WinSIRP Version 2.0 User Manual: Microsoft Windows®-based Salmonid Incubation and Rearing Programs, Designed for Microsoft Excel®

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WinSIRP VERSION 2.0 USER MANUAL: MICROSOFT WINDOWS®-BASED SALMONID INCUBATION AND REARING PROGRAMS, DESIGNED FOR MICROSOFT EXCEL®

by

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WinSIRP version 2.0 is an updated "package" of predictive models, developed to assist salmonid fish culturists and biologists with a wide range of fish culture problems. These models focus on incubation, rearing, excess total gas pressure, treatment dosage calculations, and other useful "utilities" modules. The species modelled for the incubation portion are chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), pink (*O. gorbuscha*), sockeye (*O. nerka*), steelhead or rainbow trout (*O. mykiss*), and Atlantic salmon (*Salmo salar*). For ease of use, program modules have been incorporated into specially designed Microsoft Excel® worksheets. The Incubation module consists of a series of worksheets that predict embryonic development in response to weekly mean water temperatures and associated metabolic responses (i.e. oxygen consumption and ammonia excretion), along with changes in egg sensitivity to mechanical shock and to high and low temperatures. The Treatment Module calculates chemical stock concentrations, dispensing pump flow rates, and pond flow rates for fish disease treatments with formalin used as the default chemical. In addition, there are Modules on smolt rearing (i.e. up to 50 gm), calculating the effect of excess total gas pressure, and 9 more worksheets in the "Utilities" Module. This paper is designed as a user guide or manual for the updated WinSIRP version 2.0, which can be obtained by downloading from the internet (http://www-sci.pac.dfo-mpo.gc.ca/aqua/sirp/sirp_e.htm or by contacting the primary author (John.Jensen@dfo-mpo.gc.ca). (NOTE: if the internet web address has changed, try searching the internet for the word "winsirp")

RÉSUMÉ

Jensen, J.O.T., McLean, W.E., Jensen, M.E., Sweeten, T., and Damon, W. 2009. WinSIRP version 2.0 User Manual: Microsoft Windows®-based salmonid incubation and rearing programs, designed for Microsoft Excel®. Can. Tech. Rep. Fish. Aquat. Sci. 2839: vii + 49 p.

La version 2.0 de WinSIRP est un ensemble à jour de modèles de prévision conçus pour aider les salmoniculteurs et les biologistes à régler divers problèmes liés à la salmoniculture. Ces modèles portent sur l'incubation, l'élevage, la surpression des gaz totaux, le calcul des doses thérapeutiques, et sur d'autres modules utilitaires essentiels. Les espèces modélisées pour la partie incubation étaient le quinnat (Oncorhynchus tshawytscha), le kéta (O. keta), le coho (O. kisutch), le saumon rose (O. gorbuscha), le saumon rouge (O. nerka), le saumon ou la truite arc-en-ciel (O. mykiss), et le saumon atlantique (Salmo salar). Pour en faciliter l'utilisation, les modules du programme ont été intégrés dans des feuilles de travail Microsoft Excel® spécialement conçues. Le module sur l'incubation comprend une série de feuilles de travail qui prévoient le développement embryonnaire en fonction des températures hebdomadaires moyennes de l'eau et des réactions métaboliques connexes (c'est-à-dire consommation d'oxygène et excrétion d'ammoniac), ainsi que des modifications de la sensibilité des œufs aux chocs mécaniques et aux températures élevées ou basses. Le module sur le traitement porte sur le calcul des concentrations de la solution-mère de produit chimique, du débit de la pompe de distribution et du taux d'écoulement dans le bassin dans le cas du traitement des maladies à l'aide de formol utilisé comme produit chimique par défaut. De plus, des modules portent sur l'élevage des saumoneaux (smolts) (c'est-à-dire jusqu'à 50 g), sur le calcul de l'effet de la surpression des gaz totaux; et le module utilitaire compte neuf (9) autres feuilles. Le présent document a été élaboré comme guide ou manuel à l'intention des utilisateurs de la version 2 de WinSIRP mise à jour, qui peut être téléchargée à partir d'Internet (http://www-sci.pac.dfo-mpo.gc.ca/aqua/sirp/sirp_e.htm. On peut aussi l'obtenir en communiquant avec l'auteur principal (John.Jensen@dfo-mpo.gc.ca). (NOTA : si l'adresse Internet a été changée, faites une recherche sur Internet avec l'expression « winsirp ».

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*), 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). The programs, now called WinSIRP, were updated to run in Microsoft Windows® using Microsoft Excel® (Jensen et al., 2002), with additional features in the incubation programs including ammonia excretion rates, changes in mechanical shock egg sensitivity, and temperature warnings. A new species, namely Atlantic salmon (*Salmo salar*), has since been added to the incubation module. Finally, a series of "utility" worksheets have been added that assist with several practical calculations for fish culture. This paper is designed as a user guide or manual for the updated WinSIRP version 2.0 computer program package which can be obtained by downloading from the following internet site (http://www-sci.pac.dfo-mpo.gc.ca/aqua/sirp/sirp_e.htm) or by contacting the primary author (John.Jensen@dfo-mpo.gc.ca). (NOTE: if the internet web address has changed, try searching the internet for the word "winsirp")

The programs have been reorganized from their original format in the SIRP package to include the following modules:

1. INCUBATION WIZARD: This series of excel worksheets consists of egg to fry models to predict embryonic development in response to weekly mean water temperatures and associated metabolic responses (i.e. oxygen consumption and ammonia excretion), along with changes in egg sensitivity to mechanical shock and to high and low temperatures for 6 *Oncorhynchus* and 1 *Salmo* species ,
2. TREATMENT WIZARD: This series of excel worksheets calculates chemical stock concentrations, dispensing pump flow rates, and pond flow rates for fish disease treatments (formalin is used as the default chemical, but other chemicals readily can be substituted),
3. REARING (Load Rate and Pond O2): These worksheets calculate oxygen consumption rates for salmonid fry up to about 50 grams at various temperatures and ration levels ,
4. TGP (Models 11 & 13 from Jensen et al. 1986): These worksheets calculate juvenile salmonid time to 50 % mortality in response to excess gas supersaturation, and
5. UTILITIES: A series of 9 worksheets that-
   - take re-aeration into account and predict DO at the outflow of a stack of Heath Trays,
   - predict average barometric pressure as a function of altitude and convert barometric pressure in mmHg into other common units,

- take moisture content of different Diets into account and calculate feed rate (g dry food per g of fish per day or % dry/d) and predict maximum ration from fish weight and temperature,
- calculate the % oxygen saturation of a water supply given the dissolved oxygen (DO) concentration (mg/L) and temperature and present DO criteria for salmonids,
- show how to adapt the program to other chemicals, present the equations used in WinSIRP to predict treatment concentration, duration and dose in "mixed flow" ponds (e.g. circulars, Burrows) and raceways.

Program Description

As mentioned above the re-written SIRP program is now referred to as WinSIRP (Jensen et al., 2002). For maximum flexibility and for ease of use, WinSIRP was written in Microsoft Excel. This spreadsheet is widely used and familiar to most fish culturists. All the usual Excel commands (copy, paste, sort, plot etc.) can be used in WinSIRP thereby eliminating the need for a detailed operating manual. The present manual assumes knowledge of Excel and focuses on fish culture applications and the interpretation of predicted values.

The program has now been expanded. The Incubation component includes Atlantic salmon (See Appendices 1, 5, and 6 for models used for this species) and now predicts the ammonia concentration in incubators and the effects of mechanical shock at various developmental stages. In addition, sections on treatment, mechanical shock sensitivity, and utilities (a group of worksheets for assisting with various useful fish culture tasks) have been added.

To obtain more detailed information about the development of the predictive models the reader is referred to the References section.

System Requirements

WinSIRP requires a computer capable of running Microsoft Excel in Windows and a CD ROM drive or access to the internet to download the installation package.

Getting Started

To install the program, unzip the *WinSIRP 2.0.zip* file if downloaded from the internet, run the *setup.exe* and follow the installation instructions. Then start WinSIRP by selecting *Start, Programs,* and clicking on *WinSIRP*.
A small start-up window (Fig. 1) will appear as follows:

Figure 1. WinSIRP start-up Welcome Window.

Menu Structure

After clicking *OK* on the welcome window, a familiar Excel workbook appears with three new headings on the menu bar – SIRP, SIRP Plots and SIRP HELP (Fig. 2).

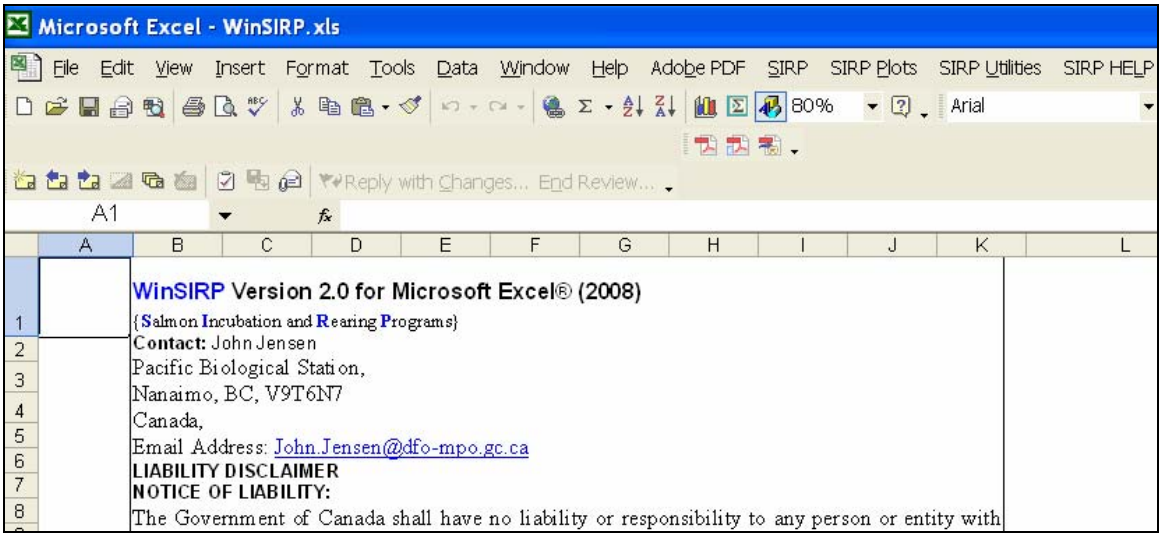


Figure 2. Part of the Excel menu bar showing the 4 new headings, SIRP, SIRP Plots, SIRP Utilities, and SIRP HELP.

The Incubation and Treatment wizards are convenient ways of entering all the input data required for these programs. The user can also change individual values on the output

spreadsheets. Rearing Load Rate and Pond O2 predict the carrying capacity of a water supply while TGP Model 11 and Model 13 predict the effects of supersaturation on rearing fish. The mechanical shock table shows sensitivity of eggs to mechanical shock at various developmental stages. Utilities programs are a group of worksheets for assisting with various useful fish culture tasks.

The SIRP drop-down menu shows the individual program components:

- Run Incubation Wizard
- Run Treatment Wizard
- View Incubation Output
- Rearing: Load Rate
- Rearing: Pond O2
- TGP Model 11
- TGP Model 13
- Mechanical Shock Table

The SIRP Plots drop-down menu shows the following useful charts:

- Incubation: Ammonia Plot
- Incubation: Oxygen Plot
- Rearing: Load Rate Ration
- Rearing: Load Rate Temperature
- Rearing: Pond O2 vs. Temperature
- TGP: Model 11
- TGP: Model 13

The SIRP Utilities drop-down menu includes the following sub-menu items:

- Introduction
- AvgWeeklyTempCal
- HeathTray
- Barometric Pressure
- Feed % Water
- OxygenSat
- Treatment Chemicals
- TreatCircular
- RacewayModel
- RacewaySimulation

Finally, the SIRP HELP menu has a *Read Me* sub-menu with a brief introduction and PDF versions of reports with additional detailed descriptions of data modelling, and an *About WinSIRP* sub-menu stating the current version, date, and contact information.

INCUBATION PROGRAMS

Description of incubation programs

The theory and model development for the incubation program modules is described in detail in McLean et al. (1991). Every module (for each of the 7 species) has similar mathematical relationships (see Appendix 1 for a listing of models and equation constants). Therefore, each module has the same required inputs. After entering species, fertilization date and other required input data at the Incubation Wizard the program calculates when the following events occur:-

Epiboly (i.e. yolk overgrowth) begins
Yolk plug closure is completed (yolk enclosed in cellular envelope)
Eyed fully pigmented, yolk sac ¾ vascularized, head free from yolk and mouth open, cerebral hemispheres forming
Hatch (50% of the eggs have hatched)
Maximum alevin wet weight achieved (MAWW), emergence from the gravel, or optimum ponding time for initial feeding.

MAWW (for *Oncorhynchus* species) is predicted from lab-generated data obtained from several sources (McLean et al. 1991). Atlantic salmon data were obtained from Jensen et al. (2004) and Jensen (unpublished data). It has been found that, although the time to MAWW is predicted fairly well, experimental trials at several hatcheries suggest that chinook fry incubated in Heath trays should be ponded slightly earlier than MAWW for optimum survival and that recently, Atlantic salmon fry, in the BC salmon farming industry, are routinely ponded much earlier than the predicted MAWW values. Also it has been observed that emergence of pink fry from gravel boxes is often later than predicted by the MAWW model (Appendix 3). For example, low temperatures in late winter delay migration. Therefore, fish culturists should conduct tests to determine a "correction factor" that relates to the predicted MAWW values calculated by WinSIRP to ensure optimum ponding times for best survival and growth.

In addition to development times, the Incubation model predicts environmental conditions every week over the incubation period. As eggs develop, oxygen consumption and ammonia production rates increase and water quality in the incubators deteriorates. The program predicts oxygen and ammonia concentrations and suggests safe levels (i.e. predicts critical dissolved oxygen levels "Pc", below which compensatory respiration occurs). It also warns of temperature extremes and predicts how sensitive the eggs are to mechanical shock (handling) at a given stage of development.

Incubation wizard

The Wizard asks for input data and also suggests typical (default) values. The user must specify: species, date of fertilization, number of eggs in the incubator, initial egg weight (mg), DO%, BP mmHg, pH, NH_3(mg/L), Flow (LPM) and Temperature (ºC). Easy to use drop-down menus are provided for species and fertilization date (Fig. 3).

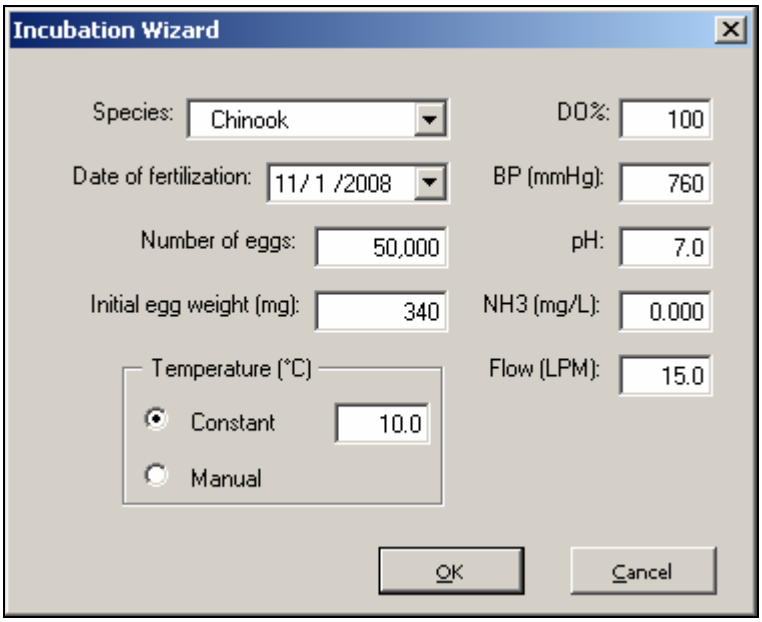


Figure 3. Incubation Wizard data input window.

