WINSIRP: NEW MICROSOFT WINDOWS®-BASED SALMONID INCUBATION AND REARING PROGRAMS, DESIGNED FOR MICROSOFT EXCEL ®.

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Abstract

Predictive models were developed to assist salmonid fish culturists and biologists with a wide range of fish culture problems by McLean et al. (1991). The species modelled were chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), pink (*O. gorbuscha*), sockeye (*O. nerka*), and steelhead or rainbow trout (*O. mykiss*). These models focussed on incubation, dissolved oxygen during rearing, and excess total gas pressure and they were incorporated into a package of computer programs for PC-compatible computers titled SIRP (i.e. Salmonid Incubation and Rearing Programs) that was easy to use (Jensen et al., 1992). Since that time computer user-interfaces have changed and part of the programs did not function properly after Y2K. Hence, these programs, now called WinSIRP, have been updated to run in Microsoft Windows® 9X using Microsoft Excel® 97, or later. Additional features in the incubation programs include information on ammonia excretion rates, mechanical shock egg sensitivity, and temperature warnings. This paper discusses the application of the Incubation portion of the WinSIRP programs.

Introduction

Predictive models were developed to assist salmonid fish culturists and biologists with a wide range of fish culture problems by McLean et al. (1991). The species modelled were chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), pink (*O. gorbuscha*), sockeye (*O. nerka*), and steelhead or rainbow trout (*O. mykiss*). These models focussed on incubation, dissolved oxygen during rearing, and excess total gas pressure. Hence, they allowed predictions of how fish may interact with the culture environment. These models were incorporated into a package of computer programs for PC-compatible computers titled SIRP (i.e. Salmonid Incubation and Rearing Programs) that was easy to use (Jensen et al., 1992). The programs dealt with:

1. the effect of temperature and ambient dissolved oxygen supply on egg and larval development rates of 6 *Oncorhynchus* species,
2. the influence of temperature, fish size and ration level on the rearing capacity of a water supply and
3. gas supersaturation and its effects on fish health.

The programs were originally designed to work as a "stand-alone" package that worked like a typical spreadsheet program. Since that time, computer user-interfaces have changed and part of the programs did not function properly after Y2K. Hence, these programs, now called WinSIRP, have been updated to run in Microsoft Windows® 9X using Microsoft Excel® 97, or later.

In the Incubation Program in SIRP, the models would calculate development time to key embryonic stages, oxygen consumption (Ro, mg/1000/hr), critical oxygen values (Pc, the dissolved oxygen level below which dependent respiration occurs), and predicted oxygen concentration in the incubator effluent. Additional features in the new WinSIRP Incubation Programs include information on ammonia excretion rates, mechanical shock egg sensitivity, and temperature warnings. Also, a series generic treatment scenarios for circular and raceway ponds have been included that allow fish culturists to quickly calculate chemical treatment concentrations and flow rates for numerous combinations of pond size, flow rates, and fish density. This paper discusses the application of the Incubation portion of the WinSIRP programs.

Additional Features in the Incubation Portion of WinSIRP

1. Ammonia excretion rates

Mclean and Lim (1985) measured ammonia excretion in chinook eggs and alevins in a hatchery production setting. An empirical ammonia excretion model was developed from their data for a given egg size and temperature. The first relationship determined is shown in the following equation

$$Y = -0.002805 + 0.0013037X + 5.916E-06X^2 \qquad \text{(Eq. 1)}$$

where Y is NH_3-N (μg/g wet wt/hr), X is ATUs (°C-days), and R^2=0.9576. This relationship was then used to generate weekly predictions of NH_3-N which we modelled against oxygen consumption (Ro, mg O_2/1000 eggs or alevins/hr); from the SIRP predictions) for chinook to yield the following equation

$$Y = 0.072836 + 111.638759/(1 + (X/11328.08987)^{-0.647114}) \qquad \text{(Eq. 2)}$$

where Y is NH_3-N (μg/g wet wt/hr), X is Ro (mg O_2/1000 eggs or alevins/hr), and R^2=0.99932.

