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# USER'S MANUAL FOR INSECT (VERSION 1.0); A SIMULATION OF WATERHYACINTH PLANT GROWTH AND *NEOCHETINA* WEEVIL DEVELOPMENT AND INTERACTION

by


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This manual was written as a practical guide for the operational use of INSECT, a personal computer-based software package that generates simulation output of the interactions between waterhyacinth plants (*Eichhornia crassipes*) and two weevil species (*Neochetina eichhorniae* and *Neochetina bruchi*). This manual includes background information and general instructions for installing and using the INSECT software package.

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# Contents



[1] A copy of the INSECT (Version 1.0) software is provided on the enclosed diskette.

# Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP), Work Unit 32438. The APCRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel was Assistant Manager, ERRAP, for the APCRP. Technical Monitor during this study was Ms. Denise White, HQUSACE.

This manual was prepared by Messrs. R. Michael Stewart and William A. Boyd of the Environmental Analysis Group (EAG), Environmental Systems Division (ESD), EL. Technical reviews of the manual were provided by Mr. Tommy D. Hutto and Ms. Katherine S. Long, ESD, and Dr. Alfred Cofrancesco, Aquatic Habitat Group, Environmental Resources Division, EL.

The work was accomplished under the direct supervision of Mr. Harold W. West, Chief, EAG, and under the general supervision of Mr. J. L. Decell, Acting Chief, ESD; Dr. John Keeley, Assistant Director, EL; and Dr. John Harrison, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

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# 1 Introduction

## Background

The U.S. Army Engineer Waterways Experiment Station (WES) is developing simulation procedures to assist in the understanding and transfer of information relevant to aquatic plant control technologies developed by the WES under the Aquatic Plant Control Research Program. Development of computer-based simulation procedures was initiated by WES several years ago. These early efforts led to the development of **HARVEST** and **AMUR/STOCK**. **HARVEST** is a mechanical control simulation model that provides information on time and cost requirements of mechanical harvesting operations for submersed aquatic plants. Information on **HARVEST** is available in Hutto (1982, 1984), Sabol (1983), and Sabol and Hutto (1984). **AMUR/STOCK** was developed to provide information useful for determining proper stocking rates of diploid white amur fish for control of hydrilla in water bodies having user-specified site characteristics. Miller and Decell (1984) provides guidance for proper use of **AMUR/STOCK**.

Simulation capabilities are under development for additional aquatic plant control techniques that are currently used operationally by aquatic plant managers. As part of this current work, personal computer-based simulations have been designed and are under development. These simulation procedures couple plant growth models with interaction models of biological, chemical, and mechanical control technologies. These simulation tools provide information to aquatic plant researchers and managers to help in understanding how a targeted plant and a control technique interact under a specific set of dynamic environmental conditions. Currently under development are plant growth models for waterhyacinth, hydrilla, and Eurasian watermilfoil. Biological control and chemical control models are also under development for selected operationally effective biological agents and herbicides labeled for aquatic use.

**INSECT** is a simulation that includes interactions between waterhyacinth plant growth and two species of *Neochetina* weevils. **INSECT** was initially described by Akbay, Wooten, and Howell (1988), and updates are given by Howell, Akbay, and Stewart (1988) and Howell and Stewart

(1989). The latest description of INSECT is presented in Akbay, Howell, and Wooten (1991).

Although it is recognized that INSECT (Version 1.0) has not yet reached its final form, the simulation is being released to researchers and managers for their evaluation. This evaluation will be used to make changes so that INSECT will ultimately be a more useful simulation tool for individuals having an interest in the waterhyacinth/*Neochetina* biocontrol system. Additionally, technical improvements will be made to the INSECT model as ongoing research improves the current understanding of key relationships of this dynamic biocontrol system. INSECT provides for a systematic procedure for evaluating new relationships derived from current research studies.

## Manual Contents

The following chapters of this user's manual provide a general overview of INSECT. Chapter 2 provides an overview of INSECT, including descriptions of the hardware requirements for installing and executing the software and general components of the software package. Chapter 3 of the manual provides information needed to execute the simulation package either from a hard drive or a floppy drive. INSECT is menu driven, and Chapter 3 includes a description of the various menu options provided during execution of the simulation. Chapter 4 of this manual contains information from two example runs. The two examples each contain data input to initialize the simulation and outputs available at the completion of the simulation run. The example simulation results included in Chapter 4 are provided to assist in the execution and interpretation of simulation output. Hopefully, review of the two examples will help the user to design additional runs for other applications and problems.

# 2 Description of INSECT Simulation Model

## Hardware Requirements

An MS-DOS or compatible computer containing an installed math coprocessor and a minimum of 260 kilobytes (KB) of free RAM is required for executing INSECT (Version 1.0). If the computer does not have a hard drive for installing the software, the floppy drive must be compatible with a high-density 1.44-megabyte (MB) floppy diskette. Software installation instructions are provided in Chapter 3.

## Software Components

INSECT is a personal computer-based, menu-driven software package written in Microsoft FORTRAN 5.0 and is being distributed with this manual on a double-sided, high-density, 1.44-MB formatted, 3.5-in. diskette. In this format, the software can be executed from a compatible floppy drive or copied to a hard disk for execution. **If your computer system will not support this type diskette, copies of the software can be ordered from the authors in the diskette varieties listed on page 7.**

The INSECT software package includes four major components: (a) a user interface module that allows easy initialization of the various modules and retrieve/display simulation output, (b) a waterhyacinth plant growth module, (c) a *Neochetina* module, and (d) external support files that store either initialization data (e.g., weather data files) or simulation output data.

### User interface module

The INSECT software package features a series of program menus that help guide the user through the INSECT software package. The major features of the menu structure are shown in Figure 1. Further discussion of the user options at each level of the menu structure is provided in Chapter 3, Executing the Simulation.

## Waterhyacinth plant/*Neochetina* modules

The waterhyacinth plant growth module and *Neochetina* modules included in INSECT produce simulation output on a daily basis for plant and insect growth/development and for interactions between plants and insects, such as impacts of *Neochetina* feeding on the plants. The plant module can be executed without including the effects of the insects. The *Neochetina* module, however, cannot be executed without the plant growth module.

Assumptions used in development of INSECT are discussed in detail by Akbay, Wooten, and Howell (1988). The model, for the most part, incorporates the simplest explanation for an observed population phenomenon. The current version of INSECT has been written to maintain as much simplicity as possible. Complexity will be added as our understanding of the dynamics of plant/weevil interactions increases.

A major assumption used in the development of the waterhyacinth growth module and the *Neochetina* module is that simulation output, which is generated for a unit area basis, can be extrapolated over the total area of a waterhyacinth infestation. Simulation updates are provided on a daily basis during the simulation period. For plant growth, photosynthesis and respiration rates are functions of the prevailing temperature, light intensity, and current plant biomass levels. Past temperature and light experience are assumed to have no effect on the current photosynthesis and respiration rates other than through effects on current mass of the plant. Nutrients and pH conditions within the study site do not limit plant growth.

The *Neochetina* module contains growth and development algorithms for both *Neochetina eichhorniae* and *N. bruchi*. Within the *Neochetina* module, average daily air temperatures determine the development rates of individual insects and the fecundity (or viable egg-laying capacity) of adult weevils. Weevil mortality rates are estimated for each development stage (i.e., eggs, larvae, pupae, and adults) and include consideration for natural mortality, predation, and subfreezing temperatures. The *Neochetina* module includes relationships for losses of adult weevils due to emigration, but additions to the adult weevil population through immigration are not considered. In regard to interactions between the plants and insects, biomass losses to the plant population are considered to result from feeding damage only from third instar larvae. Feeding by other stages of the weevils do not affect plant biomass.

## External files

Execution of **INSECT** is supported by several external data files included on the diskettes. In general, these files can be categorized as input files and output files.

**Input files.** The only input files needed by the model are weather data files containing daily solar radiation values and maximum and minimum air temperature values for specific years (i.e., Julian day 1-365) from different geographical locations in the United States. Fifteen weather data files are included on the **INSECT** model diskette(s) and can be used for model initialization. A listing of these files and instructions for reviewing their contents or selecting them for model initialization are described in Chapter 3 of this manual.

**Output files.** Numerous output files are generated for storing information obtained during the initialization process of each simulation run and for storing simulation output. A listing of the output files and a description of the variables included in each is given in Tables 1-3. The **INSECT** (Version 1.0) software package includes screen display routines for most of the variables included in the external output files. More information on this utility is provided in Chapter 3. In addition to the screen display utilities, output files contain the output of different simulation runs. Note that all output files are temporary, and the contents within these files will be overwritten each time **INSECT** is executed. If the user wants permanent copies of an output file for later use, the user should copy the contents of the file to another file name before the next run is executed. A **WARNING MESSAGE** to this effect is given before executing a simulation (see page 10).

**Table 1**
**Files Used To Store User-Supplied Initialization Input Values**

| File Name | Variable Description |
|---|---|
| weather.dta | Julian day[1] (1-365)<br>Solar radiation, Langleys per day<br>Maximum air temperature, Fahrenheit<br>Minimum air temperature, Fahrenheit |
| initial1.dta | First day of simulation period<br>Last day of simulation period<br>Type of simulation (plants only or plants and insects)<br>Initial plant biomass, kilograms |
| initial2.dta | Percentage of *N. eichhorniae*<br>Percentage of *N. bruchi*<br>Julian day insects are released<br>Life stage of insect (eggs, 1st larvae, etc.)<br>Total number of each life stage input |

[1] Julian day is defined in this manual as a sequential day number throughout a single calendar year (i.e., 1-365), two calendar years (i.e., 1-730), or three calendar years (i.e., 1-1095). The Julian day range for a given simulation run depends on the duration (i.e., number of years) of the simulation.

**Table 2**
**Files Used To Store Plant Growth Simulation Output**

| File Name | Variable Description |
| --- | --- |
| plant.dta | Julian day (1-365)<br>Plant biomass, kilograms<br>Plant density, number of plants/sq m<br>Plant loss due to insects, grams/sq m |
| growth.dta | Julian day (1-365)<br>Gross production, grams<br>Respiratory maintenance, grams<br>Daily detrital production, grams<br>Net change in plant biomass, grams |

**Table 3**
**Files Used To Store *Neochetina* Simulation Output**

| File Name | Variable Description |
| --- | --- |
| insect.dta | Julian day (1-365)<br>Total number of eggs/sq m<br>Total number of 3rd instar larvae/sq m<br>Total number of pupae/sq m<br>Total number of adults/sq m |
| neocb.dta | Julian day (1-365)<br>Total number of eggs *N. bruchi*/sq m<br>Total number of larvae *N. bruchi*/sq m<br>Total number of pupae *N. bruchi*/sq m<br>Total number of adults *N. bruchi*/sq m |
| neoce.dta | Julian day (1-365)<br>Total number of eggs *N. eichhorniae*/sq m<br>Total number of larvae *N. eichhorniae*/sq m<br>Total number of pupae *N. eichhorniae*/sq m<br>Total number of adults *N. eichhorniae*/sq m |
| eb123.dta | Julian day (1-365)<br>Number of 1st instar larvae *N. eichhorniae*/sq m<br>Number of 2nd instar larvae *N. eichhorniae*/sq m<br>Number of 3rd instar larvae *N. eichhorniae*/sq m<br>Number of 1st instar larvae *N. bruchi*/sq m<br>Number of 2nd instar larvae *N. bruchi*/sq m<br>Number of 3rd instar larvae *N. bruchi*/sq m<br>Air temperature, Celsius |
| adult.dta | Number of years of simulation<br>Julian day (1-365)<br>Number of young adults/sq m<br>Number of old adults/sq m |
| mortal.dta | Julian day (1-365)<br>Amount of egg mortality/sq m<br>Amount of 1st instar larvae mortality/sq m<br>Amount of 2nd instar larvae mortality/sq m<br>Amount of 3rd instar larvae mortality/sq m<br>Amount of pupae mortality/sq m<br>Amount of adult mortality/sq m<br>Amount of adult emigration/sq m |

# 3 Executing the Simulation

## Getting Started

INSECT is available on one of the following:

- Four 360-KB, 5.25-in. floppy diskettes.
- Two 720-KB, 3.5-in. floppy diskettes.
- One 1.2-MB, 5.25-in. floppy diskette.
- One 1.44-MB, 3.5-in. floppy diskette.

A copy of INSECT on anything other than a single 1.44-MB diskette must first be copied onto a hard disk before execution. INSECT on a 1.44-MB diskette allows an option of (a) executing directly from a compatible floppy drive or (b) copying to a hard drive before execution.

## Installing on a Hard Drive

Insert the INSECT diskette(s) into the floppy drive. Make the hard drive the default drive by typing the following:

**C:<ENTER>**

Transfer the contents of the floppy diskette to the hard drive by issuing the following command at the C:> prompt:

**copy A:*.* C:**

Repeat this step for each INSECT diskette you received until the contents of each has been transferred to the hard drive.

## INSECT Execution Procedures

### Hard drive execution

After copying the contents of the **INSECT** diskette(s) to the hard drive (see previous section), make sure that the hard drive is still the default drive by typing:

**C:<ENTER>**

The monitor should display a prompt indicating that you have access to the hard drive. Once hard drive access is assured, type in the following command at the **C:>** prompt.

C:>**INSECT <ENTER>**

The opening screen of **INSECT** will produce a color display (Figure 2) on the monitor and you are prompted to:

**PRESS THE SPACE BAR** to execute the simulation.

The space bar (as prompted) should be pressed to begin execution, allowing the first-level menu (i.e., **MAIN MENU**) to appear on the screen. The **MAIN MENU** options are displayed in the sample screen shown on page 9.

### Floppy drive execution

The following procedure should be used if the **INSECT** software package is on a 1.44-MB, 3.5-in. floppy diskette. First, place the 3.5-in. floppy diskette in the 3.5-in. floppy drive. Next, type in the alphabetic reference for that drive followed by a colon and press **<ENTER>**. For example, to make the **A** drive the default drive, type the following at the current default drive prompt.

C:>**a:<ENTER>**

This command makes the **A** floppy drive the default drive, and the following prompt will be displayed on your screen.

**A:>**

As described above for hard drive execution, the introductory screen (Figure 2) to the **INSECT** software package will be displayed on the screen and will prompt you with:

**PRESS THE SPACE BAR** to execute the simulation.

After pressing the space bar, the **MAIN MENU** will be displayed on the screen. Options available to the user from the **MAIN MENU** are discussed in the following sections.

