POND Version 3.0

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POND Version 3.0
User's Guide

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CHAPTER 1 - Overview

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Introduction

Planners and managers involved with pond aquaculture often need to make decisions relating to the following factors: site locations, target fish species, stocking densities, and feeding, fertilization, liming and water exchange rates. The POND software was developed in order to provide educators, extension agents, pond managers and researchers with a tool for rapidly exploring the effects of various combinations of the above factors on pond performance and facility-level economics. This functionality is accomplished primarily by the use of ***simulation models*** and an ***economic analysis*** package.

POND provides the following capabilities:

- Facility level or pond level analysis
- Multiple pond definitions
- Multiple fish lot definitions
- User definable model parameterization and selection
- Multilevel simulation
- Graphical viewing of simulation results
- Parameter estimation for species customization
- Fertilizer, feed, lime and water requirements determination
- Enterprise budget analysis, including user-definable costs

POND runs under the Microsoft Windows (version 3.1 and above) operating environments. A basic familiarity with Windows is assumed throughout this manual.

System Requirements

POND requires a IBM-compatible personal computer running the Microsoft Windows (version 3.1 or higher) operating environment. It requires approximately 1.5MB of available hard disk space and a minimum of 4MB RAM. A 80386 CPU is required, and a 80486 or greater CPU is recommended.

Installation

POND comes on a single 3.5" floppy disk. The program itself consists of several program files and data files. The simplest way to install POND is to make a directory on your hard disk using the DOS **md** command as follows:

> **md c:\pond**

Alternately, from within Windows you can use the File Manager to create the directory.

Once this directory is created, you may copy all of the files on the installation floppy to the POND directory using the DOS **copy** command as follows:

> **copy a:*.* c:\pond**

If you are installing from a different floppy drive or to a different directory on your hard disk, substitute the appropriate directories.

From within Windows, you may alternately copy the files from the installation floppy using the File Manager.

Once the POND files are copied to your hard disk, you are ready to run POND. First, start Windows if it is not already running. After Windows is running, you can start POND in several different ways:

1) From the File Manager, select the POND directory and double click on POND.EXE

2) From the Program Manager, select *File/Run* from the Program Manager main menu and type C:\POND\POND.EXE in the Run dialog box.

3) Set up a Program Manager group for POND. This is accomplished by selecting *File/New* from the Program Manager main menu and selecting *Program Group.* This will create a POND group. Next, select *File/New* from the main menu, select Program Item, and specify POND.EXE and C:\POND in the Command Line and Working Directory fields, respectively. Once the program item is established, double-click on the POND icon to start the program.

On-line help

On-line help in POND is obtained by selecting the <Help> button in the various dialog boxes of the program. This operation accesses the relevant section of the Users Guide.

CHAPTER 2 - POND Input Databases

BASIC DATABASE OPERATIONS
SOURCE WATER DATABASE
POND DATABASE
FISH LOT DATABASE
FISH SPECIES DATABASE
SITE DATABASE
SOIL DATABASE
FERTILIZER DATABASE
FEED DATABASE
LIME DATABASE
WEATHER DATABASE
COST DATABASE
SIMULATION DATABASE

Basic inputs to POND are provided through a series of 'mini-databases' related to particular aspects of the program. Databases containing default information have been created in POND to allow users to familiarize themselves with the program. Such default information may not be appropriate for use at some locations. However, we recommend that the existing databases be retained for future reference, and that information specific to a particular facility or site be saved as separate records.

Databases are provided for the following areas:

- Source water
- Ponds
- Fish Lots
- Fish Species
- Site
- Soil
- Fertilizers
- Feeds
- Liming Materials
- Weather
- Cost
- Simulation

Basic Database Operations

Browsing records

Adding new records

Deleting records

Saving changed records

User interaction with the databases is handled in a consistent manner across all databases. All databases share the following characteristics:

1. Each database consists of 1 or more *records*, which describe a single entity in the database,
2. Each database resides on the hard disk as an ASCII file,
3. Each database has a *dialog-based interface*, allowing the user to add, modify, copy, and delete records without having to directly edit the database file

To edit the database, select the appropriate database from the *Parameters* menu or push the appropriate toolbar button. The dialog interface window will appear. A number of functions, as follows, are common across all database editing dialogs:

Browsing records

Records in the database can be traversed by selecting the << and >> buttons, or by scrolling directly through the list of record names.

Adding new records

New records can be add to the database by selecting the <Add> button. A blank (default) record will appear for editing. Alternatively, you may make a copy an existing record by selecting the **<**Copy**>** button. In either case, you will be requested to provide a name for the new record.

Deleting records

Existing records are removed from the database by selecting the <Remove> button. The currently selected record will be removed from the database.

Saving changed records

When you are finished viewing and/or modifying pond records, you may select the <OK> button to use the updated values (without saving the changes permanently to your disk), or select the <Save to Disk> button to use the changes and save them permanently to your disk. Use the <Cancel> button to ignore any changes made to the current record.

Source Water Database

Physico-chemical characteristics of the source water used at the facility are maintained in the Source Water database. These characteristics define the quality of water released into ponds.

To define a new water source, or modify, copy or delete an existing source, select the *Parameters/Source* Water menu option. The **Source Water Parameters** dialog will appear:

Water Sources

- *Name.* The name of the water source. This is used as an identifier for the specific source of water available for use.

Common variables for all levels

- *Water Temperature.* The average temperature of the water source (°C).
- *Baseline Turbidity.* This is a measure of the non-plankton turbidity of the water source expressed in terms of *chlorophyll-a* equivalents (mg *Chlor*-a/m3).
- *pH.* pH of the source water.
- *Alkalinity.* Source water alkalinity (i.e., total base concentration) as mg/L of CaCO3.
- *Organic Carbon.* Concentration of organic carbon in the source water (mg C/L).

Level 2 variables

- *Total N.* Total nitrogen content of the source water (mg N/L).
- *Total P.* Total phosphorus content of the source water (mg P/L).

Level 3 variables

- *Organic N*. Organic nitrogen content of the source water (mg N/L).
- *Ammonia*. Total ammonia nitrogen (NH3-N + NH4-N) content of the source water.
- *Nitrate*. Nitrate-nitrogen (NO3-N) content of the source water (mg N/L).
- *Organic P*. Organic phosphorus content of the source water (mg P/L).
- *Inorganic P*. Inorganic phosphorus content of the source water (mg P/L).
- *DO*. Dissolved oxygen content of the source water (mg O2/L).

Pond Database

Water Balance Options

State Variables

POND is focused on two main concepts: 1) defining physical ponds, and 2) defining the fish populations (lots) that occupy these ponds. For a given site, any number of ponds may be defined. Lots are considered distinct from ponds to allow multiple fishlots (either the same species or differing species) to occupy the same pond, or to allow the simulation of ponds with no fish. The Lot database is discussed at a later point in this chapter.

To define a new pond, or modify, copy or delete an existing pond, select the *Parameters/Ponds* menu option or push the <Ponds> toolbar button. The **Pond Parameters** dialog will appear:

- *Pond Name.* The name of the pond. This is used as an identifier for this specific pond and can be any name.

Dimensions

- *Width.* Nominal width of the pond (meters).
- *Length.* Nominal length of the pond (meters).
- *Depth.* Average depth of the pond (meters).
- *Slope.* Levee or dike slope (rise over run).

Water Balance Options

Click on the *Use Water Balance* box to indicate that water balance calculations are to be performed for the pond. Push the <Water Balance> button to view the dialog box:

This dialog box is used to indicate the source water for the pond in question, and to select water balance and/or flow choices. These choices are strictly optional and users may select the desired ones by checking the appropriate boxes. Parameters associated with the choices can be modified after the boxes are checked.

NOTE: Water balance calculations impact the Critical Standing Crop parameter (see Fish Lot database below) and therefore fish growth predicted by the use of Level 1 models. If it is desired to predict both water requirements and fish growth by the use of Level 1 models, one possible solution is to run two simulations, one with the *Use Water Balance* box left unchecked, and the other with the desired water balance options. Use results from the first simulation to evaluate the predicted fish growth, and those from the second one to examine water requirements.

Water Inflow Options

- *Water Source.* Name of the water source for this pond. This is associated with a specific record in the Source Water database, and must be a previously defined water source.

There are two options for indicating flow rate through a pond:

- *Specify Influent Rate.* This option is to be used when the inflow rate (% pond volume/day) for the pond is already known.
- *Estimate influent to maintain operating depth .* This option is to be used when the inflow rate required to maintain the pond at the depth specified in the **Pond Parameters** dialog box is to be estimated.
- *Use Watershed inflow area.* Check this box if runoff water from the watershed surrounding the pond is to be considered in the water balance calculations. These calculations are done on the basis of the runoff model developed by the U.S. Soil Conservation Service. Refer to Yoo and Boyd (1994; Hydrology and Water Supply for Pond Aquaculture, Chapman & Hall, pgs. 97-103) for further details regarding these calculations.
- *Watershed Area*. If the above box is checked, enter an estimate of the land area (ha) that drains into the pond following a rainfall event.
- *Effective Runoff Curve Number*. This parameter is used to adjust the actual amount of water that may drain into the pond as a result of a rainfall event and is dependent on several factors including the soil moisture content and land cover type. Approaches that can be used to estimate the appropriate curve number for a given location are outlined in Yoo and Boyd (1994; see above).