Since there currently are no similar data for the other salmonid species included in SIRP, we have used the ammonia-Ro relationship developed for chinook and made the assumption that, at corresponding stages of development, the other 5 species will exhibit similar metabolism to chinook. Therefore, equation 2 is used to predict ammonia excretion for the other 5 salmonid species based on their calculated Ro values.

2. Mechanical Shock Sensitivity of eggs

Mechanical shock refers to the force on eggs that occurs as a result of disturbance to eggs. Disturbances can occur during handling (i.e., egg removal from female, pouring eggs into incubators, egg transportation, egg picking) or from outside sources such as pile driving or blasting and seismic shock. Jensen and Alderdice (1983, 1989) reported changes in shock sensitivity in units of energy (ergs) transferred to eggs on impact, based on the drop height that caused 50 % and 10 % mortality. Their work was conducted at 10°C. Assuming that the changes in mechanical shock sensitivity are associated mainly with stage of development, then it follows that the data of Jensen and Alderdice (1983, 1989) can be reported in terms of ATUs. Hence, the LC50s and LC10s (i.e. drop heights causing 50% and 10% mortality) were modelled against ATUs and have been included in WinSIRP as warnings during the sensitive periods of egg development during incubation. In the incubation program that predicts weekly changes in embryonic development rate and metabolism, an additional column has been added that warns of mechanical shock sensitivity based on LC50s. The warnings are as follows:-

1. If the LC50 is greater than 115 cm then the warning is " **Shock resistant**"
2. If the LC50 is between 115 and 50 cm then the warning is "**Sensitive**"
3. If the LC50 is between 50 and 10 cm then the warning is "**Very Sensitive**"
4. If the LC50 is less than 10 cm then the warning is "**Extremely Sensitive**"

Figure 1 illustrates the changes in egg sensitivity in chinook salmon eggs.

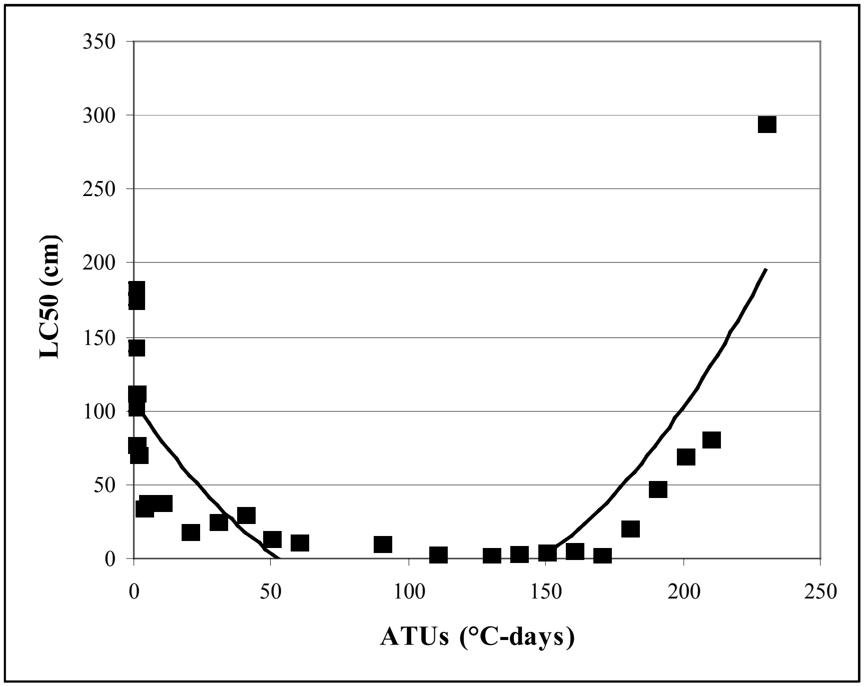

Figure 1. Chinook LC50 (i.e. drop height causing 50% egg mortality, cm) in relation to development time (ATUs). The solid line represents the equation $y=105.02387-2.70227x+0.01344x^2$; $R^2=0.6546$.