## Main Menu Options

Four options are available to the user from the **MAIN MENU**, as shown below:

```
==========================================================================
                               MAIN MENU
--------------------------------------------------------------------------

              1. EXECUTE PLANT GROWTH SIMULATION

              2. EXECUTE PLANT GROWTH/INSECT SIMULATION

              3. REVIEW SIMULATION OUTPUT

              4. EXIT INSECT
==========================================================================
   MAKE A SELECTION (1-4) AND PRESS <ENTER> --->
```

Option 1, **EXECUTE PLANT GROWTH SIMULATION**, begins initialization of a new waterhyacinth plant growth simulation without impacts from the *Neochetina* weevils. Instructions for executing an Option 1 simulation are provided in the following section. Option 2, **EXECUTE PLANT GROWTH/INSECT SIMULATION**, begins initialization of a combined waterhyacinth plant growth and *Neochetina* weevil simulation. Instructions for executing an Option 2 simulation are given in the section beginning on page 15. Option 3, **REVIEW SIMULATION OUTPUT**, provides graphics and tabular display of output of the most recent simulation run (see section, page 21). Option 4, **EXIT INSECT**, exits the INSECT model and returns to the DOS operating system.

## Executing a Waterhyacinth Plant Growth Simulation

If Option 1, EXECUTE PLANT GROWTH SIMULATION, is selected from the MAIN MENU, the following information will be displayed on the screen:

```
==========================================================================
                YOU ARE ABOUT TO INITIALIZE THE SIMULATION
--------------------------------------------------------------------------
      WARNING!!! ALL EXISTING OUTPUT FILES WILL BE DELETED ...

                     DO YOU WISH TO CONTINUE?
                 1 = YES
                 2 = NO
==========================================================================
   MAKE A SELECTION (1-2) AND PRESS <ENTER> --->
```

A number corresponding to YES (1) or NO (2) must be entered. If "2" is entered, control is sent back to the MAIN MENU.

If "1" is entered to the screen prompt shown above, current data in all existing output files will be erased as indicated by the *WARNING* message and as discussed Chapter 2. Additionally, the simulation continues with the following screen prompt:

```
==========================================================================
                      DURATION OF THE SIMULATION
--------------------------------------------------------------------------
==========================================================================
   ENTER THE YEARS OF SIMULATION (1,2 or 3) AND PRESS <ENTER> --->
```

A numeral 1, 2, or 3 must be entered, indicating the length (in years) of the simulation period.

After the length of the simulation period has been entered, the following menu is displayed:

```
==========================================================================
                     REVIEW WEATHER DATA SETS MENU
--------------------------------------------------------------------------
        WOULD YOU LIKE TO REVIEW THE POSSIBLE WEATHER DATA FILES?
     1 = YES
     2 = NO
==========================================================================
   MAKE A SELECTION (1 OR 2) AND PRESS <ENTER> --->
```

If Option 1 is selected from the above menu, the following menu is displayed to allow selection of weather data file to review. The user should type in the code number for a weather data file and press <ENTER> .

```
==========================================================================
                         WEATHER DATA SET MENU
--------------------------------------------------------------------------
     Code 1=WEST CENTRAL LA - 1974       Code 14=SOUTHEAST TX - 1987
     Code 2=SOUTHEAST LA - 1979          Code 15=SOUTHEAST TX - 1988
     Code 3=SOUTHEAST LA - 1980
     Code 4=SOUTHEAST LA - 1981

     Code 5=NORTH CENTRAL FL - 1975
     Code 6=NORTH CENTRAL FL - 1976
     Code 7=NORTH CENTRAL FL - 1977
     Code 8=NORTH CENTRAL FL - 1978
     Code 9=NORTH CENTRAL FL - 1979
     Code 10=NORTH CENTRAL FL - 1986
     Code 11=SOUTHEAST FL - 1986
     Code 12=NORTH CENTRAL FL - 1987
     Code 13=SOUTHEAST FL - 1987
```

At the bottom of the weather data file list, the following prompt will appear.

```
==========================================================================
    ENTER THE CODE FOR THE WEATHER DATA (1-15) AND PRESS <ENTER> ---->.
```

Any of the 15 weather data files can be selected for review. After selection of a weather data file, the following menu allows selection of the parameter within the selected weather data file the user is interested in graphically displaying on the screen.

```
==========================================================================
                     SCREEN PLOT FOR WEATHER DATA MENU
--------------------------------------------------------------------------
              1 = SOLAR RADIATION
              2 = AVERAGE AIR TEMPERATURE, CELCIUS
              3 = MINIMUM AIR TEMPERATURE, CELSIUS
              4 = MAXIMUM AIR TEMPERATURE, CELSIUS
              5 = EXIT TO "REVIEW WEATHER DATA SETS MENU"
==========================================================================
    MAKE A SELECTION (1-5) AND PRESS <ENTER> --->
```

After the weather parameters of interest have been reviewed for the selected weather data file, Option 5 must be selected from the above menu to allow return to the **REVIEW WEATHER DATA SETS MENU**.

After completing review of the available weather data files, or if no review is required, a "2" must be entered from the **REVIEW WEATHER DATA SETS MENU** screen prompt to continue the initialization procedure. After this is done, the following message will be displayed:

```
YOU MUST NOW SELECT A WEATHER DATA FILE TO EXECUTE THE MODEL.
PRESS <ENTER>  TO SEE ALL AVAILABLE WEATHER DATA SETS.
```

After <ENTER> has been pressed, the **WEATHER DATA SET MENU** described above is again displayed on the screen. At this point, a weather data file is selected from the menu for *initializing the simulation* and not for user review. A separate weather data file entry must be provided for each year of the simulation period. If desired, the same weather data file can be selected for each year of a multiple-year simulation period, or a different weather data file can be selected for each year.

After selecting the desired weather data file(s), the beginning and ending dates of the simulation period must be input. The following prompt requests entry of the "beginning day" of the simulation period.

```
===============================================================================
                          BEGINNING DAY OF SIMULATION
_______________________________________________________________________________
===============================================================================
ENTER JULIAN DATE FOR FIRST DAY OF SIMULATION (1-365) AND PRESS <ENTER> ---->
```

This is the first day (of a 365-calendar day year) of the simulation period. Entry of the "ending day" of the simulation period is prompted by the following:

```
===============================================================================
                           ENDING DAY OF SIMULATION
_______________________________________________________________________________
===============================================================================
ENTER JULIAN DATE FOR LAST DAY OF SIMULATION (1-365) AND PRESS <ENTER> ---->
```

This is the last day (of a 365-calendar day year) of the last year in the simulation period.

After the simulation period has been defined, the following prompt requests entry of the initial dry weight plant biomass.

```
=============================================================================
                         INITIAL DRY WEIGHT BIOMASS
-----------------------------------------------------------------------------
=============================================================================
    ENTER INITIAL DRY WEIGHT PLANT BIOMASS IN kg per sq m
    (FROM 0.001 to 3.0) AND PRESS <ENTER> --->
```

As indicated in the above prompt, the initial value for dry weight plant biomass must be between 0.001 and 3.00 kg/sq m. This range in biomass values is provided to allow realistic initialization of the model at any time during the annual growth cycle of waterhyacinth. Preferably, the user can select initialization values based on personal knowledge or from waterhyacinth biomass estimates reported in the literature. If neither is available, typical waterhyacinth biomass values for specific Julian days can be estimated from the 2-year waterhyacinth biomass curve illustrated in Figure 3.

After entering an initial dry weight plant biomass, the following message is displayed:

```
                INITIALIZATION IS NOW COMPLETE ...
   THE NEXT SCREEN WILL DISPLAY YOUR INITIALIZATION VALUES
                ***********************************
                    PRESS <ENTER> TO CONTINUE.
```

After <ENTER> has been pressed, all user-selected initialization values for the waterhyacinth plant growth simulation will be displayed on the following screen:

```
=============================================================================
                      INPUTS USED FOR THE SIMULATION
-----------------------------------------------------------------------------
    NUMBER   OF
    YEARS            WEATHER DATA USED
    ----------       -------------------------------------------
    LENGTH OF                            NAME(S) AND YEAR(S) OF WEATHER
    SIMULATION                           DATA SET(S) USED

    FIRST    LAST                                 INITIAL DRY WT.
    DAY      DAY          TYPE OF SIMULATION      BIOMASS Kg/Sq m
    ------   ------    ------------------------   -----------------
    1ST   AND LAST    PLANTS ONLY OR PLANTS/INSECTS    BEGINNING DRY
    DAY OF SIMULATION                                   WEIGHT OF
                                                      WATERHYACINTH

   PRESS <ENTER> TO CONTINUE
=============================================================================
```

In the above screen display, information shown in *italics* refers to data that will be displayed for user review of initialization values for the current simulation run. An example of an actual review screen of initialization values for a waterhyacinth plant growth simulation is provided in Chapter 4.

The following screen appears after <ENTER> has been pressed:

```
==========================================================================
      WOULD YOU LIKE TO CHANGE YOUR INITIALIZATION VALUES?
--------------------------------------------------------------------------
   Note: If you answer no (2), Execution will begin ...

            1. YES
            2. NO
==========================================================================
   MAKE A SELECTION (1-2) AND PRESS <ENTER> --->
```

If "1" is selected, the initialization process will start again, as described for EXECUTE PLANT GROWTH SIMULATION (page 10). If option 2 is selected, execution of a waterhyacinth plant growth simulation will be initiated.

During execution, the year and the day being considered are displayed in sequence. When execution of the simulation is completed, the following menu is displayed:

```
==========================================================================
                      REVIEW SIMULATION OUTPUT MENU
--------------------------------------------------------------------------
                      1.  GRAPHICS

                      2.  TABULAR

                      3.  EXIT TO MAIN MENU
==========================================================================
   MAKE A SELECTION (1-3) AND PRESS <ENTER> --->
```

For a description of options and instructions to the above menu prompt, refer to the section **REVIEW SIMULATION OUTPUT** (page 21).

# Executing a Waterhyacinth and *Neochetina* Simulation

If Option 2, **EXECUTE PLANT GROWTH/INSECT SIMULATION**, is selected from the **MAIN MENU** (page 9), the following information will be displayed on the screen:

```
==========================================================================
              YOU ARE ABOUT TO INITIALIZE THE SIMULATION...
--------------------------------------------------------------------------
       WARNING!!!   ALL EXISTING OUTPUT FILES WILL BE DELETED ...

                    DO YOU WISH TO CONTINUE ?
                       1 = YES
                       2 = NO
==========================================================================
   MAKE A SELECTION (1-2) AND PRESS <ENTER> --->
```

If Option 2 is selected, the model execution is returned to the **MAIN MENU** (see page 9).

If Option 1 is selected, resulting in continuation of the **PLANT GROWTH/INSECT SIMULATION**, the following screen will be displayed:

```
==========================================================================

                 Relationships shown below are defined in INSECT
            by a default set of tabular values.

         FECUNDITY/TEMPERATURE RELATIONSHIP
         EMIGRATION/ADULT WEEVIL DENSITY RELATIONSHIP
--------------------------------------------------------------------------
       Would you like to execute the simulation without displaying or
       modifying these default relationships?
         1 = YES
         2 = NO

==========================================================================
   MAKE A SELECTION (1-2) AND PRESS <ENTER> --->
```

To display and/or modify these relationships (before executing the simulation run), Option 2 should be selected. Fecundity refers to the proportion of maximum egg production that will result in viable eggs. Fecundity changes daily and is a function of the average air temperature for each simulation day. Because of variability in this important relationship, the user can modify the default values for this relationship. Similarly, the user has the option of modifying the default relationship for adult weevil emigration and adult weevil density.

If Option 2 is selected from the menu illustrated above, the following menu will be displayed:

```
=============================================================================
                   DISPLAY INSECT RELATIONSHIP MENU
-----------------------------------------------------------------------------
           1. FECUNDITY/TEMPERATURE RELATIONSHIP
           2. EMIGRATION/ADULT WEEVIL DENSITY RELATIONSHIP
           3. EXIT
=============================================================================

    WHICH RELATIONSHIP(S) WOULD YOU LIKE TO DISPLAY/MODIFY?
    MAKE A SELECTION (1-3) AND PRESS <ENTER> --->
```

As indicated above, the fecundity relationship or the emigration relationship can be selected for display and modification. To exit this feature of the weevil module initialization procedure, select Option 3 and press <ENTER>. If Option 1 is selected, a graphics display of the fecundity relationship is shown on the screen. After the graphics display has been reviewed, the following tabular data (used to define the default fecundity and air temperature relationship) is displayed.

FECUNDITY/TEMPERATURE RELATIONSHIP DATA

| NUMBER | AIR TEMPERATURE, C | PROPORTION FECUND |
|---|---|---|
| 1 | 0.0 | 0.00 |
| 2 | 10.0 | 0.00 |
| 3 | 15.0 | 0.48 |
| 4 | 20.0 | 1.00 |
| 5 | 22.0 | 0.78 |
| 6 | 25.0 | 0.40 |
| 7 | 30.0 | 0.10 |
| 8 | 40.0 | 0.00 |
| 9 | 50.0 | 0.00 |

```
To modify this file, enter the Number and the corresponding Air Tempera-
ture (degrees celsius) and Fecundity values.
EXAMPLE: 6 22 .65 <ENTER> - changes pair number 6 so that weevil
fecundity at 22 degC is 65 percent of the maximum fecundity
If you do not want to modify or to end modifications enter the follow-
ing:
0 0 0 <ENTER>
```

As indicated in the above tabular listing, the air temperature/fecundity relationship is defined by nine pairs of values. Follow the instructions provided in the above screen display to make modifications to the fecundity relationship.

If Option 2 is selected from the **DISPLAY INSECT RELATIONSHIP MENU**, the default relationship for adult weevil emigration as a function of adult weevil density is graphically displayed (on the screen). After review of this relationship, pressing <ENTER> will result in screen display of a tabular listing of this relationship.

```
==============================================================================
            EMIGRATION/ADULT WEEVIL DENSITY RELATIONSHIP DATA
------------------------------------------------------------------------------
                                              PROPORTION
         NUMBER            DENSITY, no./sqm   EMIGRATION

           1                     0              .00
           2                    25.0            .01
           3                    50.0            .01
           4                   100.0            .05
           5                   150.0            .10
           6                   200.0            .20
           7                   225.0            .25
==============================================================================
         To modify this file, enter the Number and the corresponding adult
         weevil density and percent emigration value.
         EXAMPLE: 3 50.0 .25 <ENTER> - changes pair number 3 so that an adult
         density of 50 adults per square meter will result in 25 percent loss
         due to emigration.
         If you do not want to modify or to end modifications/changes enter
         the following:
         0 0 0<ENTER>
```

As indicated above, the adult weevil density/emigration relationship is defined by seven pairs of values. The instructions provided at the bottom of the tabular display should be followed for making modifications to the relationship.