Water Loss Options

- *Use Maximum Pond Depth.* Maximum depth of the pond basin (m). Use this option to indicate that water in excess of this depth is to be automatically discharged from the pond.
- *Use Effluent Rate.* Use this option to specify the rate of water discharge from the pond (% pond volume/day).
- *Use Pond Seepage.* Use this option to indicate water loss or gain via seepage (mm/day). ***NOTE:*** *Positive values indicate loss and negative values indicate gain.*
- *Use Evaporation.* Use this option to indicate whether evaporative water losses (mm/day) are to be considered.

State Variables

Initial conditions of the state variables can be specified in this section of the Pond database. Because water temperature is simulated at all three modeling levels, the field for entering values of this state variable is located in the **Pond Parameters** dialog box:

- *Water Temperature.* The initial depth-averaged temperature of the pond (°C).

Other variables (used only at Level 2 and 3) are accessed by pushing the <Level 2,3 Options> button, which brings up the following dialog box:

Level 2, 3 Options

The list of state variables is organized into three categories: (a) Variables common to both Level 2 and 3, (b) Variables specific to Level 2, and (c) Variables specific to Level 3.

Variables Common to Level 2 and 3

- *Zooplankton.* Initial concentration of zooplankton (g/m3).
- *Phytoplankton A.* Initial concentration of phytoplankton pool A (gC/m3).
- *Phytoplankton B.* Initial concentration of phytoplankton pool B (gC/m3).
- *Bacteria.* Initial bacterial (detrital) concentration in the pond water (g/m3).
- *Baseline Turbidity.* This is a measure of the turbidity of the pond water without plankton, which should be estimated prior to the introduction of fish or fertilizer. In flow-through systems, it is the turbidity of the influent water. Units for this variable are *chlorophyll-a* equivalents (mg *Chlor*-a/m3).
- *Organic Carbon.* Initial concentration of organic carbon in the pond water (mgC/L).
- *Alkalinity.* Initial total alkalinity of the pond water (mg CaCO3/L).
- *pH.* Initial pH of the pond water.
- *Salinity.* Initial salinity of the pond water (ppt).

Level 2 Only

Pond Water

- *Tot N* . Total nitrogen content of the pond water (mgN/L).
- *Tot P.* Total phosphorus content of the pond water (mgP/L).

Sediments

- *Tot N.* Total nitrogen content of the pond sediment (gN/m2).
- *Tot P.* Total phosphorus content of the pond sediment (gP/m2).
- *Tot C.* Total carbon content of the pond sediment (gC/m2).

Level 3 Only

Pond Water

- *Organic N.* Organic nitrogen content of the pond water (mgN/L).
- *Ammonia.* Total ammonia nitrogen (NH3- + NH4-N) content of the pond water.
- *Nitrate.* Nitrate-nitrogen (NO3-N) content of the pond water (mgN/L).
- *Organic P.* Organic phosphorus content of the pond water (mgP/L).
- *Inorganic P.* Inorganic phosphorus content of the pond water (mgP/L).
- *DO.* Dissolved oxygen content of the pond water (mgO2/L).

Sediments

- *Organic N.* Organic nitrogen content of the pond sediment (gN/m2).
- *Ammonia.* Total ammonia nitrogen (NH3- + NH4-N) content of the pond sediment (gN/m2).
- *Nitrate.* Nitrate-nitrogen (NO3-N) content of the pond sediment (gN/m2).
- *Organic P.* Organic phosphorus content of the pond sediment (gP/m2).
- *Inorganic P.* Inorganic phosphorus content of the pond sediment (gP/m2).

- *Organic Carbon.* Organic carbon content of the pond sediment (gC/m2).

Run from File
Use this option to specify certain pond variables that may be known. These include Secchi disk visibility, and fertilization rates in terms of nitrogen, phosphorus and carbon (all in kg/ha/day). The ASCII files in which the variables are specified can be located on the appropriate drive by pushing the <Find> button. These files are comma-delimited and *must* be created outside POND (e.g., with a Windows text editor) with the following format:
Line 1: Labels for time (Julian Day; JD), Secchi depth, and fertilization rates.
Remaining lines: Daily values for each of the above items.

If variables change during the culture period, POND will simply interpolate to fill in intermediate values. If the production period starts at the end of one year and proceeds into the next, time for the second year must be specified in increasing order. For example, if data are available from October 10 of the first year upto to March 23 of the second year, the time column should start on JD 283 and proceed to JD 447.

An example pond file is as follows:

time, secchi, totNitHa, totPhosHa, totCarbHa
44,20,0.57,0.14,0.35
51,15,0.57,0.14,0.35
58,15,0.57,0.14,0.35
...
142,15,0.57,0.14,0.35
149,12,0.57,0.14,0.35

Fish Lot Database

State Variable Initial Conditions

Additional Lot Parameters

Feed Options

Fish lots are the fundamental unit of production in POND. A fish lot consists of a single group of fish with homogeneous characteristics. Any number of fish lots can be defined, and any number of lots can be present in a given pond. To define a new fish lot, or modify, copy or delete an existing lot, select the *Parameters/Fish Lots* menu option or push the <Lots> toolbar button. The **Fish Lot Parameters** dialog will appear:

- *Fish population (Lot Name).* This is used as an identifier for this lot and can be any name.

Information

- *Species Name.* Name of the species for this lot. This name is associated with a specific record in the Species database, and must be a previously defined species.
- *Associated Pond.* This defines the pond where the lot is located, and must be one of the previously defined ponds.
- *Survival Rate.* Indicates the expected survival rate of the population, expressed as a decimal percent, over the course of a simulation period.

State Variable Initial Conditions

This section is used to define initial conditions for the state variables that are maintained for each defined lot. The variables include:

- *Stocking Density.* Number of fish in this lot (no. of fish/ha).
- *Stocking Weight.* Average initial weight of an individual fish in the lot (g).

Additional Lot Parameters

Additional lot parameters are accessed by pushing the <Additional Parameters> button, which brings up the following dialog box:

Start/Harvest Dates

This section is used to specify starting (stocking) and harvest dates for the relevant lot. If the boxes adjacent to the starting/harvest dates are not checked, POND assumes that lots are stocked and harvested on the first and last days respectively of a simulation run.

***NOTE**: It is necessary to ensure that the stocking and harvest dates fall within the period of simulation* (*see the section on Running a Simulation*, *Chapter 5).*

- *Use Starting Date*. If the Use Starting Date box is checked, the date of stocking is to be specified by the use of a month-day-year format.
- *Use Harvest Date.* If the Use Harvest Date box is checked, the date of harvest is to be specified by the use of a month-day-year format.

Level 1 Options

- *Critical Standing Crop*. Refers to the Critical Standing Crop (CSC; kg/m3) of fish in the pond. This is the biomass of fish above which food limitation occurs in a fertilized pond.

NOTE: Water balance calculations (refer to section dealing with the Pond database above) impact CSC and therefore fish growth predicted by the use of Level 1 models. This is because use of the CSC assumes a constant pond volume. If it is desired to predict both water requirements and fish growth by the use of Level 1 models, one possible solution is to run two simulations, one with the *Use Water Balance* box left unchecked, and the other with the desired water balance options. Use results from the first simulation to evaluate the predicted fish growth, and those from the second one to examine water requirements.

Feed Options

This section in the **Fish Lot Parameters** dialog is used to specify the type of food available for consumption by a particular lot. Depending on the associated species and/or management practices, various feed options (natural feed only, natural and artificial feed or artificial feed only) can be specified by checking appropriate boxes. If artificial feeds are used, a feed source must be specified. Further, feeding rates can either be estimated by running the POND models or specified by the user.

- *Natural Feed.* Select this option if the lot can use natural food available in the pond.
- *Artificial Feed.* Select this option when artificial feed is presented to the lot. Use the Select Feed Type option to select the specific feed (from the previously defined list in the Feed database) presented to the lot.
- *Estimate feeding rate.* Use this option if POND is to predict the amount of artificial feed to be added so as to meet the Satiation or Target level of feeding. A target level of 50% implies that the fish in the relevant lot are to be fed to 50% of satiation.
- *Specify feeding rate from file.* Use this option if feeding rates (% body weight/day) are known and may vary during the culture period. The ASCII files in which feeding rates are specified can be located on the appropriate drive by pushing the <Find> button. These files are comma-delimited and *must* be created outside POND (e.g., with a Windows text editor) with the following format:

Line 1: Labels for time (Julian Day; JD) and feeding rates.
Remaining lines: Daily values for each of the above items.

If feeding rates are adjusted during the culture period, POND will simply interpolate to fill in intermediate values. If the production period starts at the end of one year and proceeds into the next, time for the second year must be specified in increasing order. For example, in the lot file below, feeding rates are available from October 10 (JD 283) of the first year (1993) to March 23 (JD 447) of the second year (1994). Feeding rates are adjusted after 60 days. The file format required is as follows:

time, *feedRateBW*
283, 3
343, 3
344, 1.5
447, 1.5

Fish Species Database

Level 2, 3 Options

Species characteristics are maintained in the Species database. Any number of species can be defined and used for any fish lot. This allows users to apply POND to many different culture species and to do initial experiments with polyculture representations. Each field in the species record corresponds to a model parameter used for a simulation. To define a new species record, or modify, copy or delete an existing species, select the *Parameters/Species* menu option or push the <Species> toolbar button. The **Species Parameters** dialog will appear:

The dialog contains parameters that are used at all simulation modeling levels. Additional parameters used only at Level 2 and 3 can be edited in an associated dialog box (see ***Level 2, 3 options*** below).