In addition, new units of egg sensitivity, called LC10 Velocity (i.e. the final velocity, cm/sec, reached when eggs are dropped causing 10% mortality), have also been developed to help in determining the potential hazards of seismic shock (see the Extended Abstract "NEW MECHANICAL SHOCK SENSITIVITY UNITS IN SUPPORT OF CRITERIA FOR PROTECTION OF SALMONID EGGS FROM BLASTING OR SEISMIC DISTURBANCE." by Jensen included elsewhere in this symposium). Therefore, for those that require egg sensitivity in relation to seismic disturbance an additional worksheet has been included in WinSIRP that yields expected egg mortality in response to pressure wave velocity.

3. Egg Mortality at High and Low Temperatures

Many researchers have studied and reported on pacific salmon egg mortality at high and low temperatures. Egg mortality data for the 6 *Oncorhynchus* species from Beacham and Murray (1985, 1986, 1988, and 1989), Murray et al. (1990), and Velsen (1987) were consolidated for each species and modelled using a 2^{nd} order polynomial since the data exhibited a typical parabolic shape, with increased mortality at high and low temperature extremes. Chinook egg mortality response data and the parabolic model are shown in Fig. 2 to illustrate this. The model parameters for all 6 species are tabulated in Table 1.

Table 1 . Parabola (i.e. $y=a+bx+c^2$) model parameters for the 6 salmonid species.

Parameter	Chinook	Chum	Coho	Pink	Sockeye	Steelhead or Rainbow
a	117.2522	55.920727	31.467233	114.91779	41.751667	56.168418
b	-25.35362	-11.09208	-12.20988	-25.06966	-8.556693	-13.31631
c	1.3003801	0.5849235	1.0584796	1.3147656	0.542333	0.8348565
R^2	0.7498169	0.3967366	0.8048845	0.6631796	0.2434187	0.5075305
n	101	58	96	66	63	16

There are a number of observations to be made from Table 1. Differences in R^2 values likely are due to variations in quantity of data, with the number of data records (n) for each species varying from 16 to 101. Also, data were compiled from many different sources. Therefore, we may be seeing stock differences as well as differences in how constant the temperatures were during egg incubation. In addition, there were differences in the distribution of temperatures to which the different species were exposed. Finally, these data represent the total mortality for eggs from fertilization to hatch in response to exposure to constant temperatures. Hence, since there are many variables that have influenced the predictive power of these models, it was decided that broad temperature warnings (see the vertical arrows in Fig. 2) should be given based on the models in Table 1. Four levels of temperature warnings were chosen, namely: -

1. If, at a given incubation temperature, the parabola model predicts a value of 20% mortality or less, then the following warning is given “Expect 20% or less egg mortality at this temperature”.

2. If, at a given incubation temperature, the parabola model predicts a value between 20 and 30% mortality, then the following warning is given "Expect 20 to 30% egg mortality at this temperature".
3. If, at a given incubation temperature, the parabola model predicts a value between 30 and 50% mortality, then the following warning is given "Expect 30 to 50% egg mortality at this temperature".
4. If, at a given incubation temperature, the parabola model predicts a value greater than 50% mortality, then the following warning is given "Expect greater than 50% egg mortality at this temperature".