After **0 0 0<ENTER>** is input (following display of the tabular listing of the fecundity/temperature relationship or the emigration/density relationship), the program returns to the **DISPLAY INSECT RELATIONSHIP MENU** (page 16). If Option 3 is selected from the **DISPLAY INSECT RELATIONSHIP MENU**, the program again prompts the user with the following screen.

```
==============================================================================
              Relationships shown below are defined in the INSECT
            model by a default set of tabular values.


        FECUNDITY/TEMPERATURE RELATIONSHIP
        EMIGRATION/ADULT WEEVIL DENSITY RELATIONSHIP
------------------------------------------------------------------------------

      Would you like to execute a simulation run without displaying or
      modifying these default relationships?

        1 = YES
        2 = NO
==============================================================================
    MAKE A SELECTION (1-2) AND PRESS <ENTER> --->
```

By selecting Option 1 to this screen prompt, execution will continue with the following screen display.

```
================================================================================
                         DURATION OF THE SIMULATION
--------------------------------------------------------------------------------
================================================================================
    ENTER THE YEARS OF SIMULATION (1,2 OR 3) AND PRESS <ENTER> --->
```

(A description of this entry prompt and subsequent prompts for initializing the plant growth module is given on pages 10-13.

After the initial dry weight plant biomass has been entered (see page 13), model execution returns to initialization of the *Neochetina* module. Initialization values for the relative percentages of *N. eichhorniae* and *N. bruchi* are input in response to the following screen display.

```
================================================================================
                           INSECT PERCENT RATIO
--------------------------------------------------------------------------------
================================================================================
    ENTER PERCENT N.EICHHORNIAE AND N. BRUCHI AND PRESS <ENTER>
    SUM MUST = 100%
    EXAMPLE: 50 50 means - 50% N. eichhorniae and 50% N. bruchi -->
```

The above prompt, as indicated, allows execution of a simulation run with a mixture of both species of weevils, or with only one of the weevil species.

After entering the relative percent values of the two weevil species, the following will be displayed on the screen:

```
================================================================================
                  SELECTION OF STARTING NUMBERS FOR YEAR ?
--------------------------------------------------------------------------------
      Codes for NEOCHETINA life stages

          1 = EGGS
          2 = 1ST INSTAR LARVAE
          3 = 2ND INSTAR LARVAE
          4 = 3RD INSTAR LARVAE
          5 = PUPAE
          6 = YOUNG ADULTS (.LE. 77 degree days)
          7 = OLD ADULTS   (.GT. 77 degree days)
          8 = TERMINATE INPUTS FOR CURRENT YEAR
================================================================================
    MAKE A SELECTION (1-8) AND PRESS <ENTER> --->
```

Response to the above input prompt allows input for starting numbers for each of the seven life stages during each year of the simulation period. If no input is provided for a life stage, zero individuals of that life stage are used for initialization. After selecting the desired *Neochetina* life stage, the following will be displayed on the screen:

```
==============================================================================
                              NEOCHETINA LIFE STAGE?
------------------------------------------------------------------------------
             SELECTION OF STARTING NUMBERS FOR YEAR ?
    JDAY   = JULIAN DATE FOR THE INPUT (1 - 365)
    AMOUNT = NUMBER OF INDIVIDUALS per sq m

==============================================================================

    ENTER THE JDAY AND THE AMOUNT AND PRESS <ENTER>
    EXAMPLE: 10 50 - On Jday 10, 50 individuals are entered for the selected
     life stage
    SEPARATE ENTRIES WITH A SPACE --->
```

Response to this input prompt allows input of the Julian day during the simulation period for which initial numbers of individuals (**AMOUNT**) are input for the simulation run. Error checks prevent inputting a Julian day (**JDAY**) prior to the starting Julian day (1-365) of the first year of the simulation period and inputting a Julian day (**JDAY**) after the last Julian day (1-365) of the last year of the simulation period. Individuals of a given life stage can be considered for any year of the simulation period. For multiple-year simulation periods, individual numbers input after the first year will be added to the population already considered.

After input is complete, the following screen will be displayed:

```
             INITIALIZATION IS NOW COMPLETE ...
     THE NEXT SCREEN WILL DISPLAY YOUR INITIALIZATION VALUES
             ***********************************
                 PRESS <ENTER> TO CONTINUE.
```

After <ENTER> has been pressed, all user-selected initialization values for the waterhyacinth plant growth simulation will be displayed on the following screen:

```
                    INPUTS USED FOR THE SIMULATION
---------------------------------------------------------------------------
  NUMBER  OF
  YEARS              WEATHER DATA USED
  ----------         -------------------------------------------------
  LENGTH OF          NAME(S) AND YEAR(S) OF WEATHER
  SIMULATION          DATA SET(S) USED

  FIRST    LAST                                   INITIAL DRY WT.
  DAY      DAY          TYPE OF SIMULATION        BIOMASS Kg/Sq m
  ------   ------    --------------------------  -------------------
  1ST  AND LAST      PLANTS ONLY OR PLANTS/INSECTS   BEGINNING DRY
 DAY OF SIMULATION                                    WEIGHT OF
                                                    WATERHYACINTH

 PRESS <ENTER> TO CONTINUE
===========================================================================
```

The above illustrates the first of two screen displays that are provided for user review of initialization values for a waterhyacinth plant growth and *Neochetina* simulation. In the above screen display, information shown in *italics* refers to data input by the user. An example of this first review screen for a plant growth/*Neochetina* simulation is provided in Chapter 4 (page 27).

After reviewing the above information and pressing the **ENTER** key, the second initialization review screen, as illustrated below, will be displayed.

```
===========================================================================
                  INSECT VALUES USED IN THE SIMULATION
---------------------------------------------------------------------------
 PERCENT N. EICHHORNIAE, N. BRUCHI    ?    ?

 JDINS = JULIAN DATE FOR INSECT INPUT:  LSTAGE = LIFE STAGE
 (1=EGGS, 2=1ST INSTAR LARVAE, 3=2ND INSTAR LARVAE, 4=3RD INSTAR LARVAE,
  5=PUPAE, 6=YOUNG ADULTS, 7=OLD ADULTS)   AMOUNT = NUMBER PER SQ M.
 ---------------------------------------------------------------------
          YEAR 1      .          YEAR 2          .          YEAR 3
 JDINS LSTAGE AMOUNT       JDINS LSTAGE AMOUNT        JDINS LSTAGE AMOUNT
 ----- ------ ------       ----- ------ ------        ----- ------ ------
  ###    #     ###          ###    #     ###           ###    #     ###
   .     .      .            .     .      .             .     .      .

   0     0      0            0     0      0             0     0      0
PRESS <ENTER> TO CONTINUE
===========================================================================
```

Again, note that information shown in *italics* represents data that would be input during the initialization steps described above. An example of this second review screen for an example simulation is also provided in Chapter 4 (page 28).

Pressing <ENTER> while the above screen is displayed will result in the following prompt:

```
==============================================================================
              WOULD YOU LIKE TO CHANGE YOUR INITIALIZATION VALUES?
------------------------------------------------------------------------------
     Note: If you answer no (2), Execution will begin ...

              1. YES
              2. NO
==============================================================================
    MAKE A SELECTION (1-2) AND PRESS <ENTER> --->
```

If "1" is selected, the initialization process will begin. If Option 2 is selected, execution of a combined waterhyacinth plant growth and *Neochetina* simulation will be initiated.

Upon completion of a simulation run, the program displays the following menu:

```
==============================================================================
                        REVIEW SIMULATION OUTPUT MENU
------------------------------------------------------------------------------
                             1.  GRAPHICS

                             2.  TABULAR

                             3.  EXIT TO MAIN MENU
==============================================================================
    MAKE A SELECTION (1-3) AND PRESS <ENTER> --->
```

See the following section for a discussion of the output options available from this menu.

## Review Simulation Output

If Option 3, **REVIEW SIMULATION OUTPUT**, is selected from the **MAIN MENU** or if execution of a simulation has been completed, the **REVIEW SIMULATION OUTPUT MENU** shown below will be displayed on the screen.

```
================================================================================
                         REVIEW SIMULATION OUTPUT MENU
--------------------------------------------------------------------------------
                         1.  GRAPHICS

                         2.  TABULAR

                         3.  EXIT TO MAIN MENU
================================================================================
    MAKE A SELECTION (1-3) AND PRESS <ENTER> --->
```

As indicated, simulation output can be displayed from the most recent simulation in either graphics or tabular format.

## Graphics output

If Option 1, **GRAPHICS**, is selected, the following menu will appear on the screen:

```
================================================================================
                               GRAPHICS MENU
--------------------------------------------------------------------------------
           1.  PLANTS

           2.  INSECTS

           3.  SELECTED WEATHER DATA SET

           4.  EXIT TO REVIEW SIMULATION OUTPUT MENU
================================================================================
    MAKE A SELECTION (1-4) AND PRESS <ENTER> --->
```

From the **GRAPHICS MENU**, the user has the option of displaying simulation output for plants and insects, or displaying information about the weather data file used in the most recent simulation run.

If Option 1 (PLANTS) is selected from the **GRAPHICS MENU**, the following menu is displayed.

```
================================================================================
                           SCREEN PLOT FOR PLANTS
--------------------------------------------------------------------------------
      1. BIOMASS                .           5. PLANT LOSS
                                               (DETRITUS)
      2. NUMBER OF PLANTS       .           6. PLANT LOSS
                                               (INSECTS)
      3. GROSS                  .           7. NET CHANGE
         PRODUCTION                            IN BIOMASS
      4. RESPIRATORY            .           8. EXIT TO
         MAINTENANCE                           GRAPHICS MENU
================================================================================
    MAKE A SELECTION (1-8) AND PRESS <ENTER> --->
```

This menu allows graphics display for seven plant growth parameters on a daily basis for the duration of the simulation period.

If Option 2 (INSECTS) is selected from the **GRAPHICS MENU**, the following menu is displayed:

```
===============================================================================
                         SCREEN PLOTS FOR INSECTS
-------------------------------------------------------------------------------
                         1. EGGS
                         2. LARVAE
                         3. PUPAE
                         4. ADULTS
                         5. EXIT TO GRAPHICS MENU
===============================================================================
    MAKE A SELECTION (1-5) AND PRESS <ENTER> --->
```

From the above menu, insect numbers and mortality values can be graphically displayed for each insect life stage, as can emigration numbers for adults. If the simulation run had a mixture of both species of weevils, the insect numbers will be plotted in this order: *N. eichhorniae*, *N. bruchi*, and the total of both species combined.

If Option 3 (SELECTED WEATHER DATA SET) is selected from the **GRAPHICS MENU**, the following menu of four weather parameters is displayed to allow graphics display of each weather parameter for the weather data file used in the most recent simulation run.

```
===============================================================================
                         SCREEN PLOT FOR WEATHER DATA
-------------------------------------------------------------------------------
                         1. SOLAR RADIATION
                         2. AVERAGE TEMPERATURE
                         3. MINIMUM TEMPERATURE
                         4. MAXIMUM TEMPERATURE
                         5. EXIT TO GRAPHICS MENU
===============================================================================
    MAKE A SELECTION (1-5) AND PRESS <ENTER> --->
```

## Tabular output

If Option 2 (TABULAR) is selected from the **REVIEW SIMULATION OUTPUT MENU**, the following menu will be displayed.

```
===============================================================================
                              TABULAR MENU
-------------------------------------------------------------------------------
                    1. DISPLAY FILE TO SCREEN
                    2. DUMP FILE TO PRINTER
                    3. EXIT TO REVIEW SIMULATION OUTPUT MENU
===============================================================================
    MAKE A SELECTION (1-3) AND PRESS <ENTER> --->
```

After selecting the output device for the tabular listing, the following files list and selection prompt will appear on the screen:

```
==============================================================================
                               FILE LIST MENU
------------------------------------------------------------------------------
      1. TOTAL INSECTS                          6. PLANT GROWTH (File 1)
      2. N. eichhorniae (All stages)            7. PLANT GROWTH (File 2)
      3. N. bruchi (All stages)                 8. INITIALIZATION VALUES
      4. WEEVIL LARVAE                          9. USER SELECTED WEATHER
      5. WEEVIL ADULTS                         10. INSECT MORTALITY/EMIGRATION
                                               11. EXIT TO TABULAR MENU
==============================================================================
    MAKE SELECTION (1-11) AND PRESS <ENTER> --->
```

The contents of the simulation output files listed above and described in Tables 1-3 can be copied into permanent files for further analysis. (These output files are discussed in Chapter 2, page 5.)

# 4 Example Runs and Applications Using INSECT

Example simulations using INSECT were made to provide further information to facilitate proper execution and to demonstrate applications. The following summary includes example runs for each of the two generalized types of simulation runs available from INSECT. These include a waterhyacinth plant growth simulation *without* impacts from *Neochetina* weevils, and a waterhyacinth plant growth simulation *with* impacts from *Neochetina* weevils. For each of these two types of runs, the example includes a review of proper initialization procedures and a demonstration of simulation model results.

## Run 1: Waterhyacinth Plant Growth Simulation

This simulation is provided to illustrate the operational procedure of the plant growth module and to briefly discuss example simulation output. The first-time user may wish to follow instructions in Chapter 3 of this manual and conduct a practice simulation run with the data provided in this example.

### Initialization

To run a plant growth only simulation (i.e., without impacts from *Neochetina* weevils), the user must select Option 1 from the MAIN MENU. For this example, a 2-year simulation period was selected. Weather data for the 2 years were taken from two single-year weather data files representing daily air temperature and solar radiation values for 1986 southeast Florida weather conditions (Code 11) and for 1987 southeast Florida weather conditions (Code 13), respectively. These weather data files were selected by code number from a list of 15 available weather data files (see page 11). The beginning and ending dates of the simulation period were input as Julian day 10 of Year 1 and Julian day 365 of Year 2, respectively. Initial plant biomass (dry weight) was input as 0.50 $kg/m^2$.