DO% refers to the dissolved oxygen (as a percentage of saturation) of the water flowing to the incubator. With good aeration it is usually above 95%. Flow LPM is the water flow (in litres per minute) to an incubator or a series of incubators (see Heath Tray in Utilities for re-aeration calculation). The number of eggs refers to total number in the series i.e. enter 50,000 if there are 10 Heath trays at 5000 eggs per tray. For Heath tray incubation the program also needs the number of trays per stack. The initial egg weight is the egg weight (mg) before fertilization and water activation (often called green egg weight) – default values are suggested for each species.

BP is the barometric pressure in mmHg and is ideally measured with a barometer or saturometer (average value is 760 mmHg at sea level). Local current values* may sometimes be obtained from the Environment Canada website weatheroffice.com (*note that these values are corrected to sea level). Barometric pressure decreases with altitude – the relationship between BP and altitude is given in "Utilities"

The NH_3 (mg/L) is the measured ammonia value at the inflow of the incubator – in most water supplies it is usually 0 mg/L. The program will calculate the ammonia excreted by the eggs or alevins and add it to the inflow to predict the value at the outflow of the incubator. The pH value is used to calculate the toxic ammonia (i.e. un-ionized ammonia) in the outflow water and is measured at the outflow of the incubator.

Temperature input requires special consideration. If the incubation temperature is reasonably constant (e.g. well water, ± 2 ^{o}C) choose "constant" and enter the average value. Click OK to display the incubation output table. However if the temperature is variable (e.g. surface water) it has to be entered manually. To do this, click "Cancel" on the Wizard and go to the worksheet named "IncubationInput". The average weekly temperature can be entered manually or copied from another Excel spreadsheet (Note. A

worksheet has been added to WinSIRP in the Utilities Programs section that calculates weekly temperatures from daily temperatures). After this operation, re-enter the Wizard and click "variable" temperature. Click OK to see the output table.

The incubation programs are designed to generate predictions for typical conditions. Predictions will be reasonable only if the inputs are within the following limits (Table 1):

Table 1. Upper and lower limits for the Incubation Wizard data input window.

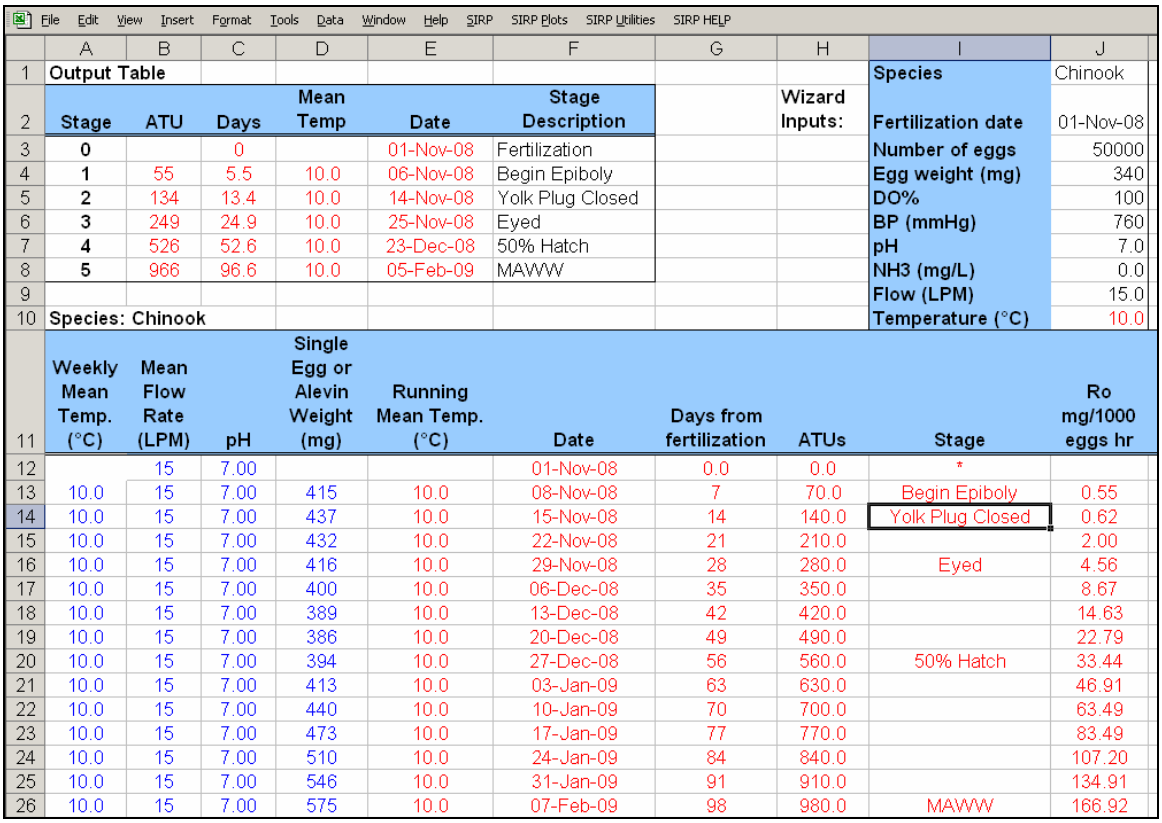
	Lower Limit (*)	*Upper Limit*
Number of eggs	1	10,000,000
Egg weight	- 30 % default	+30% default
Temperature	1	25
DO%	25	200
BP mmHg	650	850
PH	5	9
NH_3 (mg/L)	0	10
Flow (LPM)	0.1	Depends on incubator

(* entering 0 will cause error in most cases)

Incubation output

Program output is displayed in the worksheet named "IncubationOutput". Input values (blue cells) can be changed at any time and the spreadsheet will re-calculate automatically. Thus new scenarios can be generated without re-entering the Wizard. Predicted values are displayed in red cells and are locked.

The upper left part of the worksheet is shown in Fig. 4 (i.e. columns A to J) and includes the following information. The precise number of days and ATUs (accumulated temperature units or ˚C-days) to reach important developmental stages are summarized in the Output Table at the top of the worksheet, with the inputs displayed to the right. Weekly output is displayed near the bottom of the figure. ATUs at the end of each week are calculated; followed by developmental stages occurring within that week, as well as the oxygen consumption rate Ro (mg per 1000 eggs per hour).



	A	B	C	D	E	F	G	H	I	J
1	Output Table								Species	Chinook
2	Stage	ATU	Days	Mean Temp	Date	Stage Description		Wizard Inputs:	Fertilization date	01-Nov-08
3	0		0		01-Nov-08	Fertilization			Number of eggs	50000
4	1	55	5.5	10.0	06-Nov-08	Begin Epiboly			Egg weight (mg)	340
5	2	134	13.4	10.0	14-Nov-08	Yolk Plug Closed			DO%	100
6	3	249	24.9	10.0	25-Nov-08	Eyed			BP (mmHg)	760
7	4	526	52.6	10.0	23-Dec-08	50% Hatch			pH	7.0
8	5	966	96.6	10.0	05-Feb-09	MAWW			NH3 (mg/L)	0.0
9									Flow (LPM)	15.0
10	Species: Chinook								Temperature (°C)	10.0
11	Weekly Mean Temp. (°C)	Mean Flow Rate (LPM)	pH	Single Egg or Alevin Weight (mg)	Running Mean Temp. (°C)	Date	Days from fertilization	ATUs	Stage	Ro mg/1000 eggs hr
12		15	7.00			01-Nov-08	0.0	0.0	*	
13	10.0	15	7.00	415	10.0	08-Nov-08	7	70.0	Begin Epiboly	0.55
14	10.0	15	7.00	437	10.0	15-Nov-08	14	140.0	Yolk Plug Closed	0.62
15	10.0	15	7.00	432	10.0	22-Nov-08	21	210.0		2.00
16	10.0	15	7.00	416	10.0	29-Nov-08	28	280.0	Eyed	4.56
17	10.0	15	7.00	400	10.0	06-Dec-08	35	350.0		8.67
18	10.0	15	7.00	389	10.0	13-Dec-08	42	420.0		14.63
19	10.0	15	7.00	386	10.0	20-Dec-08	49	490.0		22.79
20	10.0	15	7.00	394	10.0	27-Dec-08	56	560.0	50% Hatch	33.44
21	10.0	15	7.00	413	10.0	03-Jan-09	63	630.0		46.91
22	10.0	15	7.00	440	10.0	10-Jan-09	70	700.0		63.49
23	10.0	15	7.00	473	10.0	17-Jan-09	77	770.0		83.49
24	10.0	15	7.00	510	10.0	24-Jan-09	84	840.0		107.20
25	10.0	15	7.00	546	10.0	31-Jan-09	91	910.0		134.91
26	10.0	15	7.00	575	10.0	07-Feb-09	98	980.0	MAWW	166.92

Figure 4. This figure shows the upper left-hand side of the incubation ouput worksheet.

The column “Single Egg or Alevin Weight” is a “rough” calculation of total egg or alevin biomass based on changes in chinook egg and alevin weight reported by Mclean and Lim (1985). Actual measured weights can be inserted to obtain more precise estimates of ammonia excretion (which is calculated based on biomass; see description below and in Appendix 5).

The rest of the weekly table (Fig. 5, showing columns K to R) calculates the critical oxygen level Pc and the dissolved oxygen concentration (DO) at the inflow and outflow of the incubator. The critical level (Pc) is the minimum environmental oxygen concentration that can be tolerated by the eggs or alevins -- values below Pc cause a drop in their respiration rate (Ro). DO concentrations below Pc are too low for incubation.

The DO at the outflow of the incubator (DO OUT) is the minimum value encountered by the eggs and should always be greater than Pc. This predicted value assumes that there is no re-aeration within the incubator. In Heath incubators water picks up oxygen as it falls from tray to tray and so is greater than DO Out. To calculate the effect of Heath stack re-aeration see “Utilities: Heath Tray”.

Ammonia excretion rates are predicted in units of µg of ammonia nitrogen per gram of biomass per hour. The ammonia concentration at the outflow is the sum of excreted ammonia and the background concentration of the water supply. Ammonia dissolves in water to form ionized (NH_4+) and un-ionized (NH_3) ammonia. Un-ionized ammonia is

calculated from the total ammonia, temperature and pH and is expressed in units of µg/L (micrograms per liter). The un-ionized form is toxic above 10 µg/L.

The last 2 columns (Q & R) give warnings about mechanical shock sensitivity and temperature effects, respectively. Sensitivity to shock is covered in much more detail in a separate worksheet known as the "Mechanical Shock Table".

K	L	M	N	O	P	Q	R
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)	Mechincal Shock Warning	Temperature Warning
2.00	11.26	11.23	0.25	0.01	0.01	Extremely Sensitive 'LC50<10cm'	mortality<=20%
2.42	11.26	11.22	0.27	0.01	0.01	Extremely Sensitive 'LC50<10cm'	mortality<=20%
3.59	11.26	11.14	0.49	0.01	0.02	Shock Resistant 'LC50>115cm	mortality<=20%
4.76	11.26	11.00	0.78	0.02	0.03	Shock Resistant 'LC50>115cm	mortality<=20%
5.92	11.26	10.77	1.14	0.03	0.05	Shock Resistant 'LC50>115cm	mortality<=20%
7.07	11.26	10.44	1.56	0.03	0.06	Shock Resistant 'LC50>115cm	mortality<=20%
8.22	11.26	9.99	2.05	0.04	0.08	Shock Resistant 'LC50>115cm	mortality<=20%
4.40	11.26	9.40	2.59	0.06	0.11		
4.40	11.26	8.65	3.19	0.07	0.14		
4.40	11.26	7.73	3.84	0.09	0.17		
4.40	11.26	6.62	4.54	0.12	0.22		
4.40	11.26	5.30	5.29	0.15	0.28		
4.40	11.26	3.76	6.08	0.18	0.34		
4.40	11.26	1.98	6.91	0.22	0.41		

Figure 5. This figure shows the right-hand side of the incubation output worksheet.

Mechanical shock table

For a given species the sensitivity of eggs to mechanical shock varies with stage of development (and hence ATUs). The "Mechanical Shock Table" predicts the magnitude of shock that will kill 50 % of the eggs (LD50) at different ATUs (Fig. 6 shows LD50's for 7 species combined in one figure; in WinSIRP, each species has a separate figure showing changes in egg sensitivity). The models for predicting changes in egg sensitivity are listed in Appendix 5. Shock sensitivity was determined by probit analyses of egg mortality after dropping the eggs from several heights onto a solid surface for sudden standardized impacts (Jensen and Alderdice, 1983, 1986; Sweeten et al., 2004). The LD50s are calculated for ATUs corresponding to specific times of interest, focussing on early developmental intervals, when rapid changes in sensitivity take place, and then on a daily-basis until eggs become resistant to shock. The default temperature is set at 10 °C, but can be changed to match specific incubation conditions; this changes the ATU values accordingly.

The velocity at the moment of impact has also been quantified for 10% egg mortality and is reported as LD10 velocities (cm/s) (Jensen, 2003; Sweeten et al., 2004). Drop height (h, cm) is related to velocity (v, cm/s) by the formula: $h = v^2/1960$. For example, an egg dropped from a height of 30 cm (1 ft) has a velocity on impact of 243 cm/sec.

The times to minimum LD50s and LD10 velocities (i.e. the most sensitive time) are reported in ATUs for all 7 species, for convenience. These values are not identical for all species, since the response slopes (i.e. log-probit plots) for determining LD50s and LD10s are different for each species. Also, the statistical power for LD50 (50 % population response) is much greater than LD10 (10 % population response).

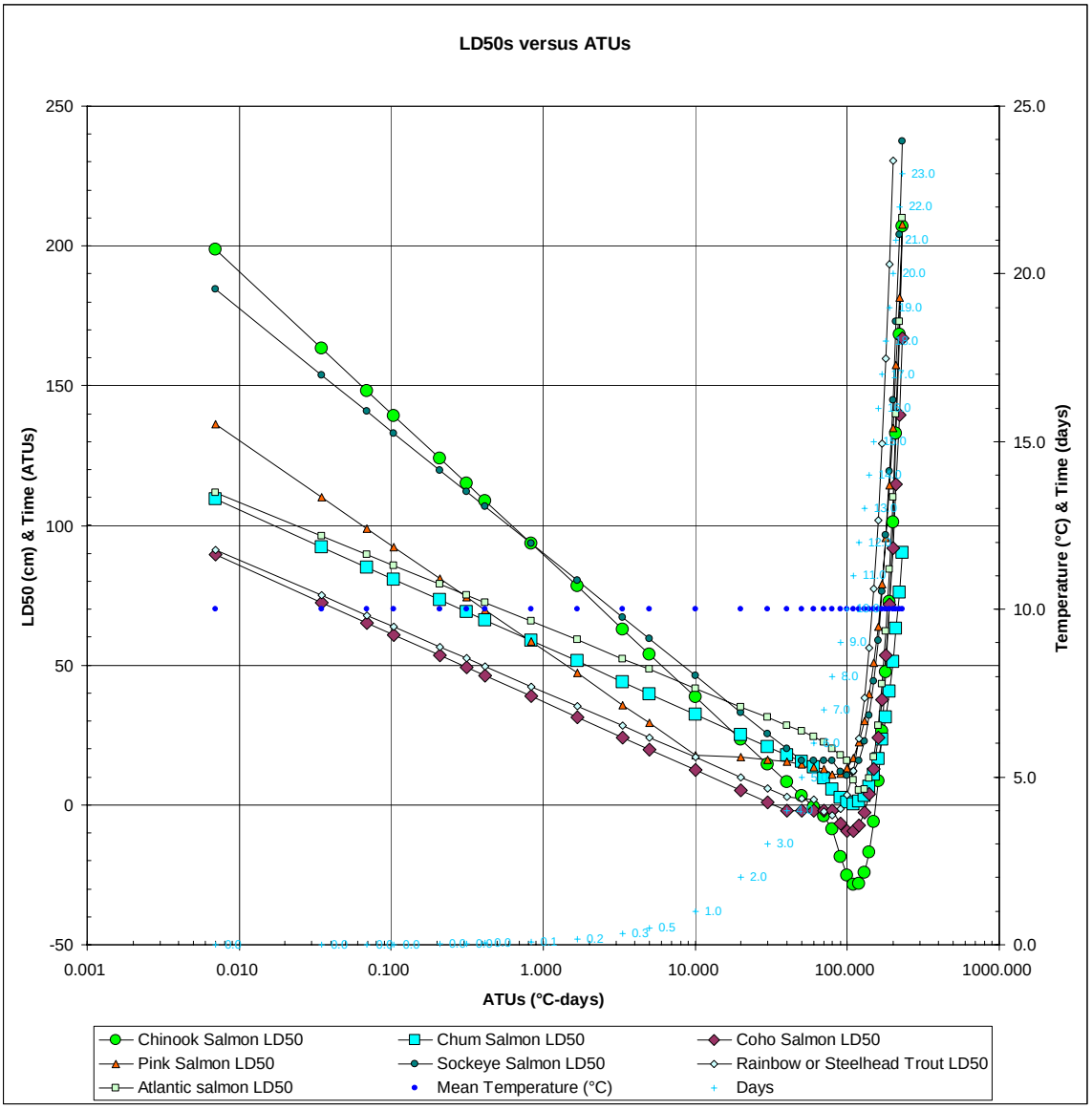


Figure 6. Changes in egg sensitivity to mechanical shock is illustrated by plotting LD50's (drop height causing 50% mortality, cm) for all 7 species included in WinSIRP against development time (ATUs, °C-days). For this scenario, the incubation temperature was 10 ºC.