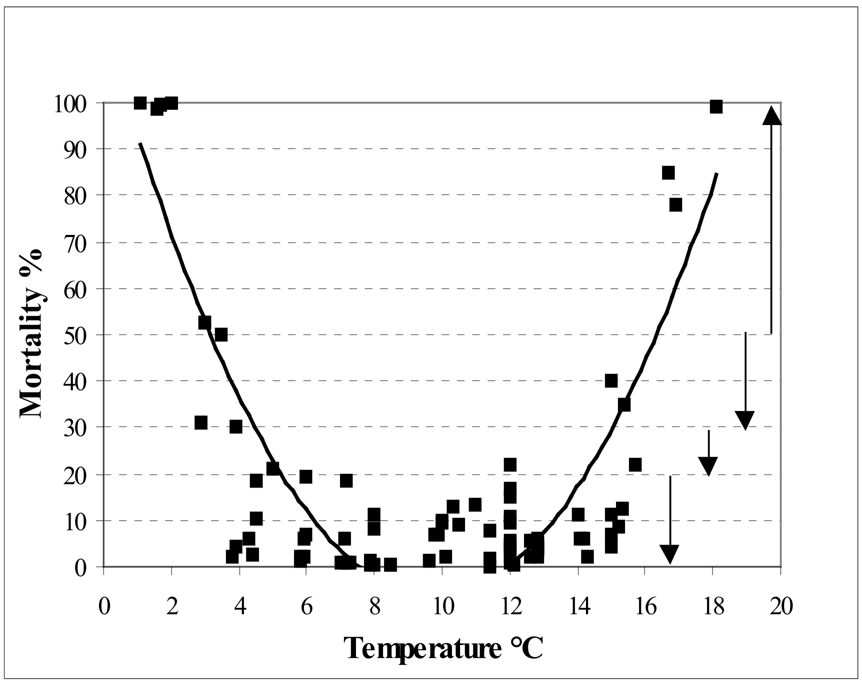

Figure 2. Chinook egg mortality in response to constant temperature from fertilization to hatch. The solid line represents the equation y=117.252220-25.3536221x+1.30038x^2; R^2=0.7498. The vertical arrows represent warning levels described in the text above.

Description of the Incubation Portion of WinSIRP

In the remainder of this paper, a brief description of the Incubation portion of WinSIRP follows.

System Requirements

WinSIRP has been installed and tested to run successfully on a number of PCs with Windows 95 and Excel 97. It should be compatible with all newer versions of Windows and Excel. The minimum CPU type is a Pentium or equivalent with a minimum speed of 133 MHz and a minimum of 32 Megs of RAM. The program installation set up files can be obtained on a CD by contacting the principle author. Also, look for a downloadable version of this program in the "What's New" section of the Pacific Region's Fisheries and Oceans Canada Aquaculture web site
(i.e. http://www-sci.pac.dfo-mpo.gc.ca/aqua/english/default.htm).

Starting WinSIRP and Menu Buttons

Once WinSIRP has been installed, the user starts WinSIRP from the Programs list. After noting the information on the introduction screen and clicking OK the user will see a typical Excel screen, with a brief introductory description of the programs. To use the various components of WinSIRP, new menu buttons have been added to the toolbar menu. These menu buttons are SIRP, SIRP Plots, and SIRP HELP. Selecting SIRP reveals a menu of choices shown in Fig. 3 below.

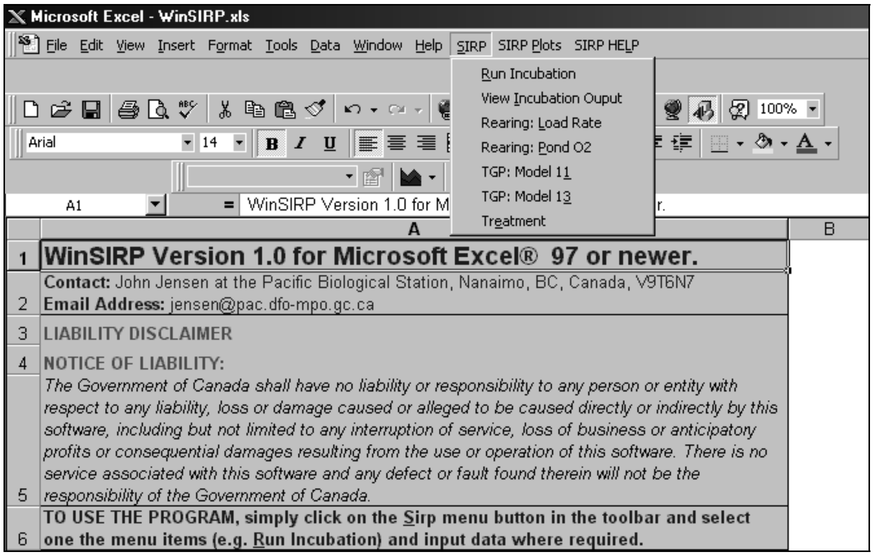

Figure 3. First worksheet when WinSIRP is started illustrating the drop-down menu for SIRP, one of the 3 new menu buttons.

