrease, waste products accumulate and overall stress increases. Fish thus become more susceptible to disease transmission. AQUA was programmed to simulate harmful effects by directly introducing a disease outbreak or by indirectly reducing the quality of the fish every time the MPI is exceeded.

The next question asks:

"Do you wish to move the fish to raceways?"

The student can move the fish to the raceways after one period, but is encouraged by the model from instructions of hatchery practices to wait until the fish are around two inches long. Trout reach this length usually after the second or third period.

If the fish stay in the deep tanks, the computer asks:

"Do you wish to split the lot?"

The student will usually need to split the lot into more deep tanks because of the rapid rate of growth the small fish are undergoing.

If splitting is desired, the statement is printed:

"Type in the number of new ponds to have fish added

to them and type in the new starting pond weights for

each pond."

Refusing to heed a warning about crowding can lead to unnecessary mortalities. If, during the first two growth periods, the ponds were not split and the MPI is exceeded, then an outbreak of bacterial gill disease occurs. Implicit with this disease occurrence in AQUA would be the increased ammonia concentrations and dissolved oxygen reductions resulting from crowded conditions in a real hatchery. The accumulated waste products irritate gill tissue and set the stage for a bacterial infection.

The student must treat the trout fry outbreak by choosing the correct treatment from four possible choices. If the wrong treatment is picked, 5% of the fish die and the statement is printed:

"The fish are showing no response to your treatment.

Morts are still climbing. Treat again."

The student must keep treating the fish until he chooses the correct method according to Wood (1974). Every time an incorrect treatment is tried, another 5% of the student's fish die. This mortality closely simulates a hatchery situation where poor choices mean dead fish, caused either by the disease raging through an ineffectual treatment or by a detrimental effect of the treatment itself. The careful student will have split the fish into an adequate number of ponds and avoided this predicament.

When fish are moved over into raceways, the computer prints:

"Type in the number of raceways to be loaded and

their loading weights.

This procedure is identical to the previous loading into deep tanks.

Loading densities below 0.1 pounds/cubic foot/inch will cause the model to remand the student into consolidating ponds.

After the raceways are loaded, the computer calculates the loading Density Index and prints it for the student. This reinforces the relation of initial loading weights to general densities and corroborates the student's own loading density calculations.

Several problems relating to raceway water flows follow the loading of the ponds. Three water parameters: water turnovers/hour, water inflow and average water velocity are considered at this time. The computer types the amount of water available as determined by the product definition.

"Each raceway has an inflow of 2.2 CFS of water.

Type in the water turnovers/hour."

A water turnover (RΔ) is the number of times an empty pond can be filled in one hour and can be found using the inflow in CFS (Rw). The equation is:

$$R\Delta = \frac{Rw \times 3600}{V} \,,$$

where: V is the pond volume in cubic feet.

Besides water turnovers, the student is asked to convert the inflow to gallons per minute and then calculate the average water velocity in feet/ second, entering both answers into the computer. The inflow relationship is a direct conversion, 1 CFS = 449 gpm. Water velocity is an average across the width of the pond and is calculated from the equation:

$$Velocity = \frac{Lc \times Rw}{V \times a} \,,$$

where: Lc is the length of the container;

Rw is the inflow in CFS;

V is the pond volume; and

a is the friction coefficient (0.9 for concrete ponds) (Klontz, 1973).

Once the trout are placed into raceways, the fish grow according to the predetermined growth rate and the student must keep aware of pond densities. Every 2 weeks the model asks if an inventory is wanted and if the student would like to split out the ponds. If the pond density is greater than 0.4 pounds/cubic foot/inch at the end of a period, a warning statement is printed saying:

"The fish appear crowded. Fins are being nipped

off. You are raising swimming frankfurters."

Every time the warning statement is printed, a few points are deducted from a fish quality index number, twenty points being perfect quality. The final fish quality is evaluated by either positive or negative comments depending on how often crowding occurs.

Interspersed at distinct points throughout the routine culture part of AQUA are potential disease outbreaks. Seven diseases can occur in the model, including three bacterial infections, three parasites and a virus. Some occur randomly and some result from poor growing conditions brought on by crowded ponds. The maladies that can occur are appropriate to the life stage of the fish. For example, very young fish are susceptible to bacterial gill disease while older trout are more vulnerable to external parasites such as Gyrodactylus sp. Parasites are included as diseases, for they affect the health and growth of the trout and must be treated. A random number generator incorporated into AQUA assures variation of these diseases to reduce predictability, making the model more challenging.

After the fourth two-week growth period, the first random disease appearance can occur. One of three possible diseases - bacterial gill disease, infectious pancreatic necrosis (IPN) or Hexamita sp. is picked by the model. The student must treat the disease, again choosing the best

treatment (Wood, 1974) among those listed as possibilities. The ensuing

mortalities are related to the severity of the specific disease, i.e., a

virus will cause more deaths than an external parasite. To avoid repetition,

the student will not get any disease in this group if he has already

encountered bacterial gill disease in the deep tanks.

Three periods later, the second set of diseases can occur during the

seventh growth period. Enteric redmouth disease or furunculosis are possible

ailments to be contracted by the fish at this time. To increase variation,

it is possible that no disease problems would occur.

After period ten, the third set of diseases can occur. Gyrodactylus

sp. or Ichthyopthirius sp. are potential external parasites. Again, there

is a possibility of not getting either of these problems.

If the growth season lasts 13 or 15 periods and the student did not

treat for a parasite in period 10, the possibilities of period 10 are

repeated at period 13.

At the end of the yearly growth program, several evaluation comments

are made. The first concerns the biomass and ending length of the final

product grown by the student. For example, the computer might print:

"It is August 1st. You have raised 96039 pounds

of 7.300 inch trout. This is 96.0% of your goal."

Positive or negative feedback then follows, depending on the

culturist's skill. If the fish are less than 90% of the projected length,

the comment is printed:

"Fishermen are complaining that the fish are

small this year."

This should indicate to the student that he calculated the ΔL incorrectly.

If the biomass grown is more than 10% over the projected biomass, the computer comments:

"Your boss is angry because you blew your budget

on extra feed."

This can occur because of an incorrect ΔL or incorrect initial egg take calculation and is an appropriate comment heard at hatcheries.

If the fish have been crowded too often with the resulting quality points having been deducted from the ideal quality number, the computer writes:

"Fishermen are complaining that the hatchery plants

look terrible."

However, if the student has been careful and did not allow crowding, the comment is written:

"Fishermen are happy with the quality of your

rainbow trout."

If the total fish biomass is less than 75% of the goal, the comment is printed:

"Your boss is unhappy with your job performance."

This should put pressure on the student to perform better in the next run.

The final question asks the student:

"Do you wish to be manager for another year?"