- *Fish Species*. The name of the species. This is used as an identifier for specific records and can be any name.

Anabolism parameters

- *Efficiency of Assimilation.* Refers to the proportion of food intake that is available for metabolism (i.e., metabolizable food).
- *Anabolism Exponent.* Refers to the exponent that relates anabolism to fish weight.
- *Food Consumption Coeff.* This coefficient relates food consumption to fish weight.

Catabolism parameters

- *Feeding Catab Coeff.* Refers to the proportion of metabolizable food used for digestion and assimilation.
- *Catabolism Exponent.* Refers to the exponent that relates catabolism to fish weight.
- *Minimum Catab Coeff.* Refers to the coefficient of catabolism at the minimum temperature (see below) for the species.

Temperature scalers

- *Minimum Temperature.* The minimum temperature (°C) below which food intake will not occur.
- *Maximum Temperature.* The maximum temperature (°C) above which food intake will not occur.
- *Optimum Temperature.* The temperature (°C) at which food intake is at a maximum.

Level 2, 3 Options

Species parameters that are used only at Level 2 and 3 can be accessed by pushing the <Level 2, 3 Options> button from the Species Parameters dialog box. This brings up another dialog box:

Half-Saturation Constants

In this section, users can indicate food resources that the fish species is known to consume by checking the appropriate boxes. The associated half-saturation constants can be used to adjust the rate of uptake of the specified resources. A relatively high half-saturation rate indicates a lower rate of food intake. For example, if a certain fish species prefers food represented by Phytoplankton Pool A as opposed to Phytoplankton Pool B, a lower half-saturation constant should be specified for the former relative to the latter:

- *Phytoplankton A.* Monod half-saturation value (gC/m3) for fish uptake from the first phytoplankton pool.
- *Phytoplankton B.* Monod half-saturation value (gC/m3) for fish uptake from the second phytoplankton pool.
- *Artificial Feed*. The half-saturation constant for artificial feed is handled somewhat differently from other food resources because is difficult to estimate feed concentrations in a pond. Preference is indicated by the use of a 0-1 scale, with a lower value implying high preference.
- *Zooplankton*. Monod half-saturation value (g/m3) for fish uptake of zooplankton.
- *Bacteria.* Monod half-saturation value (g/m3) for fish uptake of bacteria (detritus).

Minimum thresholds for uptake

These parameters are used to define the minimum concentrations of natural food resources above which the fish species will commence consumption:

- *Phytoplankton A .* Minimum concentration of phytoplankton pool A above which consumption occurs (gC/m3).
- *Phytoplankton B.* Minimum concentration of phytoplankton pool B above which consumption occurs (gC/m3).
- *Zooplankton* . Minimum concentration of zooplankton above which consumption occurs (g/m3).
- *Bacteria.* Minimum concentration of bacteria/detritus above which consumption occurs (g/m3).

Oxygen Scalers

- *Minimum DO.* Minimum dissolved oxygen concentration in the pond water below which fish will not feed (mgO2/L).
- *Critical DO.* Dissolved oxygen concentration of the pond water above which food intake is not affected (mgO2/L).

Unionized Ammonia Scalers

- *Maximum.* Maximum concentration of unionized ammonia nitrogen (NH3-N) in the pond water above which fish will not feed (mgN/L).
- *Critical.* Concentration of unionized ammonia nitrogen (NH3-N) in the pond water below which food intake is not affected (mgN/L).

Site Database

POND allows the definition of site parameters for any number of sites. At any given time, only one site can be active. The site parameters give basic locational data which are used for climate calculations. To define a new site, or modify, copy or delete an existing site, select the *Parameters/Site* menu option or push the <Site> toolbar button. The **Site Parameters** dialog will appear:

- *Site name.* This is used as an identifier for the site and can be any name.

Location

- *Latitude.* Latitude for this site (degrees). Minutes of latitude must be specified as a decimal fraction of a degree.
- *Longitude.* Longitude for this site (degrees). Minutes of longitude must be specified as a decimal fraction of a degree.
- *Altitude.* Altitude (above mean sea level) of the site (m).

Hemisphere

- *Northern.* North of the Equator.
- *Southern.* South of the Equator.

Meridian

- *West.* West of the Greenwich meridian.
- *East.* East of the Greenwich meridian.

Soil Database

Soil characteristics are defined in the Soils database. At any given time, only one soil can be active. The soils parameters give basic information about the soil, and are currently used only for the lime requirements calculations (see Chapter 4). To define a new soil, or modify, copy or delete an existing soil, select the *Parameters/Soils* menu option or push the <Soil> toolbar button. The **Soil Parameters** dialog will appear:

Soil inputs

- *Soil Name.* This is used as an identifier for the soil type and can be any name.
- *Soil pH.* pH of the soil.
- *Soil PBS.* Refers to the Percent Base Saturation, which is the percentage of the CEC (see below) occupied by basic cations. This should be entered as a decimal fraction.
- *Desired PBS.* Refers to the desired or target Percent Base Saturation. This should also be entered as a decimal fraction.
- *CEC.* Refers to the Cation Exchange Capacity (millequivalents/100g), which is the capacity of the soil to adsorb exchangeable cations.
- *Liming Depth.* This is the depth of the pond soil (cm) up to which lime reaction is expected to occur.
- *Soil Density.* Refers to the weight of one cubic centimeter of dry soil (g/cc). This property of soils is also called bulk density.

Fertilizer Database

Fertilizer characteristics are defined in the Fertilizer database. The fertilizer parameters give basic information about the nutrients available in the fertilizer, and are used to determine fertilizer amounts required to meet specific productivity levels. Typical characteristics of several synthetic fertilizers and manures have been made available in POND. It is important to note that fertilizer characteristics vary greatly and that some of the values (e.g., inorganic/organic nitrogen and phosphorus contents) in the database are essentially 'best guesses'. Therefore, nutrient characteristics of fertilizers that may actually be used in ponds should preferably be estimated and entered into the Fertilizer database wherever possible.

Total nitrogen (N) in any fertilizer is assumed to be the sum of organic-, ammonia- and nitrate-N forms. Similarly, total phosphorus (P) is the sum of organic- and inorganic-P forms. The term 'availability' that is used for nitrogen (N) and phosphorus (P) refers to the expected proportion of these nutrients that is expected to become available for phytoplankton uptake following fertilizer application. For all practical purposes, synthetic fertilizers may be assumed to have a nutrient availability of 100%. However, nutrient availability from organic fertilizers such as manures is typically lower.

In POND, available N and P are assumed to be equivalent to the sum of ammonia- and nitrate-N forms, and inorganic-P respectively. In other words, the sum of these forms should be equivalent to the proportion entered in the 'Availability' fields below. Data for the ammonia and nitrate-N, and inorganic-P fields below are required only if more complex simulation Level 3 models are to be used (see the *Introduction* section in Chapter 5).

Users may optionally add any number of other fertilizers, or modify, copy or delete the existing ones by selecting the *Parameters/Fertilizers* menu option or pushing the <Fertilizers> toolbar button. The **Fertilizer Parameters** dialog will appear.

Fertilizer types

- *Name.* The name of the fertilizer. This is used as an identifier for the fertilizer and can be any name.
- *Nitrogen.* Total nitrogen content of the fertilizer (% wet weight).
- *Availability.* Refers to the proportion (%) of the total N in the fertilizer that is expected to become available as dissolved inorganic nitrogen after fertilizer application to the pond.
- *Organic.* Refers to the proportion of the total nitrogen in the fertilizer that is in organic form (as % total N). This is considered to be unavailable for algal uptake.
- *Ammonia.* Refers to the proportion of ammonia-N (NH3-N + NH4-N) in the fertilizer (as % total N) at the time of application.
- *Nitrate.* Refers to the proportion of the nitrate-N (NO3-N) in the fertilizer (as % total N) at the time of application.
- *Phosphorus.* Total phosphorus content of the fertilizer (% wet weight).
- *Availability.* Refers to the proportion (%) of the total P in the fertilizer that is expected to become available as dissolved inorganic phosphorus after fertilizer application to the pond.
- *Organic.* Refers to the proportion of the total P in the fertilizer that is in organic form (as % total P). This is considered to be unavailable for algal uptake.
- *Inorganic.* Refers to the proportion (%) of the total P in the fertilizer that is expected to become available as dissolved inorganic phosphorus after fertilizer application to the pond.
- *BOD.* 5-day Biochemical Oxygen Demand of the fertilizer (% wet weight). For inorganic fertilizers, this is generally zero. For organic fertilizers, BOD is used in POND as a measure of the biologically available carbon in the fertilizer.
- Cost. Local cost (per kg) of the fertilizer. The currency used is arbitrary, but consistency must be maintained across POND.