Incubation Programs

To start the Incubation programs, the user selects Run Incubation. This opens the input menu screen…

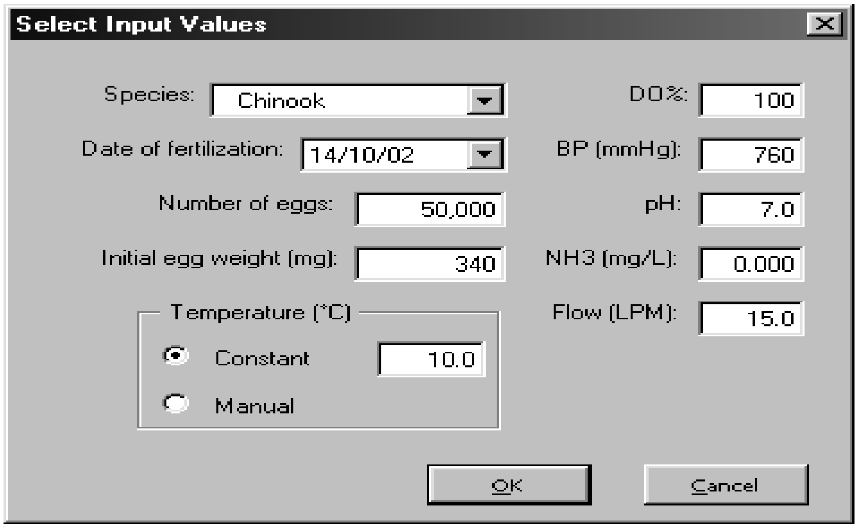

Figure 4. Input menu box with values used for the chinook egg incubation example below.

The user first chooses a species from a drop-down list of the 6 salmonid species (i.e. chinook, chum, coho, pink, sockeye, and steelhead). The fertilization date then is selected by using the calendar presented.

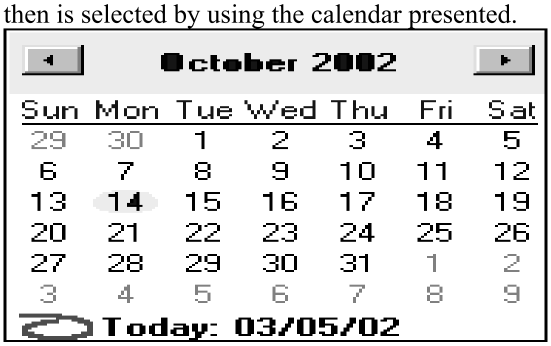

Figure 5. Calendar for selecting fertilization date.

The next choice to make is egg size, which is important for calculations of development and ammonia production. The user can then either select "constant" and type in a constant temperature or can select "manual" and input a series of average weekly temperatures. The user can also change important inflow water quality parameters or "inputs" in the menu. These "inputs" are dissolved oxygen (DO), barometric pressure (BP), pH, ammonia (NH_3-N), and water flow rate. When all inputs have been selected the user clicks OK and a series of calculations are performed, based on the models described by McLean et al. (1991) and Jensen et al.(1992). Values for developmental stages (i.e. beginning of epiboly, yolk plug closure, eyed, hatch, and maximum alevin wet weight "MAWW"), oxygen consumption (Ro), critical oxygen level (Pc), (DO) at inflow and outflow, ammonia production, mechanical shock sensitivity of eggs, and temperature warnings for eggs are then displayed for weekly time periods in the "Incubation Output" worksheet. To illustrate the many potential uses for this worksheet the following example with chinook is presented.

Chinook Egg Incubation Example

Using the input values in Figure 4, resulted in the following worksheet.