If the student does not want to continue, then the model ends. If the answer is yes, then the student starts over with a new product. After each year's management cycle, the random number generator changes the product and associated variables mentioned at the beginning of AQUA. This prevents repitition of the identical product goals in subsequent runs with resulting identical calculations.

If the student cycles the model through several times in succession and is warned about an unhappy boss three times, the model terminates after the comment:

"Your boss is angry with your job performance.

You have been demoted to pond mucker."

It is hoped the whimsical insult will goad the student to better learn the concepts of fish culture and eventually run AQUA correctly.

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APPENDIX I

AQUA EXAMPLE

USER NUMBER, PASSWORD?
XXXXXXXXXXXXXX
ready
run aqua
AQUA   14:36 03/14/79 Wednesday

This model simulates a fish hatchery. You are the manager and must make
several calculations and decisions to produce your product.

Type in a number from 1 to 32.
?1
Do you want rules for the model? Type in 1 for yes and 2 for no.
?1
You will need a calculator and some scratch paper. Refer to the handout
for the necessary equations.

You will take a lot of fish from egg to planting truck. A preliminary
program is available if needed. When splitting and loading ponds, all
ponds are to be equally loaded with the same number of fish. To answer
questions, type in 1 for yes 2 for no. Separate input numbers by commas.
Units are in English, such as inches and pounds.

Your product is 140000. pounds of 7.00 inch rainbow trout with a K-factor
of 0.00039 for planting in a put and take fishery. The truck comes August
1st, which gives you 182 growing days. Your facility has 12 deep tanks
20 feet by 5 feet by 3 feet and two banks of ten raceways 10 feet by
100 feet by 3 feet. The water temperature is a constant 56 degrees F.

Do you want a preliminary program?
?1
Type in number of fish at start, number of 14-day growing periods, and

the daily Delta-L.
?1104159, 13, .033.
Start of

Period	Length	#/lb	No. of Fish	Fish Wt.	Morts/Period
1	1.000	2564.10	1104159.	430.6	4637.
2	1.462	820.53	1099521.	1340.0	4618.
3	1.924	360.02	1094903.	3041.3	4599.
4	2.386	188.77	1090304.	5775.9	4579.
5	2.848	111.00	1085724.	9781.4	4560.
6	3.310	70.71	1081164.	15291.1	4541.
7	3.772	47.78	1076623.	22534.2	4522.
8	4.234	33.78	1072101.	31736.0	4503.
9	4.696	24.76	1067598.	43117.8	4484.
10	5.158	18.68	1063114.	56896.8	4465.
11	5.620	14.45	1058648.	73286.4	4446.
12	6.082	11.40	1054201.	92496.7	4428.
13	6.544	9.15	1049773.	114733.0	4409.
14	7.006	7.46	1045364.	140197.7	4391.

If the eggs need 570. temperature units to hatch and the incubating water
temperature is a constant 47 degrees F., how many days will pass before the
eggs hatch?

?38

Type in the number of eggs needed to be taken to produce the product.

?1339069

The eggs have hatched.
The number of fry on feed is 1104160.
The fry are 1.00 inches long and ready for the deep tanks. Type in the
number of tanks to be loaded and the loading weight for each tank.

?6,71.77

Your loading density is 0.239 pounds/cubic foot/inch of body length.

The water turnovers are 2.00 times an hour. What is the velocity (ft/sec)?

?.0178

What is the inflow in gallons/minute.

?108.75

Type in the daily Delta-L.

?.033

Type in the food in pounds to be fed each tank on the fourth day of the first period. The conversion is 1.4 lbs. of feed/1 lb. fish gain.

?12.73

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for period   1

```
Length      =           1.462 inches
No/lb   =               820.5
Number of fish  =       1101068.
Pond Weight     =       233.7 pounds
Number of tanks used = 6.
PLI*Length      =       254.4 pounds/pond
MDI*Length      =       219.3 pounds/pond
```

The fish appear very crowded.
Do you wish to move the fish to raceways?

?2

Do you wish to split the lot?

?1

Type in the number of new ponds to have fish added to them and type in the new starting pond weights for each pond.

?6,111.85

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   2

Length   =   1.924 inches
No/lb   =   360.0
Number of fish   =   1097985.
Pond Weight   =   254.2 pounds
Number of tanks used = 12.
PLI*Length   =   334.8 pounds/pond
MDI*Length   =   288.6 pounds/pond

Do you wish to move the fish to raceways?

?1

Type in the number of raceways to be loaded and their loading weights.

?4,762.4

The loading density is 0.132 pounds/cubic foot/inch of length.
Each raceway has an inflow of 2.20 CFS of water. Type in the pond
turnovers/hour.

?2.63

What is the inflow in GPM?

?987.6

What is the water velocity in ft/sec?

?.08

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   3

```
Length   =            2.386 inches
No/lb    =            188.8
Number of fish =      1094910.
Pond Weight    =      1450.1 pounds
Number of tanks used = 4.
PLI*Length     =      3779.4 pounds/pond
MDI*Length     =      2863.2 pounds/pond
```

Do you wish to split the lot?

?2

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   4

```
Length   =            2.386 inches
No/Lb    =            188.8
```

```
Number of fish  =      1091844.
Pond Weight     =      2459.1 pounds
Number of tanks used = 4.
PLI*Length      =      4511.2 pounds/pond
MDI*Length      =      3417.6 pounds/pond
```

Do you wish to split the lot?

?2

Morts are rising. Moribund fish were analyzed and found to have large amounts of bacteria clogging gill lamellae. The outbreak has been diagnosed as Bacterial Gill Disease. You must treat immediately! Your choices are:

1. Feed TM50 medicated feed for 6 days.
2. Administer a one hour drip of malachite green for 3 days and feed 2% $MGSO_4$ in feed for 6 days.
3. Starve the fish for 3 days, then administer a 1:400,000 dose of $KMNO_4$ on 4 consecutive days.
4. Administer a 1:4000 dose of acriflavine for 1 hour.

?3

The fish are responding well to your treatment. Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   5

```
Length  =          3.310 inches
No/lb   =          70.7
Number of fish =   1045235.
Pond Weight     =  3695.7 pounds
Number of Tanks used = 4.
```

```
PLI*Length      =      5243.0 pounds/pond
MDI*Length      =      3972.0 pounds/pond
```

Do you wish to split the lot?

?1

Type in the number of new ponds to have fish added to them and type in the new starting pond weights for each pond.

?4,1847.85

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   6

```
Length  =               3.772 inches
No/lb   =               47.8
Number of fish =        1042309.
Pond Weight     =       2727.0 pounds
Number of tanks used = 8.
PLI*Length      =       5974.8 pounds/pond
MDI*Length      =       4526.4 pounds/pond
```

Do you wish to split the lot?