Feed Database

Feed characteristics are defined in the Feed database. These characteristics give basic information about feed composition. At the current time, some feed characteristics (energy, protein, lipid and carbohydrate) are not used in the POND models. However, it is anticipated that they will be used in future releases of the software. Further, note that several feed characteristics are to be specified on a percent dry matter (%DM) basis.

Feeds can be optionally added, modified, copied or deleted by selecting the *Parameters/Feed* menu option or pushing the <Feed> toolbar button. The **Feed Characteristics** dialog will appear:

Feed types

- *Name.* The name of the feed type.
- *Cost.* Cost of the feed (per kg). The currency used is arbitrary, but consistency must be maintained across POND.
- *Moisture.* Total moisture content of the feed (%).
- *Energy.* Total energy content of the feed (Kcal/kg).
- *Protein.* Total protein content of the feed (%DM).
- *Lipid .* Total lipid content of the feed (%DM).
- *Carbohydrate.* Total carbohydrate content of the feed (%DM).
- *Total Nitrogen.* Total nitrogen content of the feed (%DM).
- *Total Phosphorus.* Total phosphorus content of the feed (%DM).
- *Total Carbon.* Total carbon content of the feed (%DM).
- *Quality Coefficient.* Refers to the coefficient of feed quality (0-1). This parameter is used as a lumped measure of feed accessibility, feeding practices and feed quality. A value of one implies that all of the feed added is available for consumption. A value of 0.5 implies that 50% of the added feed is available for consumption; the remaining feed being wasted.

Lime Database

Liming material characteristics are defined in the Lime database. Any number of materials can be defined by the user. The information entered is a measure of the efficacy of the liming material to neutralize soil acidity. To define a new liming material, or modify, copy or delete an existing material, select the *Parameters/Liming Material* menu option or push the <Lime> toolbar button. The **Liming Material Parameters** dialog will appear.

Liming sources

- *Name.* The name of the liming material. This is used as an identifier for the material and can be any name.
- *Liming Coefficient.* Refers to the ratio of the neutralizing value of pure calcium carbonate (mg CaCO3) to that of the liming material (mg).
- *Cost.* Local cost (per kg) of the material. The currency used is arbitrary, but consistency must be maintained across POND.

Weather Database

Weather parameters are set somewhat differently from the other records in the input databases, in that only one record can be defined at any given time. The parameters allow high-level control of weather conditions during a simulation run.

To set the weather parameters, select the *Parameters/Weather* menu option or push the <Weather> toolbar button. The **Weather Parameters** dialog will appear.

The sections in this dialog box that relate to *Cloud Cover*, *Season*, *Wind Speed Parameters* and *Additional Parameters* should be modified only if the weather generator within POND is to be used. If actual weather data are available, use the *Run from File* option.

Cloud Cover
This section is used to specify the predominant type of cloud cover (Clear, Broken, Scattered or Overcast) to be used for a simulation period. The selection determines (a single) cloud cover value that will be used by the weather generator inside POND for an entire simulation. An additional option (*Random*) causes cloud cover values to be generated randomly for each day of the simulation. This is achieved by the use of a random number generator which assumes cloud cover to be normally distributed for a given season. Random generation of cloud cover data is somewhat different depending on whether the season is primarily wet or dry (see below).

Season
This field is active only if the *Random* cloud cover option is selected. The season may be specified to be either predominantly *Wet* or *Dry*.

Wind speed parameters
This section handles use of wind speed data.

- *Mean Speed.* Refers to the mean wind speed at the location (meters/sec). If the *Generate Wind Data Randomly* box below is ***not*** checked, the mean wind speed (i.e., a constant value) is used for the entire period of simulation.
- *Generate Wind Data Randomly.* Check this box if wind speed data are to be generated for each day of a simulation. In this case, the data are generated by the use of a normal distribution which assumes a mean wind speed (as specified above) and a standard deviation (see below).
- *Standard Deviation.* This field is active only if the Generate Wind Data Randomly box is checked. It is used to enter the standard deviation of the normal distribution from which wind speed data are to be drawn.

Additional parameters
- *Temperature Change Factor.* Indicates the rate at which temperate changes as a function of altitude. The value represents the decrease in temperature for each 100 m of altitude above sea level.
- *Daily Air Temperature Amplitude.* Indicates the typical range of daily temperature fluctuations (°C) at the site.
- *Relative humidity.* Indicates the typical relative humidity at the site.

Run from file
If actual weather data for a given location are available and weather simulation is *not* desired, the *Run from file* option can be used. In this case, an input file must be specified. Data required in the input file are as follows:

Time (Julian day),

Minimum air temperature (°C),
Maximum air temperature (°C),
Incident solar radiation (kJ/m2/day),
Solar radiation penetrating the water surface (kJ/m2/day),
Cloud cover (decimal percent),
Wind speed (m/s),
Precipitation (mm/day), and
Relative humidity (%).

The input file *must* follow the following format:

Line 1: Labels for the time, minimum temperature, maximum temperature, solar radiation, solar radiation penetrating water surface, cloud cover, wind speed, precipitation and relative humidity.

Remaining lines: Daily values for each of the above parameters, separated by *commas*, in increasing order. Missing data in the weather data set are allowed; POND will simply interpolate between the closest days to fill in missing daily values.

For simulations that span multiple years or to simulate a production period that starts towards the end of one year and proceed into the next, the Julian day (JD) for the second and following years must be specified in increasing order. For example, in the input file below, data are available from October 10 (JD 283) of the first year (1989) to March 23 (JD 447) of the second year (1990). Data for this file were extracted from the PD/A CRSP database for the site in Butare, Rwanda.

Example: (HWP5TMPA.WDB)

```
time,minTemp,maxTemp,solRad,solRadWater,cloudCover,windSpeed,Precip,RelHumid
283,11,29,13435.92,12629.76,0.5,1.636574,0,80
284,12,30,8545.992,8033.232,0.5,0.944444,18,80
285,12,28,9183.149,8632.16,0.5,1.157407,25,80
286,11,29,13183.08,12392.09,0.5,1.197917,0,80
...
442,13,26,11023.82,10362.39,0.5,0.782407,20,80
443,12,29,13724.15,12900.71,0.5,0.729167,14,80
444,14,29,11256.44,10581.05,0.5,1.061343,3,80
445,13,29,15190.63,14279.19,0.5,0.62037,0,80
446,14,30,16454.83,15467.54,0.5,0.797454,0,80
447,12,29,12894.84,12121.15,0.5,0.767361,0,80
```

Note that values of solar radiation penetrating the water surface were not available; instead, such values were calculated from incident solar radiation data in the PD/A CRSP database assuming shortwave reflective losses to approximate 6%. Further, cloud cover data were also not available. Therefore, a value of 0.5 for 'clear conditions' was assumed. Finally, relative humidity data are not routinely reported in the CRSP database and a constant value of 80% was assumed for the entire weather dataset.

Other example weather files (also with the .wdb extension) that have been extracted from the PD/A CRSP database are provided on the POND diskette.

Cost Database

Any cost and income items associated with the aquaculture facility can be defined in the Economics database. There is no limit on the number of items that can be defined by the user. The cost parameters provide information required to build an enterprise budget. To define a new item, or modify, copy or delete an existing item, select the *Parameters/Economics* menu option or push the <Cost> toolbar button. The **Economic Parameters** dialog will appear.

Cost/income items

- *Name.* The name of the cost or income item. This is used as an identifier for the item and can be any name.
- *Price.* This field represents a generic variable, which assumes different meanings when used for depreciable assets, fixed cost items, variable cost items, and income. For a depreciable asset, the value entered is assumed to be the *purchase price* for the item whereas for a fixed cost item, the value entered should reflect the cost of the item over the analysis period, which is usually for one year. For variable cost items, the cost per unit of the item should be entered. For income items, the income per unit of the item should be entered. The currency used is arbitrary, but must be used consistently across POND. The actual number of units should be consistent with the cost basis specified in the Cost Basis field (see below).
- *Variance.* Not used at this time.
- *Number of Units.* Refers to the number of units of the material used or produced during production.
- *Unit Descriptor.* Refers to the appropriate description of the units that are used for a particular item (e.g., per kg or per liter). This is an optional field and is solely intended to help the user keep track of various cost and income items.

Cost Basis

This refers to the cost basis that has been used to enter information about the price and number of units of the cost/income items. Three options are supported:

- *Per Unit of Production.* This is to be used when the price and number of units of the cost/income items are expressed on the basis of a unit of fish production (e.g., per kg).
- *Per Unit of Area.* This is to be used when the price and number of units of the cost/income items are expressed on the basis of a unit of pond area (e.g., per ha).
- *Total.* This is to be used when the price and number of units of the cost/income items are expressed on the basis of totals for the entire enterprise or facility.

Cost type

- *Depreciable Cost.* For items which are purchased for long-term use and then depreciated over the lifetime of service for the item. Examples include pumps, heavy equipment, and buildings. For these items, a *salvage value* must also be specified. This value is subtracted from the item cost to determine a fixed depreciation schedule for the item.
- *Fixed Cost.* For items which incur a known, constant expense over the multiple periods of analyses. Examples include land and pond costs. For these items, a *useful life* must be specified.
- *Variable Cost.* For items which incur costs that vary with factors such as the amount of production and type of management. Examples include costs for fingerlings, fertilizers, feed, and fuel.
- *Income.* For items that can be sold for profit. Typically, this includes only marketable fish. If you want to use this item as part of the production basis, check the Is this a production item box.
- *Include in Budget Calculations.* Check the *Include in Budget Calculations* button to include the currently active item in the enterprise budget. To exclude the item from the budget, uncheck this button.