Incubation program examples

Example 1: A stack of 8 Heath trays is loaded at 6000 chinook eggs per tray (N = 48,000), the water flow is 15 LPM and the temperature of the well water is a constant 10 °C. The hatchery has an elevation of 100 m so the average BP = 750 mmHg (see Utilities). DO measurements of the incubation inflow show that it is only 90 % of saturation. If eggs are fertilized on November 1, when do the eyed, hatch and MAWW (maximum alevin wet weight) stages occur? Is the oxygen supply adequate? To get a projection, enter these parameters in the Incubation Wizard. Default values are assumed for initial egg weight, pH and ammonia.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**Output Table**								**Species**	Chinook						
2	**Stage**	**ATU**	**Days**	**Mean Temp**	**Date**	**Stage Description**		**Wizard Inputs:**	**Fertilization date**	01-Nov-08						
3	**0**		0		01-Nov-08	Fertilization			**Number of eggs**	48000						
4	**1**	55	5.5	10.0	06-Nov-08	Begin Epiboly			**Egg weight (mg)**	340						
5	**2**	134	13.4	10.0	14-Nov-08	Yolk Plug Closed			**DO%**	90						
6	**3**	249	24.9	10.0	25-Nov-08	Eyed			**BP (mmHg)**	750						
7	**4**	526	52.6	10.0	23-Dec-08	50% Hatch			**pH**	7.0						
8	**5**	966	96.6	10.0	05-Feb-09	MAWW			**NH3 (mg/L)**	0.0						
9									**Flow (LPM)**	15.0						
10	**Species: Chinook**								**Temperature (°C)**	10.0						
11	**Weekly Mean Temp. (°C)**	**Mean Flow Rate (LPM)**	**pH**	**Single Egg or Alevin Weight (mg)**	**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)**
12		15	7.00			01-Nov-08	0.0	0.0								
13	10.0	15	7.00	415	10.0	08-Nov-08	7	70.0	Begin Epiboly	0.55	2.00	9.99	9.97	0.25	0.01	0.01
14	10.0	15	7.00	437	10.0	15-Nov-08	14	140.0	Yolk Plug Closed	0.62	2.42	9.99	9.96	0.27	0.01	0.01
15	10.0	15	7.00	432	10.0	22-Nov-08	21	210.0		2.00	3.59	9.99	9.89	0.49	0.01	0.02
16	10.0	15	7.00	416	10.0	29-Nov-08	28	280.0	Eyed	4.56	4.76	9.99	9.75	0.78	0.02	0.03
17	10.0	15	7.00	400	10.0	06-Dec-08	35	350.0		8.67	5.92	9.99	9.53	1.14	0.02	0.04
18	10.0	15	7.00	389	10.0	13-Dec-08	42	420.0		14.63	7.07	9.99	9.21	1.56	0.03	0.06
19	10.0	15	7.00	386	10.0	20-Dec-08	49	490.0		22.79	8.22	9.99	8.78	2.05	0.04	0.08
20	10.0	15	7.00	394	10.0	27-Dec-08	56	560.0	50% Hatch	33.44	4.40	9.99	8.21	2.59	0.05	0.10
21	10.0	15	7.00	413	10.0	03-Jan-09	63	630.0		46.91	4.40	9.99	7.49	3.19	0.07	0.13
22	10.0	15	7.00	440	10.0	10-Jan-09	70	700.0		63.49	4.40	9.99	6.61	3.84	0.09	0.17
23	10.0	15	7.00	473	10.0	17-Jan-09	77	770.0		83.49	4.40	9.99	5.54	4.54	0.11	0.21
24	10.0	15	7.00	510	10.0	24-Jan-09	84	840.0		107.20	4.40	9.99	4.28	5.29	0.14	0.27
25	10.0	15	7.00	546	10.0	31-Jan-09	91	910.0		134.91	4.40	9.99	2.80	6.08	0.18	0.33
26	10.0	15	7.00	575	10.0	07-Feb-09	98	980.0	MAWW	166.92	4.40	9.99	1.09	6.91	0.21	0.39

Figure 7. Incubation output table illustrating extremely low DO *OUT* levels at >910 ATUs.

The above output Table (Fig. 7) predicts that the eyed, hatch and MAWW stages occur on: Nov 25 (ATU = 249), Dec 23 (ATU = 526) and Feb 5 (ATU = 966 C days), respectively. DO at the outflow of the incubator drops to 2.80 mg/L at about 910 ATUs. However WinSIRP predictions are for a closed system. As a general rule re-aeration in Heath stacks (8 vertical trays) increases the outflow DO by 1.5 to 2.0 mg/L when the metabolic demand is high and the inflow DO is near saturation. The "Heathtray" worksheet in Utilities calculates the outflow DO with re-aeration. To use this program copy: Ro = 134.91 (cell J25), DOIN = 9.99 (L25), DO out = 2.80 (M25), DO% = 90% (J5) and the number of trays per stack, n = 8 into the program. The calculated outflow DO with re-aeration is 4.58 mg/L. Even with re-aeration the DO is near the critical level (Pc) so alevins would be affected as incubation progresses. This condition could be alleviated by: decreasing the number of trays in the stack, reducing the total number of eggs at the eyed stage, increasing water flow (upper limit for a Heath stack is about 18 LPM) or by increasing the inflow DO. The user can test different scenarios by entering new values in the "Incubation Wizard" and re-running the program. For faster changes of weekly temperature, flow, pH, and egg or alevin weight (blue cells in the first 4 columns) the user can insert new values and the spreadsheet will automatically recalculate all predictions directly on the "Incubation-Output" screen. For instance, increasing flow at 910 ATU from 15 to 18 L/min increases DO by almost 1.0 mg/L.

Example 2. A bulk incubator (no re-aeration) is loaded with 500,000 chinook eggs and the flow is 50 = LPM. The temperature varies according to the following Table (Fig. 8):

Week	Temperature	
0	17.3	*Week 0 & 1 must be the same value*
1	17.3	
2	16.2	
3	13.4	
4	11.4	
5	10.0	
6	9.4	
7	8.7	
8	7.5	
9	8.0	
10	9.0	
11	9.0	
12	10.0	
13	10.0	
14	10.0	
15	10.0	
16		

Figure 8. Temperature input table for manual, weekly varying mean temperatures showing the first 15 weeks.

At the eyed stage the eggs will be moved to Heath trays at 6500 per tray and incubated to ponding (MAWW). If eggs are fertilized on Nov 1, when is the eyed stage reached so that the eggs can be moved? The pH of the water supply is very high and stable at 8.0 and the inflow ammonia concentration is 0.4 mg/L. What are the ammonia concentrations in the bulk incubator and in a Heath stack (8 trays per stack, N = 52,000) with a flow of 15 LPM? Assume BP = 750 mmHg, DO% = 95 and the initial egg weight is 340 mg.

Before entering the Incubation Wizard, go to the worksheet titled “IncubationInput” and enter the temperature for each week (or copy and paste from another spreadsheet). Then go to the Wizard and enter the other parameters for the bulk incubator (eggs = 500,000, flow = 50 LPM etc,). Make sure that “temperature” in the Input Wizard is set to “manual”.

The Output Table (Fig. 9) shows that eggs reach the eyed stage on Nov 14 at 211 ATUs. The un-ionized ammonia concentration at the outflow of the bulk incubator one week after the eyed stage (i.e. 28 days or 408.1 ATUs post-fertilization) is 10.23 ug/L and the DO is 7.66 mg/L. These values are acceptable at the eyed stage – however conditions become detrimental as the eggs approach hatch (i.e. DoOut is less than Pc on Dec 27).

Also a temperature warning appears in Column R because of the high temperatures during the first 2 weeks of incubation.

		Species	Chinook						
	Wizard Inputs:	**Fertilization date**	01-Nov-08						
		Number of eggs	500000						
		Egg weight (mg)	340						
		DO%	95						
		BP (mmHg)	750						
		pH	8.0						
		NH3 (mg/L)	0.4						
		Flow (LPM)	50.0						
		Temperature (°C)	Manual Temperature Input						

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)
0.0	0.0	*							
7	121.1	Begin Epiboly	0.91	2.00	8.97	8.81	0.32	0.42	13.31
14	234.5	Yolk Plug Closed	4.37	6.78	9.18	8.45	0.76	0.45	13.18
21	328.3	Eyed	9.57	7.22	9.75	8.16	1.21	0.48	11.36
28	408.1		15.29	7.58	10.21	7.66	1.60	0.50	10.23
35	478.1		21.23	8.02	10.55	7.01	1.96	0.53	9.59
42	543.9	50% Hatch	28.97	4.40	10.70	5.87	2.37	0.55	9.66
49	604.8		36.46	4.40	10.89	4.81	2.73	0.58	9.63
56	657.3		40.12	4.40	11.21	4.52	2.90	0.60	9.07
63	713.3		54.01	4.40	11.07	2.07	3.48	0.66	10.28
70	776.3		77.19	4.40	10.81	0.00	4.33	0.74	12.55
77	839.3		96.58	4.40	10.81	0.00	4.96	0.82	13.87
84	909.3		134.61	4.40	10.55	0.00	6.07	0.95	17.36
91	979.3	MAWW	166.58	4.40	10.55	0.00	6.90	1.06	19.35

Figure 9. Part of the Incubation output worksheet for example 2.

After moving the eggs to Heath trays, conditions are acceptable until the last two weeks of incubation -- ammonia is over 10 µg/L and DO drops below the critical level of 4.4 mg/L (Fig. 10). The combination of high ammonia and low DO increases alevin mortality, delays development and reduces the conversion of yolk to tissue (i.e. decreases fry size) (Jensen 1981).

	G	H	I	J	K	L	M	N	O	P	Q	R
1			Species	Chinook								
2		Wizard Inputs:	Fertilization date	01-Nov-08								
3			Number of eggs	52000								
4			Egg weight (mg)	340								
5			DO%	95								
6			BP (mmHg)	750								
7			pH	8.0								
8			NH3 (mg/L)	0.4								
9			Flow (LPM)	15.0								
10			Temperature (°C)	Manual Temperature Input								
11	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)	Mechincal Shock Warning	Temperature Warning
12	0.0	0.0	*									
13	7	121.1	Begin Epiboly	0.91	2.00	8.97	8.91	0.32	0.41	12.83	Extremely Sensitive 'LC50<10cm'	mortality>50%
14	14	234.5	Yolk Plug Closed	4.37	6.78	9.18	8.92	0.76	0.42	12.15	Shock Resistant 'LC50>115cm	30%<mortality<=50%
15	21	328.3	Eyed	9.57	7.22	9.75	9.20	1.21	0.43	10.11	Shock Resistant 'LC50>115cm	mortality<=20%
16	28	408.1		15.29	7.58	10.21	9.33	1.60	0.44	8.85	Shock Resistant 'LC50>115cm	mortality<=20%
17	35	478.1		21.23	8.02	10.55	9.32	1.96	0.44	8.09	Shock Resistant 'LC50>115cm	mortality<=20%
18	42	543.9	50% Hatch	28.97	4.40	10.70	9.03	2.37	0.45	7.90		
19	49	604.8		36.46	4.40	10.89	8.78	2.73	0.46	7.65		
20	56	657.3		40.12	4.40	11.21	8.89	2.90	0.47	7.07		
21	63	713.3		54.01	4.40	11.07	7.95	3.48	0.49	7.64		
22	70	776.3		77.19	4.40	10.81	6.35	4.33	0.52	8.76		
23	77	839.3		96.58	4.40	10.81	5.23	4.96	0.55	9.22		
24	84	909.3		134.61	4.40	10.55	2.77	6.07	0.59	10.78		
25	91	979.3	MAWW	166.58	4.40	10.55	0.93	6.90	0.63	11.48		

Figure 10. This figure shows DO conditions have improved until the last 3 weeks of development, where DO OUT falls below critical oxygen (Pc; mg/L) value of 4.40.

The low DO OUT conditions can be alleviated by increasing the flow or DO%, as in example 1. Several iterations, with new inputs can quickly be tried until conditions become acceptable.

Graphing incubation data

It is usually helpful to graph your data. "SIRP Plot" in the menu bar has ready-made graphs for ammonia and oxygen. "Incubation: Oxygen Plot" for Example 1 is shown in Figure 11. Custom graphs can be built by highlighting columns and using the Excel graphics function. Also Columns can be copied to other spreadsheets and incorporated into graphs. Figure 12 shows a custom plot of ammonia production vs oxygen consumption rates from Example 2. Values from columns J and M were copied and pasted to another worksheet and then graphed. To paste data to a new workbook use the "special paste" function and choose the "Microsoft Excel Format".

Figure 11 shows the rapid increase in oxygen consumption with development (days from fertilization). The outflow oxygen concentration is for a closed incubator (no re-aeration) and so is an underestimate for a stack of Heath Trays. At hatch, the critical oxygen concentration (Pc) drops dramatically. In this example the oxygen levels drop below Pc in the later stages of incubation and so alevins are jeopardized.