?2

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   7

```
Length    =              4.234 inches
No/lb     =              33.8
Number of fish =         1039390.
Pond Weight     =        3846.0 pounds
Number of tanks used = 8,
PLI*Length      =        6706.6 pounds/pond
MDI*Length      =        5080.8 pounds/pond


Do you wish to split the lot?


?2


Two weeks have passed.   Do you want an inventory?


?1


Inventory Data for Period    8


Length   =              4.696 inches
No/lb    =              24.8
Number of fish =        1026480.
Pond Weight     =       5232.6 pounds
Number of tanks used = 8.
PLI*Length      =       7438.5 pounds/pond
MDI*Length      =       5635.2 pounds/pond


Do you wish to split the lot?


?1


Type in the number of new ponds to have fish added to them and type in the
new starting pond weights for each pond.


?8,2616.3
```

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   9

Length =   5.158 inches
No/lb   =   18.7
Number of fish =   1033578
Pond Weight   =   3457.3 pounds
Number of tanks used = 16.
PLI*Length   =   8170.3 pounds/pond
MDI*Length   =   6189.6 pounds/pond

Do you wish to split the lot?

?2

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   10

Length =   5.620 inches
No/lb   =   14.4
Number of fish =   1030684
Pond Weight   =   4459.4 pounds
Number of tanks used = 16.
PLI*Length   =   8902.1 pounds/pond
MDI*Length   =   6744.0 pounds/pond

Do you wish to split the lot?

?2

The fish are flashing badly. Some fish have gray-white specks on the dorsal surface and fins.

This has been diagnosed as Ich. You need to treat. Your options are:

1. Crowd the fish to the head end. Then give a 1:5000 malachite green flush.
2. Run a continual drip of 25 PPM formalin on day to day basis.
3. Split out the lot and double vitamin pack the feed.
4. Feed TM50 treated feed for 14 days.
5. 1:6000 formalin bath for one hour, repeated daily until the parasite is gone.

?5

The fish are responding well to your treatment. Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   11

Length =	6.082 inches
No/lb =	11.4
Number of fish =	1027798.
Pond Weight =	5636.3 pounds
Number of tanks used = 16.	
PLI*Length =	9633.9 pounds/pond
MDI*Length =	7298.4 pounds/pond

Do you wish to split the lot?

?2

Two weeks have passed. Do you want an inventory?

?2

Do you wish to split the lot?

?2

Two weeks have passed. Do you want an inventory?

?1

Inventory Data for Period   13

Length   =   7.006 inches
No/lb   =   7.5
Number of fish =   1022050.
Pond Weight   =   8567.0 pounds
Number of tanks used = 16.
PLI*Length   =   11097.5 pounds/pond
MDI*Length   =   8407.2 pounds/pond

It is August 1st. You have raised 137070.9 pounds of 7.006 inch trout.
This is 97.9% of your goal. Fishermen are happy with the quality of your
rainbow trout.

Do you wish to be manager for another year?

?2

Stop

Time 15 seconds

off
Off at 14:59
Proc Time   15 sec.
Term Time   23 min.