Other

In addition to the fields above (which are relevant to specific items), the following *global* fields are provided:

- *Interest Rate*. This section is used to specify the annual interest rate in percent per year for *Variable Costs* and *Fixed Costs*. Because interest rates typically vary for these two categories of costs, separate fields are provided to enter the rates.
- *Area for Reporting*. Specifies the pond area to be used to account for the *Per Area* option indicated above. If the budget is generated from a simulation run, this will automatically be set based on the area of the ponds in the simulation.

Simulation Database

Level 1 Options

Level 2 Options

Level 3 Options

POND allows users to specify different *simulation scenarios* that can be used to control simulation runs. These scenarios contain information on the level of resolution of the simulation, parameters for the associated models, and specifications for fertilizer management during the simulation run. To define a new item, or to modify, copy or delete an existing item, select the *Parameters*/*Simulation* menu item. Alternatively, it can be accessed by pushing the <Simulation> button from within the **Pond Simulation Control** dialog when starting a simulation run.

Simulation Scenario
Name. The name of the scenario. This is used as an identifier for the particular scenario and can be any name.

Simulation Levels
This section is used to select the desired level of modeling (*Level 1*, *Level 2* or *Level 3*).
Once a modeling level is selected, the adjacent push button becomes active and can be used to access various options associated with the level as described below.

Level 1 Options

Specify Fertilization Parameters

Nutrient Thresholds

Other Sources and Sinks

Options available within a simulation scenario for Level 1 modeling are limited to specification of **Fertilization Options**:

Fertilizer Options

Available fertilizer options include:

- *Specify by Rate*. Use this option to specify a known application rate (kg/ha/day) of nitrogen (N), phosphorus (P) and carbon (C).
- *Specify by Type*. Use this option to specify a known application rate (kg/ha/day) of a single fertilizer.
- *Estimate Fertilizer Needs*. Use this option if fertilizer requirements are to be estimated by the software. The associated push button becomes active once the selection is made and leads to additional dialog boxes that can be used to edit various parameters as described below.

Specify Fertilization Parameters

When the <Specify Parameters> button is pushed, the **Fertilization Parameters** dialog appears:

Phytoplankton Parameters

This section provides access to parameters associated with the phytoplankton model used to estimate fertilizer requirements.

Maximum Gross Primary Productivity. Refers to the maximum, light-limited value of gross primary productivity for the particular location. Units are gC/m3/day.

Limiting Factors

Nutrients that may limit phytoplankton growth (i.e., inorganic nitrogen, phosphorus and carbon) are indicated by checking the appropriate boxes. If it is desirable to examine fertilizer requirements under conditions where one or more of the nutrients are non-limiting to phytoplankton growth, the associated boxes can be unchecked. Half-saturation constants (mg/L) for nutrient uptake by phytoplankton can also be edited once the associated boxes are checked. Higher half-saturation constants for any nutrient indicate a slower uptake rate by phytoplankton. Conversely, lower values for the constants are indicative of more rapid uptake rates.

Temperature scalers

- *Minimum Temperature.* The minimum temperature (°C) below which phytoplankton will not grow.
- *Maximum Temperature.* The maximum temperature (°C) above which phytoplankton will not grow.
- *Optimum Temperature.* The temperature (°C) at which phytoplankton growth is at a maximum.

Nutrient Thresholds

When the <Nutrient Thresholds> button is pushed, the **Nutrient Parameters** dialog box appears:

Threshold Concentrations

This dialog box is used to edit minimum (threshold) concentrations of *inorganic* nitrogen, phosphorus and carbon (all in mg/L). The underlying assumption with such thresholds is that phytoplankton may be able to use the associated nutrients only if their concentrations exceed the threshold values.

Other Sources and Sinks

Pushing the <Other Sources and Sinks> button brings up the following dialog box:

Nutrient sources and sinks

This dialog box is used to specify nutrient sources or sinks that are not included in the mass balance equations for *inorganic* nitrogen, phosphorus and carbon. These additional sources or sinks may be specified in terms of either percent/day or g/m2/day.

***NOTE**: Sources and Sinks must be indicated as positive and negative values respectively.*

Level 2 Options

Nutrient Thresholds
Other Sources and Sinks
Zooplankton Parameters

Several options may be edited to set up a Level 2 simulation scenario. Access to these options is available via the **Level 2 Parameters** dialog.

Phytoplankton Parameters
This section deals with different parameters/methods associated with the phytoplankton model used at Level 2.

Maximum Specific Growth Rate. Refers to the maximum growth rate per unit of phytoplankton biomass. Units are gC/gC/day = 1/day.

Limiting Factors
Nutrients that potentially limit phytoplankton growth (i.e., total nitrogen, phosphorus and carbon) are indicated by checking the appropriate boxes. The half-saturation constants (mg/L) for their uptake by phytoplankton can also be edited. Higher half-saturation constants for any nutrient indicate a slower uptake rate by phytoplankton. Conversely, lower values for the constants are indicative of more rapid uptake rates.

***NOTE**: Units for the nutrients are expressed in terms of their **total** concentrations. In other words, Level 2 does not distinguish between organic and inorganic forms of the nutrients.*

Multiple Limiting Factors Analysis
Growth limitation of phytoplankton by nutrients (as specified under *Limiting Factors* above), light and/or temperature may be described by one of the following methods:

- *Use Minimum*. This method calculates the individual effects of light, temperature and each of the limiting nutrients on phytoplankton growth, and sets the overall effect of limiting factors to the individual effect with the lowest value (i.e., to the one that is most limiting to growth).
- *Use Inverse Sum*. This method sets the overall effect of the limiting factors to the sum of the inverse value of the individual effects of light, temperature and each of the limiting nutrients on phytoplankton growth.
- *Use Mean*. This method sets the overall effect of the limiting factors to the mean value of the individual effects of light, temperature and each of the limiting nutrients on phytoplankton growth.

Temperature scalers
- *Minimum Temperature.* The minimum temperature (°C) below which phytoplankton will not grow.
- *Maximum Temperature.* The maximum temperature (°C) above which phytoplankton will not grow.
- *Optimum Temperature.* The temperature (°C) at which phytoplankton growth is at a maximum.

Other Coefficients
- *Respiration.* Refers to the phytoplankton respiration rate (1/day) at a base water temperature of 20°C.
- *Death*. Refers to the phytoplankton death rate (1/day).

Light Extinction/Secchi Model Parameters

Alpha, *Beta*. These parameters are used in a POND function that predicts Secchi depth in ponds as a function of turbidity due to plankton and non-plankton sources.

Secchi Constant. This parameter is used to estimate light extinction in ponds as a function of Secchi depth.

Nutrient Thresholds

Pushing the <Nutrient Thresholds> button in the above dialog box brings up the **Nutrient Parameters** dialog.

Threshold Concentrations

The Nutrient Parameters dialog box is used to edit minimum (threshold) concentrations of *total* nitrogen, phosphorus and carbon (all in mg/L). The underlying assumption with such thresholds is that phytoplankton may be able to use the associated nutrients only if their concentrations exceed the threshold values.

Other Sources and Sinks

Pushing the <Other Sources and Sinks> button in the Level 2 Model Parameters dialog box brings up the **Additional Sources and Sinks** dialog.

Nutrient sources and sinks

Use this dialog box to specify nutrient sources or sinks that are not included in the mass balance equations for *total* nitrogen, phosphorus and carbon. These additional sources or sinks may be specified in terms of either percent/day or g/m2/day.

***NOTE**: Sources and Sinks must be indicated as positive and negative values respectively.*

Zooplankton Parameters

Pushing the <Zooplankton Parameters> button in the Level 2 Model Parameters dialog box brings up the **Zooplankton Parameters** dialog.

Maximum Specific Growth Rate. Refers to the maximum growth rate per unit of zooplankton biomass. Units are g/g/day = 1/day.

Phytoplankton Consumption

This section deals with different parameters associated with the consumption of phytoplankton by zooplankton. The *phytoplankton half-saturation* constants can be used to adjust the rate of uptake of the respective pools (e.g., a relatively high half-saturation rate indicates a lower rate of intake). For example, if the zooplankton pool prefers food represented by Phytoplankton Pool A as opposed to Pool B, a lower half-saturation constant should be specified for the former relative to the latter.

- *Pool A Half-saturation.* Monod half-saturation value (gC/m3) for zooplankton uptake from the first phytoplankton pool.
- *Pool B Half-saturation.* Monod half-saturation value (gC/m3) for zooplankton uptake from the second phytoplankton pool.
- *Minimum threshold for uptake*. Minimum concentration of the phytoplankton pools (gC/m3) above which consumption by zooplankton occurs.

Bacterial Consumption

This section deals with parameters associated with the consumption of bacteria (detritus) by zooplankton. These parameters essentially have the same meaning as those relating to phytoplankton (see preceding section), except that they relate to bacterial uptake.