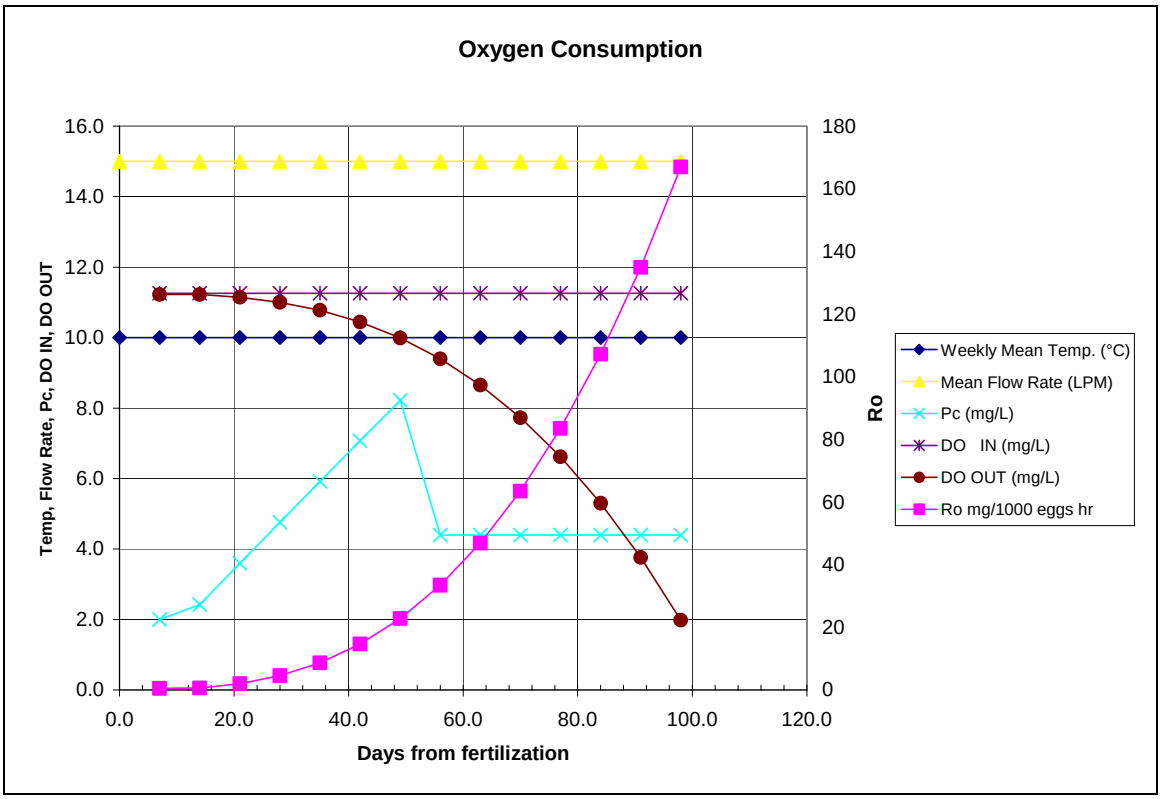


Figure 11. Oxygen plot from example 1. Included in the figure are weekly mean temperatures, flow rate, Pc, DO in, DO out, and Ro.

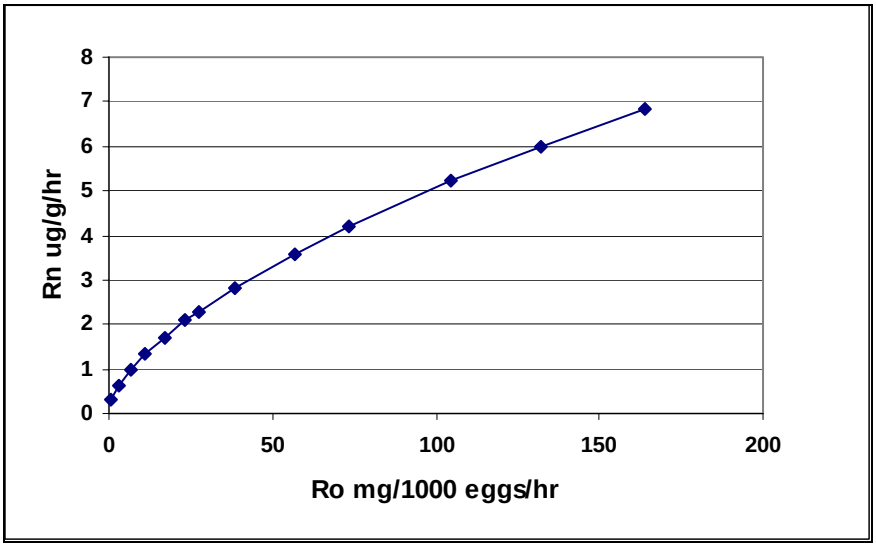


Figure 12. Custom plot of ammonia production vs oxygen consumption rates in example 2.

REARING PROGRAMS

Description of Rearing Programs

Theory and model development for the rearing programs, Pond O2 and Load Rate, are described in McLean et al. (1991). "Pond O2" predicts the outflow DO for a pond with a specified load (biomass) of fish while "Load Rate" predicts the maximum allowable load for maintenance of acceptable oxygen levels at the pond outflow. Both programs are based on a predictive model for the oxygen consumption rate (Ro). This model was derived for juvenile fish actively feeding and growing in a large scale fish culture environment.

Juvenile fish in hatcheries and streams are vulnerable to excessive total gas pressure (TGP) or gas supersaturation. Models 11 and 13 predict the impact of TGP on fish under different rearing conditions by calculating ET50 or the estimated time to 50 % mortality. Models were developed from a set of data that has an upper ET50 limit of 50 days (Jensen et al. 1986) – values beyond this limit are calculated by extrapolation. An ET50 of 500 days is considered "safe" i.e. there is no chance of even the most sensitive members of a population developing gas bubble trauma.

Rearing programs are accessed from the WinSIRP drop-down menu. They appear as typical Excel worksheets with each row being a separate rearing scenario. As with the incubation program, blue cells can be changed by the user (inputs) and red cells are calculated values (output). The workbooks have been set for automatic recalculation.

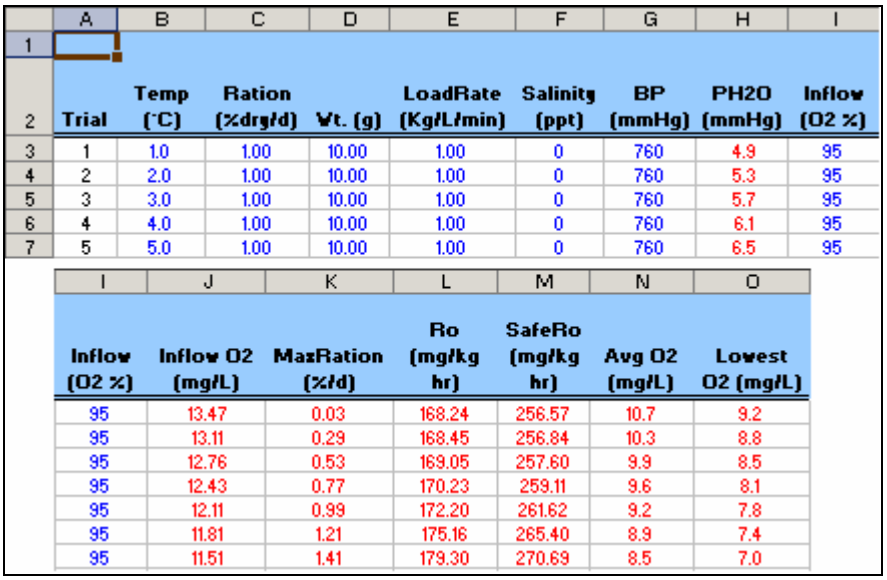
Pond O2

This module requires the following information: average daily temperature (ºC), ration level, mean fish weight (g), load rate (kg fish per LPM), BP or barometric pressure mmHg, and inflow DO%. Some of these inputs require further explanation.

Ration level is expressed in units of % dry food per day i.e. grams of dry food per 100 grams of fish per day. If the food has a moisture content of 30 % (so dry material = 70%) and 5 g is presented to 100 g of fish per day then the dry ration level (% dry/day) is 3.5 (0.7*5g). This is a critical parameter because the oxygen consumption rate is dependent on ration level -- fish consume oxygen when they capture and process food. As ration increases, Ro increases and outflow DO drops. It should be cautioned that the program will continue to generate values even if ration is above satiation -- this will lead to an overestimate of Ro. To guard against this, column K shows a suggested maximum ration or satiation level. This model was derived by Stauffer (1973) and is a function of water temperature and fish size. It is recommended that ration level should not exceed the maximum ration presented in column K (see Utilities).

Load Rate is the ratio of the biomass of fish (kg) to water flow in litres per minute (LPM) or kg per LPM. Barometric Pressure affects the solubility of gases in solution and hence affects the initial oxygen concentration; the default for this column is 760 mmHg (Utilities: Barometric Pressure). Inflow DO (% saturation) has a default of 95% -- most

hatcheries meet or exceed this level during rearing operations. The program will convert DO% to mg/L (column J) when calculations are performed (Fig. 13).



	A	B	C	D	E	F	G	H	I
1									
2	Trial	Temp (°C)	Ration (%drg/d)	Wt. (g)	LoadRate (Kg/L/min)	Salinity (ppt)	BP (mmHg)	PH2O (mmHg)	Inflow (O2 %)
3	1	1.0	1.00	10.00	1.00	0	760	4.9	95
4	2	2.0	1.00	10.00	1.00	0	760	5.3	95
5	3	3.0	1.00	10.00	1.00	0	760	5.7	95
6	4	4.0	1.00	10.00	1.00	0	760	6.1	95
7	5	5.0	1.00	10.00	1.00	0	760	6.5	95

I	J	K	L	M	N	O
Inflow (O2 %)	Inflow O2 (mg/L)	MaxRation (%/d)	Ro (mg/kg hr)	SafeRo (mg/kg hr)	Avg O2 (mg/L)	Lowest O2 (mg/L)
95	13.47	0.03	168.24	256.57	10.7	9.2
95	13.11	0.29	168.45	256.84	10.3	8.8
95	12.76	0.53	169.05	257.60	9.9	8.5
95	12.43	0.77	170.23	259.11	9.6	8.1
95	12.11	0.99	172.20	261.62	9.2	7.8
95	11.81	1.21	175.16	265.40	8.9	7.4
95	11.51	1.41	179.30	270.69	8.5	7.0

Figure 13. Pond O2 example, showing inputs (in blue) and calculated outputs (in red).

Inputs for Pond O2 should be within the following limits shown in Table 2:

Table 2. Pond O2 lower and upper data input limits.

	Lower Limit	Upper Limit
Temperature (oC)	5	19
Ration (%dry/day)	0	Maximum Ration
Weight (g)	0.5	50
BP (mmHg)	600	800
Inflow DO %	50	200
Load Rate (kg per LPM)	0	4

Pond O2 predicts the average daily oxygen consumption rate Ro (mg of oxygen consumed per kg of fish per hour) in column L. This value determines the average daily DO concentration (mg/L) at the pond outflow (column N). In large scale fish culture Ro varies during a 24 hour period, so the outflow DO is actually less than column N for many hours per day. To take this variation into account, a safe Ro or maximum daily Ro is calculated (column M). This gives the daily minimum DO level experienced by the fish (column O). It should be emphasized that "SafeRo" and "Lowest O2" are statistical in nature i.e. they are accurate most of the time (84%). Ro varies so much in production facilities (eg. during pond disturbances) that these values will be exceeded some of the time. The program also predicts the maximum ration (discussed above) and the water vapour pressure mmHg. This is used in the calculation of the inflow DO in mg/L (column J).

In Federal Rearing operations in B.C. the minimum allowable DO at the pond outflow is based on criteria developed by Davis (1975), typically above 6 mg/L. Minimum concentrations for different temperatures and degrees of protection are presented in Utilities.

Load Rate

Load Rate is based on the same Ro models as Pond O2 and has the same limitations. The only new input is the dissolved oxygen concentration at the pond outflow. The program calculates the maximum load rate (kg of fish per LPM) to satisfy this specified DO level.

Examples using Pond O2 and Load Rate

Example 3. Predict the outflow DO for a pond containing 100,000 1 gram fish (biomass = 100 kg). The flow rate is 200 LPM and 2.22 kg of food (10 % moisture, 90% dry) is fed per day. Assume the following inputs: inflow DO = 95 % saturated, average daily water temperature = 12 °C, and BP = 760 mmHg (sea level).

Choose "Rearing: Pond O2" in the main menu and enter the temperature and fish weight (1 g). Calculate daily ration as the percentage dry food to biomass and enter this value in column C – in this example the dry food per day is 0.9*2.22 kg/d = 2.0 kg/d and so the ration is: 2.0 kg/d/100 kg * 100% = 2.0 %/day. The Load Rate is: 100 kg/200 LPM = 0.5 kg per LPM. Note that BP and Inflow (760 mmHg and 95%) are the same as the default values and so do not have to be re-entered.

The program predicts that the average daily outflow DO is 7.5 mg/L and that the minimum DO during a day is 6.4 mg/L. To see how an increase in fish weight from 1 to 2 g affects DO, copy and paste the input values (blue cells) from Trial 1 to Trial 2 and change the fish weight in Trial 2 to 2 grams. If the pond flow and the number of fish are unchanged the load rate in Trial 2 is 200 kg/200 LPM = 1 kg per LPM. With the Ration the same as in Trial 1 (2 %/d), the average daily DO and minimum daily DO are 4.9 and 2.6 mg/L respectively. This is below the 6 mg/L criteria and requires corrective action, for example; a reduction in the number of fish, an increase in flow, an increase in inflow DO or a decrease in Ration. These scenarios can be tested by running new trials.

Example 4. For the 2 gram fish in example 1, find the load rate that gives a daily minimum DO of 6 mg/L (inputs are the same as above).

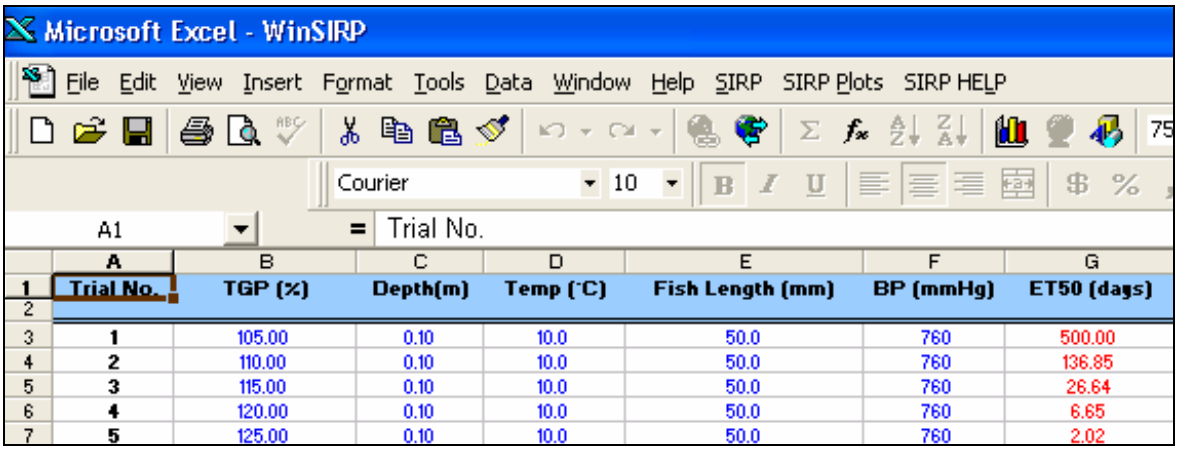
In the "Rearing: Load Rate" program input temperature, ration, fish weight and a minimum outflow DO of 6.0 mg/L. The program calculates a maximum allowable load rate of 0.556 kg per LPM. This could be achieved by increasing the flow to 360 LPM (200 kg/0.556 kg per LPM = 360 LPM). Alternatively, if additional flow was not available, the number of fish could be reduced to 55,600 (2 g/fish*55600 fish/(1000 g/kg*200 LPM) = 0.556 kg per LPM)

Pond DO levels could also be kept at 6.0 mg/L by oxygen supplementation of the inflow. Using the "Rearing Pond O2" program with the load rate at 1.0 kg per LPM, the inflow

O2 % (blue cell) is increased by trial and error until the minimum DO reaches 6.0 mg/L -- this occurs when the inflow is 126 % of saturation (13.55 mg/L).

Model 11 (gas supersaturation)

Model 11 predicts ET50 (exposure time to 50% mortality) for juvenile salmonids exposed to excess total gas pressure (TGP) or gas supersaturation (Fig. 14). In addition to the effect of TGP, this model also includes water depth, temperature, fish length and barometric pressure as ancillary factors. The model requires the user to input TGP (%), water depth (meters), average daily water temperature (oC), fish length (mm) and BP barometric pressure (mmHg). TGP (%) is usually calculated from: TGP (%) = (BP + Delta P)/BP * 100%, where Delta P is the excess gas pressure (mmHg) measured with a tensionometer.