Output Table

Stage	ATU	Days	Mean Temp	Date	Stage Description
0		0		14-Oct-02	Fertilization
1	55	5.5	10.0	19-Oct-02	Begin Epiboly
2	135	13.5	10.0	27-Oct-02	Yolk Plug Closed
3	252	25.2	10.0	08-Nov-02	Eyed
4	526	52.6	10.0	05-Dec-02	50% Hatch
5	964	96.4	10.0	18-Jan-03	MAWW

Species	Chinook
Fertilization date	14-Oct-02
Number of eggs	50000
Egg weight	340
DO%	100
BP	760
pH	7.0
NH3	0.0
Flow	15.0
Temperature	10.0

Species: Chinook

Weekly Mean Temp. (°C)	Mean Flow Rate (LPM)	pH	Running Mean Temp. (°C)	Date	Days from fertilization	ATUs	Stage	Ro mg/1000 eggs hr	Pc (mg/L)	DO *IN* (mg/L)	DO *OUT* (mg/L)	NH3-N ug/g wet wt/hr	Total NH3-N *OUT* (mg/L)	un-ionized NH3-N *OUT* (ug/L)
10	15	7.00	10.0	14-Oct-02	0	0.0	*							
10	15	7.00	10.0	21-Oct-02	7	70.0	Begin Epiboly	0.55	2.00	11.26	11.23	0.25	0.01	0.01
10	15	7.00	10.0	28-Oct-02	14	140.0	Yolk Plug Closed	0.62	2.42	11.26	11.22	0.27	0.01	0.01
10	15	7.00	10.0	04-Nov-02	21	210.0		2.00	3.59	11.26	11.14	0.49	0.01	0.02
10	15	7.00	10.0	11-Nov-02	28	280.0	Eyed	4.56	4.76	11.26	11.00	0.78	0.02	0.03
10	15	7.00	10.0	18-Nov-02	35	350.0		8.67	5.92	11.26	10.77	1.14	0.03	0.05
10	15	7.00	10.0	25-Nov-02	42	420.0		14.63	7.07	11.26	10.44	1.56	0.03	0.06
10	15	7.00	10.0	02-Dec-02	49	490.0		22.79	8.22	11.26	9.99	2.05	0.04	0.08
10	15	7.00	10.0	09-Dec-02	56	560.0	50% Hatch	33.44	4.40	11.26	9.40	2.59	0.06	0.11
10	15	7.00	10.0	16-Dec-02	63	630.0		46.91	4.40	11.26	8.65	3.19	0.07	0.14
10	15	7.00	10.0	23-Dec-02	70	700.0		63.49	4.40	11.26	7.73	3.84	0.09	0.17
10	15	7.00	10.0	30-Dec-02	77	770.0		83.49	4.40	11.26	6.62	4.54	0.12	0.22
10	15	7.00	10.0	06-Jan-03	84	840.0		107.20	4.40	11.26	5.30	5.29	0.15	0.28
10	15	7.00	10.0	13-Jan-03	91	910.0		134.91	4.40	11.26	3.76	6.08	0.18	0.34
10	15	7.00	10.0	20-Jan-03	98	980.0	MAWW	166.92	4.40	11.26	1.98	6.91	0.22	0.41

Figure 6. Incubation Output worksheet illustrating Ro, Pc, Do in, DO out, and NH_3 production for chinook eggs at 10°C.

To illustrate the cause and effect relationships of the inputs (i.e. temperature, flow, DO, pH, and the number of eggs) on the outputs (i.e. Ro, Pc, DO out, and NH_3 production) four figures are included. The "Incubation: Ammonia Plot"

(Fig. 7) illustrates the increase in ammonia production from fertilization to MAWW.

The user can then change inputs such as number and size of eggs, flow rate, initial NH_3 level, and pH and immediately see the consequences on ammonia production. For example, if the source water contains a background level of 1 mg/L and a pH of 7.9 the resultant ammonia in the outflow of the incubator (i.e. un-ionized NH_3-N) increased from a maximum of 0.41 μg/l (Fig. 7) at MAWW to 17.75 μg/l (Fig. 8).