APPENDIX II

```
C*****************************************************************************
C************* START OF MAIN PROGRAM ****************************************
C*****************************************************************************
      WRITE(6,1)
      IY=2287
      X=.6
      P=0.
    1 FORMAT(2X,'THIS MODEL SIMULATES A FISH HATCHERY.'/2X,
     *'YOU ARE THE MANAGER AND MUST MAKE SEVERAL CALCULATIONS AND ',2X,/
     *2X,'DECISIONS TO PRODUCE YOUR PRODUCT.'/)
      WRITE(6,221)
  221 FORMAT(2X,'TYPE IN A NUMBER FROM 1 TO 32.')
      READ(5,*)KX
  222 CONTINUE
      WRITE(6,2)
    2 FORMAT(2X,'DO YOU WANT RULES FOR THE MODEL? TYPE IN 1 FOR YES AND
     *2 FOR NO')
      READ(5,*)IR
      IF(IR.EQ.2)GO TO 5
      WRITE(6,4)
    4 FORMAT(2X,'YOU WILL NEED A CALCULATOR AND SOME SCRATCH PAPER.'/2X,
     *'REFER TO THE HANDOUT FOR THE NECESSARY EQUATIONS. '/)
      WRITE(6,400)
  400 FORMAT(2X,'YOU WILL TAKE A LOT OF FISH FROM EGG TO PLANTING TRUCK.
     *A PRELIMINARY PROGRAM'/2X,'IS AVAILABLE IF NEEDED.')
      WRITE(6,401)
  401 FORMAT(2X,'WHEN SPLITTING AND LOADING PONDS, ALL PONDS ARE TO BE'/
     *2X,'EQUALLY LOADED WITH THE SAME NUMBER OF FISH. ')
      WRITE(6,402)
  402 FORMAT(2X,'TO ANSWER QUESTIONS,TYPE IN 1 FOR YES 2 FOR NO. SEPARAT
     *E INPUT NUMBERS BY'/2X,'COMMAS OR BLANKS.'/2X,
     *'UNITS ARE IN ENGLISH, SUCH AS INCHES AND POUNDS.'//)
    5 CALL RANDU(KX,IY,X)
      X=X*10000
  888 IF(X.GT..1)GO TO 889
      X=X*9.7
      GO TO 888
  889 IF(X.LT.1.)GO TO 890
      X=X*.15
      GO TO 889
  890 CONTINUE
      IF(X.LT..4)GO TO 97
      IF(X.LT..7)GO TO 98
      ENDLEN=7.3
      RDELTD=2.3
      CFSRAC=2.4
      ZKFACT=.00041
      ENDWT=100000.
      NUMDAY=210
      DDAY=600
      GO TO 99
   97 ENDLEN=7.0
      RDELTD=2.9
      CFSRAC=2.2
```

```
      ZKFACT=.00039
      ENDWT=140000.
      NUMDAY=182
      DDAY=570
      GO TO 99
   98 ENDLEN=6.7
      RDELTD=2.6
      CFSRAC=1.9
      ZKFACT=.00043
      ENDWT=90000.
      NUMDAY=154
      DDAY=630
   99 CONTINUE
      BOSS=0.
      WRITE(6,6)ENDWT,ENDLEN,ZKFACT,NUMDAY
    6 FORMAT(2X,'YOUR PRODUCT IS ',F7.0,' POUNDS OF',F5.2,' INCH RAINBOW
     * TROUT WITH A K-FACTOR'/2X,'OF ',F7.5/2X,
     *'FOR PLANTING IN A PUT AND TAKE FISHERY. THE TRUCK COMES AUGUST 1
     *ST'/2X,'WHICH GIVES YOU ',I3,
     *' GROWING DAYS.')
      WRITE(6,7)
    7 FORMAT(2X,'YOUR FACILITY HAS 12 DEEP TANKS 20FTX5FTX3FT AND TWO BA
     *NKS OF TEN RACEWAYS'/2X,'10FTX100FTX3FT.'/2X,
     *'THE WATER TEMPERATURE IS A CONSTANT 56 DEGREES F.'/)
      WRITE(6,8)
    8 FORMAT(2X,'DO YOU WANT A PRELIMINARY PROGRAM?')
      READ(5,*)I
      IF(I.EQ.2)GO TO 10
      CALL PRELIM(I,ZKFACT)
   10 CONTINUE
      ZKF=ZKFACT
      WRITE(6,111)DDAY
  111 FORMAT(2X,'IF THE EGGS NEED ',F4.0,' TEMPERATURE UNITS TO HATCH AN
     *D'/2X,
     *'THE INCUBATING WATER TEMPERATURE IS A CONSTANT 47 DEGREES F.'/2X,
     *'HOW MANY DAYS WILL PASS BEFORE THE EGGS HATCH?'/)
      READ(5,*)DDDAY
      XLDAY=.8*(DDAY/15)
      XUDAY=1.2*(DDAY/15)
      IF(DDDAY.LT.XLDAY)CALL GOOF(XLDAY,XUDAY)
      IF(DDDAY.GT.XUDAY)CALL GOOF(XLDAY,XUDAY)
      WRITE(6,11)
   11 FORMAT(2X,'TYPE IN THE NUMBER OF EGGS NEEDED TO BE TAKEN TO PRODUC
     *E THE PRODUCT.')
      READ(5,*)EGGNUM
      FRYNUM=(EGGNUM/1.1)/1.05/1.05
      WRITE(6,117)
  117 FORMAT(2X,'THE EGGS HAVE HATCHED.')
      WRITE(6,12)FRYNUM
   12 FORMAT(2X,'THE NUMBER OF FRY ON FEED IS ',F10.0,/)
      WRITE(6,13)
   13 FORMAT(2X,'THE FRY ARE 1.00 INCHES LONG AND READY FOR THE DEEP TAN
     *KS.'/2X,'TYPE IN THE NUMBER OF TANKS TO BE LOADED AND THE LOADING
     *WEIGHT FOR'/2X,'EACH TANK.')
```

```
      READ(5,*)TANK,TANKWT
      IF(TANK.GT.12.)TANK=12.
      ZLONG=1.00
      ZNUMB=FRYNUM
      TANKW=ZNUMB*ZKFACT*ZLONG**3/TANK
      DTVOL=300.
      XDI=TANKW/(DTVOL*ZLONG)
      QUALPT=20.
      TANKDI=XDI
      WRITE(6,14)TANKDI
   14 FORMAT(2X,'YOUR LOADING DENSITY IS',F6.3,' POUNDS/CUBIC FOOT/INCH
     *OF BODY LENGTH.'//)
      WRITE(6,142)RDELTD
  142 FORMAT(2X,'THE WATER TURNOVERS ARE ',F5.2,' TIMES AN HOUR. WHAT IS
     * THE VELOCITY (FT/SEC)?'/)
      READ(5,*)VEL
      XLVEL=.8*RDELTD/(180*.9)
      XUVEL=1.2*RDELTD/(180*.9)
      IF(VEL.LT.XLVEL)CALL GOOF(XLVEL,XUVEL)
      IF(VEL.GT.XUVEL)CALL GOOF(XLVEL,XUVEL)
  144 FORMAT(2X,'WHAT IS THE INFLOW IN GALLONS/MINUTE.'/)
      WRITE(6,144)
      READ(5,*)GPM
      XLGPM=RDELTD*.8*300/8.
      XUGPM=RDELTD*1.2*300/8.
      IF(GPM.LT.XLGPM)CALL GOOF(XLGPM,XUGPM)
      IF(GPM.GT.XUGPM)CALL GOOF(XLGPM,XUGPM)