	A	B	C	D	E	F	G
1	Trial No.	TGP (%)	Depth(m)	Temp (°C)	Fish Length (mm)	BP (mmHg)	ET50 (days)
2							
3	1	105.00	0.10	10.0	50.0	760	500.00
4	2	110.00	0.10	10.0	50.0	760	136.85
5	3	115.00	0.10	10.0	50.0	760	26.64
6	4	120.00	0.10	10.0	50.0	760	6.65
7	5	125.00	0.10	10.0	50.0	760	2.02

Figure 14. Model 11 gas supersaturation example.

The water depth available to the fish is a critical factor because it reduces the impact of TGP (longer ET50s). If water has a Delta P of 74 mmHg and a fish swims from the surface to a 1 meter depth, the gas supersaturation experienced by the fish drops from 74 to 0 mmHg. Even if the fish only spends a portion of the day at this depth there is a sparing effect. Lower temperature and increased BP have a slight sparing effect on the mortality response to TGP whereas large fish die more quickly than small fish.

Model 11 predicts ET50 values up to 500 days however inputs must be within the limits shown in Table 3.

Table 3. Input data limits for TGP Model 11.

	Lower Limit	Upper Limit
TGP (%)	100	140
Depth (m)	0.01	3
Temperature (ºC)	2	20
Fish Length (mm)	10	250
BP (mmHg)	600	780

The program will accept and calculate ET50 at any water depth greater than zero. However the depth column numbers are rounded to the nearest 0.1 m. Therefore if the

user enters a water depth of 0.01 m, it will show as 0.0 m and the program will calculate based on a depth of 0.01 m.

Model 13 (gas supersaturation)

Model 13 predicts ET50 in response to excess gas pressure (Delta P as measured on a tensionometer) and dissolved oxygen. The model requires the user to input DO (mg/L) temperature (ºC), Delta P (mmHg), BP (mmHg) and salinity (ppt) if the fish are in seawater. The program calculates TGP (%), O2 (%), N2(%) and ET50 (days). Inputs should be within the limits shown in Table 4:

Table 4. Input data limits for TGP Model 13.

	Lower Limit	Upper Limit
DO (mg/L)	4	28
Temperature (ºC)	2	20
Delta P (mmHg)	76	300
BP (mmHg)	600	780
Salinity (ppt)	0	35

Examples using Gas Supersaturation Programs

Example 5. Construct a graph showing the effect of water depth on ET50 if TGP (%) = 120%, fish length = 5 cm, temperature = 8 °C and BP = 760 mmHg.

Click on "TGP model 11" in the WinSIRP menu and enter TGP = 120%, Depth = 0 m, temperature = 8 ºC, length = 50 mm and BP = 760 mmHg in row 1 (blue cells). WinSirp automatically calculates ET50 (red cell). Copy and paste these input variables in the blue cells from trial 1 to 10. ET50 is protected and cannot be copied. To see the effect of water depth, enter a range of values from 0 m at trial 1 to 2.28 m at trial 10 in steps of 0.2533. The program calculates ET50s ranging from 7.33 days at 0 m to 500 days (safe) at 2.28 m.

To graph the relationship between depth and ET50, the sheet must be unprotected (from tools menu). Depth and ET50 columns can then be graphed in the current worksheet. They can also be copied to a separate workbook and graphed. To "special paste" ET50 values to a new worksheet choose as "Excel data" when prompted for the type of data. The graph shown below (Fig. 15) was constructed from data copied to a separate workbook.

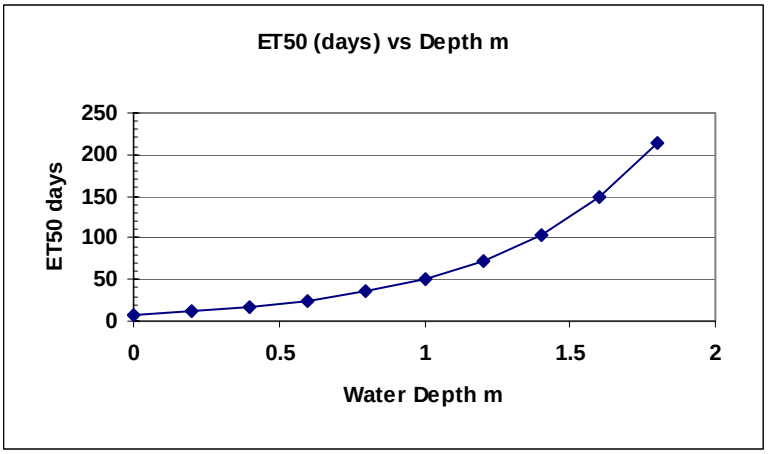


Figure 15. This figure illustrates the sparing effect of depth-compensation (i.e. 50 days to 50% mortality at 1 meter compared to greater than 200 days to 50% mortality at 1.75 meters).

Example 6. TGP is more harmful to fish if it is caused by N2 as opposed to O2 gas. Illustrate this by constructing a graph relating ET50 and N2 (%) when the total excess pressure (Delta P) is 95 mmHg. Assume that the water supply consists of natural fresh water open to the atmosphere and that BP = 760 mmHg and temperature = 10 ºC.

Click on "TGP model 13" in the WinSIRP menu and enter Delta P = 95 mmHg in column D plus appropriate values for BP, temperature and salinity. Copy these values down the worksheet to row 10. Note that each scenario now has the same TGP. To see the effect of different O2 and N2 levels, enter O2 values ranging from 11.26 mg/L in trial 1, to 20 mg/L in trial 10 in steps of .971

As O2 increases from 11.26 to 20 mg/L (100 to 177.6%) the N2 level decreases from 116.1 % to 95.5 %. This happens because the TGP is the same in each row -- as O2 increases N2 must decrease. With the high nitrogen level in row 1, the ET50 is only 17.4 days but by row 10 ET50 increases to 55.8 days. This shows that in fish culture a tensionometer reading by itself is not an adequate check of gas supersaturation.

To construct a graph, highlight N2 (%) and ET50 columns (I and J) and copy them to a separate worksheet; use special paste as in example 1. The graph below (Fig. 16) was constructed using the "XY scatter" option.

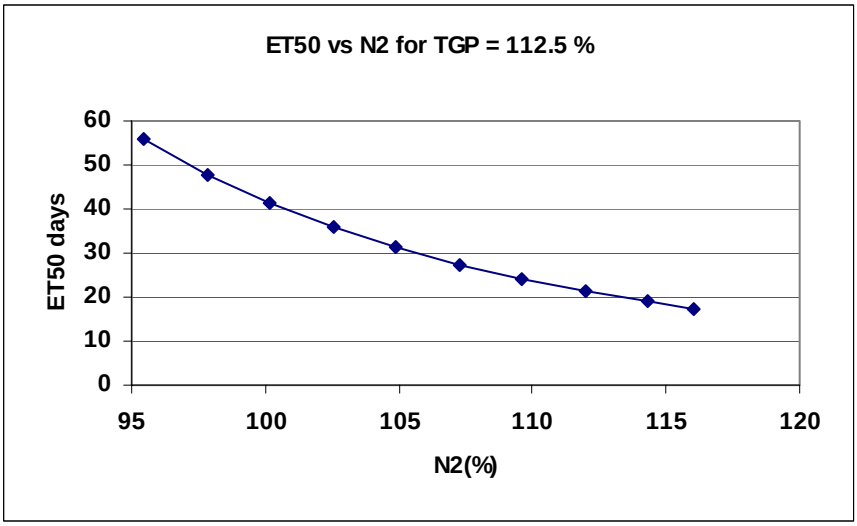


Figure 16. This figure illustrates the adverse effect of increased N2% on time to 50% mortality.

TREATMENT PROGRAMS

Introduction

These programs help hatchery workers treat fish in rearing or adult-holding ponds. They are designed for "flow-through" treatments – i.e. water flow is maintained during the procedure. The treatment chemical is delivered by metering pump or constant rate siphon to the inflow water. The objective is to expose fish to a "target concentration" for a specified duration. This target dose must be effective against pathogens and must also be safe for the fish.

The program asks the user to set the target concentration and treatment duration. Some standard treatments are given in Appendix 4. Although the targets recommended in this program are safe for typical conditions, it is still wise to be on the lookout for toxic effects. If conditions are unusual or the treatment chemical is unfamiliar, a small group of fish should be tested first. These standard treatments are guidelines and should be modified according to experience and site specific information. The default settings for the program are for Parasite S – with this chemical, ppm (parts per million) is the same as micro-litres of pure Parasite S per litre of solution (uL/L) (see Utilities).

Achieving the exact target dose is impossible in a large rearing pond. The concentration builds slowly as the treatment chemical is pumped to the pond inflow and gradually decays after the pump is turned off and the chemical is diluted. If the pond volume is large in relation to the water flow, the dose is difficult to control and the fish can receive a much longer exposure than desired. Increasing the flow (flushing flow) after treatment decreases exposure. The program shows this graphically and also calculates the actual dose experienced by the fish.

The program considers two idealized pond types: mixed flow and plug flow. In "mixed flow" the water circulates so a treatment chemical is quickly mixed into the water volume. In "plug flow" the chemical flows as a plug from inflow to outflow (with little longitudinal dispersion). Real ponds usually fall somewhere between these two ideal types. In most cases raceways are closer to plug flow, while circular and Burrows ponds are more like the mixed flow containers.

Concentration profiles for circular ponds are derived from simple dilution models. These models and the equations used to calculate dose (concentration ppm * duration hr) are presented in Utilities. Concentration profiles for raceways are based on a simple model of longitudinal dispersion and field tests (see Utilities).

Description of Treatment Programs

The program can only be accessed through the Treatment Wizard in the WinSirp menu. After choosing container type (circular or raceway) the user is asked for a number of inputs (see Fig. 17).

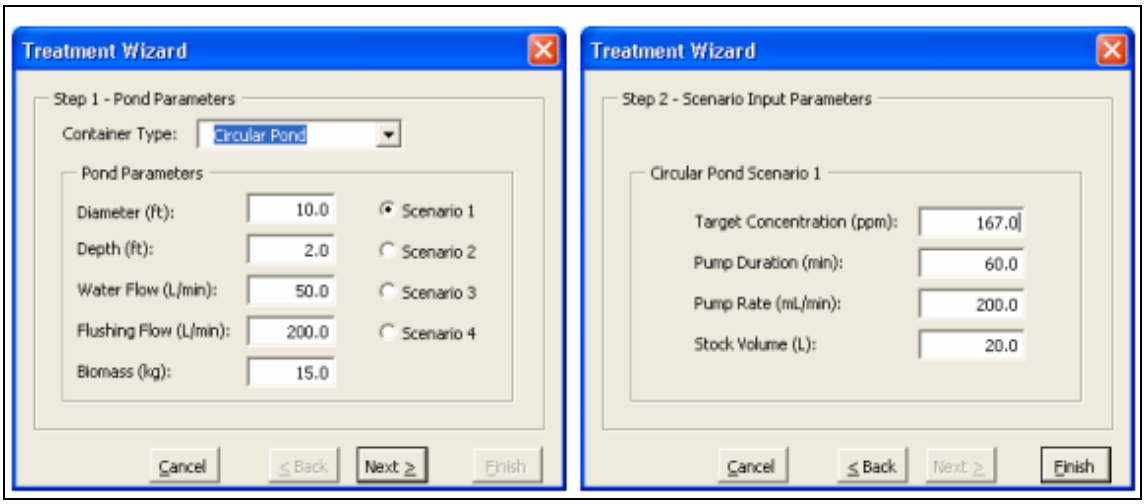


Figure 17. Illustration of 2 Treatment Wizard Window menus.

Circular Ponds

Step 1 requires the input of pond parameters: enter the pond diameter (ft), average water depth (ft), water flow during treatment (LPM), flushing flow (flow following treatment LPM) and fish biomass (kg). Often it is not possible to increase the water flow after the treatment – in this case flushing flow is the same as water flow. A treatment scenario must be chosen before going to the next screen, step 2.

Scenario 1.. This option describes how to prepare the required chemical stock solution after the injection rate of the metering pump is specified. After selecting scenario 1, the next screen asks for the target concentration (ppm), pump duration (min), pump rate (mL/min)and required stock volume (L). The program default settings are for Parasite S – in rearing containers the target concentration is 167 ppm and the exposure time is 60 min (target dose = 167 ppm * 60 min = 10,020 ppm min). For a conservative treatment the pump duration should be no longer than the target exposure time (60 minutes for Parasite S). The goal in scenario 1 is to attain the target concentration in the pond at the end of the pump duration.

The pump rate entered on the screen should reflect the capacity of the particular treatment pump being used – rates must be constant over the treatment period. Pump rates near the extreme limit of the pump's capacity should be avoided. The stock volume is determined by the pump rate. Enough volume should be prepared so that the treatment can be continuous. If the pump operates at 200 mL/min for 60 minutes the minimum stock volume is 12 Litres.

After entering the treatment information, click "Finish" to see program output. The final screen summarizes the Input data, gives instructions for preparing the stock and shows a plot of pond concentration vs. time. The treatment dose experienced by the fish is also calculated. If the ratio of biomass to flow (kg per LPM) is high (0.8 or above) a warning is displayed "for juveniles, consider increasing flow or adding oxygen".

Example 7 (Scenario 1)
Treat a 10 ft diameter, 2 ft deep circular pond with parasite S. The water flow is 50 L/min, biomass is 15 kg and the flushing flow (after treatment) is also 50 L/min. The target concentration is 167 ppm and the target exposure time (pump duration) is 60 min. In this case we have the metering pump set to deliver 200 mL/min and we want to know the recipe for making up 20 Liters of stock. The stock volume depends on how many ponds are being treated that day and the size of the available stock bucket. It is best to prepare just enough for one day -- the default volume is 20 L.

Using the "Treatment Wizard" enter pond and input parameters. In this Scenario the program calculates the stock concentration so that the target concentration is attained after 60 minutes. The pump is turned off and the concentration slowly decreases as the chemical is flushed out of the pond. To make 20 L of stock the program says that we need 1.7 L of Parasite S mixed with 18.3 L of water. The program gives the concentration of this stock solution (1.7 L *1,000,000 uL/L/20 L = 85,208 uL/L = 85,208 ppm) and the volume of stock used per treatment (200 mL/min * 60 min = 12,000 mL = 12 L) (Fig. 18). The concentration vs time plot (Fig. 19) shows that after 60 minutes the pond concentration reaches 167 ppm. The pump is turned off and concentration slowly decays – the graph shows that the fish are exposed to 85.1 ppm 2 hours after the start of the treatment. Because of the slow decay, the actual dose is much higher than the target dose (20,428 vs 10,020 ppm min) and the program displays a warning "Dose is high, consider increasing flushing flow after treatment". If the new flushing flow of 100 L/min is entered at cell D9, the dose falls to 12999 ppm min. This is because the Parasite S is flushed out of the pond more quickly – the concentration at 2 hours is only 43.3 ppm.