After completing entry of the above input information, the following screen was provided for user review:

```
================================================================================
                         INPUTS USED FOR THE SIMULATION
--------------------------------------------------------------------------------
     NUMBER OF
      YEARS             WEATHER DATA USED
     ----------         ------------------------------------
       1                SOUTHEAST FL - 1986
       2                SOUTHEAST FL - 1987

     FIRST    LAST                                   INITIAL DRY WT.
     DAY      DAY        TYPE OF SIMULATION          BIOMASS Kg/Sq M
     -----    ----     -------------------------     -------------------
      10      365      PLANTS GROWTH ONLY              0.500

     DATE  09-05-91         TIME  15:37
================================================================================
```

After reviewing the above input data, the user would proceed with execution without changing the initialization conditions. (Note: If errors had been detected on the screen, the initialization data could have been changed.)

## Plant growth simulation output

The simulation outputs for plant growth parameters produced for the above simulation conditions are presented in Figures 3-9. The outputs illustrated in these figures were obtained by selecting Option 1, PLANTS, from the **GRAPHICS MENU** and by selecting each available option (1-7) from the **SCREEN PLOT FOR PLANTS** menu. This procedure was described in the section REVIEW SIMULATION OUTPUT (page 21).

As illustrated in Figure 3, plant biomass varied seasonally over the 2-year period, with high biomass levels being maintained throughout late spring and summer months (i.e., approximately Julian day 150-270). Comparison of the biomass data with plant density data shown in Figure 4 indicates that, although biomass levels were fairly constant during spring and summer days, partitioning of this biomass shifted from many small plants in spring to fewer larger plants in summer. Daily net production values (Figure 5), which accounted for the daily changes in plant biomass, were calculated in the simulation with daily estimates of gross production, respiration estimates, and detritus production (shown in Figures 6-8, respectively).

The simulation output presented above demonstrates that the plant growth module included in **INSECT** produces plant biomass estimates representative of seasonal changes in waterhyacinth biomass under representative field conditions. Under the conditions used for this particular simulation run, the simulated waterhyacinth biomass attained levels that are indicative of a nuisance infestation throughout spring and summer months. Additionally, plant biomass simulation output remained at nuisance levels throughout the 1986-87 winter period, even though fall and winter reductions occurred as a result of sustained consecutive days of negative net production (Figure 5). More significant winter declines in biomass levels would have occurred, if the weather data had contained days with minimum air temperatures below freezing. The occurrence of a year-round nuisance level of waterhyacinth is not uncommon in climates that do not experience freezing conditions, and this type climate is normal in southeast Florida.

## Run 2: Waterhyacinth Plant Growth/*Neochetina* Simulation

This example run is also provided to illustrate procedures for initializing INSECT. This example run differs from Run 1 (above) in that Option 2 (EXECUTE PLANT GROWTH/INSECT SIMULATION) has been selected from the MAIN MENU.

### Initialization

Default values for adult weevil fecundity and emigration relationships are used. Initialization values for simulation duration, beginning and ending dates of the simulation period, weather data files, and initial plant biomass were identical to initialization values used in Run 1. For initialization of the *Neochetina* module, weevil population was selected to be 100 percent *N. eichhorniae* and 0 percent *N. bruchi*. Starting numbers of insects for the simulation were 100 eggs, 25 first and second instar larvae, 50 third instar larvae, 100 pupae, 50 young adults, and 50 old adults. All insects were input on the first day of the simulation period (i.e., Julian day 10 of Year 1). After completing input of the above information, the model displayed the following information.

```
================================================================================
                         INPUTS USED FOR THE SIMULATION
--------------------------------------------------------------------------------
      NUMBER OF
      YEARS              WEATHER DATA USED
      ----------         -----------------------------------
        1                SOUTHEAST FL - 1986
        2                SOUTHEAST FL - 1987

      FIRST    LAST                                    INITIAL DRY WT.
      DAY      DAY        TYPE OF SIMULATION           BIOMASS Kg/Sq M
      -----    ----     -------------------------     ------------------
       10      365      PLANTS & INSECTS                    0.500

      DATE  09-04-91         TIME  15:12
================================================================================
```

After pressing the Enter key, the following screen will be displayed. This screen shows initialization values for the *Neochetina* module.

INSECT VALUES USED IN THE SIMULATION

PERCENT N. EICHHORNIAE & N. BRUCHI 100 0

JDINS = JULIAN DATE FOR INSECT INPUT: LSTAGE = LIFE STAGE (1=EGGS, 2=1ST INSTAR LARVAE, 3=2ND INSTAR LARVAE, 4=3RD INSTAR LARVAE, 5=PUPAE, 6=YOUNG ADULTS, 7=OLD ADULTS): AMOUNT=NUMBER PER SQ METER.

| YEAR 1 | | | YEAR 2 | | | YEAR 3 | | |
|---|---|---|---|---|---|---|---|---|
| JDINS | LSTAGE | AMOUNT | JDINS | LSTAGE | AMOUNT | JDINS | LSTAGE | AMOUNT |
| 10 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 2 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 3 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 4 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 6 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 7 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |

DATE 09-04-91 TIME 15:12

After reviewing the input data, the simulation was executed. Note: If an error had been detected in the initialization values, the user could have changed the initialization values before executing the simulation run.

## Plant growth simulation output

Simulation output for plant growth parameters produced during this simulation run is shown in Figures 10-16. These outputs were obtained by following output procedures presented in the section REVIEW SIMULATION OUTPUT (page 21), and as described above for the Run 1 example. In Figures 10 and 11, the presence of *N. eichhorniae* weevils in this simulation has greatly reduced the estimates for plant biomass during the first year of the simulation period when compared with Run 1 (Figure 3), which was without insects present. The reduced level of biomass can be attributed mainly to plant losses resulting from feeding by *Neochetina* third instar larvae. Daily values for the amount of herbivory are shown in Figure 16.

## *Neochetina* simulation output

Daily estimates for densities of *Neochetina* eggs, larvae, pupae, and adults over the 2-year simulation period are shown in Figures 17-20, respectively. Output illustrated in these figures was obtained by selecting Option 2, INSECTS, from the **GRAPHICS MENU** and by selecting each available option (1-4) from the **SCREEN PLOTS FOR INSECTS** menu (page 23).

In general, the alternation of abundances of individuals as they cycle through the different developmental stages is depicted by the simulation output. By comparison of Figures 16 and 18, plant losses resulting from insect herbivory did indeed occur when third instar larvae were at peak levels. As a general trend, there were overall reductions in the population of individuals in all life stages toward the end of the first year of the simulation period. A large portion of these lower population levels can be accounted for by the increased mortality values for each *Neochetina* life stage depicted in Figures 21-24. Additional reductions in the *Neochetina* population resulted from increased emigration of adult weevils (see Figure 25). *Neochetina* population losses resulting from both mortality and emigration coincided with the dramatic reduction in waterhyacinth biomass during the first year of the simulation period. These *Neochetina* population dynamic events that occurred are based on the relationships included in INSECT which determine the effects of weevil density (i.e., number per kilogram of plant tissue) on mortality and emigration.

In Figure 10 it is noteworthy that the plant biomass levels are higher in Year 2 than in Year 1. In fact, Year 2 biomass levels are similar to simulated biomass levels (Figure 3) resulting from Run 1 input conditions that included no *Neochetina* weevils. This illustrates that, under Run 2 conditions, the plant population was able to more quickly rebound from the Year 1 reductions than was the *Neochetina* population. In general, INSECT has generated output similar to what could be expected to occur under actual field conditions.

## General Comments on Example Simulations

INSECT was developed to provide information needed to systematically evaluate how environmental conditions affect the growth and development of waterhyacinth and *Neochetina* populations, as well as influence the plant/herbivore interactions that drive this biological control system. Example runs provided in this report hopefully will help users conceptualize simulation runs that will generate information useful in examining these interactions. For example, the user could evaluate the effects of freezing temperatures during winter months on waterhyacinth and *Neochetina* populations by simply using 1986 weather data for north-central Florida (Code 10). Comparison of outputs resulting from such a simulation run with outputs from a sumulation that do not consider subfreezing temperature conditions would allow evaluation of the effects of subfreezing conditions on the individual components and on the overall interactions of this system.

## Planned Updates to INSECT

The development of INSECT has been based on our current knowledge and understanding of the relationships that govern this biological system. In several areas, we are aware that knowledge of certain relationships is inadequate. As a result, WES will continue the development of INSECT in order to provide updates. As these updates are completed, changes to the support documentation will be distributed.

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Sabol, B. M. 1983. Simulated mechanical control of aquatic plants in Buffalo Lake, Wisconsin. Miscellaneous Paper A-83-8. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Sabol, B. M., and Hutto, T. D. 1984. Simulating mechanical control operations. *Aquatic Plant Control Research Program Information Exchange Bulletin*, Vol A-84-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