- *Half-saturation.* Monod half-saturation value (g/m3) for bacterial uptake by zooplankton.
- *Minimum threshold for uptake*. Minimum bacterial concentration (g/m3) above which uptake by zooplankton occurs.

Temperature Scalers

- *Minimum Temperature.* The minimum temperature (°C) below which zooplankton will not grow.
- *Maximum Temperature.* The maximum temperature (°C) above which zooplankton will not grow.
- *Optimum Temperature.* The temperature (°C) at which zooplankton growth is at a maximum.

Other Coefficients

- *Respiration.* Refers to the zooplankton respiration rate (1/day) at a base water temperature of 20°C.
- *Death*. Refers to the zooplankton death rate (1/day).

Level 3 Options

Nutrient Thresholds

Additional Level 3 Parameters

Set Fertilizer Options

Zooplankton Parameters

Several options may be edited to set up a Level 3 simulation scenario. Access to these options is available via the **Level 3 Parameters** dialog.

Phytoplankton parameters
This section is identical to that described under Level 2 Model Parameters with the exception that half-saturation constants for nutrient uptake are specified in terms of *inorganic* nitrogen, phosphorus and carbon.

Nutrient Thresholds

This section is identical to that described under Level 1 Options.

Additional Level 3 Parameters

Pushing the <Additional Level 3 Parameters> button in the Level 3 Model Parameters dialog box brings up the **Additional Level 3 Parameters** dialog, which is used to edit bacterial parameters and access fertilizer options.

Bacterial Parameters

This section deals with different parameters or methods associated with the bacterial model.

Maximum Specific Growth Rate. Refers to the maximum growth rate per unit of bacterial biomass. Units are g/g/day = 1/day.

Limiting Factors

Nutrients that potentially limit bacterial growth (i.e., *nitrogen*, *phosphorus* and *carbon*) can be indicated by checking the appropriate boxes; the half-saturation constants (mg/L) for their uptake can also be edited. Higher half-saturation constants for any nutrient indicate a slower uptake rate. Conversely, lower values for the constants are indicative of more rapid uptake rates.

NOTE: *The method chosen within the* **Phytoplankton parameters** *field in the* **Level 2 (3) Model Parameters** *dialog is also used for the analysis of nutrients that limit bacterial growth*.

Temperature scalers

- *Minimum Temperature.* The minimum temperature (°C) below which bacteria will not grow.
- *Maximum Temperature.* The maximum temperature (°C) above which bacteria will not grow.
- *Optimum Temperature.* The temperature (°C) at which bacterial growth is at a maximum.

Other coefficients

- *Respiration.* Refers to the bacterial respiration rate (1/day) at a base water temperature of 20°C.
- *Death*. Refers to the bacterial death rate (1/day).

Set Fertilizer Options

Pushing the <Set Fertilizer Options> button from within the Additional Level 3 Model Parameters dialog brings up the **Fertilization Options** dialog box.

Fertilizer Options

This field allows specification of fertilizer options for Level 3 modeling. Available options include:

- *Specify by Rate*. Use this option to specify a known application rate (kg/ha/day) of nitrogen (N), phosphorus (P) and carbon (C).
- *Specify by Type*. Use this option to specify a known application rate (kg/ha/day) of a single fertilizer.
- *Estimate Fertilizer Requirements*. ***This option is not available in this version of POND***.

Zooplankton Parameters

As described under Level 2 options.

CHAPTER 3 - Determining Fertilizer Requirements

INTRODUCTION
FERTILIZER REQUIREMENTS SETUP

Introduction

POND contains a utility which allows users to estimate fertilizer requirements for individual ponds in the facility independent of a simulation activity. POND calculates nutrient requirements for a pond based on data entered in the Pond database (see Chapter 2) and a simple model of phytoplankton growth. Upon selection of one or more fertilizers from the Fertilizer database, the software then calculates the quantity of a single fertilizer (if only one fertilizer type is specified) or the least-cost combination of different fertilizers needed to meet nutrient requirements of the pond. There is no restriction on the number of fertilizers that can be considered in estimating requirements for a given pond.

Fertilizer Requirements Setup

Edit Fertilizers

Edit Ponds

Adjust Parameters

Other sources and sinks

Run Optimizer

To set up the fertilizer requirements module, run the **Fertilizer Requirements Setup** dialog shown below by selecting the *Management/Fertilizer Requirements* menu option.

The dialog contains the following fields:

Fertilizer Selection

- *Fertilizers in Database*. This part of the dialog box lists fertilizers defined in the database.
- *Fertilizers to Consider*. The section is used to indicate the fertilizers in the database that are to be considered in estimating requirements for the pond(s).

***NOTE*:** Push the <Add> button below the database field to move the currently highlighted fertilizer to the *Fertilizers to Consider* section. The <Add All> button causes all the fertilizers in the database to be considered in estimating requirements. The <Remove> and <Remove All> buttons are used in a similar manner to remove fertilizers from consideration.

Nutrient Summary

- *Pond.* Use this field to select the pond for which fertilizer requirements are to be estimated.
- *Average Net Primary Productivity*. This field reports the expected average net primary productivity (gC/m3/day) for the pond that is currently selected. There is no need to edit this field because the value is automatically calculated on the basis of phytoplankton parameters (which can be accessed as described below).

Weekly Requirements

This section of the dialog box lists the weekly nutrient requirements of the pond as predicted by the POND models.

- *Nitrogen.* POND automatically calculates the expected daily nitrogen requirements for the pond (in g/m3 and kg/ha) and displays it in adjacent fields. The value can be over-ridden if desired.
- *Phosphorus.* As described for the nitrogen field above.
- *Carbon.* As described for the nitrogen field above.

Edit Fertilizers

Push the <Edit Fertilizers> button to access the Fertilizer database (see Chapter 2). Fertilizer parameters can then be edited if desired.

Edit Ponds

Access to pond data (see the Pond database in Chapter 2 for details regarding the variables) required for fertilizer calculations is provided via the **Pond Characteristics** dialog box which is obtained by pushing the <Edit Ponds> button.

Adjust Parameters

When the <Adjust Parameters> button is pushed, the **Fertilization Parameters** dialog appears:

Phytoplankton Parameters

This section provides access to parameters associated with the phytoplankton model used to estimate nutrient requirements for a pond.

Maximum Gross Primary Productivity. Refers to the maximum, light-limited value of gross primary productivity for the particular location. Units are gC/m3/day.

Limiting Factors

Nutrients that may limit phytoplankton growth (i.e., *inorganic* nitrogen, phosphorus and carbon) are indicated by checking the appropriate boxes. If it is desirable to examine fertilizer requirements under conditions where one or more of the nutrients are non-limiting to phytoplankton growth, the associated boxes can be unchecked. Half-saturation constants (mg/L) for nutrient uptake by phytoplankton can also be edited once the associated boxes are checked. Higher half-saturation constants for any nutrient indicate a slower uptake rate by phytoplankton. Conversely, lower values for the constants are indicative of more rapid uptake rates.

Temperature scalers

- *Minimum Temperature.* The minimum temperature (°C) below which phytoplankton will not grow.
- *Maximum Temperature.* The maximum temperature (°C) above which phytoplankton will not grow.
- *Optimum Temperature.* The temperature (°C) at which phytoplankton growth is at a maximum.

Nutrient Thresholds

When the <Nutrient Thresholds> button is pushed, the **Nutrient Parameters** dialog box appears:

Threshold Concentrations

This dialog box is used to edit minimum (threshold) concentrations of *inorganic* nitrogen, phosphorus and carbon (all in mg/L). The underlying assumption with such thresholds is that phytoplankton may be able to use the associated nutrients only if their concentrations exceed the threshold values.

Other sources and sinks

Pushing the <Other Sources and Sinks> button brings up the following dialog box:

Nutrient sources and sinks

This dialog box is used to specify nutrient sources or sinks that affect *inorganic* nitrogen, phosphorus and carbon concentrations. These additional sources or sinks may be specified in terms of either percent/day or g/m2/day.

***NOTE**: Sources and Sinks must be indicated as positive and negative values respectively*.

Run Optimizer

When this button is pushed, POND calculates the quantity of a single fertilizer (if only one fertilizer type is selected) or the least-cost combination of different fertilizers that would meet the predicted nutrient requirements, and displays the **Fertilizer Recommendations** dialog, shown below.

- *Fertilizer Listing.* This table lists the type of fertilizer(s), quantity to be used (kg/ha/week), and the expected weekly cost for each fertilizer type.
- *Total Cost.* Indicates the overall weekly cost of fertilization.
- *Nutrient Listing.* This table shows the amounts of nitrogen, phosphorus, and carbon (all in g/m3) *required* on a daily basis and the amounts that are actually expected to be provided by the fertilizer combination suggested by POND. Any *excess* amounts are also shown.

CHAPTER 4 - Determining Lime Requirements

POND contains a utility which allows users to estimate static lime requirements for individual ponds in a facility. Lime requirements are calculated on the basis of soil properties defined in the Soil database (see Chapter 2). To access the lime requirements utility, select the *Management/Lime Requirements* menu option. The **Lime Requirements Setup** dialog box will appear.