	A	B	C	D	E	F	G	H	I	J	K
1	**Scenario 1:**										
2	**Find the stock concentration, at a given a pump rate, to reach the target concentration for a given duration**										
3	**Given a pump rate, find stock concentration**										
4											
5	**Pond Parameters**										
6	Diameter (ft)			10.0							
7	Depth (ft)			2.0							
8	Water Flow "Q" (L/min)			50.0	(flow during treatment)						
9	Flushing Flow (L/min)			50.0	(flow following treatment)						
10	Biomass (kg)			15.0							
11											
12	Pond Volume "V" (L)			4448							
13	Density (kg/m^3)			3							
14	Load Rate (kg per LPM)			0.3							
15	Mean Residence Time "MRT" (min)			89							
16											
17	**Given a pump rate, pond volume and flow rate, prepare a stock so**										
18	**that the target concentration is achieved after given period of pumping.**										
19	Target Concentration (ppm)			167.0							
20	Pump Duration (min)			60.0							
21	Pump Rate "q" (mL/min)			200.0							
22	Stock Volume (L)			20.0							
23											
24	Treatment chemical required (L)			1.70							
25	Volume of water required (L)			18.30							
26	Stock Concentration (ppm)			85208							
27	Stock used per treatment (L)			12							
28											
29	Mean Residence Time (min)			89	(includes pump flow)						
30	Target Dose "C x T" (ppm min)			10020							
31	Actual Dose (ppm min)			20428	**Dose is high, consider increasing flushing flow after treatment**						
32											

Figure 18. Circular pond treatment scenario output worksheet.

Prediction -- Concentration in Pond Outflow vs Time

Time min	Outflow Concentration ppm	Flow during treatment (LPM)	Flow following treatment (LPM)
0	0.0	50.0	
15	52.9	50.0	
30	97.5	50.0	
45	135.2	50.0	
60	167.0	50.0	
75	141.1		50
90	119.2		50
105	100.7		50
120	85.1		50
150	60.7		50
180	43.3		50

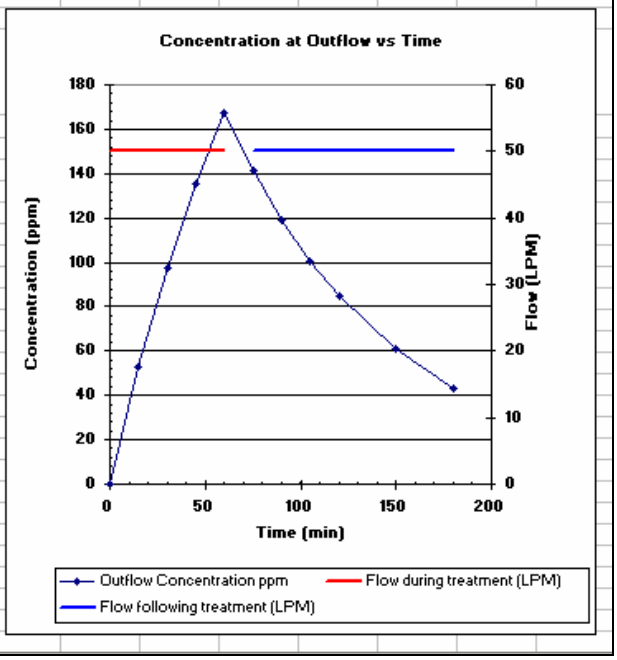


Figure 19. Circular pond scenario 1 plot, illustrating the concentration at outflow versus time.

Scenario 2. WinSIRP predicts the pump rate required to achieve the target concentration given a specified stock concentration. As in scenario 1, the target is achieved at the end of the pump duration. After entering the pond parameters, the next screen asks for information about the treatment – the "target concentration" and "pump duration" default settings are for Parasite S (167 ppm for 60 min). The default settings for "stock volume" and "volume of the treatment chemical" are arbitrarily set at 20 L. This means that 20 litres of Parasite S have been used to prepare a stock volume of 20 liters i.e. there is no water added so the stock concentration is 20/20*1,000,000 ppm = 1,000,000 ppm (pure Parasite S). If 10 liters of chemical were used to prepare 20 liters of stock, the concentration would be: 10/20*1,000,000 = 500,000 ppm.

After entering the treatment information, click "Finish" to see program output. The final screen summarizes the Input data, calculates the required pump rate and dose and also shows a plot of pond concentration vs time.

Example 8 (scenario 2).
Using the same pond parameters as in example 1, find the required pump rate to achieve 167 ppm after 60 minutes if the stock solution consists of 1.70 L for the volume of Parasite S mixed with 18.30 L of water (total stock volume = 20 L).

Choose scenario 2 at the first page of the "Treatment Wizard" and follow the data entry steps. Enter 1.70 for the "volume of treatment chemical"and 20 for the "stock volume". The output screen calculates a required pump rate of 200 mL/min. This is the same treatment regime as in example 1 so the graphical output and dose are the same.

The stock used per treatment is 12 L (200 mL/min * 60 min = 12,000 mL) and the stock concentration is 85,000 ppm. We initially prepare 20 L of stock so there will be 6 L left over at the end of the treatment. If we want to prepare just 12 L of stock so there is none remaining, the stock recipe is: mix 1.02 L of Parasite S (12 L * 85000/1000000) with 10.98 L of water (12.00 – 1.02).

Scenarios 1 and 2 are often effective and are frequently used in practise. However they do not achieve the target concentration until the end of the pump duration and so tend to under-treat the fish. Scenarios 3 and 4 are more complex treatments that achieve the target concentration for the prescribed time.

Scenario 3. In this option, the pump rate is initially elevated for a short time (default time = 15 min) so that the target concentration (167 ppm) is quickly achieved. At the end of this initial period the pump rate is reduced so that the target is maintained for the prescribed time (60 min). The stock concentration is specified by the user and is the same over the entire treatment.

Example 9 (scenario 3).
Determine the pump rates required to treat the pond in example 1 so that the target concentration is achieved after 15 minutes and is maintained for 60 minutes. Assume the stock solution is 85,000 ppm (1.70 L of Parasite S + 18.30 L of water).

On the "Pond Parameters" page of Treatment Wizard enter a flushing flow of 50 L/min and choose scenario 3. On the next page enter the stock concentration of 85000 ppm – the default values for pump times are set for 15 and 60 minutes and do not have to be changed. The output page shows that a pump rate of 634 mL/min is required for the first 15 minutes – it must then be decreased to 98 mL/min for 60 minutes. The program also warns that the dose (26,164 ppm min) is too high. This can be reduced by increasing the flushing flow. If the high initial pump rate is beyond the capacity of the metering pumps, then increase the stock concentration. This can be changed at cell E19 on the output page. If the stock concentration is increased to 1,000,000 ppm, the initial pump rate is 54 mL/min and 60 minute rate is 8 mL/min.

Scenario 4. In this case, a strong stock solution is pumped initially to quickly increase the pond concentration to the target level. A second weaker stock is then pumped for 60 minutes. The same pump rate is used throughout the treatment. Depending on the meter pump, this option can be simpler to set up than scenario 3. It requires careful labelling of the two stock buckets and also requires that the inlet line of the metering pump be moved from the high (stock 1) to the low (stock 2) concentration bucket at 15 minutes.

Example 10 (scenario 4)
If the metering pump is set to 30 mL/min, determine the concentrations of stock 1 and 2 so that the target level is achieved in 15 minutes and then held for 60 minutes.

Using the same pond parameters as in the previous examples choose scenario 4 and go to step 2. Enter the pump rate (30 mL/min) and make sure that the pump duration for stock

1 and stock 2 are 15 and 60 minutes respectively. The volume of each stock is arbitrarily set to 20 L.

The program warns that stock 1 is over the maximum concentration because the pump rate is too low. In this case the target concentration cannot be reached. The pump rate can be increased at cell D19 on the output page. At a pump rate of 100 mL/min, stock 1 is 538,224 ppm and stock 2 is 83,667 ppm. The recipe for stock 1 is 10.76 L of Parasite S and 9.24 L of water while stock 2 is 1.67 L of Parasite S and 18.33 L of water. The program also shows that 1.5 L of stock 1 and 6.0 L of stock 2 were used in the treatment (out of the 20 L prepared). To prepare just enough stock for a single treatment (i.e. none left over), enter 1.5 L in cell K23 and 6 L in cell K34. The program automatically calculates new recipes for these smaller volumes. As in the other examples blue cells can be changed directly on the output page.

Raceways

Select "Raceway" at the dropdown menu in the Treatment Wizard. Step 1 requires input of pond parameters - length, width, water depth, flow and biomass. Default settings for "target concentration" and "pump duration" are for Parasite S. Choose scenario 1 if you have the pump rate set and want the recipe for the stock solution and choose scenario 2 if you have a known stock concentration and want to calculate the pump rate to achieve the treatment target.

After choosing scenario 1, step 2 asks for the pump rate (mL/min) and the required stock volume – as in the previous program the default is 20 L. The output screen gives the stock concentration and recipe and also calculates the volume and "mean residence time" for the pond. It also displays a message that the target concentration in the downstream portion of the pond may not be achieved and that the Raceway program in Utilities should be consulted for more detail. If dispersion is too great the lower half of the pond may have to be treated independently or the treatment time may have to be extended. In a long pond it may not be possible to achieve the target at the downstream end. The "Utilities" raceway program is divided into two parts -- "RacewayModel" gives the model assumptions while "RacewaySimulation" predicts concentration profiles for a particular treatment.

Example 11.
A raceway (length = 150 ft, width = 10 ft, depth = 3.5 ft) containing 300 kg of fish must be treated with Parasite S. If the pond flow is 1200 LPM and the metering pump delivers 250 mL/min, find the required stock concentration. As with circular ponds, the recommended target concentration is 167 ppm and the pump time is 60 minutes.

Enter the Raceway option through the Treatment Wizard at the main menu and input the pond and treatment parameters as step 1. Choose scenario 1 and enter a pump rate of 250 mL/min and a stock volume (20 L) at step 2. The final screen calculates the required stock concentration of 801,767 ppm – to make 20 L, mix 16.04 L of Parasite S with 3.96 L of water (or measure 16.04 L of Parasite S and make up to 20 L with water). The program warns about under-treatment and directs the user to Utilities.

In Utilities, enter the pond parameters into "RacewaySimulation" (copy and paste can be used). Also enter manually (or copy and special paste) the stock concentration Cs = 801,767 ppm (to cell C17). The program automatically displays concentration profile graphs for halfway down the pond (75 ft from inlet) and at the pond outlet (150 ft). Also there is a summary table below each graph giving the peak concentration (Cp), dose (ppm min) and the number of minutes that the concentration was near the target (> 90% of target ppm). In this example, the target concentration of 167 ppm was reached at the halfway point but not at the pond outlet (Cp = 162 ppm). The concentration was greater than 150 ppm (90% of target) for 38 and 24 minutes at the halfway point and outlet respectively. Dose (10,022 ppm min) was the same at both sites. If the treatment time (cell C10) is increased from 60 to 100 minutes, the target is maintained for 60 minutes at the outlet however the dose increases to 16,703 ppm min. Also with a treatment time of 100 minutes the fish at the upstream end of the pond are over-treated. In large-scale fish culture, it is usually impossible to achieve the recommended targets for the entire population and a compromise must be chosen.

The Treatment Wizard was designed for Parasite S (liquid). However the "Treatment Chemicals" program in Utilities allows it to be used with other chemicals. In the following example a circular pond is treated with "Chloramine T" (dry powder).

Example 12. A circular pond (diameter = 10 ft, depth = 2 ft, flow = 100 LPM) is treated with Chloramine T. The target concentration is 7 mg/L and the treatment duration is 60 minutes. If the metering pump runs at 200 mL/min, find the stock concentration and recipe so that the target concentration is achieved after a 1 hour of treatment.

Open the Treatment Wizard and enter the input values in Circular Pond (scenario 1). This program shows that a stock concentration of 4732 mg/L (cell D26) is required to achieve the target concentration of 7 mg/L. However the recipe in the Treatment Wizard is only for Parasite S and is not relevant to other chemicals. To find the recipe for Chloramine T, the stock concentration is entered in cell D92 (Cs = 4732 mg/L) in the "Treatment Chemical" program (Utilities). Cells D94-D96 show that to prepare 20 L of stock solution, 94.64 grams of Chloramine T must be dissolved in 20 L of water.

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APPENDIX

Appendix 1. Incubation models and equation constants.

Table 5. Embryonic development stage equation constants for the 2 models used to predict development time (y=days) in response to average temperature (T °C).

Embryonic Stage constants							
Species	p_1	p_2	p_3	p_4	Description	Models *	Data source
Chinook	647018722.5	4.962747222	-32.3110703		Beginning of epiboly and convergence	BLM	Velsen 1987
Chinook	207.1222814	1.143230343	-1.001756111		Yolk plug closed; completion of epiboly	BLM	Velsen 1987
Chinook	883.2385275	1.414574147	-2.457463872		Eyed; 3/4 yolk vascularized	BLM	Velsen 1987
Chinook	0.0983194	-0.0371603	239.1483	27.76088	50% hatch	SG	Velsen 1987
Chinook	524090774	3.9184502	-19.0720758		MAWW or fry emergence	BLM	McLean 1991
Chum	235.8554168	1.529119598	-2.535180846		Beginning of epiboly and convergence	BLM	Velsen 1987
Chum	510.6446646	1.50313419	-1.325714686		Yolk plug closed; completion of epiboly	BLM	Velsen 1987
Chum	2378.325397	1.76190458	-3.947781414		Eyed; 3/4 yolk vascularized	BLM	Velsen 1987
Chum	0.1362313	0.7193096	177.8355	25.8466	50% hatch	SG	Velsen 1987
Chum	314.4147	0.51820524	1.6820473		MAWW or fry emergence	BLM	McLean 1991
Coho	58.50977413	1.030026354	-0.320168036		Beginning of epiboly and convergence	BLM	Velsen 1987
Coho	1303048.207	3.436728916	-19.21278684		Yolk plug closed; completion of epiboly	BLM	Velsen 1987
Coho	16661.25802	2.255270212	-8.618379214		Eyed; 3/4 yolk vascularized	BLM	Velsen 1987
Coho	0.0964044	0.0790329	213.1596	21.6462	50% hatch	SG	Velsen 1987
Coho	923367.4542	2.8995311	-15.02834151		MAWW or fry emergence	BLM	McLean 1991
Pink	13.51459541	0.671480565	2.871384151		Beginning of epiboly and convergence	BLM	Velsen 1987
Pink	704.6378875	1.567007981	-1.593069		Yolk plug closed; completion of epiboly	BLM	Velsen 1987
Pink	390.088759	1.209049777	-0.343034298		Eyed; 3/4 yolk vascularized	BLM	Velsen 1987
Pink	0.5672965	4.4479179	180.4144	49.6946	50% hatch	SG	Velsen 1987
Pink	977660.4608	2.7231174	-18.8391622		MAWW or fry emergence	BLM	McLean 1991
Sockeye	1062965550	5.230163115	-28.85483811		Beginning of epiboly and convergence	BLM	Velsen 1987
Sockeye	1071672210	5.1092889	-25.64585479		Yolk plug closed; completion of epiboly	BLM	Velsen 1987
Sockeye	1097342643	4.801222359	-29.07423777		Eyed; 3/4 yolk vascularized	BLM	Velsen 1987
Sockeye	0.1730653	1.0483823	212.4232	36.4204	50% hatch	SG	Velsen 1987
Sockeye	34186861.2	3.56109377	-24.96801241		MAWW or fry emergence	BLM	McLean 1991

Table 5 (cont'd)

Embryonic Stage constants							
Species	p_1	p_2	p_3	p_4	Description	Models *	Data source
Steelhead	10273.9215	2.539328995	-11.38116408		Beginning of epiboly and convergence	BLM	Velsen 1987
Steelhead	394.1655832	1.500516	-2.941684794		Yolk plug closed; completion of epiboly	BLM	Velsen 1987
Steelhead	3223106353	5.173971576	-29.75685594		Eyed; 3/4 yolk vascularized	BLM	Velsen 1987
Steelhead	0.408414	2.3613821	139.2562	18.3476	50% hatch	SG	Velsen 1987
Steelhead	922049.74	3.00725581	-14.1975994		MAWW or fry emergence	BLM	McLean 1991
Atlantic salmon	218.6657338	1.353599203	-1.645090069		Beginning of epiboly and convergence	BLM	Jensen et al. 2008
Atlantic salmon	373.8155046	1.302028459	-1.966134234		Yolk plug closed; completion of epiboly	BLM	Jensen et al. 2008
Atlantic salmon	128.0814132	0.683225404	1.173276793		Eyed; 3/4 yolk vascularized	BLM	Jensen et al. 2008
Atlantic salmon	11248.32224	2.019841837	-5.394375865		50% hatch	BLM	Jensen et al. 2008
Atlantic salmon	2839.288975	1.416333719	-2.781366584		MAWW or fry emergence	BLM	Jensen et al. 2008