      WRITE(6,143)
  143 FORMAT(2X,'TYPE IN THE DAILY DELTA-L.'/)
      READ(5,*)DELTAL
      WRITE(6,145)
  145 FORMAT(2X,'TYPE IN THE FOOD IN POUNDS TO BE FED EACH TANK ON THE F
     *OURTH DAY OF THE FIRST'/2X,'PERIOD. THE CONVERSION IS 1.4.'/)
      ZZL=1.0+3*DELTAL
      CONV=1.4
      PBWD=(CONV*3.0*DELTAL)/ZZL
      BIOM=(ZZL**3.0)*ZKFACT*(ZNUMB*.9991)
      XFD=PBWD*BIOM/TANK
      XLFD=.8*XFD
      XUFD=1.2*XFD
      READ(5,*)FOOD
      IF(FOOD.LT.XLFD)CALL GOOF(XLFD,XUFD)
      IF(FOOD.GT.XUFD)CALL GOOF(XLFD,XUFD)
      NUMPER=0
      DO 40 JJ=1,6
      ZLONG=ZLONG+14.*DELTAL
      PCMORT=.0002
      ZMORT=14*PCMORT*ZNUMB
      NUMPER=NUMPER+1
      ZNUMB=ZNUMB-ZMORT
      ZNOLB=1./(ZKFACT*ZLONG**3.)
      TANKWT=(ZNUMB*(ZKFACT*ZLONG**3.0))/TANK
   15 WRITE(6,16)
   16 FORMAT(2X,'TWO WEEKS HAVE PASSED. DO YOU WANT AN INVENTORY?'/)
```

```
      READ(5,*)NAA
      IF(NAA.NE.1)GO TO 18
      CALL INV(ZLONG,TANKWT,ZNUMB,NUMPER,ZNOLB,TANK,DTVOL,RDELTD)
      DI=TANKWT/DTVOL/ZLONG
      IF(DI.GT..5)WRITE(6,581)
  581 FORMAT(2X,'THE FISH APPEAR VERY CROWDED.'/)
   18 WRITE(6,19)
   19 FORMAT(2X,'DO YOU WISH TO MOVE THE FISH TO RACEWAYS?'/)
      READ(5,*)NA
      IF(NA.NE.2)GO TO 50
      WRITE(6,20)
   20 FORMAT(2X,'DO YOU WISH TO SPLIT THE LOT?'/)
      READ(5,*)NB
      IF(NB.EQ.1)GO TO 27
      DI=TANKWT/DTVOL/ZLONG
      IF(DI.GT..5)GO TO 21
      GO TO 40
   21 QUALPT=QUALPT-1.
      WRITE(6,58)
   22 WRITE(6,23)
   23 FORMAT(2X,'MORTS ARE RISING. MORIBUND FISH WERE ANALYZED AND FOUND
     * TO HAVE LARGE AMOUNTS'/2X,'OF BACTERIA CLOGGING GILL LAMELLAE.'/)
      WRITE(6,24)
   24 FORMAT(2X,'THE OUTBREAK HAS BEEN DIAGNOSED AS BACTERIAL GILL DISEA
     *SE.YOU MUST TREAT'/2X,'IMMEDIATELY! YOUR CHOICES ARE:')
      WRITE(6,241)
  241 FORMAT(2X,'1 FEED TM50 MEDICATED FEED FOR 6 DAYS')
  242 FORMAT(2X,'2 ADMINISTER A ONE HOUR DRIP OF MALACHITE GREEN FOR 3 D
     *AYS AND FEED 2 PER CENT MGSO4'/2X,'IN FEED FOR 6 DAYS')
      WRITE(6,242)
      WRITE(6,244)
  244 FORMAT(2X,'3 STARVE THE FISH FOR 3 DAYS, THEN ADMINISTER A 1:400,0
     *00 DOSE OF KMNO4 ON 4 CONSECUTIVE DAYS.')
      WRITE(6,243)
  243 FORMAT(2X,'4 ADMINISTER A 1:4000 DOSE OF ACRIFLAVINE FOR 1 HOUR'/)
   26 CONTINUE
      READ(5,*)NC
      IF(NC.NE.3)GO TO 255
      ZNUMB=ZNUMB*.95
      GO TO 398
  255 CONTINUE
      WRITE(6,25)
   25 FORMAT(2X,'THE FISH ARE SHOWING NO RESPONSE TO YOUR TREATMENT.MORT
     *S ARE STILL CLIMBING.'/2X,'TREAT AGAIN!!!')
      ZNUMB=ZNUMB*.9
      GO TO 26
   27 CALL SPLIT(TANK,TANKWT,DTVOL,ZLONG)
      GO TO 40
  398 WRITE(6,399)
  399 FORMAT(2X,'THE FISH ARE RESPONDING WELL TO YOUR TREATMENT.')
      P=1.
   40 CONTINUE
   50 NIP=0
      VOL=3000.
```

```
      WRITE(6,51)
   51 FORMAT(2X,'TYPE IN THE NUMBER OF RACEWAYS TO BE LOADED AND THEIR L
     *OADING WEIGHTS.'/)
      READ(5,*)TANK,TANKWT
      IF(TANK.GT.20.)TANK=20.
   52 FORMAT(2X,'EACH RACEWAY HAS AN INFLOW OF ',F8.2,' CFS OF WATER. TY
     *PE IN THE POND'/2X,'TURNOVERS/HOUR.'/)
      RDELTA=CFSRAC*3600/VOL
      TANKW=(ZNUMB*ZKFACT*ZLONG**3)/TANK
      DI=TANKW/(VOL*ZLONG)
      WRITE(6,53)DI
   53 FORMAT(2X,'THE LOADING DENSITY IS',F6.3,' POUNDS/CUBIC FOOT/INCH O
     *F LENGTH'/)
      IF(DI.LT..1)CALL LOWDI(DI,TANK,TANKW,VOL,ZLONG)
      WRITE(6,52)CFSRAC
      READ(5,*)TURN
      XLTURN=CFSRAC*.8*3600/3000
      XUTURN=CFSRAC*1.2*3600/3000
      IF(TURN.LT.XLTURN)CALL GOOF(XLTURN,XUTURN)
      IF(TURN.GT.XUTURN)CALL GOOF(XLTURN,XUTURN)
      WRITE(6,522)
  522 FORMAT(2X,'WHAT IS THE INFLOW IN GPM?'/)
      READ(5,*)GPMM
      XLGPM=CFSRAC*.7*449
      XUGPM=CFSRAC*1.3*449
      IF(GPMM.LT.XLGPM)CALL GOOF(XLGPM,XUGPM)
      IF(GPMM.GT.XUGPM)CALL GOOF(XLGPM,XUGPM)
      WRITE(6,523)
  523 FORMAT(2X,'WHAT IS THE WATER VELOCITY IN FT/SEC?'/)
      READ(5,*)RVEL
      XLRVEL=.8*CFSRAC*100/(.9*3000)
      XURVEL=1.2*CFSRAC*100/(.9*3000)
      IF(RVEL.LT.XLRVEL)CALL GOOF(XLRVEL,XURVEL)
      IF(RVEL.GT.XURVEL)CALL GOOF(XLRVEL,XURVEL)
  533 CONTINUE
      IF(NUMPER.EQ.4)GO TO 776
      IF(NUMPER.EQ.6)P=0.
      IF(NUMPER.EQ.7)GO TO 776
      IF(NUMPER.EQ.10)GO TO 776
      IF(NUMPER.EQ.13)GO TO 776
      GO TO 538
  776 CONTINUE
      CALL PARA(KX,IY,X,ZNUMB,ZLONG,ZKFACT,DELTAL,NUMPER,TZWT,P)
  538 CONTINUE
      ZKFACT=ZKF
      ZLONG=ZLONG+14*DELTAL
      ZMORT=14*PCMORT*ZNUMB
      NUMPER=NUMPER+1
      ZNUMB=ZNUMB-ZMORT
      ZNOLB=1/(ZKFACT*ZLONG**3)
      TANKWT=ZNUMB/TANK/ZNOLB
   54 WRITE(6,16)
      READ(5,*)NBB
      DI=TANKWT/VOL/ZLONG
```