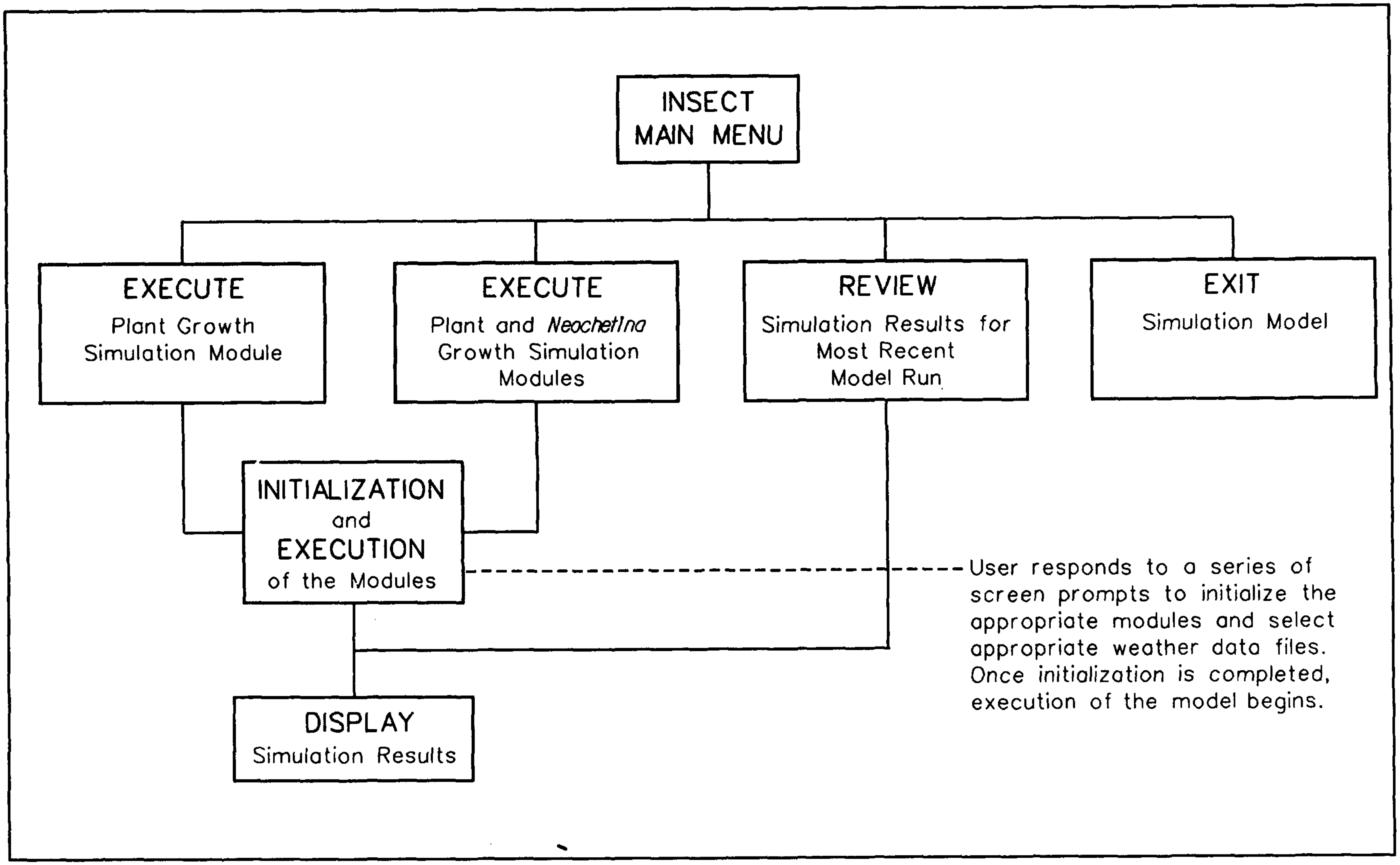


**Figure 1. Menu structure for INSECT software package**

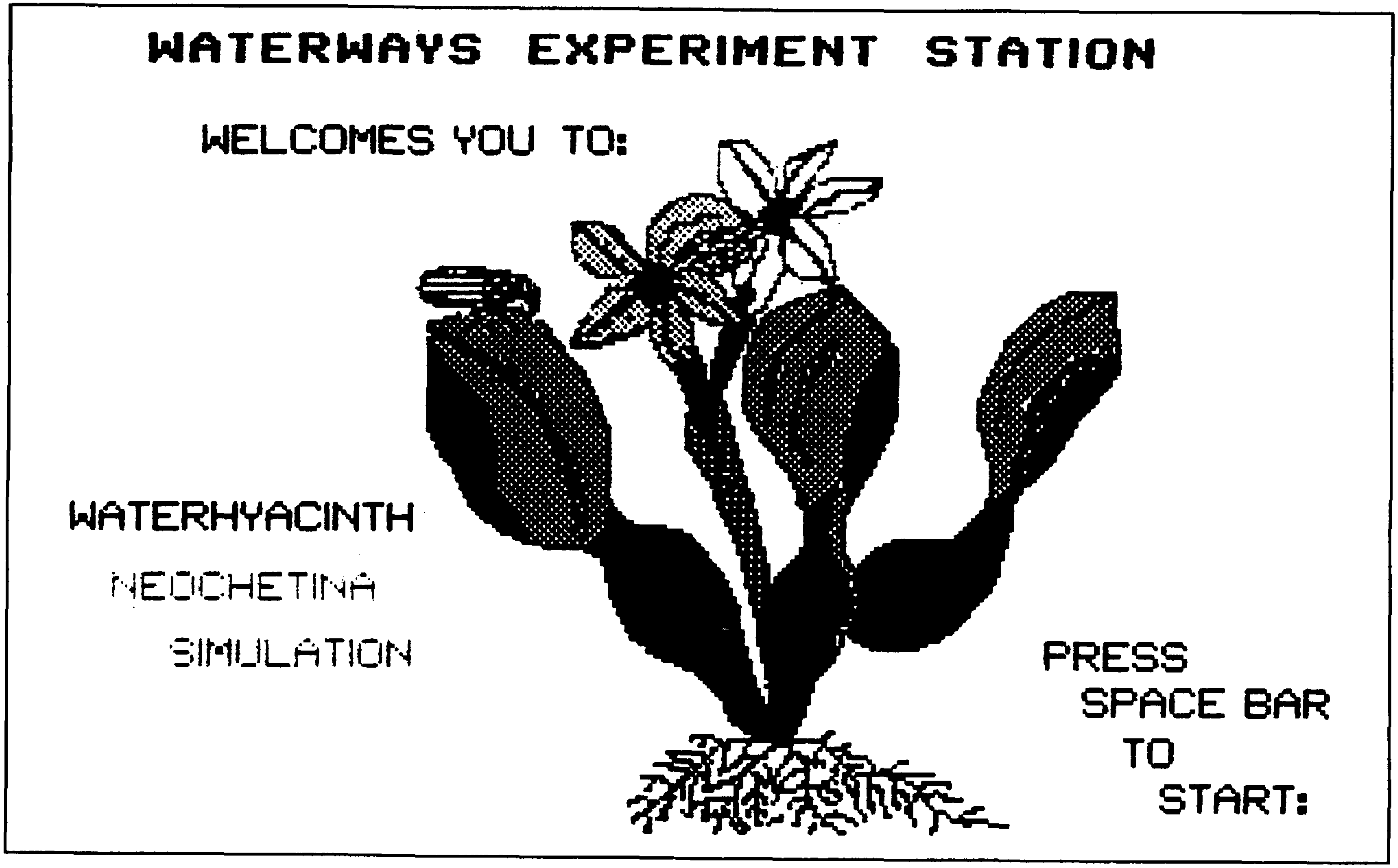


Figure 2. Introductory screen display for **INSECT** software package

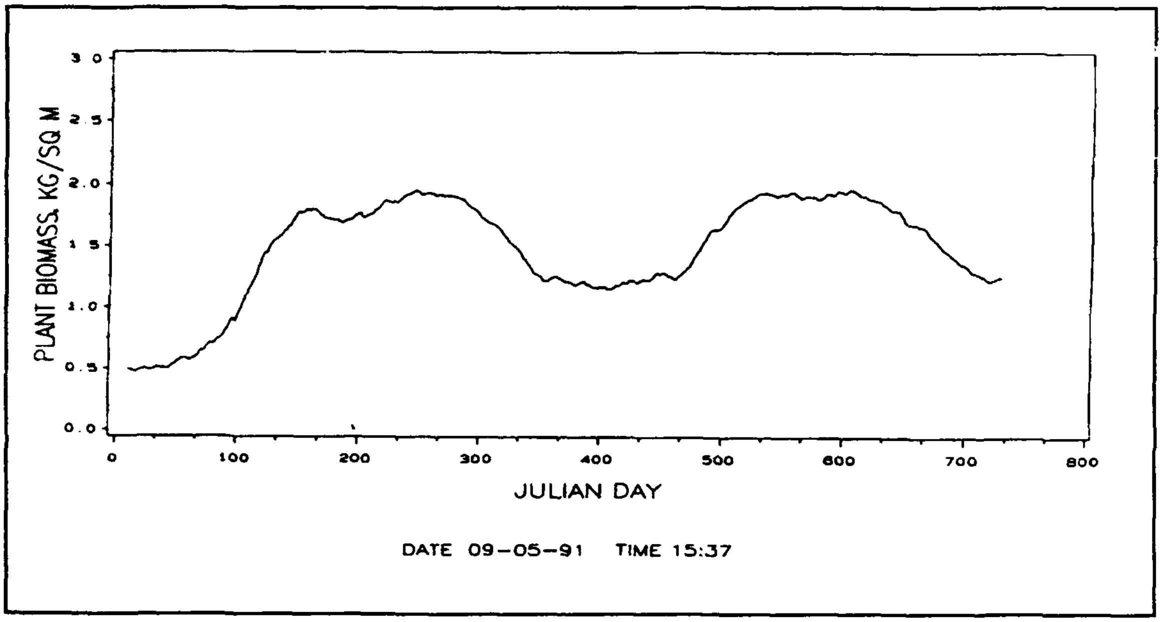


**Figure 3.** Simulation output for plant biomass under Run 1 conditions

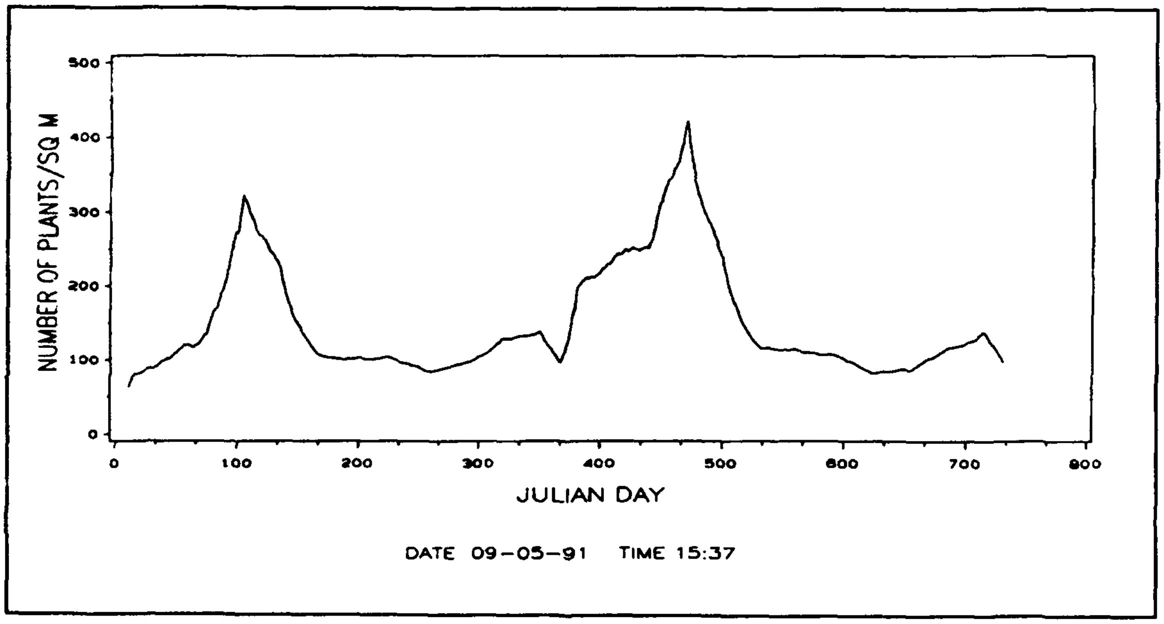


**Figure 4.** Simulation output for numbers of plants under Run 1 conditions

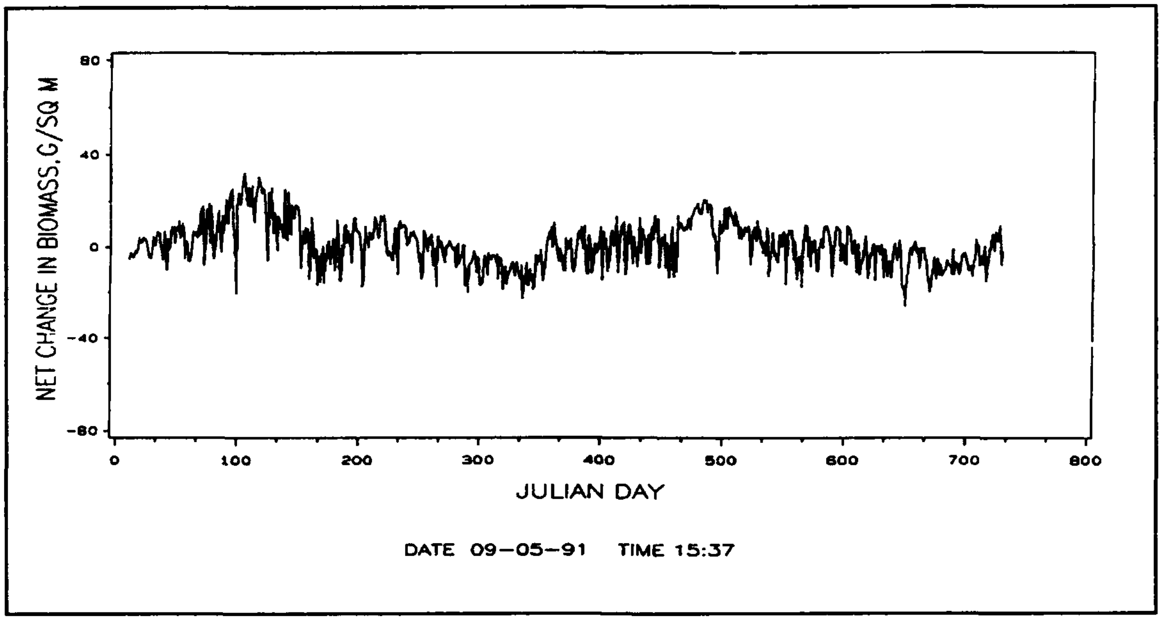


Figure 5. Simulation output for daily net change in plant biomass for Run 1 conditions

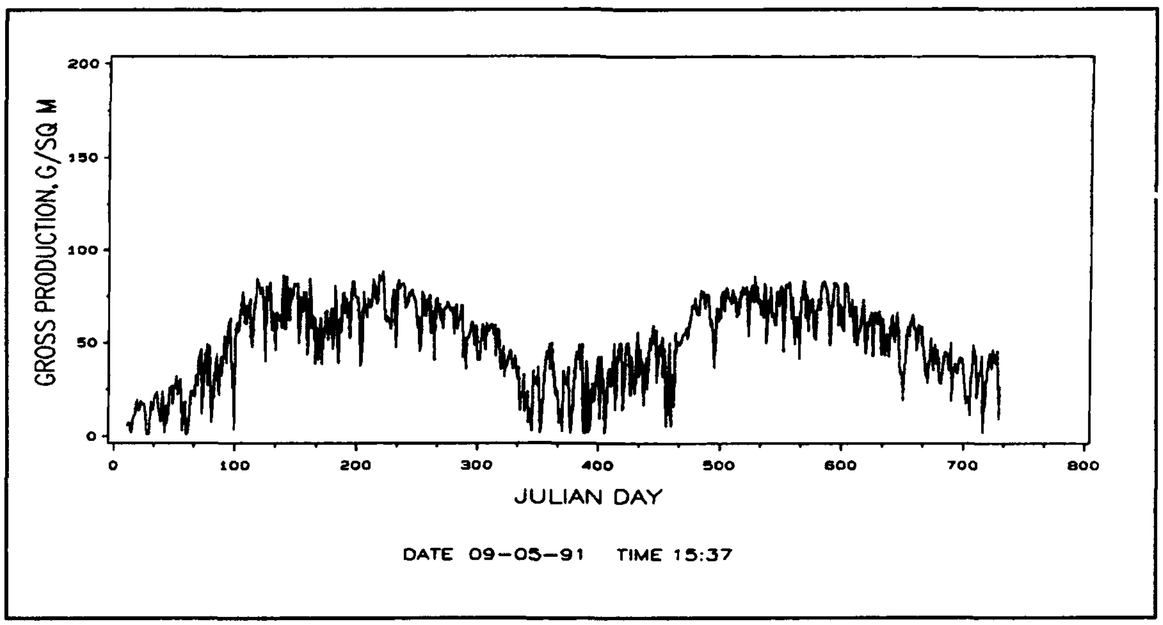


Figure 6. Simulation output for daily gross production of plant biomass for Run 1 conditions

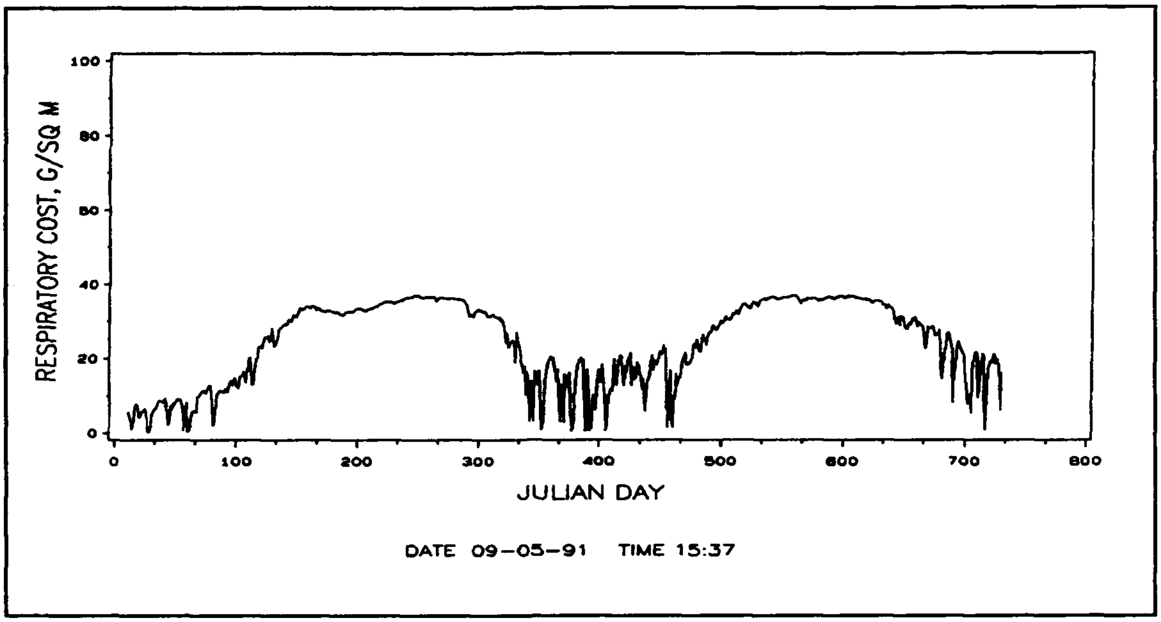


Figure 7. Simulation output for daily respiration costs in terms of biomass loss for Run 1 conditions