* BLM = Modified Belehadrek model (where y=days and T=°C):

$$y=p1/(T-p_3)^{p2}$$

SG = Schnute Growth model (where y=days and T=°C):

$$y= (p_3{}^{p2} + (p_4{}^{p2} - p_3{}^{p2}) * (1 - \mathrm{Exp}(-p_1 * (T - 1))) / (1 - \mathrm{Exp}(-p_1 * 19)))^{(1 / p2)}$$

Table 6. Model coefficients for mechanical shock and temperature warnings (polynomial model $y=a+bx+cx^2$). For the mechanical shock model, y=LD50 cm and x=ATU ºC-days. For the temperature warnings, y=LD50 % egg mortality and x=temperature ºC.

chinook	Mechanical shock constants	Temperature warning constants
Parameter	Value	Value
a	105.0238702	110.9404788
b	-2.70227473	-24.1488958
c	0.01343607	1.25806343
chum		
Parameter	Value	Value
a	63.69858692	90.28733234
b	-1.24863876	-17.9755668
c	0.005957915	0.887393073
coho		
Parameter	Value	Value
a	72.81728299	57.4770217
b	-1.95341902	-15.5908092
c	0.010376686	1.110897223
pink		
Parameter	Value	Value
a	73.19026618	122.4460644
b	-1.45661082	-24.8079008
c	0.0082806	1.261781575
sockeye		
Parameter	Value	Value
a	106.8271202	88.89141181
b	-2.16715479	-16.9765793
c	0.011795433	0.915673029
steelhead		
Parameter	Value	Value
a	52.50293168	90.85614168
b	-1.65399851	-21.4230171
c	0.011982812	1.289032797
Atlantic salmon		
Parameter	Value	Value
a	78.5523742	48.1172
b	-1.739165882	-15.8019
c	0.009589321	1.419607

Table 7. Model coefficients for "standardized" changes in egg to alevin total weight (based on egg and alevin weight changes observed by Mclean and Lim, 1985). These predicted egg or alevin weights are only approximate estimates and are used for Ro and ammonia calculations (see Appendix 5).

coefficients	chinook	chum	coho	pink	sockeye	steelhead	Atlantic salmon
a	0.992394481	0.999743722	0.999716384	0.997831895	0.997898957	0.998199169	0.992394481
b	0.005200704	0.005057141	0.005063384	0.005613015	0.00553697	0.005752556	0.005200704
c	-0.000044233	-0.000043068	-0.000043003	-0.000053429	-0.000051149	-0.000058534	-0.000044233
d	2.21977E-06	2.16355E-06	2.14091E-06	2.77503E-06	2.58901E-06	3.20076E-06	2.21977E-06
e	-3.0445E-08	-2.9735E-08	-2.8684E-08	-3.9247E-08	-3.5613E-08	-4.7077E-08	-3.0445E-08

Appendix 2. Introduction to WinSIRP Utilities Programs

The Utilities package augments WinSIRP. Each worksheet is described below:

1 AvgWeeklyTempCal –
Calculates weekly average temperatures from daily temperatures that can be copied and inserted into the IncubationInput worksheet.

2 HeathTray –
Takes re-aeration into account and predicts DO at the outflow of a stack of Heath Trays.

3 Barometric Pressure –
Predicts average barometric pressure as a function of altitude. Also converts barometric pressure in mmHg into other common units.

4 Feed % Water –
Takes moisture content of different Diets into account and calculates feed rate (g dry food per g of fish per day or % dry/d). Also predicts maximum ration from fish weight and temperature.

5 OxygenSat –
Calculates the % oxygen saturation of a water supply given the oxygen concentration (mg/L) and temperature. Also presents DO criteria for salmonids.

6 Treatment Chemicals –
WinSIRP uses Parasite S as the default chemical in the treatment programs. This "Utility" shows how to adapt the program to other chemicals.

7 TreatCircular –
Presents the equations used in WinSIRP to predict treatment concentration, duration and dose in "mixed flow" ponds (e.g. circulars, Burrows).

8 RacewayModel –
Describes the model used in WinSIRP to predict the effect of longitudinal dispersion on treatment chemical passing down a raceway.

9 RacewaySimulation –
Predicts the concentration profiles for Parasite S treatment halfway down the length of the pond and at the pond outlet.

Appendix 3. Emergence of Pink Fry from Gravel Box Incubators

WinSIRP predicts the time required for alevins to attain "maximum alevin wet weight" (MAWW). Models were derived from data based on constant temperature regimes. In this case, MAWW is a good indicator of fry emergence and downstream migration. For highly variable temperatures, fry emergence (and migration) can differ markedly from the predicted MAWW. This difference is particularly noticeable for pink fry migrating from gravel boxes in early spring.

The examples below show the daily pink fry emergence from gravel boxes incubated at Quinsam Hatchery on river water. Figure 20 shows migration from a box where the average incubation temperature was 4.8 °C. The predicted MAWW occurred on March 31 (853 ATUs) while emergence (50%) actually occurred on April 8. Figure 21 shows a more extreme difference between the observed emergence and predicted MAWW. In this case the average temperature was 6.5 °C and emergence was almost 1 month later than the WinSIRP prediction (956 ATUs). Fry emergence was suppressed by the decreasing temperature in late February and then triggered by the sharp temperature increase in mid-March. These examples show the difficulty of predicting emergence for variable temperature regimes.

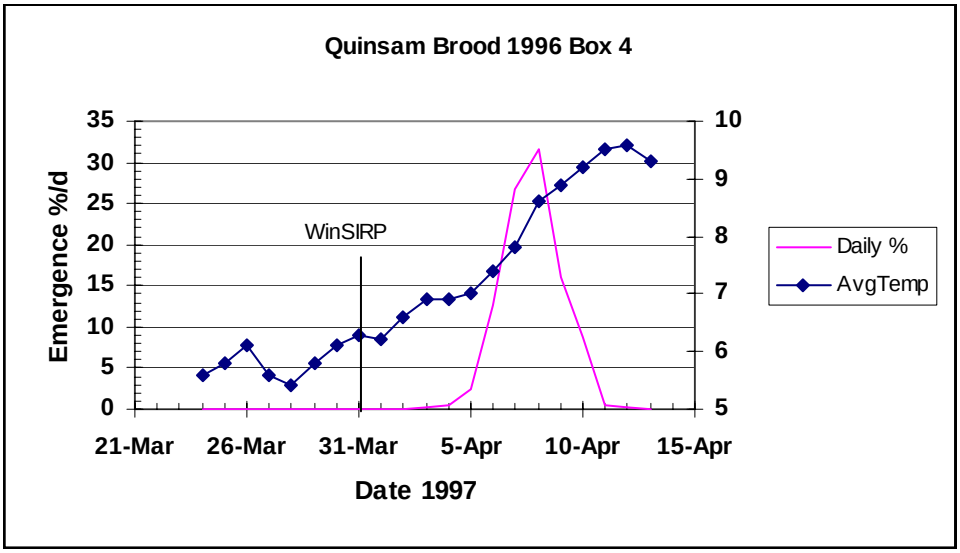

Figure 20. Pink fry emergence and water temperature for 1996 brood, gravel box #4 at Quinsam Hatchery. The value predicted by WinSIRP is one week earlier than the observed 50% emergence.

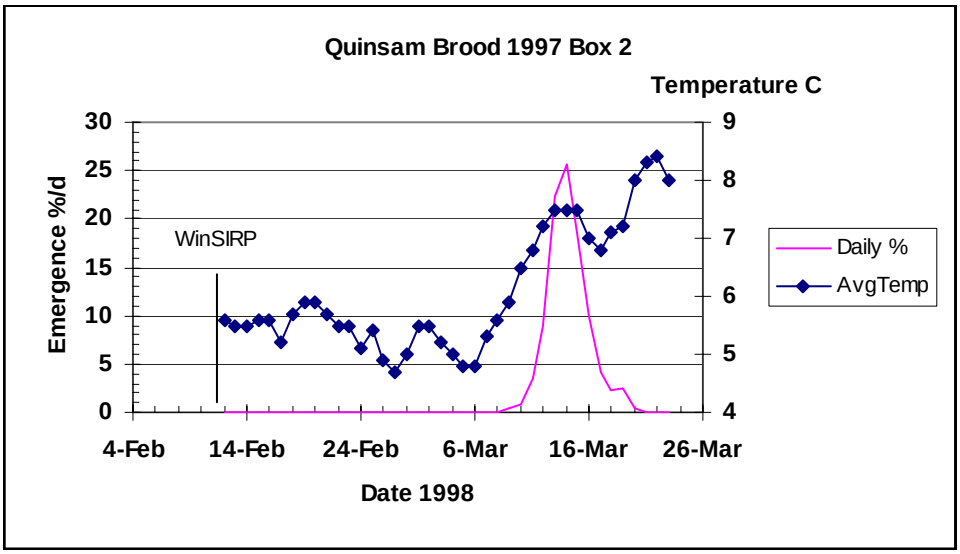

Figure 21. Pink fry emergence and water temperature for Quinsam Hatchery 1997 Brood, gravel box #2. The WinSIRP value is too early and emergence does not begin until the temperature increases.

Because of these differences, a separate model was developed for the emergence of pink fry from gravel boxes on surface water (variable temperature). Figure 22 shows a plot of ATUs to 50% emergence against the average incubation temperature – the new model (line) and observed points from Quinsam, Puntledge and Headquarters Creek Hatcheries are displayed. More detail regarding this model is presented in the Utilities worksheet "PinkEmerge".

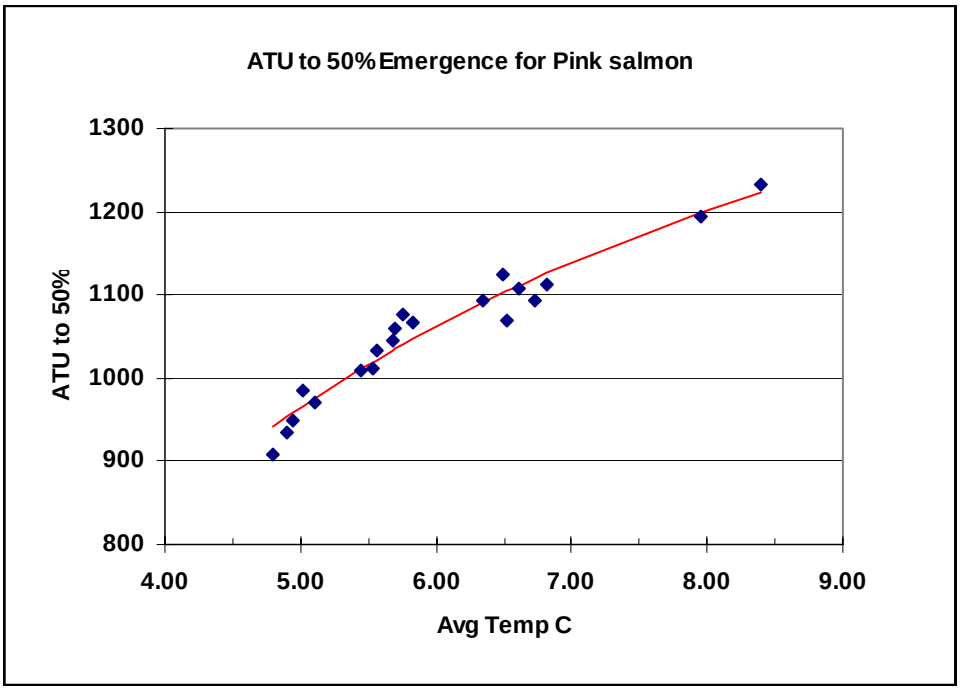

Figure 22. Predicted ATUs to 50 % emergence and observed points for pink fry in gravel box incubators on surface water (see Utilites for more detail).

In the "variable temperature model", eggs are fertilized in early fall at above 10 ºC, develop through the winter at much lower temperatures and migrate as fry in early spring at 6 to 8 ºC. A typical temperature regime is shown in Figure 23.

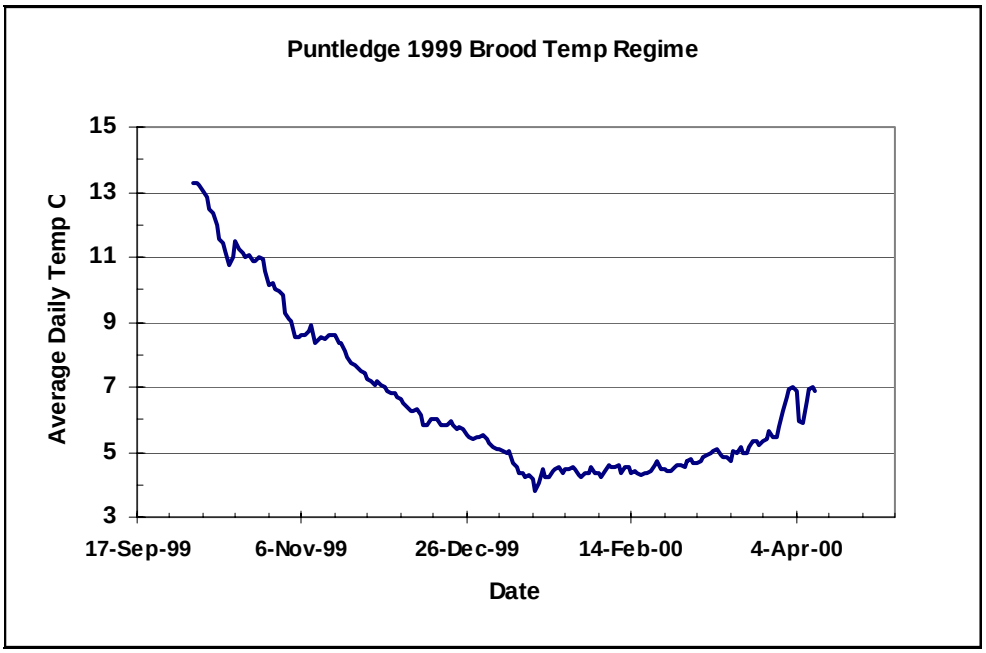

Figure 23. Typical surface water temperature regime – Puntledge Hatchery 1999 brood.

Appendix 4. Some standard treatments for fish culture.

In large-scale fish culture, flow-through treatments are sometimes preferable to static bath treatments. In the flow-through case, the therapeutant is mixed with the pond inflow water, which then carries the chemical to the fish. Water flow is maintained during the treatment supplying the fish with oxygen and flushing away metabolites. Static treatments are simpler conceptually but are often difficult or impossible to carry out in practise. Sometimes a treatment bath is prepared in a container and fish are moved in for a specific exposure period. The handling stress often eliminates any benefit of the treatment. Static treatments are sometimes performed in rearing ponds by simply turning off the flow and attempting to quickly mix the treatment chemical into the entire pond volume. In large ponds, this usually produces localized "hot-spots" and is very stressful to the fish. If the exposure time is longer than a few minutes, oxygen has to be added and distributed over the pond volume to prevent suffocation.

Some common flow-through and static treatments are listed below (Table 8). They are used for a variety of purposes in fish culture e.g. disease treatment, water conditioning, disinfection and as anesthetics. A more complete list of recommended treatments is given in Hoskins et al. 1983. Before any treatment is started; please contact a vet or fish health specialist, for the recommended treatment and dose. Some of these treatments require an "Emergency Drug Release" permit from the Bureau of Veterinary Drugs. Depending on the local conditions, some may require effluent treatment or neutralization.