Similarly, oxygen consumption changes from fertilization to MAWW are illustrated in Fig. 9. Notice, in Fig. 9, that the DO OUT (mg/L) curve drops below the Pc (mg/L) level at 91 days post-fertilization. To fix this serious risk to late yolk sac alevins, we could increase the flow, decrease the temperature, add supplemental oxygen, or reduce the number of alevins in the incubator. For this example the flow was increased from 15 LPM to 25 LPM. The resultant improvement in DO OUT is shown in Figure 10.

This example was meant to illustrate how quickly and easily one can view the impact of the important factors that influence salmon egg and larval development and metabolism. Furthermore, the worksheets have been designed to calculate critical values of oxygen consumption and ammonia production in ways that are useful for fish culturists, field biologist, and researchers. By presenting the numerous models in an up-to-date Windows® Microsoft Excel® format, the dynamic nature of the input and output factors can easily be explored.

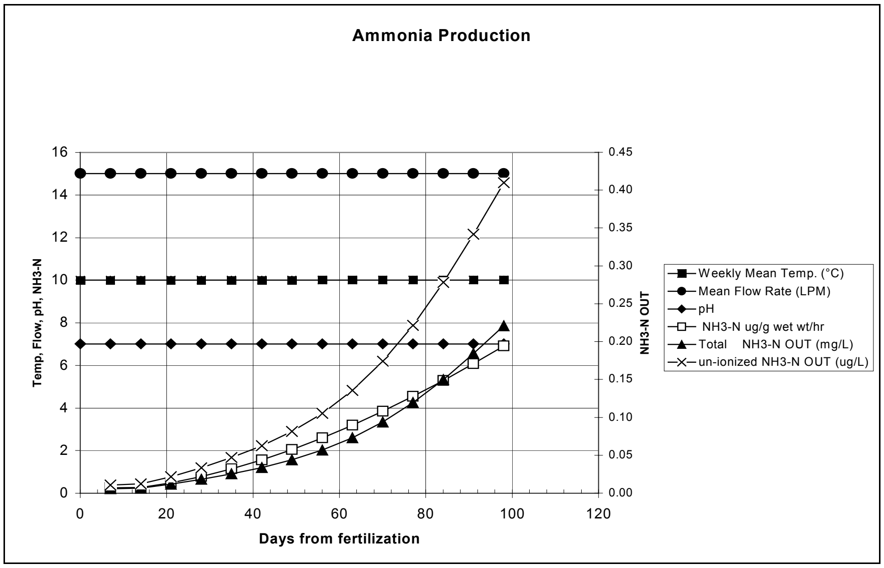

Figure 7. Incubation: Ammonia Plot. Ammonia production from fertilization to MAWW.

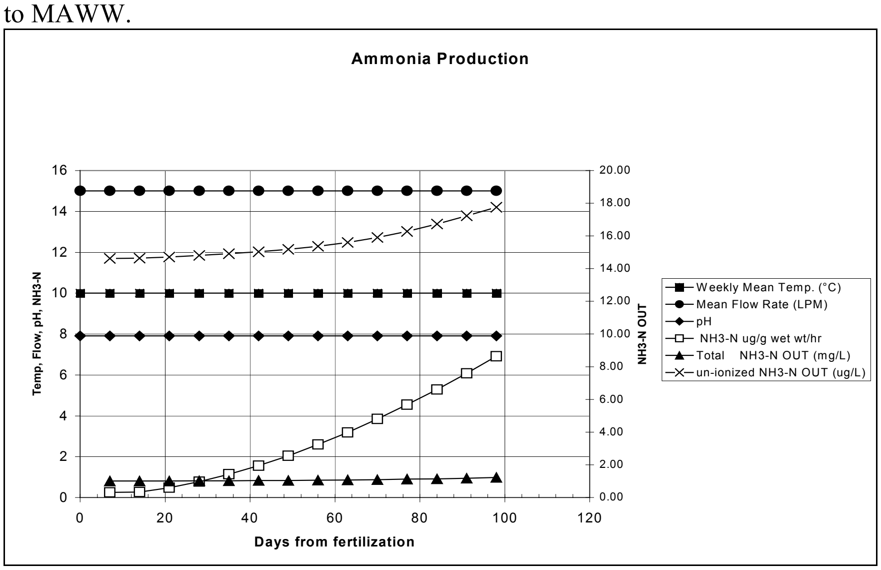

Figure 8. Incubation: Ammonia Plot with initial background NH_3-N level changed to 1 mg/L and pH changed to 7.9.

