A COMPUTER SIMULATION MODEL FOR BIOLOGICAL CONTROL OF AQUATIC PLANTS

Kunter S. Akbay, Dept. of Engineering Technology
Jean W. Wooten, Dept. of Biological Sciences
Fred G. Howell, Dept. of Biological Sciences
University of Southern Mississippi

ABSTRACT

A first generation computer simulation model has been developed for biological control of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms.) by two species of weevils (*Neochetina bruchi* Hustache and *N. eichhorniae* Warner). In this paper, the conceptual model is presented. It is a dynamic model which simulates the plant growth, insect development, and the plant-insect interactions on a daily basis. This model will allow aquatic plant managers to evaluate different control strategies before they are actually implemented.

INTRODUCTION

The U.S. Army Corps of Engineers Aquatic Plant Control Research Program (APCRP) is responsible for the development of new methodologies for the management of problem aquatic plant species in the Nation's waterways. One element of the program involves the development of biological control agents for the management of these troublesome aquatic plant species. The importation and establishment of a safe, natural enemy from the home range of the target plant is a desirable procedure that alleviates the need to use chemicals for control of these aquatic weeds. Biological control is environmentally acceptable because it aids in preservation of the integrity of water quality and protects the ecosystem from the effects produced by chemical applications.

One of the results of APCRP sponsored research is the control of alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.) by the alligatorweed flea beetle (*Agasicles hygrophila* Selman and Vogt). Another successful effort appears to be control of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) using two species of weevils (*Neochetina bruchi* Hustache and *N. eichhorniae* Warner).

Waterhyacinth is a floating aquatic plant native to South America. It flourishes in most parts of the world where winters are mild. In some developing countries the plants are used for cleansing water in local sewage ponds and for animal food (Vaas, 1951). Since waterhyacinth was reportedly introduced into the United States in 1884, it has spread throughout the southeastern United States and west into California. During the years 1958 to 30 June 1964 Federal funds totaling $6,750,000 were spent in the eight coastal states from North Carolina to Texas to control waterhyacinths (Blakey, 1966). Yet, the plants still create problems by consuming and transpiring tremendous quantities of water through the leaves, obstructing water flow, preventing proper drainage of land, interfering with navigation, and preventing fishing and recreation (Holm et al., 1969).

Many systems emphasizing positive uses for these plants have been developed. High quality paper can be made from these plants. The plants can be used to extract toxic materials from water systems. Since waterhyacinths take up extraordinary amounts of nutrients from enriched waters, they can provide a maintenance diet for cattle. In our developed society, however, most uses for the plant have not been shown to be economically attractive (Little, 1968).

Many years of intensive herbicide spraying of infested areas have proven that such activities can reduce the number of plants but are ineffective in eradicating them. Such efforts are extremely expensive and often affect the biological balance of treated areas. In South America, native predators often keep the plant numbers at acceptable levels.

Two species of *Neochetina* from Argentina were determined to be the most promising organisms for introduction into the United States to control waterhyacinth (Deloach and Cordo, 1976). The weevils are small, and feed by scraping epidermis and parenchyma from leaves and petioles, creating lesions in the host plant. Larvae burrow in the petioles and the rhizomes of the plants. Because rhizomes are frequently killed by this activity, production of new plants is effectively reduced.

Through a series of field studies the weevils were shown to be host specific and to impact growth of waterhyacinths. The USDA Animal and Plant Health Inspection Service authorized permission to release the two weevil species from quarantine. The weevils appeared to provide acceptable levels of control to waterhyacinth populations in Florida, Louisiana, and Texas.

In 1984 Waterways Experiment Station (WES) personnel felt that the results of these field tests were very promising and that the next step to encourage their use in the United States was to develop a computer simulation model expressing the results of using these weevils to control waterhyacinth growth.

THE MODEL

Simulation is the process of forming a model of a system and conducting experiments with this model. The system modeled in this study is the waterhyacinth - *Neochetina* spp. ecosystem. The model includes separate components of plants and insects as well as the interactions between them. Once the model is completed and validated, a variety of experiments can be conducted by altering certain parameters. The major objective of this research is to predict the effects of insects in controlling plant populations. The model can also be used to identify data needs to better understand the system. Ultimately, this model can be utilized by the plant managers to improve their decision making skills.

One alternative to simulation is to develop an analytical model of the system. However, in modeling of biological systems, analytical models may be very difficult to develop since the system and the interaction among its components are very complex and, therefore, not easily represented by mathematical equations. Another alternative to simulation is actual field experimentations. This method also has disadvantages since it is very difficult to maintain different parameters at the same level while changing the others.