Table 8. Common flow-through and static treatments used for disease treatment, water conditioning, disinfection and as anaesthetics

Treatment	***Target ppm***	***Target min***	***Purpose in Fish Culture***
Parasite S, rearing	167	60	Fungus, external parasites – rearing
Parasite S incubation	1667	15	Fungus control – eggs
Malachite Green – rearing	0.1-0.2	60	Fungus, external parasites – rearing
HydrogenPeroxide	350	60	Fungus, external parasites – eggs, rearing
Salt (NaCl)	20,000	60	Fungus – eggs, rearing fish
Calcium Chloride	20	Inc.	Increase Water Hardness for egg incubation
Ovadine- incubation	100	10	Egg disinfection
Chloramine T	5-10	60	BGD, rearing
Carbon Dioxide	200 –400	4	Anesthetic
Furanace	1-2		BGD, rearing
Potassium Permanganate	1	60	BGD, rearing
HTH Bleach	158		Equipment, Pond Disinfection
Bleach NaOCl	158		Equipment, Pond Disinfection
Roccal	600		Equipment Disinfection
TMS	75	3	Anesthetic
Eugenol	50	3.5	Anesthetic
Sodium Thiosulfate			Chlorine, Iodine neutralization

Appendix 5. Details on 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

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

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

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

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 6 species will exhibit similar metabolism to chinook. Therefore, equation 2 is used to predict ammonia excretion for the other 6 salmonid species based on their calculated Ro values.

2. Ro (oxygen consumption) rates

The Ro models used for all salmonid species, with the exception of Atlantic salmon, described below in Appendix 6, were developed Dr. Peter Rombough and reported in Mclean et al. (1991), from which the the Ro equations were obtained.

3. 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) and more recently Jensen (2003) and Sweeten et al. (2004) can be reported in terms of ATUs. Hence, the LD50s were modelled against ATUs and have been included in WinSIRP as a separate menu item (Mechanical Shock Table). Table 9, below, shows these predicted values based on the models in Table 10, that follows.

Table 9. Predicted LD50s (drop heights, cm, causing 50% egg mortality) from 0.007 to 230 ATUs (ºC-days) for 7 salmonid species.

Temperature (°C)	Days (@Temp °C)	Hours (@Temp °C)	Minutes (@Temp °C)	ATUs (°C-days)	Chinook Salmon	Chum Salmon	Coho Salmon	Pink Salmon	Sockeye Salmon	Rainbow or Steelhead Trout	Atlantic salmon
10	0.0007	0.02	1	0.007	198.8	109.4	89.5	136.2	184.4	91.3	111.7
10	0.0035	0.08	5	0.035	163.4	92.4	72.5	110.1	153.9	74.9	96.3
10	0.0069	0.17	10	0.069	148.1	85.0	65.2	98.8	140.7	67.8	89.6
10	0.0104	0.25	15	0.104	139.2	80.7	60.9	92.2	133.0	63.6	85.7
10	0.0208	0.50	30	0.208	124.0	73.4	53.5	80.9	119.8	56.6	79.0
10	0.0313	0.75	45	0.313	115.0	69.1	49.2	74.3	112.1	52.4	75.1
10	0.0417	1.00	60	0.417	108.7	66.1	46.2	69.6	106.7	49.5	72.4
10	0.0833	2.00	120	0.833	93.5	58.7	38.9	58.4	93.5	42.4	65.7
10	0.1667	4.00	240	1.667	78.2	51.4	31.5	47.1	80.3	35.3	59.0
10	0.3333	8.00	480	3.333	62.9	44.1	24.2	35.8	67.2	28.3	52.4
10	0.5000	12.00	720	5.000	54.0	39.8	19.9	29.2	59.5	24.1	48.5
10	1.0000	24.00	1440	10.000	38.8	32.4	12.6		46.3	17.0	41.8
10	2.0000	48.00	2880	20.000	23.5	25.1	5.2		33.1	10.0	35.1
10	3.0000	72.00	4320	30.000	14.6	20.8	0.9		25.4	5.8	31.2
10	4.0000	96.00	5760	40.000	8.3	17.8	-2.1	29.2	20.0	2.9	28.4
10	5.0000	120.00	7200	50.000	3.4		-4.5	21.8	15.7		26.3
10	6.0000	144.00	8640	60.000		14.9		16.4		2.0	24.5
10	7.0000	168.00	10080	70.000		9.6		12.7		-2.4	
10	8.0000	192.00	11520	80.000	-8.6	5.4	-2.1	**11.0**	15.7	**-3.5**	
10	9.0000	216.00	12960	90.000	-18.7	2.6	-6.8	11.1	11.7	-1.5	26.4
10	10.0000	240.00	14400	100.000	-25.3	0.9	-9.2	13.0	**10.4**	3.7	15.7
10	11.0000	264.00	15840	110.000	**-28.5**	**0.4**	**-9.3**	16.9	11.8	12.1	8.7
10	12.0000	288.00	17280	120.000	-28.1	1.2	-7.2	22.5	15.9	23.6	**5.4**
10	13.0000	312.00	18720	130.000	-24.2	3.2	-2.8	30.1	22.6	38.4	5.6
10	14.0000	336.00	20160	140.000	-16.8	6.4	3.9	39.5	32.0	56.3	9.6
10	15.0000	360.00	21600	150.000	-5.9	10.8	12.9	50.7	44.1	77.4	17.2
10	16.0000	384.00	23040	160.000	8.5	16.5	24.2	63.9	58.9	101.7	28.5
10	17.0000	408.00	24480	170.000	26.3	23.3	37.7	78.8	76.4	129.1	43.4
10	18.0000	432.00	25920	180.000	47.7	31.4	53.5	95.7	96.5	159.8	62.0
10	19.0000	456.00	27360	190.000	72.6	40.7	71.6	114.4	119.3	193.6	84.3
10	20.0000	480.00	28800	200.000	101.0	51.3	92.0	134.9	144.8	230.6	110.2
10	21.0000	504.00	30240	210.000	132.9	63.0	114.7	157.4	173.0	270.8	139.8
10	22.0000	528.00	31680	220.000	168.3	76.0	139.6	181.6	203.9	314.1	173.0
10	23.0000	552.00	33120	230.000	207.1	90.2	166.9	207.8	237.4	360.7	209.9

NOTE:
The white coloured cells are are left blank to simplify the transition between the log-linear and the parabola models
The LD50 predictions with blue background are calculated by the log-linear model
The LD50 predictions with turquoise background are calculated by the parabola model
The LD50 values with the red background are the Minimum LD50 values (occurring to the nearest 10 ATUs)

Table 10. Model coefficients for mechanical shock sensitivity (i.e. LD50; cm drop height causing 50% egg mortality).

Species	Model type	Model coefficients			Time period modelled		
		a	b	c	ATUs (°C-days)	n	r^2
Chinook	y=a+blnx	89.4382	-22.0048		0 - 50	14	0.874338
	$y=a+bx+cx^2$	198.3172	-3.9866	0.0175	50 - 230	14	0.780007
Chum	y=a+blnx	56.8127	-10.5833		0 - 40	13	0.529776
	$y=a+bx+cx^2$	72.5059	-1.3262	0.0061	60 - 240	20	0.971673
Coho	y=a+blnx	36.9368	-10.5855		0 - 50	16	0.686024
	$y=a+bx+cx^2$	117.5622	-2.4077	0.0114	50 - 180	5	0.89506
Pink	y=a+blnx	55.3994	-16.2661		0 - 30	13	0.762435
	$y=a+bx+cx^2$	77.1386	-1.571	0.0093	30 - 190	17	0.809475
Sockeye	y=a+blnx	90.041	-18.9923		0 - 50	16	0.733368
	$y=a+bx+cx^2$	144.0172	-2.6759	0.0134	50 - 200	16	0.915053
Steelhead	y=a+blnx	40.5516	-10.2118		0 - 40	15	0.664983
	$y=a+bx+cx^2$	94.783	-2.501	0.0159	40 - 150	12	0.867079
Atlantic salmon	y=a+blnx	63.9363	-9.6211		0 - 60	16	0.889292
	$y=a+bx+cx^2$	287.269	-4.5453	0.0183	70 - 200	16	0.936795

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 (Jensen, 2003; Sweeten et al. 2004). Therefore, for those that require the development time (ATUs) to maximum egg sensitivity in relation to drop height and seismic disturbance an

additional table (Table 11) has been included in the WinSIRP Mechanical Shock Table module that shows Minimum LD50s and LD10 velocities.

Table 11. Minimum LD50s and LD10 velocities (both predictors of the most senstive time for mechanical shock sensitivity).

Species	Minimum LD50 (cm)	ATUs (C°-days)	Species	Minimum LD10 Velocity (cm/sec)	ATUs (C°-days)
Chinook	-28.6	113.84	Chinook	14.6	110.8
Chum	0.54	108.53	Chum	41.6	99.8
Coho	-9.57	105.61	Coho	23.1	94.7
Pink	10.88	84.35	Pink	62.3	87.8
Sockeye	10.79	99.58	Sockeye	83.8	90.6
Steelhead	-3.53	78.62	Steelhead	33.2	78.3
Atlantic salmon	5.49	123.99	Atlantic salmon	20.9	128

Also, 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 LD50s. The warnings are as follows:-

1. If the LD50 is greater than 115 cm then the warning is " **Shock resistant**"
2. If the LD50 is between 115 and 50 cm then the warning is "**Sensitive**"
3. If the LD50 is between 50 and 10 cm then the warning is "**Very Sensitive**"
4. If the LD50 is less than 10 cm then the warning is "**Extremely Sensitive**"

The plot of LD50s (see Fig. 6 in the earlier section of this report) illustrates the typical changes in egg sensitivity to mechanical shock for all 7 salmonid species. In WinSIRP, the temperature can be changed from 10 ºC, and the subsequent development times to various ATUs are calculated, allowing the user to better predict changes in egg sensitivity with fluctuating water temperatures.

4. 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 2nd 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 below in Fig. 24 to illustrate this. Recent research at PBS on Atlantic salmon (*Salmo salar*) has now been modelled (Jensen et al. 2004) and is included with the other 6 species model parameters below in Table 12.

Table 12. Second order polynomial (i.e. $y=a+bx+cx^2$) model parameters for the 7 salmonid species.

Parameter	Chinook	Chum	Coho	Pink	Sockeye	Steelhead or Rainbow	Atlantic Salmon
a	117.2522	55.92073	31.46723	114.9178	41.75167	56.16842	48.1172
b	-25.3536	-11.0921	-12.2099	-25.0697	-8.55669	-13.3163	-15.8019
c	1.30038	0.584924	1.05848	1.314766	0.542333	0.834857	1.419607
R^2	0.749817	0.396737	0.804885	0.66318	0.243419	0.50753	0.808135
n	101	58	96	66	63	16	60
Min temp (°C)	1.1	1.1	1.3	2.0	2.0	1.0	3
Max temp (°C)	18.1	16.0	17.0	16.0	16.9	16.0	14

There are a number of observations to be made from Table 12. 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 (except for Atlantic salmon, mortality is from egg to swim-up) 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. 24) should be given based on the models in Table 12. Four levels of temperature warnings were chosen, namely: -

1. If, at a given incubation temperature, the second order polynomial 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 second order polynomial 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 second order polynomial 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 second order polynomial model predicts a value greater than 50% mortality, then the following warning is given "Expect greater than 50% egg mortality at this temperature".

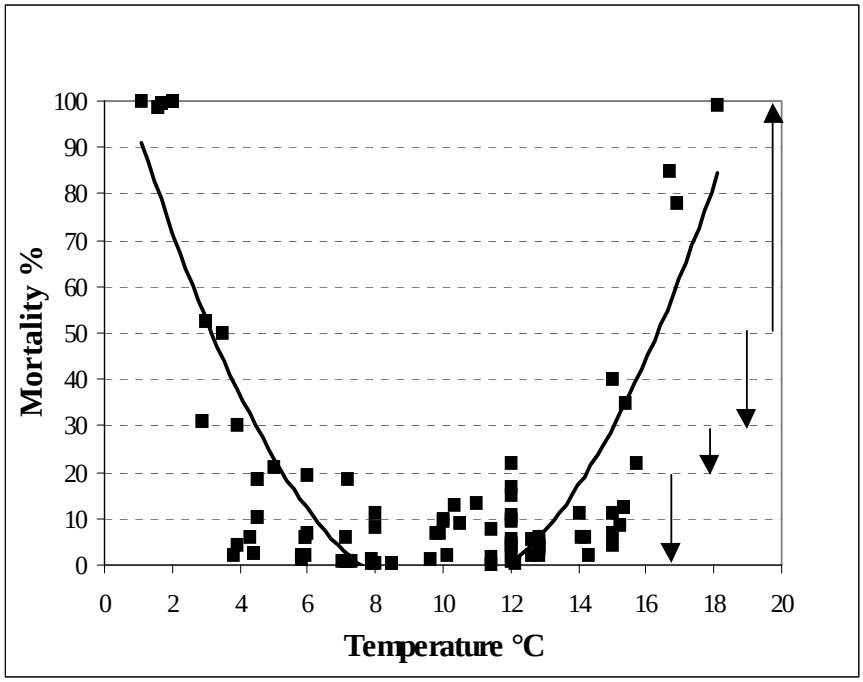

Figure 24. Chinook egg mortality in response to constant temperature from fertilization to hatch. The solid line represents the equation $y=117.252220-25.3536221x+1.30038x^2$; $R^2=0.7498$. The vertical arrows represent warning levels described in the text above.

Appendix 6. New Models used for Atlantic salmon.

The following models were developed from data produced from several year's of collaborative research with Fisheries and Oceans Canada and Marine Harvest Ltd. The models are as follows:

1. Incubation development stages 1 to 5 utilized in the in the incubation wizard
2. Ro – oxygen uptake models

1. Incubation development stages 1 to 5

The following model equation parameters (Table 13) for 5 key development stages for Atlantic salmon have been produced after 2 years of collaborative research between DFO, Stolt Sea Farms and Pan Fish Canada (Jensen et al., 2004). The eggs came from the MOWI and Cascade stocks maintained at the Glacier Bay broodstock site in Jervis Inlet for the 2 brood years 2002 and 2003.

Table 13. Atlantic salmon embryonic stage model parameters.

Stage 1 WinSIRP beginning of epiboly	*Parameters*
a	218.6657338
b	1.353599203
c	-1.645090069
r^2=	0.999512414
Stage 2 WinSIRP yolk plug closure	Parameters
a	373.8155046
b	1.302028459
c	-1.966134234
r^2=	0.995764667
Stage 3 WinSIRP Eyed	Parameters
a	128.0814132
b	0.683225404
c	1.173276793
r^2=	0.994609787
Stage 4 WinSIRP 50% hatch	Parameters
a	11248.32224
b	2.019841837
c	-5.394375865
r^2=	0.995694482
Stage 5 WinSIRP MAWW/Emergence/Ponding	Parameters
a	2839.288975
b	1.416333719
c	-2.781366584
r^2=	0.998059381
2003_2004 modelled MAWW for 3 to 11 C BLM(a,b,c) $y=a/(x-c)^b$ MAWW=time post-fertilization (d)	

2. Ro – oxygen uptake models

Ro (mg/1000/h) for Atlantic salmon embryos modelled as a function of accumulated temperature units (ATU) and ambient temperature (T) for one phase of incubation (i.e. from 200 to 800 ATUs at temperatures ranging from 4 to 10 °C.

The model developed and employed in WinSIRP for Atlantic salmon is as follows:-

Ro(mg/1000/h)= Exp(-14.9529 + 2.6113 * Ln(ATU / T°C) + 2.9654 * Ln(T°C));
R2=0.7291, N=97.

Critical oxygen concentration Pc (mg/L) was not determined for Atlantic salmon eggs to fry. Hence, the Pc calculated in WinSIRP uses the Coho model due to its similarity (i.e. similar sensitivity to cold water).

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