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      IF(DI.GT..5)WRITE(6,581)
      IF(NBB.NE.1)GO TO 57
      CALL INV(ZLONG,TANKWT,ZNUMB,NUMPER,ZNOLB,TANK,VOL,RDELTA)
   57 ANUMDA=NUMDAY
      AA=ANUMDA/14.
      IF(NUMPER.GE.AA)GO TO 70
      WRITE(6,20)
      READ(5,*)NCC
      IF(NCC.NE.2)GO TO 59
      DI=TANKWT/VOL/ZLONG
      IF(DI.LT..4)GO TO 533
      NIP=NIP+1
      QUALPT=QUALPT-2
   58 FORMAT(2X,'THE FISH APPEAR CROWDED. FINS ARE BEING NIPPED OFF. YOU
     * ARE RAISING SWIMMING'/2X,'FRANKFURTERS!')
      WRITE(6,58)
      IF(DI.GT..45)QUALPT=QUALPT-2.
      GO TO 533
   59 CALL SPLIT(TANK,TANKWT,VOL,ZLONG)
      GO TO 533
   70 TOTWT=TANK*TANKWT
      TOTWT=ZNUMB*ZKFACT*ZLONG**3.
      PCT=100*TOTWT/ENDWT
      WRITE(6,71)TOTWT,ZLONG,PCT
   71 FORMAT(2X,'IT IS AUGUST 1ST. YOU HAVE RAISED ',F8.1,' POUNDS OF ',
     *F5.3,' INCH TROUT. THIS IS ',F5.1,'% OF YOUR GOAL.')
      IF(NIP.GT.3)QUALPT=QUALPT-5
      IF(ZLONG.LT.(ENDLEN*.9))WRITE(6,76)
   76 FORMAT(2X,'FISHERMEN ARE COMPLAINING THAT THE FISH ARE SMALL THIS
     *YEAR.'/)
      IF(TOTWT.GT.(1.1*ENDWT))WRITE(6,77)
   77 FORMAT(2X,'YOUR BOSS IS ANGRY BECAUSE YOU BLEW YOUR BUDGET ON EXTR
     *A FISH FEED.'/)
      IF(QUALPT.LE.16)WRITE(6,78)
      IF(QUALPT.GE.19)WRITE(6,79)
   78 FORMAT(2X,'FISHERMEN ARE COMPLAINING THAT THE HATCHERY PLANTS LOOK
     * TERRIBLE.'/)
   79 FORMAT(2X,'FISHERMEN ARE HAPPY WITH THE QUALITY OF YOUR RAINBOW TR
     *OUT.'/)
      IF(PCT.LT.75)WRITE(6,82)
      IF(PCT.LT.70)BOSS=BOSS+1.
   82 FORMAT(2X,'YOUR BOSS IS UNHAPPY WITH YOUR JOB PERFORMANCE.'/)
      IF(BOSS.GT.2.)WRITE(6,83)
   83 FORMAT(2X,'YOUR BOSS IS ANGRY WITH YOUR JOB PERFORMANCE! ',
     .'YOU HAVE BEEN DEMOTED TO POND MUCKER.'/)
      IF(BOSS.GT.2.)GO TO 85
   80 WRITE(6,81)
   81 FORMAT(2X,'DO YOU WISH TO BE MANAGER FOR ANOTHER YEAR?')
      READ(5,*)M
      IF(KX-11)86,87,87
   86 KX=15
      GO TO 84
   87 IF(KX-22)88,88,89
   88 KX=31
```