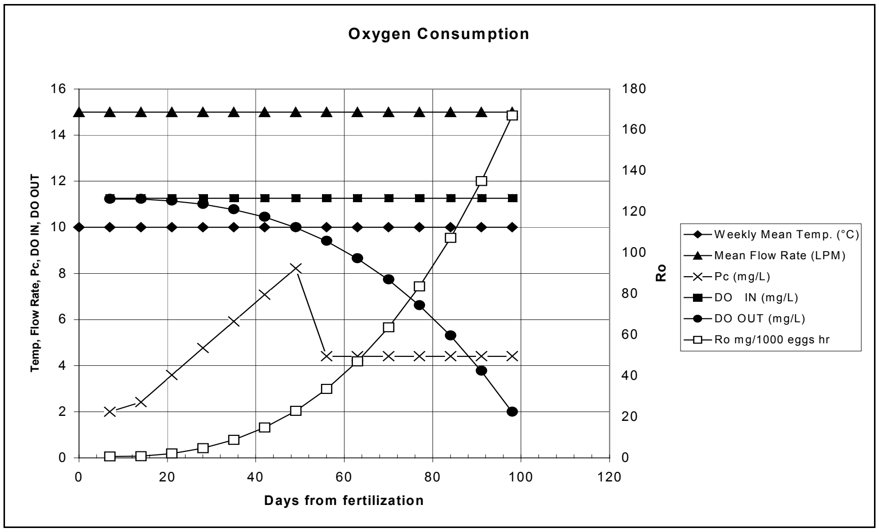

Figure 9. Incubation: Oxygen Plot showing Ro (mg O_2 consumed per 1000 eggs per hr) in response to temperature and flow.

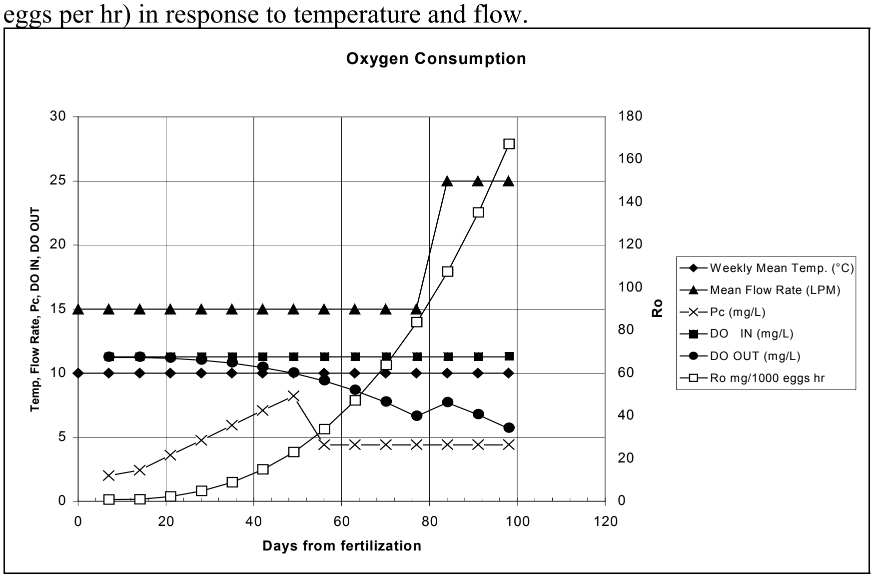

Figure 10. Incubation: Oxygen Plot illustrating the improvement in the DO OUT levels by increasing flow from 15 to 25 LPM in the last 3 weeks.

Acknowledgements

We gratefully acknowledge Bill Damon and Georgia Borgford for their helpful comments and for testing initial trial-versions of these programs.

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