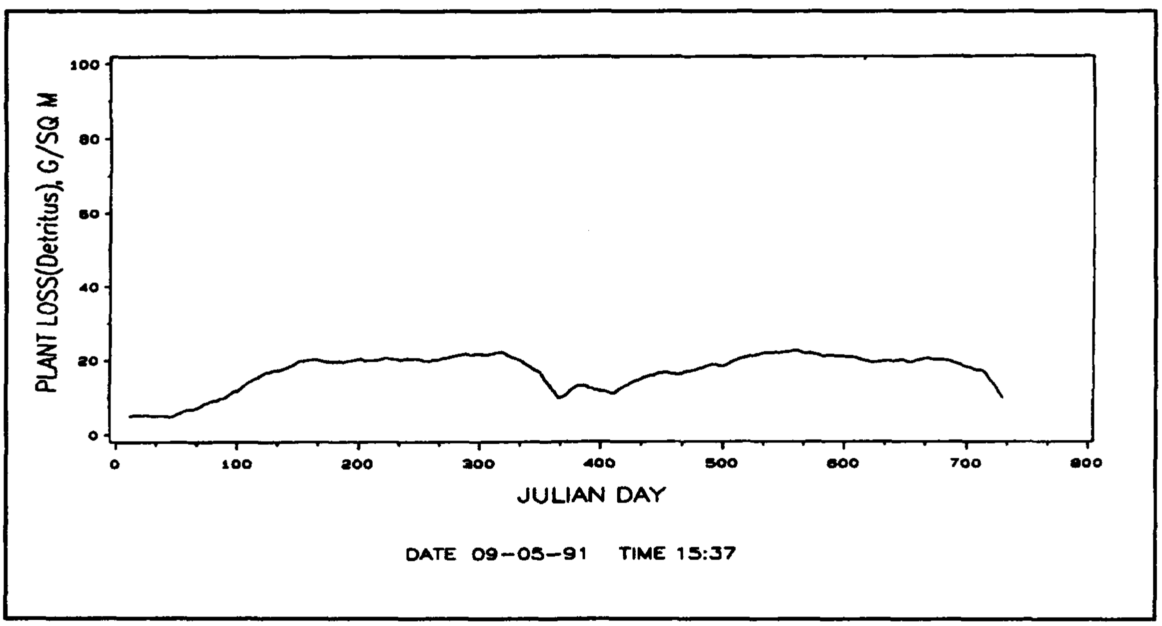


Figure 8. Simulation output for daily biomass losses resulting from plant detritus production for Run 1 conditions

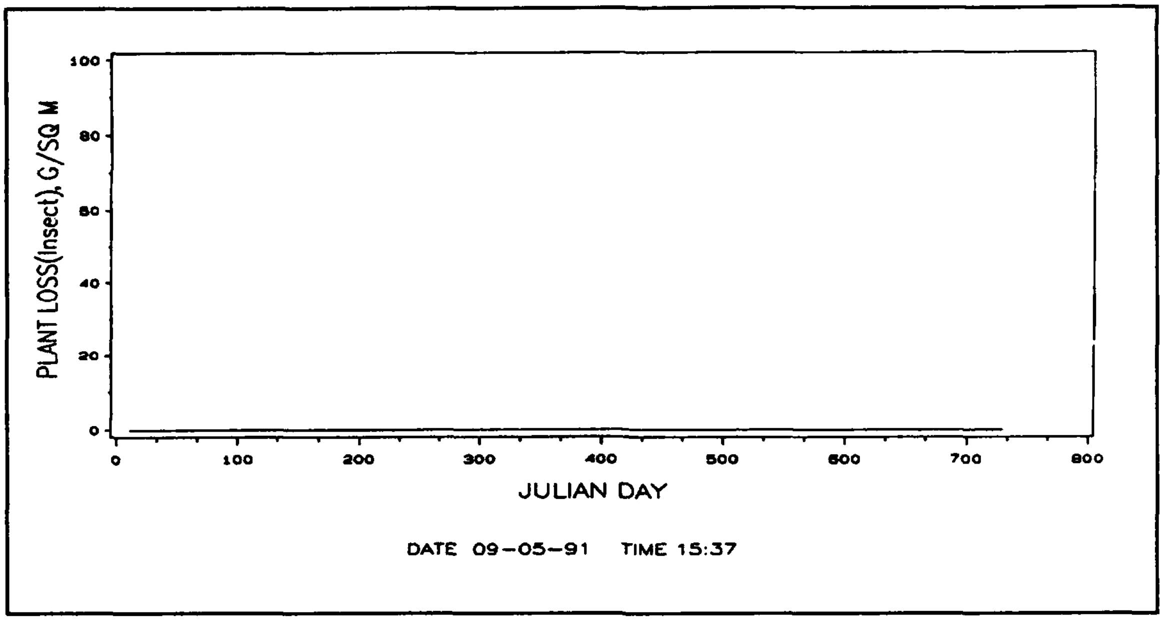


Figure 9. Simulation output for daily biomass losses resulting from *Neochetina* feeding for Run 1 conditions

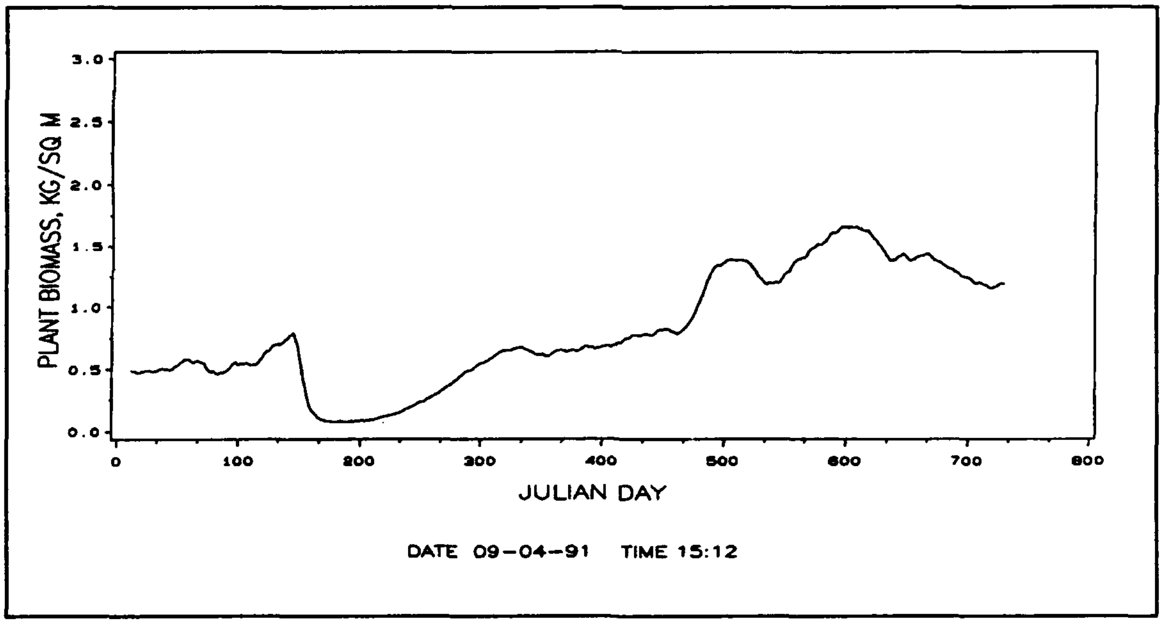


Figure 10. Simulation output for plant biomass under Run 2 conditions

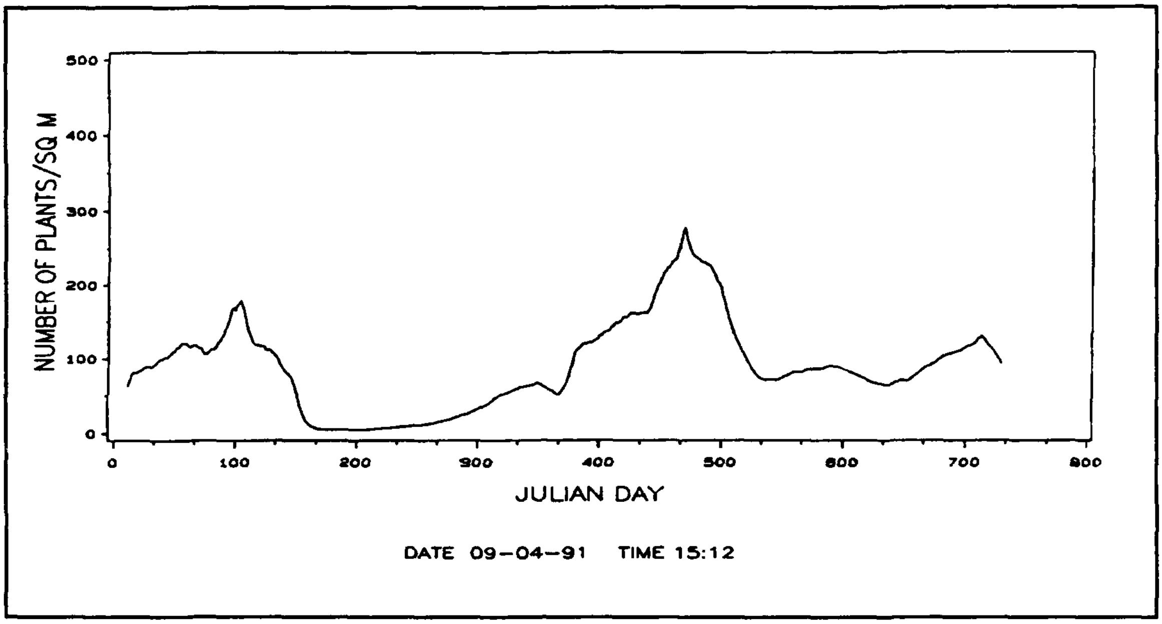


Figure 11. Simulation output for numbers of plants under Run 2 conditions

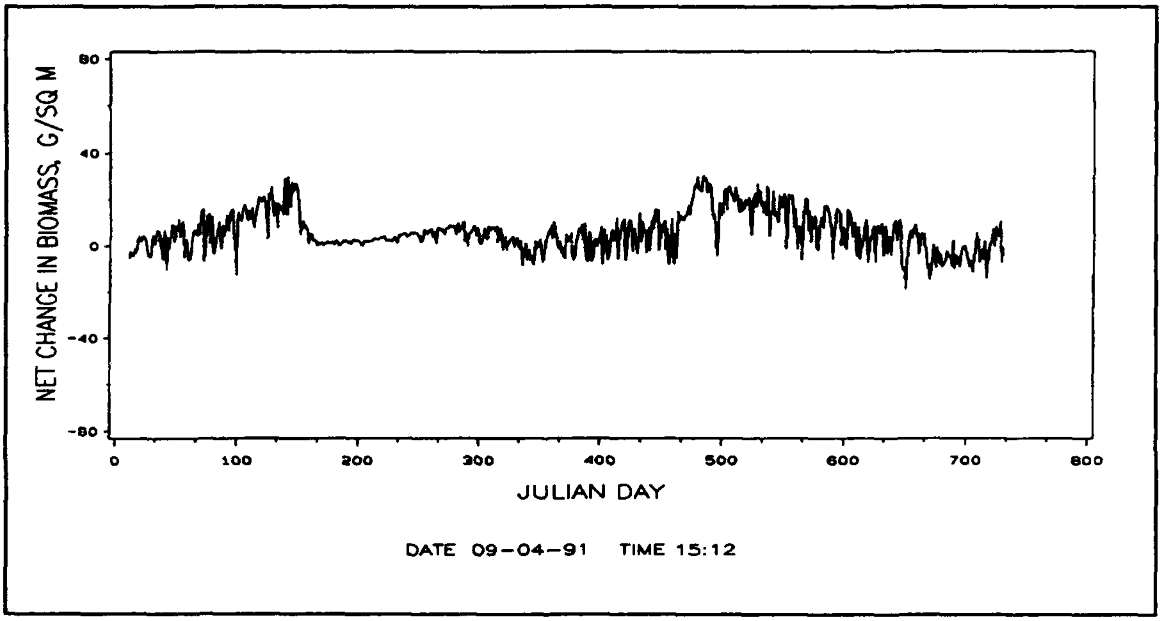


Figure 12. Simulation output for daily net change in plant biomass for Run 2 conditions

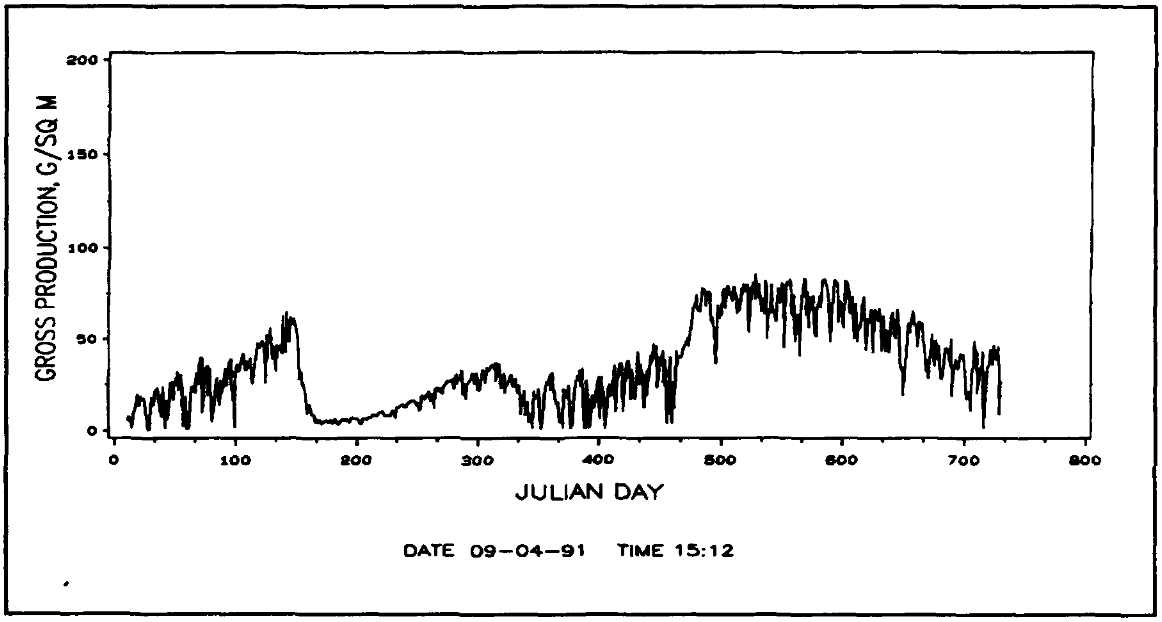


Figure 13. Simulation output for daily gross production of plant biomass for Run 2 conditions