```
      GO TO 84
   89 KX=1
      GO TO 84
   84 IF(M.EQ.1)GO TO 222
      CONTINUE
   85 STOP
      END
C*********************************************************************
C******************** END OF MAIN PROGRAM ***************************
C*********************************************************************
C*********************************************************************
C****************** INVENTORY SUBROUTINE ****************************
C*********************************************************************
      SUBROUTINE INV(ZLONG,TANKWT,ZNUMB,NUMPER,ZNOLB,TANK,VOL,RDELTA)
      XMDI=.4
      IF(ZLONG.LT.2.3)XMDI=.5
      WRITE(6,250)NUMPER
  250 FORMAT(7X,'INVENTORY DATA FOR PERIOD ',I3,/)
      PLIWT=.2*RDELTA*VOL*ZLONG
      XMDIWT=XMDI*VOL*ZLONG
      WRITE(6,251)ZLONG,ZNOLB,ZNUMB,TANKWT,TANK
  251 FORMAT(5X,'LENGTH = ',F8.3,' INCHES',//,5X,'NO/LB = ',F10.1,//,
     *5X,'NUMBER OF FISH = ',F10.0,//,5X,'POND WEIGHT = ',F9.1,' POUNDS'
     *,//
     *5X,'NUMBER OF TANKS USED =',F5.0,/)
      WRITE(6,252)PLIWT,XMDIWT
  252 FORMAT(5X,'PLI*LENGTH = ',F9.1,' POUNDS/POND',5X,//,
     *5X,'MDI*LENGTH = ',F9.1,' POUNDS/POND',//)
      RETURN
      END
C*********************************************************************
C********************** PRELIMINARY SUBROUTINE **********************
C*********************************************************************
      SUBROUTINE PRELIM(I,ZKFACT)
      WRITE(6,302)
  302 FORMAT(2X,'TYPE IN NUMBER OF FISH AT START,NUMBER OF 14-DAY GROWIN
     *G PERIODS,AND THE DAILY'/2X,'DELTA-L.')
      READ(5,*)PNUM,NPER,DELTAL
      WRITE(6,303)
  303 FORMAT(2X,'START OF',/,2X,'PERIOD LENGTH #/LB  NO. OF FISH FISH WT
     *. MORTS/PERIOD'/)
      PKFACT=ZKFACT
      PDELTL=DELTAL
      PCMORT=.0003
      PLONG=1.00
      NPER=NPER+1
      DO 310 JJ=1,NPER
      PFWT=PNUM*PKFACT*PLONG**3.0
      PNOLB=PNUM/PFWT
      PMORT=14.*PCMORT*PNUM
      WRITE(6,305)JJ,PLONG,PNOLB,PNUM,PFWT,PMORT
  305 FORMAT(I5,F8.3,F9.2,F10.0,F10.1,F10.0,/)
      PLONG=PLONG+14.*PDELTL
      PNUM=PNUM-PMORT
```