The dialog box contains the following fields:

- *Pond.* Use this field to select the pond for which lime requirements are to be estimated. If dimensions of the relevant pond are to be modified, push the <Edit> button.
- *Soil type.* Use this field to select the type of soil associated with the pond. To edit any properties of the selected soil type, push the <Edit> button.
- *Liming Source.* Use this field to select the liming source or material. To edit its characteristics, push the <Edit> button.
- *Use Soil pH to calculate PBS*. Check this button to have POND estimate the percent base saturation (PBS) for the selected soil from the corresponding soil pH. However, if PBS of the soil has been measured directly, this value should be retained and the box left unchecked.
- *Lime Requirements.* This field displays lime requirements in terms of pure calcium carbonate (kg CaCO3/ha) and the liming material (kg/ha). The total amount of liming material for the pond is also displayed.
- *Lime Costs.* This field displays lime costs on a per ha basis as well as the total costs for the particular pond.

CHAPTER 5 - POND Simulation

INTRODUCTION
SIMULATION SETUP
RUNNING A SIMULATION
PLOTTING SIMULATION RESULTS
PRINTING AND WRITING TO FILE OPTIONS

Introduction

Simulation models are the primary analysis tool in POND. These models are essentially collections of mathematical equations that describe fundamental relationships between components within the system of interest. Simulation models in POND can be used to predict the response of the system to a particular set of operation conditions or environmental constraints, and are intended to be used as tools for pond management, analysis and decision-making. These simulation models are deterministic in nature, and are formulated as a set of ordinary differential equations which are solved numerically over time. They provide opportunity to address fish growth, water/sediment quality dynamics, and primary and secondary productivity under different pond conditions. POND supports both daily and diurnal simulations of pond facilities. Details of the simulation models are provided in the POND Technical Manual.

Simulation models were chosen as the main tool for analyzing pond ecosystems for a variety of reasons. They provide an opportunity for *knowledge synthesis*, whereby a large body of knowledge about ponds can be represented as a single entity, which can then be used to explore 'what-if' scenarios in the pond ecosystem. Simulation model development also imposes a rigorous framework on the model builder. This forces the model builder to clearly articulate knowledge of the fundamental relationships that govern a pond's response to external stimuli, simultaneously exposing gaps in the knowledge base. The rigorous nature of model specification results in a *testable hypothesis* about the system, i.e., the model can be run for a known set of conditions to determine whether its output is adequate to represent our knowledge of systems processes.

Simulation models are also useful tools for predicting system response to conditions that are either too complex or expensive to explore experimentally. Because model-based experiments can be completed in seconds on a computer, rather than months or years in the field, models provide opportunity for exploring a much larger set of operating conditions, environments, management strategies, and constraints than traditional experiments allow. Further, results of such numerical experiments are useful in evaluating model assumptions, and refining the models.

It is important to note that ponds are complex, rather unpredictable ecosystems. Therefore, ecosystem-level validation of the models in POND is a difficult task. Further, data are often not available to validate certain model components. However, some POND models (e.g., fish growth, water temperature, etc) have been validated with favorable results (see the POND Technical Manual for details). Validation of other components is an on-going activity.

POND simulations are dynamic, providing time series analysis for a range of variables that are dependent on the level of resolution requested prior to simulation. During the simulation, POND accumulates time series data for each variable; these data may be viewed in plots or tables at the end of the simulation run. Simulation models in pond are organized hierarchically into three levels. This scheme allows users to perform different kinds of analyses based on data availability and output resolution requirements. Each of these levels are briefly described below.

Level 1: Level 1 models are fairly simple and require minimal data inputs. State variables maintained are fish growth (based on a bioenergetics model), water temperature, pond volume, and inorganic (nitrogen, phosphorus and carbon) nutrients. Weather data that are required for the latter two variables may either be generated by a simple weather generator embedded in POND or read from ASCII files provided by the user. Consumption of natural food by fish is assumed to be a function of fish biomass and appetite. Fertilizer application rates and supplementary feeding schedules are either optionally generated or specified by the user.

Level 2: Level 2 models provide a substantially more sophisticated view of pond dynamics, allowing prediction of phytoplankton, zooplankton and nutrient dynamics (total carbon, nitrogen and phosphorus) in the pond water, in addition to all the functionality of Level 1. At Level 2, steady state bacterial concentrations are maintained, and nutrient exchange between pond water and sediments is assumed to depend on the concentration gradient between these two components. Fish can feed from a pool of natural food resources and/or artificial feed. Consumption of natural food (phytoplankton, zooplankton

and bacterial pools) by fish is predicted on the basis of a resource competition model, and is dependent on the concentrations of the natural food pools and artificial feed (if specified), food preference of fish species, and fish appetite. At this level, both fertilizer and feed requirements may be user-specified or optionally generated by the model.

Level 3: Level 3 models inherit all the functionality of Level 2, and provide additional capabilities for simulating bacterial kinetics, and detailed pond water/sediment quality dynamics. Additional state variables for pond water include dissolved oxygen and alkalinity. Further, state variables are also maintained for organic, ammonia and nitrate nitrogen, as well as organic and inorganic phosphorus and carbon in both pond water and sediments. User-specified fertilization and feeding regimes, coupled to pond process-based nutrient mass balances, are used to estimate nutrient consumption and production rates.

Simulation Setup

Basic simulation setup is controlled by the Simulation Parameters Setup dialog shown previously. It is accessed from the *Parameters/Simulation* menu. Alternatively, it can be accessed from the Pond Simulation Control dialog when a simulation run is being set up. Details of this dialog are described in Chapter 2 (see the section on *Simulation Database*). Select and modify the desired simulation scenario to run. These parameters will be used for the next simulation run.

Running a Simulation

Other Simulation Control Options
Optimize

To actually run a simulation, select the *Management/Run Pond Simulation* option from the main menu, or push the <Run> button on the toolbar. You will be presented with the **Pond Simulation Control** dialog.

This dialog contains the following fields:

Clock Settings

- *Start, Stop Dates.* Use this field to specify the starting and ending dates for the simulation run.
- *Time Step.* POND can run as either a daily or diurnal model. Specify daily to run as quickly as possible, ignoring diurnal effects. Specify diurnal to capture effects due to 24-hr fluctuations in solar radiation. In practice, daily simulation is generally preferred. This field is also be used to set the actual time step that the integrator should use. For daily simulations that use Level 1 models, a time step of 1 day is usually adequate. For daily simulations with Level 2 and 3 models, a time step of 0.05-0.1 days is advisable. Finally, a one hour time step appears to be adequate for all diurnal simulations.
- *Save to Disk*. Use this button to save the current Simulation Control Settings.

Parameter Setup

The <Fish Lots>, <Ponds> and <Simulation> buttons provide quick access to the appropriate database dialogs. Details about the use of the databases have been described previously (see Chapter 2).

Set Ponds to Simulate

Available options include:

- *Use All*. Selecting this option indicates that all the defined ponds are to be simulated.
- *Use Selected*. This field allow selection of a subset of the currently defined ponds to simulate. Push the <Select Ponds> button to specify the subset of ponds to simulate. This is useful if you have defined a large facility with numerous ponds, but only want to simulate one or two of the ponds.

Results

These fields let you set how frequently simulation results are collected and stored internally. Specifying a large value saves time and space at the expense of resolution accuracy of your plots, while specifying a low value does the opposite. Usually, setting a value of 24 hours is appropriate.

Other Simulation Control Options

- *Run.* The <Run> button starts a simulation using the currently defined parameters. The *Progress* box indicates the extent to which a simulation is completed.
- *Close.* The <Close> button closes the dialog window.
- *Summary.* The <Summary> button displays the dialog summarizing the results of a simulation. It is active only after a simulation has completed.

The summary dialog displays results on a pond by pond basis. Check the *Show All* box to scroll through individual ponds. Data summarized include the final fish weight and gross yields, as well as the total fertilizer (nutrient) and feed requirements.

Optimize

Push the <Optimize> button to access the fertilizer optimization routines which can be used to explore least-cost fertilizer combinations that meet nutrient requirements for the pond(s). The following dialog box appears:

- *Edit Fertilizers*. Push the <Edit Fertilizers> button to access the Fertilizer database (see Chapter 2). Fertilizer parameters can then be edited if desired.
- *Run Optimizer*. When this button is pushed, POND calculates the quantity of a single fertilizer (if only one fertilizer type is selected) or the least-cost combination of different fertilizers that would meet the predicted nutrient requirements.

Further details about using the fertilizer optimization routines may be found in the *Run Optimizer* section of Chapter 3.

- *Plot.* The <Plot> button provides access to the plotting module, providing plotting capabilities for any variable defined in the simulation. See the section on **Plotting Simulation Results** described below.

Plotting Simulation Results

After a simulation has run, you may plot any of the variables included in the simulation against time or any other variable. There are three ways to initiate plotting: 1) press the <Plot> button on the **Pond Simulation Control** dialog, 2) select *Window/Create Graph* from the main menu, or 3) press the <Plot> icon on the toolbar. If data are available, the **Select Graph Items** dialog will be displayed.

This dialog allows you to specify which variables you wish to plot. Any number of variables may be selected for plotting. Data are stored internally on a "per object" basis; each object which contains data is listed in the *Data Source* combobox in the dialog.