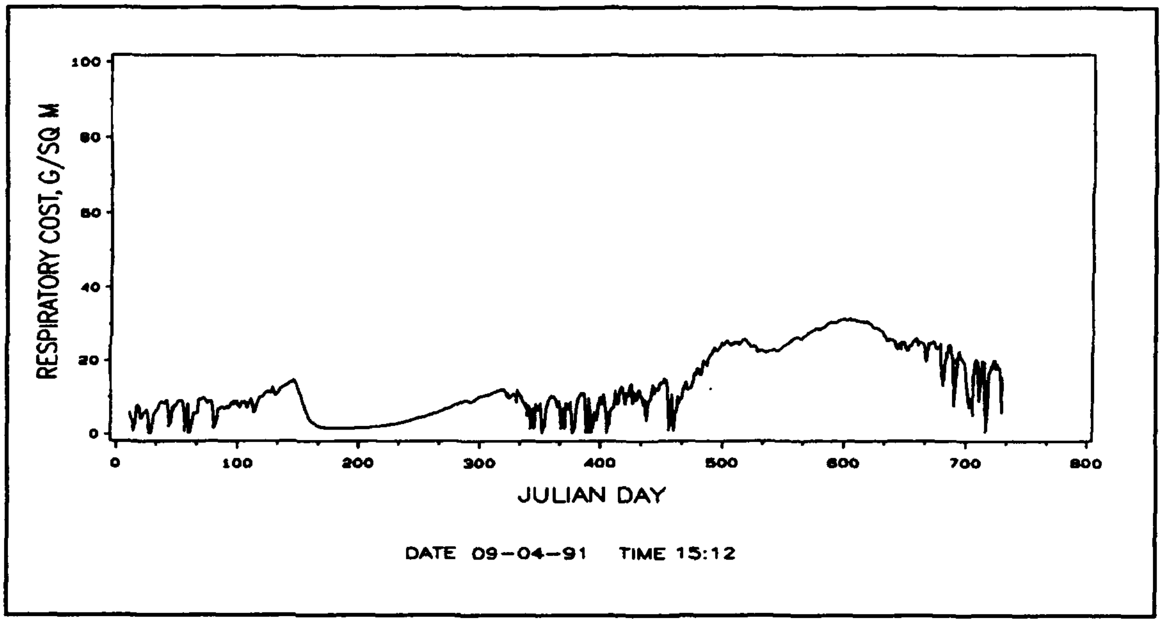


Figure 14. Simulation output for daily respiration costs in terms of biomass loss for Run 2 conditions

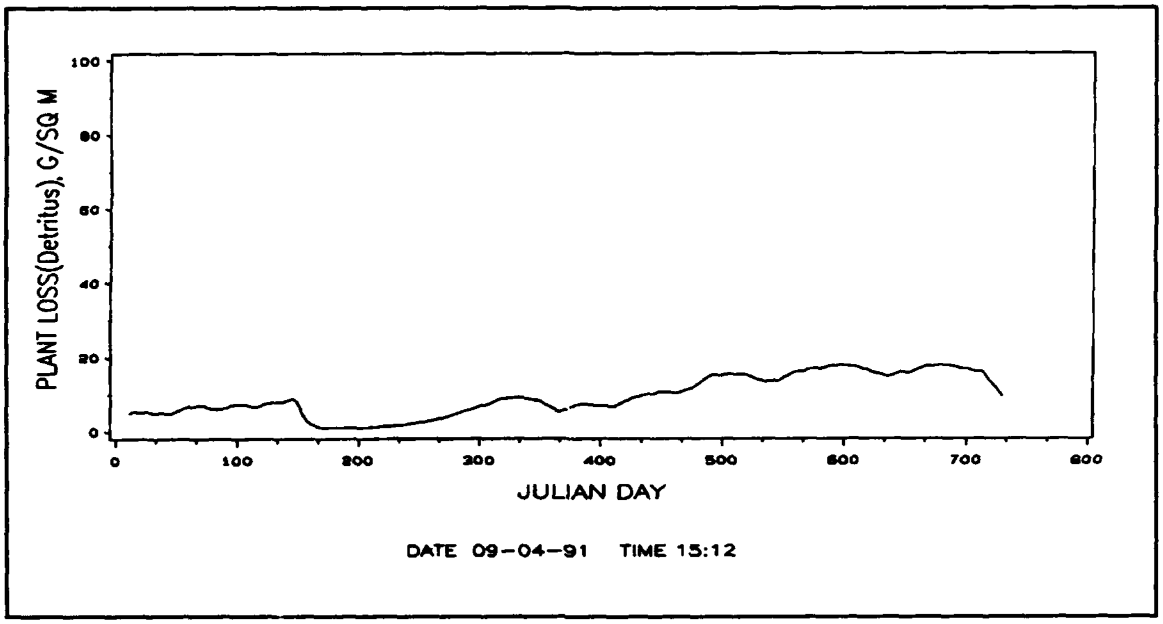


Figure 15. Simulation output for daily biomass losses resulting from plant detritus production for Run 2 conditions

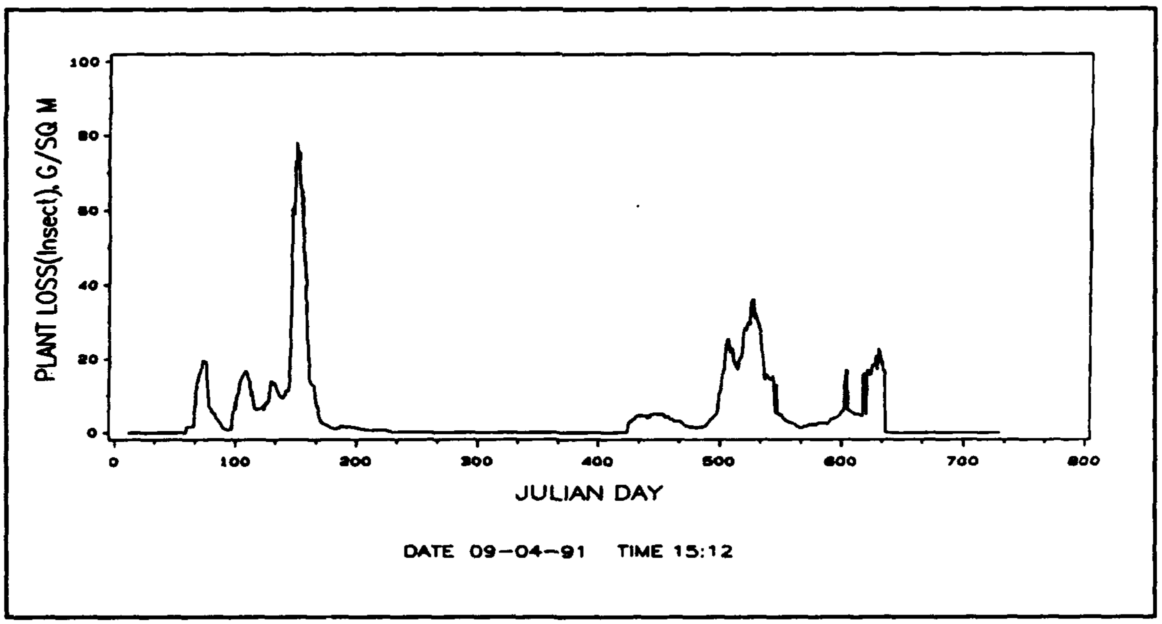


Figure 16. Simulation output for daily biomass losses resulting from *Neochetina* feeding for Run 2 conditions

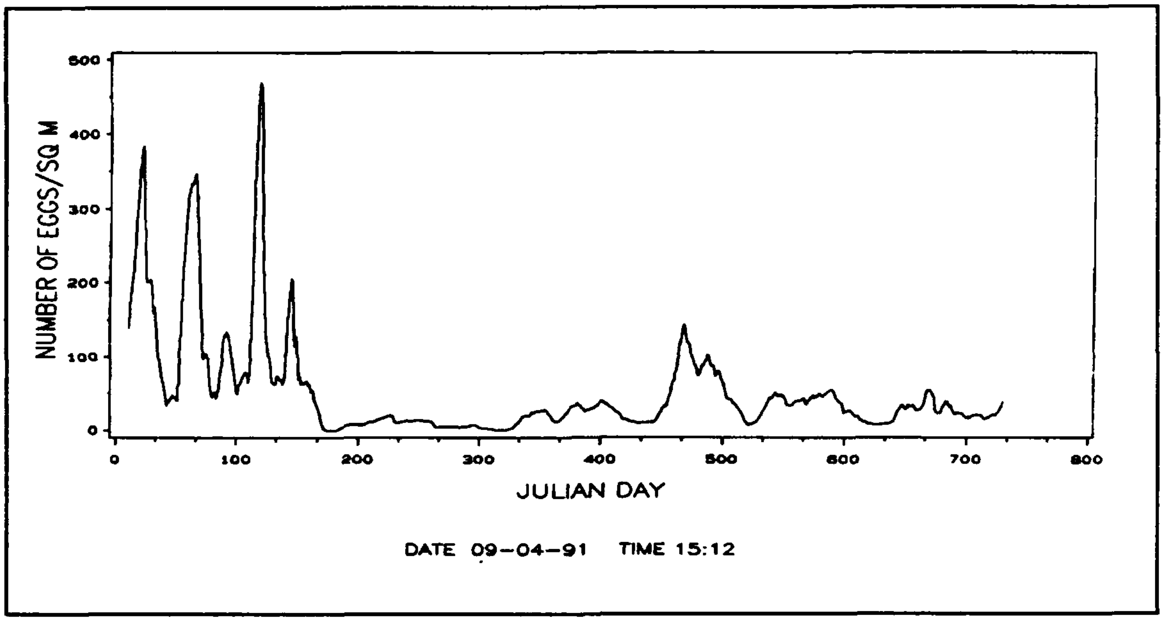


Figure 17. Simulation output for numbers of *Neochetina* eggs under Run 2 conditions

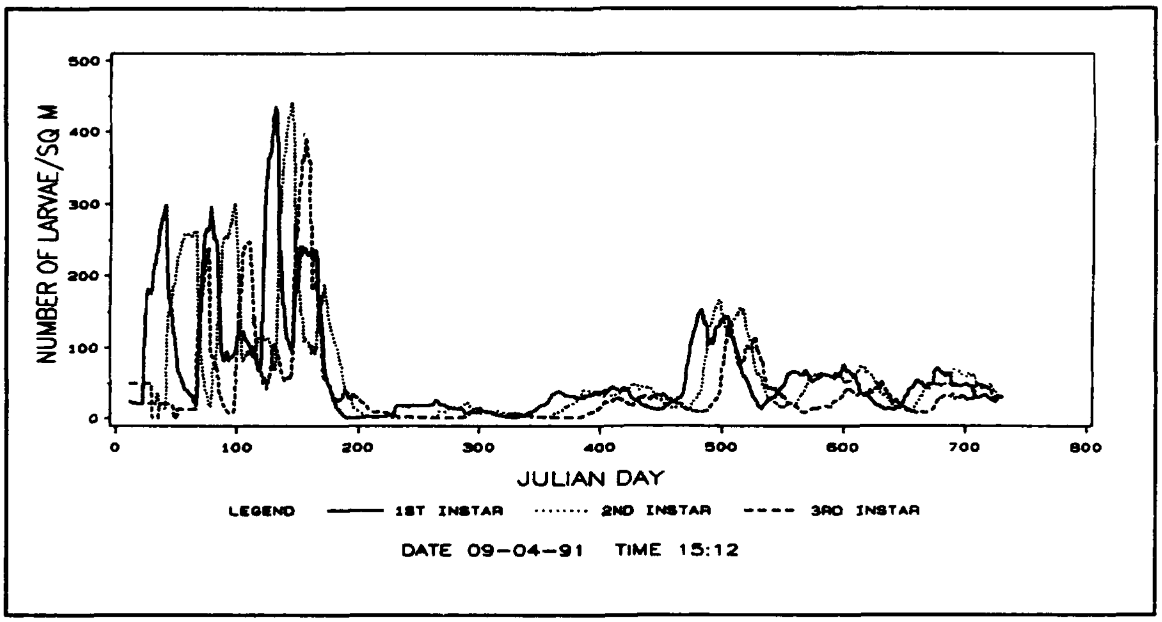


Figure 18. Simulation output for numbers of *Neochetina* larvae under Run 2 conditions

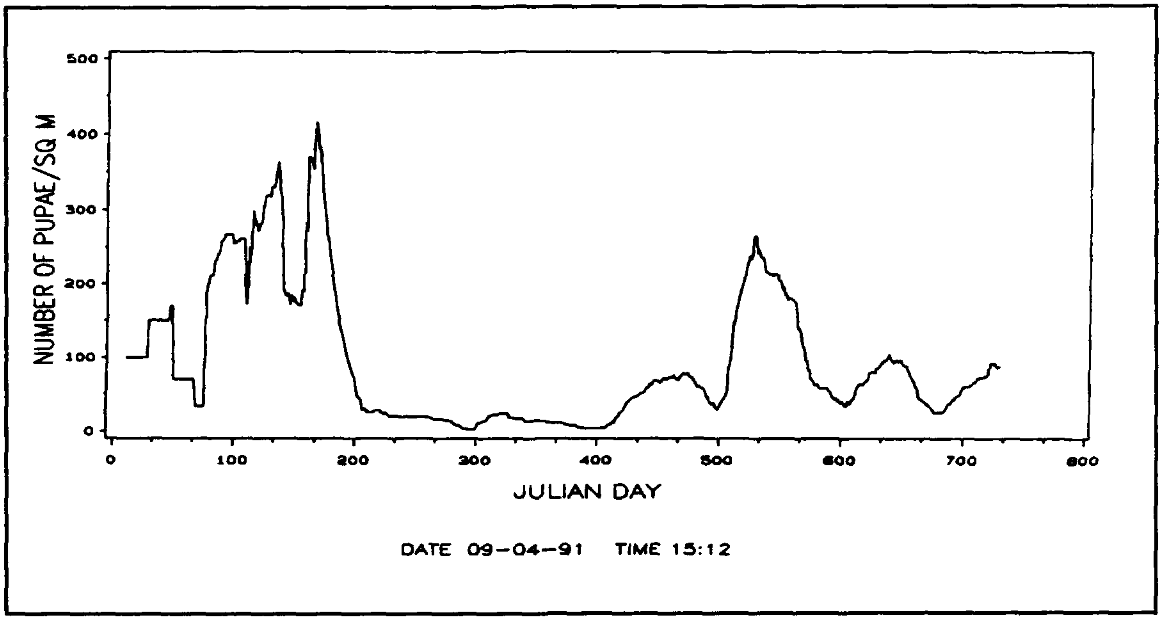


Figure 19. Simulation output for numbers of *Neochetina* pupae under Run 2 conditions