To be effective, the model should have the following characteristics: (1) it must contain variables that permit choices that make it valid when used by personnel located in geographic areas that differ environmentally; (2) it should be complex enough to produce realistic results, yet simple enough to be understood; (3) it must be developed in such a way that it is easy to correct, modify, and/or improve; (4) it must be "user friendly" so that no computer background is required of the user (Akbay, 1979). Since the model must be easily accessible to potential users in the field, (5) it should be developed for personal computers in a universal format. In order to provide answers to "what if" questions, (6) the computer response time must be fast. Also, (7) it is essential that well-written documentation accompany the model. Finally, since validation is a continual process, (8) the model must be updated as new data and information become available.

The model presented in this paper is the conceptual model for waterhyacinth growth, *Neochetina* spp. development, and plant-insect interactions on a daily basis. After the plant and insect components of the model are initialized on the first day of simulation, an interactive logic simulates the aquatic plant ecosystem. First, on each simulation day, daily weather data are read. Then, the plant model is called to calculate the total biomass available to insects. The insect model is composed in logic of two submodels which are almost identical. Due to differences in the developmental times and feeding behaviors, *Neochetina bruchi* and *N. eichhorniae* are modeled separately. After both the plant and insect models are called, damage done to waterhyacinths by the *Neochetina* spp. is calculated and the daily results are printed.

Waterhyacinth model: This model is intended for simulating growth of waterhyacinth and the interaction with the weevils in environments where nutrients are not limiting. It is formulated in terms of the dry weight per m^2 occupied by plants and ultimately extrapolated to the area of the body of water covered by waterhyacinth plants.

Major simplifying assumptions in the model are that photosynthesis and respiration rates of the plants are functions of the prevailing temperature and light intensity and that the past temperature and light experience have no effect on the current photosynthesis and respiration rates other than through effects on the size of the plant. Growth is assumed to take place by a series of additive daily increments in leaf, rhizome, and root tissue, each determined by the prevailing temperature and light intensity and the biomass density. Also, day and night respiration rates are assumed to be equal. Rates of respiration are not dependent on plant age and size. It is recognized that when plants such as waterhyacinth die, nutrients contained in the plants are returned to the water system.

Neochetina spp. model: Important parameters needed to develop a model of the insects include population estimates of the weevil through time, number of generations per growing season, number of individuals overwintering and their development stages, life spans and duration of developmental stages of the insects, oviposition and feeding rates and estimates of plant damage. The model allows development of the insects through life stages at a rate which is temperature dependent (Brown et al., 1982).

Coupled waterhyacinth and Neochetina models: The amount of reduction in plant biomass due to insects is a function of the number of insects in different stages, temperature, plant phenology, and time. The two models interact also in determining fecundity and mortality rates for the insects.

DISCUSSION

This model, once developed and validated, will offer several advantages to the aquatic plant managers. The model can be used as an effective tool to evaluate alternative control strategies (i.e., timing of insect releases, what stages to release, etc.). It will also serve as an educational tool for use by scientists, engineers, and students in related areas to aid them in becoming familiar with the growth of waterhyacinths and their biological control agents. It can be used as an aid in assessing effectiveness of control agents. In addition, it can serve as a prototype model for future work with other aquatic plant-insect interactions.

ACKNOWLEDGEMENTS

This work was conducted for the U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, Mississippi (contract No. DACW39-85-K-0002).

REFERENCES

1. Akbay, K.S. 1979. COTGAME: An Interactive Computer Simulation Game applied to Cotton Ecosystem. M.S. Thesis, Mississippi State University, Mississippi State, Mississippi. 83 pp.

2. Blakey, H.L. 1966. Outlook for weed control activities. Hyacinth Control Journal 5:18-20.

3. Brown, L.G., R.W. McClendon, and J.W. Jones. 1982. A Cotton Insect Management Simulation Model. In: Agricultural Handbook No. 589: Cotton Insect Management with Special Reference to the Boll Weevil. Eds. R.L. Ridgeway, E.P. Lloyd, and W.H. Cross, United States Department of Agriculture, pp. 437-479.

4. DeLoach, C.J. and H.A. Cordo. 1976. Ecological studies of *Neochetina bruchi* and *N. eichhorniae* on waterhyacinth in Argentina. Journal of Aquatic Plant Management 14:53-64.

5. Holm, L.G., Weldon, L.W., and Blackburn, R.D. 1969. Aquatic weeds. Science 166:699-709.

6. Little, E. (ed.) 1968. Handbook on utilization of aquatic plants. Food and Agricultural Organization of the United Nations, Rome, Italy. 121p.

7. Vaas, K.F. 1951. Notes on the waterhyacinth in Indonesia and its eradication by spraying with 2,4-D. Contributions of the General Agricultural Research Station, Bangor, Indonesia 120:1-59.