```
  310 CONTINUE
      RETURN
      END
C*************************************************************************
C****************** RANDOM NUMBER GENERATOR SUBROUTINE ******************
C*************************************************************************
      SUBROUTINE RANDU(KX,IY,X)
      IY=KX*65539
      IF(IY)555,666,666
  555 IY=IY+2147483647+1
  666 X=IY
      X=X*.4656613E-9
      RETURN
      END
C*************************************************************************
C******* TANK OR POND SPLITTING SUBROUTINE ****************************
C*************************************************************************
      SUBROUTINE SPLIT(TANK,TANKWT,VOI,ZLONG)
      WRITE(6,200)
  200 FORMAT(2X,'TYPE IN THE NUMBER OF NEW PONDS TO HAVE FISH ADDED TO T
     *HEM AND TYPE IN THE'/2X,'NEW STARTING POND WEIGHTS FOR EACH POND.'
     */)
      READ(5,*)NSPLIT,TNKWT
      ZWT=TANKWT*TANK
      TNK=TANK
      TANK=NSPLIT+TANK
      ZTWT=ZWT/TANK
      ZDI=ZTWT/(VOL*ZLONG)
      IF(VOL.EQ.300.)GO TO 201
      IF(ZDI.LT..1)CALL LOWDI(ZDI,TANK,ZTWT,VOL,ZLONG)
  201 CONTINUE
      IF(TANK.LT.TNK)TANK=TNK
      IF(TANK.GT.20.)TANK=20.
      IF(VOL.NE.300.)GO TO 212
      IF(TANK.GT.12.)TANK=12.
  212 CONTINUE
      RETURN
      END
C*************************************************************************
C********************** GOOF SUBROUTINE ********************************
C*************************************************************************
      SUBROUTINE GOOF(XLOW,XUPPER,COUNT)
      COUNT=0.
  501 CONTINUE
      WRITE(6,500)
  500 FORMAT(2X,'YOUR ANSWER IS WAY OFF. RECALCULATE AND TYPE IN THE COR
     *RECT NUMBER.'/)
  502 CONTINUE
      READ(5,*)G
      IF(G.LT.XLOW)GO TO 505
      IF(G.GT.XUPPER)GO TO 505
      GO TO 503
  505 CONTINUE
      COUNT=COUNT+1.
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      IF(COUNT.GE.2.)GC TC 503
      WRITE(6,506)
  506 FORMAT(2X,'YOUR ANSWER IS STILL OFF. PLEASE TRY AGAIN.'/)
      COUNT=COUNT+1.
      GO TO 502
  503 CONTINUE
      IF(COUNT.GE.2.)WRITE(6,777)
  777 FORMAT(2X,'YOU BLEW IT!'/)
      RETURN
      END
C***********************************************************************
C********** SUBROUTINE FCR WHEN THE DENSITY INDEX IS LESS THAN .1 *******
C***********************************************************************
      SUBROUTINE LOWDI(XDI,TANK,TANKW,VOL,ZLONG)
  176 CONTINUE
      WRITE(6,177)
  177 FORMAT(2X,'YOU HAVE USED TOO MANY PONDS. THE FISH ARE TOO SCATTERE
     *D AND ARE NOT FEEDING WELL.PLEASE CONSOLIDATE YOUR PONDS.'/2X,
     *'TYPE IN THE NEW NUMBER OF PCNDS TC BE USED.'/)
      READ(5,*)ZNP
      ZZDI=(TANKW*TANK/ZNP)/VOL*ZLONG
      IF(ZZDI.LT..1)GO TO 176
      TANK=ZNP
      RETURN
      END
C***********************************************************************
C* SUBROUTINE FOR CALCULATING POUNDS CF FED TO BE FEED DAILY FOR PERIOD
C***********************************************************************
      SUBROUTINE FEED(ZLN,ZNB,ZKFACT,DELTAL,NUMPER,TZWT)
      TZWT=0.0
      ZLN=ZLN+DELTAL
      NUMP=NUMPER+1
      WRITE(6,922)NUMP
  922 FORMAT(5X,'FEED SCHEDULE FCR PERICD ',I2,/)
      WRITE(6,923)
  923 FORMAT(2X,'DAY   LENGTH   NUMBER  LBS FISH   %BODY WT FED   FEED(LBS)
     *'/)
      DO 920 KK=1,14
      ZWT=ZNB*ZKFACT*ZLN**3
      PCTT=1.4*DELTAL*3/ZLN
      FD=ZWT*PCTT
      PC=PCTT*100
      TZWT=TZWT+FD
      WRITE(6,921)KK,ZLN,ZNB,ZWT,PC,FD
  921 FORMAT(2X,I2,F10.4,2F10.0,F9.2,F11.1,/)
      ZLN=ZLN+DELTAL
      ZMRT=.0003*ZNB
      ZNB=ZNB-ZMRT
  920 CONTINUE
      ZLN=ZLN-15*DELTAL
      RETURN
      END
C***********************************************************************
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C********************* DISEASE SUBROUTINE ********************************
C***********************************************************************
      SUBROUTINE PARA(KX,IY,X,ZNUMB,ZLONG,ZKFACT,DELTAL,NUMPER,TZWT,P)
      CALL RANDU(KX,IY,X)
  885 IF(X.GT..1)GO TO 886
      X=9.7*X
      GO TO 885
  886 IF(X.LT.1.)GO TO 887
      X=X*.15
      GO TO 886
  887 CONTINUE
      IF(NUMPER.LE.4)GO TO 600
      IF(NUMPER.LE.8)GO TO 700
      IF(P.EQ.1.)GO TO 730
      IF(X.LT..4)GO TO 720
      IF(X.LT..7)GO TO 730
      P=1.
      WRITE(6,532)
      WRITE(6,534)
  801 CONTINUE
      READ(5,*)ND
      IF(ND.EQ.1)GO TO 802
      IF(ND.EQ.2)GO TO 803
      WRITE(6,535)
      GO TO 801
  802 WRITE(6,530)
      WRITE(6,540)
      ZNUMB=ZNUMB*.5
      WRITE(6,535)
      GO TO 801
  803 WRITE(6,399)
  804 GO TO 730
  720 WRITE(6,532)
      P=1.
  721 FORMAT(2X,'SOME FISH HAVE GRAY-WHITE SPECKS ON THE DORSAL SURFACE
     *AND FINS.'/)
      WRITE(6,721)
      WRITE(6,722)
  722 FORMAT(2X,'THIS HAS BEEN DIAGNOSED AS ICH.YOU NEED TO TREAT.'/)
      WRITE(6,62)
      WRITE(6,723)
  723 FORMAT(2X,'2 RUN A CONTINUAL DRIP OF 25PPM FORMALIN ONDAY TO DAY B
     *ASIS.')
      WRITE(6,622)
      WRITE(6,623)
      WRITE(6,724)
  724 FORMAT(2X,'5 1:6000 FORMALIN BATH FOR ONE HOUR,REPEATED DAILY UNTI
     *L THE PARASITE IS GONE.'/)
  727 CONTINUE
      READ(5,*)NC
      IF(NC.EQ.2)GO TO 726
      IF(NC.EQ.5)GO TO 726
      WRITE(6,535)
      GO TO 727
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  726 WRITE(6,399)
      GO TO 730
  700 IF(X.LT..4)GO TO 730
      IF(X.LT..7)GO TO 810
  710 WRITE(6,61)
      WRITE(6,62)
      WRITE(6,621)
      WRITE(6,622)
      WRITE(6,623)
  711 ZNUMB=ZNUMB*.95
      READ(5,*)NC
      IF(NC.EQ.4)GO TO 715
      WRITE(6,63)
      GO TO 711
  715 NCOUNT=1
      TZWT=0.
      CALL FEED(ZLONG,ZNUME,ZKFACT,DELTAL,NUMPER,TZWT)
      WRITE(6,9999)
 9999 FORMAT(2X,'HOW MUCH ACTIVE INGREDIENT TM IN GRAMS WILL BE FED DURI
     *NG THE PERIOD?')
      XLFEED=.5*4.*(TZWT/100)
      XUFEED=1.5*4.*(TZWT/100)
      READ(5,*)FEEDD
      IF(FEEDD.LT.XLFEED)CALL GOOF(XLFEED,XUFEED,COUNT)
      IF(FEEDD.GT.XUFEED)CALL GOOF(XLFEED,XUFEED,COUNT)
      WRITE(6,399)
      GO TO 730
  810 WRITE(6,850)
  850 FORMAT(2X,'MORTS ARE RISING.THE DISEASE IS DIAGNOSED AS FURUNCULOS
     *IS.'/)
      WRITE(6,62)
      WRITE(6,621)
      WRITE(6,622)
      WRITE(6,623)
  851 ZNUMB=ZNUME*.95
      READ(5,*)NCH
      IF(NCH.EQ.4)GO TO 852
      WRITE(6,63)
      GO TO 851
  852 NKOUNT=1
      WRITE(6,399)
      GO TO 730
  532 FORMAT(2X,'THE FISH ARE FLASHING BADLY.')
  534 FORMAT(2X,'YOUR FISH HAVE GYRODACTYLUS SP. AS AN EXTERNAL PARASITE
     *.YOUR CHOICES OF'/2X,'TREATMENT ARE:'/2X,
     *'1. SOAK FEED IN WESCODYNE FOR 3 DAYS.'/2X,
     *'2. 1:6,000 FORMALIN TREATMENT.'/2X,
     *'3.  .5PPM DRIP OF MALACHITE GREEN.'/)
  535 FORMAT(2X,'THE TREATMENT WAS INEFFECTIVE. TREAT AGAIN.'/)
  530 FORMAT(2X,'THE TREATMENT KILLED 50% OF YOUR FISH.GET OUT THE BACKH
     *OE!'/)
  540 FORMAT(2X,'THIS DISASTER OCCURRED BECAUSE YOU DID NOT TEST TREAT A
     * SMALL GROUP OF FISH PRIOR TO TREATING THE WHOLE LOT.'/)
  399 FORMAT(2X,'THE FISH ARE RESPONDING WELL TO YOUR TREATMENT'/)
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 62 FORMAT(2X,'YOUR OPTIONS ARE: 1 CROWD THE FISH TO THE HEAD END. THE
   *N GIVE A 1:5,000'/2X,'MALACHITE GREEN FLUSH.')
622 FORMAT(2X,'3 SPLIT OUT THE LOT AND DOUBLE VITAMIN PACK THE FEED.')
623 FORMAT(2X,'4 FEED TM50 TREATED FEED FOR 14 DAYS.')
 61 FORMAT(2X,'YOUR FISH ARE DYING OF ENTERIC REDMOUTH DISEASE. YOU NE
   *ED TO TREAT.')
621 FORMAT(2X,'2 ADMINISTER A 1:6000 FORMALIN TREATMENT.')
 63 FORMAT(2X,'THE TREATMENT HAD NO EFFECT.FISH ARE STILL DYING.TREAT
   *AGAIN.')
 25 FORMAT(2X,'THE FISH ARE SHOWING NO RESPONSE TO YOUR TREATMENT.MORT
   *S ARE STILL CLIMBING.TREAT AGAIN.')
 23 FORMAT(2X,'MORTS ARE RISING. MORIBUND FISH WERE ANALYZED AND FOUND
   * TO HAVE LARGE AMOUNTS OF BACTERIA CLOGGING GILL LAMELLAE.'/)
 24 FORMAT(2X,'THE OUTBREAK HAS BEEN DIAGNOSED AS BACTERIAL GILL DISEA
   *SE.YOU MUST TREAT IMMEDIATELY!YOUR CHOICES ARE:')
241 FORMAT(2X,'1 FEED TM50 MEDICATED FEED FOR 6 DAYS.')
242 FORMAT(2X,'2 ADMINISTER A ONE HOUR DRIP OF MALACHITE GREEN FOR 3 D
   *AYS AND FEED 2 % MGSO4 IN FEED FOR 6 DAYS.')
244 FORMAT(2X,'3 STARVE THE FISH FOR 3 DAYS, THEN ADMINISTER A 1:400,0
   *00 DOSE OF KMNO4 ON 4 CONSECUTIVE DAYS.')
243 FORMAT(2X,'4 ADMINISTER A 1:4000 DOSE OF ACRIFLAVINE FOR 1 HOUR.'/
   *)
600 CONTINUE
    IF(P.EQ.1.)GO TO 730
    IF(X.LT..4)GO TO 610
    IF(X.LT..7)GO TO 620
    GO TO 630
610 WRITE(6,23)
    WRITE(6,24)
    WRITE(6,241)
    WRITE(6,242)
    WRITE(6,244)
    WRITE(6,243)
611 CONTINUE
    READ(5,*)NC
    IF(NC.NE.3)GO TO 615
    ZNUMB=ZNUMB*.96
    GO TO 616
615 CONTINUE
    WRITE(6,25)
    ZNUMB=ZNUMB*.92
    GO TO 611
616 WRITE(6,399)
    GO TO 730
620 WRITE(6,740)
740 FORMAT(2X,'MORTS ARE RISING DRASTICALLY.THE LARGEST FISH ARE DYING
   * AND MANY FISH ARE'/2X,'WHIRLING. THERE ARE PETECHIAL HEMORRAGES
   *IN THE PYLORIC CAECA.'/)
    WRITE(6,741)
741 FORMAT(2X,'THIS HAS BEEN DIAGNOSED AS IPN VIRUS. YOU MUST TREAT!'/
   *)
    WRITE(6,743)
742 FORMAT(2X,'3 DOUBLE VITAMIN PACK THE FEED FOR A WEEK.'/)
    WRITE(6,621)
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      WRITE(6,742)
743   FORMAT(2X,'1 CLEAN THE PONDS AND SPLIT OUT THE FISH.'/)
      WRITE(6,623)
744   CONTINUE
      READ(5,*)NC
      IF(NC.EQ.1)GO TO 747
      ZNUMB=ZNUMB*.95
      WRITE(6,25)
      GO TO 744
747   WRITE(6,399)
      ZNUMB=ZNUMB*.9
      GO TO 730
630   CONTINUE
      WRITE(6,631)
631   FORMAT(2X,'YOUR FISH ARE BECOMING PINHEADED.THEIR ABDOMENS ARE PIN
     *CHED IN AND THEY ARE'/2X,'SWIMMING IN A SPIRAL MOTION.  THERE ARE
     *SOME MORTALITIES. THESE SIGNS ARE'/2X,'DIAGNOSED AS HEXAMITA.'/)
      WRITE(6,62)
      WRITE(6,621)
      WRITE(6,632)
632   FORMAT(2X,'3 PUT 3 PERCENT EPSOM SALTS IN THE FEED FOR 3 DAYS.')
      WRITE(6,243)
634   CONTINUE
      READ(5,*)NC
      IF(NC.NE.3)GO TO 633
      ZNUMB=ZNUMB*.99
      GO TO 730
633   ZNUMB=ZNUMB*.99
      WRITE(6,25)
      GO TO 634
C     COUNT=0.
730   CONTINUE
      RETURN
      END
```