Select the object you wish to view in the *Data Source* combobox. To view all of the objects simultaneously, check the *Show All* checkbox. Then, double click on the item to plot; it should appear in the *Y-Axis* list. When you have selected all the items you wish to plot, press the <OK> button to generate the plots. To plot each variable on its own graph, check the *Individual Plots* option. Otherwise, all variables will be set to the same scale and plotted on one graph.

By default, variables are plotted against time to get a dynamic trace of the variable's behavior. To plot one or more variables against a different X-axis variable, simply select that variable into the *X-Axis* list box.

Printing and Writing to File options

To print a plot that is displayed on the screen, click the top left button on the plot window and select the *Print* option from the menu displayed. Users may also want a text file containing simulation data for use in other software programs. To create such a file, first select the *Table* option from the above menu. A table containing simulation data for the selected data object is displayed. This table can be written to a comma-delimited ASCII text file by clicking the top left button on the table window, and selecting the *Write to File* option.

CHAPTER 6 - Parameter Estimation

INTRODUCTION
SETTING UP THE PARAMETER ESTIMATION PROCEDURE
ESTIMATING MODEL PARAMETERS

Introduction

Users of POND may be interested in tailoring the models to one or more fish species at a given location. Essentially, this involves estimating suitable values of the various parameters used in the models. Although manual parameter estimation may be possible, it is usually very tedious because of the potentially high degree of interaction between variables and the large parameter spaces that need to be searched in order to adequately calibrate complex, non-linear ecological simulation models.

A sophisticated non-linear, adaptive search procedure has been implemented in POND to enable automatic parameter estimation for different species/culture conditions. Use of this procedure requires observed fish growth datasets to be available. The estimation procedure automatically conducts multiple simulations with different combinations of parameter values, ultimately terminating with a set of parameters that provides the closest fit of predicted fish growth to observed values. Because the procedure of parameter estimation is rather complicated, we recommend that you contact us should calibration for new fish species/culture conditions be desired. However, a brief description of the procedure is provided below for more advanced users who may be familiar with parameter estimation procedures.

NOTE: It is necessary to perform an initial simulation (see the section on *Running a Simulation* in Chapter 5) with the desired lots before commencing parameter estimation.

Setting up the Parameter Estimation Procedure

To access the parameter estimation utility, select the *Management/Estimate Model Parameters* menu option. The **Parameter Estimation** dialog box will appear.

The following fields are provided in the dialog box:

Observed Data Source
This field is used to enter the name of the file that contains observed fish weights. The comma-delimited ASCII files containing these data can be located on the appropriate drive by pushing the <Browse> button. These files should have a *.dat* extension and *must* be created outside POND (e.g., with a Windows text editor) with the following format:
Row 1: Labels for Date, Lot-1, Lot-2, etc.
Remaining rows: Data for each of the above items.

NOTE: Date values must be specified in Julian Day format. The labels for lot information in Row 1 should preferably be identical to the lot names created in POND for the relevant lots. For example, if the lots associated with the fish species for which parameters are to be estimated are named as Lot-1 and Lot-2 respectively in the lot database, the labels in the file containing observed data should also be similar. This is particularly important when several lots have been created in POND, but only one or two lots of the new species are to be used to estimate parameters. The actual procedure of mapping observed data to associated lots is done in the *Data Mapping* field (see below).

If the observed fish growth data were collected for a period that starts at the end of one year and proceeds into the next, time for the second year must be specified in increasing order. For example, if data are available from October 10 of the first year upto to March 23 of the second year, the date column should start on JD 283 and proceed to JD 447.

An example observed fish growth data file (*growth.dat*) is as follows:

date, Lot-1, Lot-2
1,5.3,4.6
37,18.2,9.7
56,25.1,17.5
77,26.4,19.3
100,28.6,21.4
127,32.3,24.5
148,34.1,26.8
161,44,33.3
182,64.8,52.3
199,76.4,68.2
218,137.9,103.2
246,234.3,218.2

Data mapping
This *observed data* and *associated lot* fields are used to map observed fish growth data columns from the input file to the corresponding lots in the lot database. This is to ensure that the appropriate lots are used in multiple simulations that are run during parameter estimation.

Parameter Setup
This section deals with the selection and editing of parameters that need to be estimated. The list of parameters that can be manipulated is loaded in the list box. The allowable range (i.e., *min* and *max*

values) of the currently selected parameter can also be edited. The default range is displayed as 25% of the current value of the parameter.

The *Use?* box indicates whether the corresponding parameter should be estimated or not.

The *Group* boxes indicate the categories to which various parameters belong. Clicking only the *Level 1* box indicates that only Level 1 bioenergetic parameters for the species (see Species database in Chapter 2) are to be estimated. Clicking both *Level 1* and *Level 2* boxes indicates that all the available parameters are to estimated. If there is no need to estimate some of these parameters, the *Use?* box can be unchecked. Similarly, if only phytoplankton parameters are to be estimated, the *Phytoplankton* box can be checked leaving the *Level 2* box can be unchecked.

NOTE: Parameter estimation has been adequately tested only at Level 1. We recommend that you contact us for assistance in estimating Level 2 or other categories of parameters.

GA Setup

GA's refer to Genetic Algorithms, an artificial intelligence strategy that actually performs the parameter estimations. It is recommended that the default values for the GA parameters be retained as follows:

- *Population Size*: 20
- *Max Generations* 20
- *Crossover Rate*: 0.25
- *Carryover Rate*: 0.2
- *Mutation Rate*: 0.15
- *Number to* Show: 5

The *Number to Show* field indicates the number of plots (of observed vs. predicted fish weights with different parameter sets) to be displayed at the end of the estimation procedure.

Estimating Model Parameters

Once all the required information has been entered/edited (see above section), parameter estimation can proceed. Push the <Run> button to commence the procedure. Because multiple simulations are conducted, parameter estimation may take several minutes. Wait until the progress box at the bottom left corner of your screen is competely filled before proceeding further. This occurs when the required plots (based on the *Number to Show* value entered earlier) have been automatically created in the background.

To display results relevant to the GA's, push the <Plot GA Results> button. Similarly, the 'best-fit results are plotted by pushing the <Plot Best Fit Results> button. To save the settings for the parameter estimation package, push the <Save> button. To exit from the procedure, push the <Close> button.

NOTE: The 'best-fit' parameter values are automatically entered in the appropriate database (e.g., Level 1 bioenergetic parameters for the fish species in the Species database). Because these values replace the existing database values, we recommend that a back-up copy of all the relevant databases be maintained should there be the need to revert to the original species or other parameters.

CHAPTER 7 - Economic Analysis

INTRODUCTION
GENERATING ENTERPRISE BUDGETS
PRINTING AND WRITING TO FILE OPTIONS

Introduction

POND provides economic analysis capabilities in the form of enterprise budgeting. An enterprise budget is essentially a tabulation of the costs and income for a farm operation. The three categories of costs are *depreciable* (e.g., buildings, heavy equipment, pumps, etc), *fixed* (e.g., land and pond costs) and *variable* (e.g., feed and fertilizer) costs. Income accrues from the economic value of the fish and other items produced, if any (e.g., crops in an integrated farm enterprise).

The main purpose of the economic analysis package is to allow rapid assessment of different pond configuration or management scenarios that can be created in POND. For example, the program can be used to set up facilities with different pond dimensions or numbers. Multiple simulations can then be conducted to examine the effects of these factors on fish yields and facility-level economics. Alternately, management strategies such as feeding, fertilization and stocking can be varied, and enterprise budgets generated between simulation runs to examine effects of such strategies on production economics.

It is important to note that the economic analysis package can be used independent of the simulation capabilities of POND. For example, users may want to generate enterprise budgets for situations where actual fish production data and cost information are available. In such cases, data may be directly entered into the enterprise budgets.

Generating Enterprise Budgets

To generate an enterprise budget for a facility, select the *Economics/Generate Summary Budget* option from the main menu. You will be presented with three options for calculating production costs and income: (1) Facility basis, (2) Unit area, and (3) Unit production. If the 'Facility basis' is selected, the enterprise budget will reflect costs and income for the overall *facility* (one or more ponds). Similarly, if the 'Unit Area' option is selected, budget calculations are based on a per *unit area* (e.g., per ha) basis. Finally, if the 'Unit production' option is selected, budget calculations are based on a per *unit of production* (e.g., per kg of fish) basis.

Selection of any of the above options results in the *Economic Summary Sheet* being displayed. Line items in the budget are grouped into gross income, fixed costs, depreciation, and variable costs. The sum of the latter three groups reflects overall production costs. Net income (= Gross income - Production costs) is displayed at the end of the summary sheet. Individual fields in the summary sheet that correspond to cost or income line items may be directly edited. Alternately, data can be edited via the Cost database (see Chapter 2), which can be activated by double clicking on any field in the summary sheet. Changes to existing information can then be made in the economics database. In either case, the summary sheet will be immediately updated.

Printing and Writing to File options

To print the enterprise budget, click the top left button on the summary sheet and select the *Print* option from the menu displayed. Users may also want a text file containing budget information for use in other software programs. The summary sheet can be written to a comma-delimited ASCII text file by selecting the *Write to File* option from the above menu.