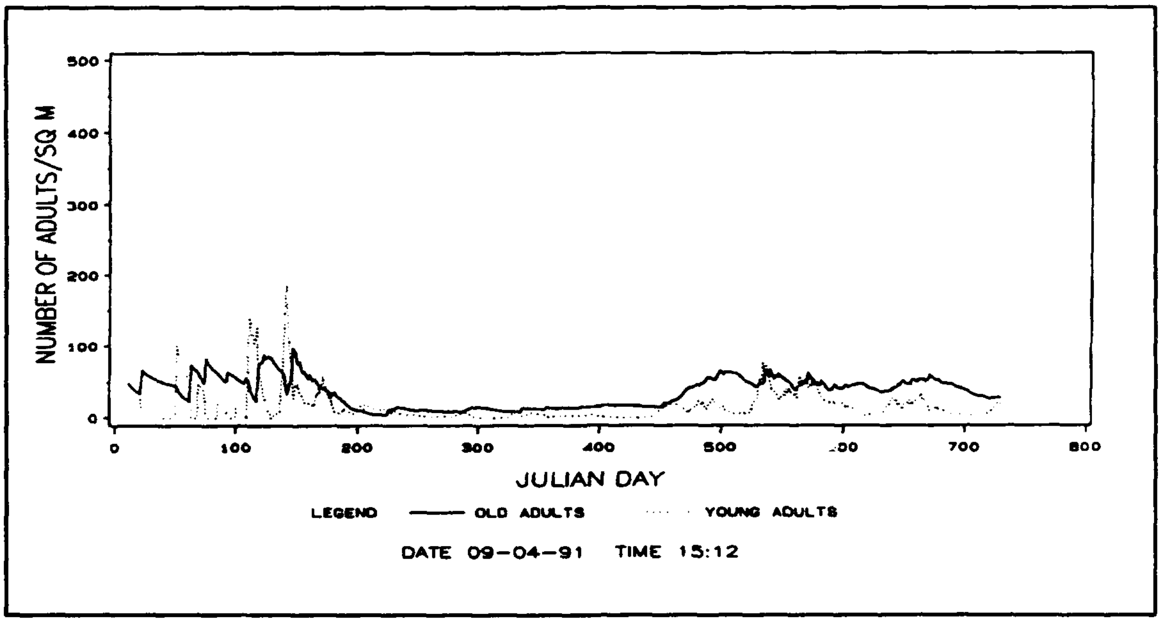


Figure 20. Simulation output for numbers of *Neochetina* adults under Run 2 conditions

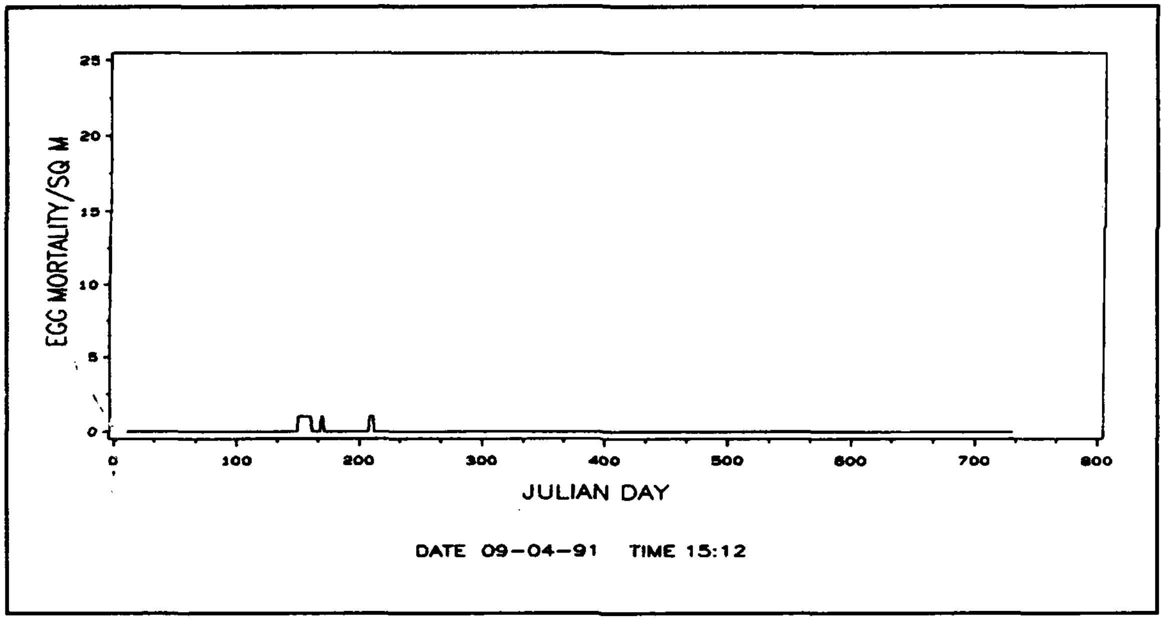


Figure 21. Simulation output for *Neochetina* daily mortality of eggs under Run 2 conditions

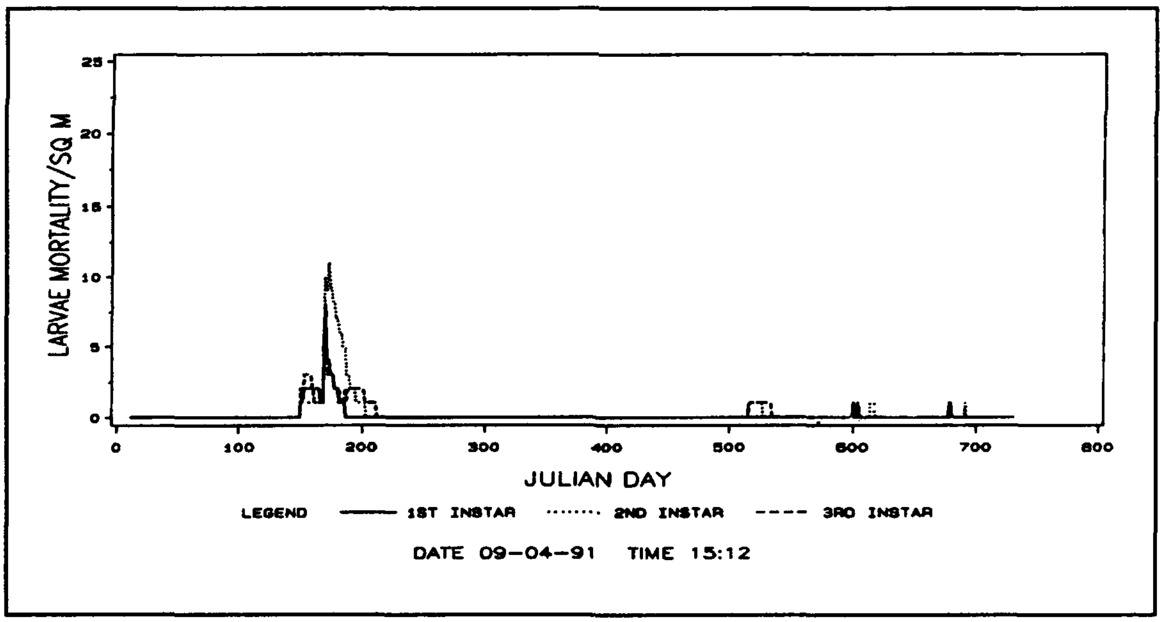


Figure 22. Simulation output for *Neochetina* daily mortality of larvae under Run 2 conditions

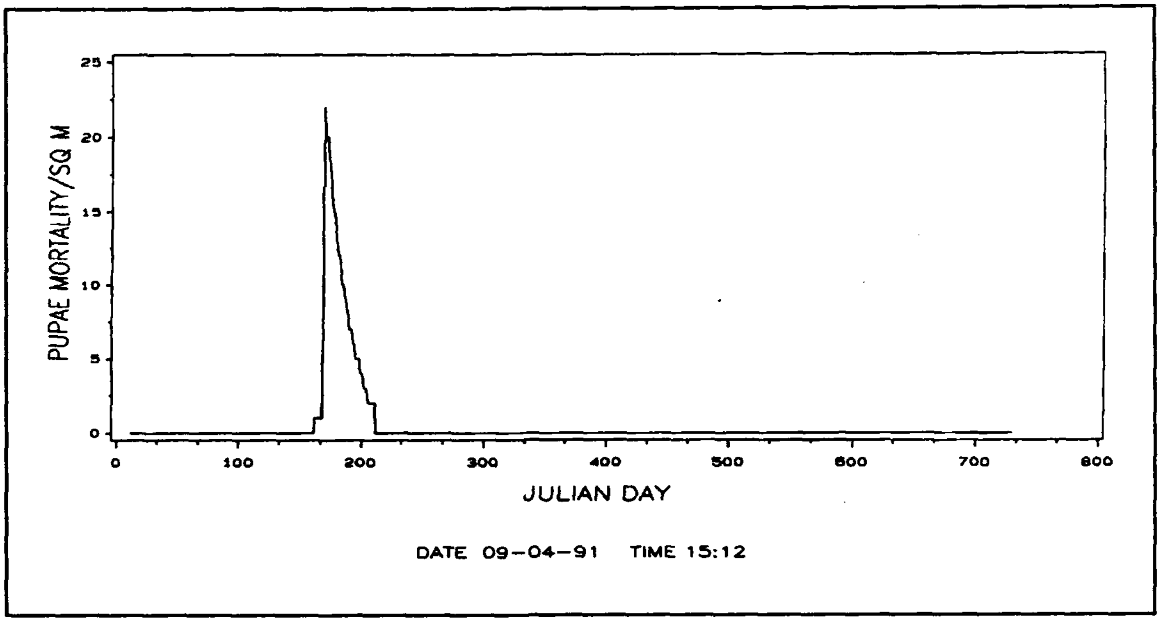


Figure 23. Simulation output for *Neochetina* daily mortality of pupae under Run 2 conditions

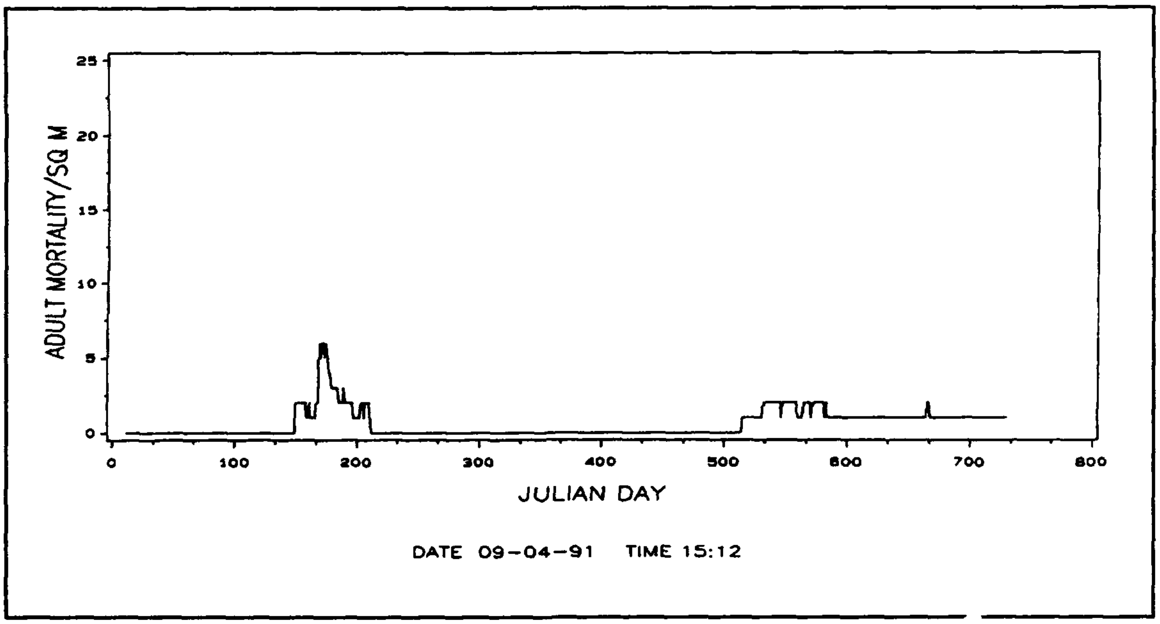


Figure 24. Simulation output for *Neochetina* daily mortality of adults under Run 2 conditions

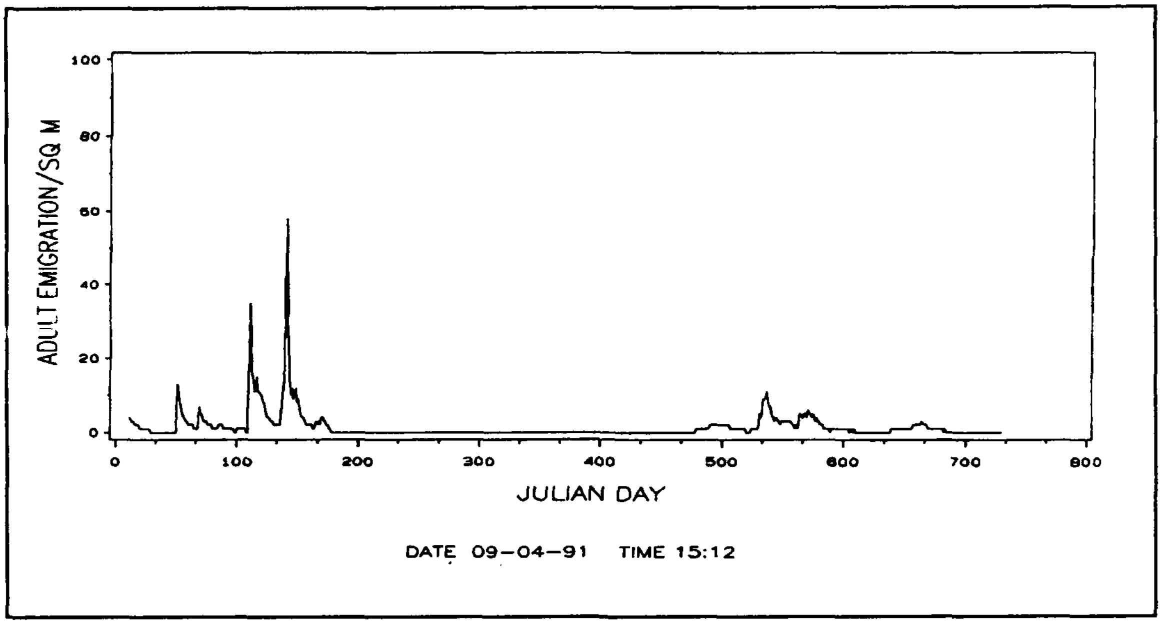


Figure 25. Simulation output for *Neochetina* daily emigration of adults under Run 2 conditions