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AQUATIC PLANT CONTROL RESEARCH PROGRAM

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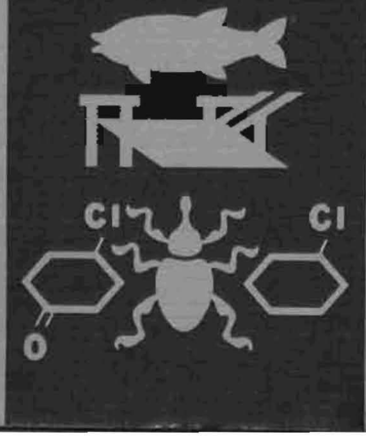
PROCEEDINGS, RESEARCH PLANNING CONFERENCE ON THE AQUATIC PLANT CONTROL PROGRAM

22-24 OCTOBER 1975
CHARLESTON, S. C.



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Final Report

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PREFACE

A Research Planning Conference on the Aquatic Plant Control Program was held at the Holiday Inn Downtown, Charleston, South Carolina, on 22-24 October 1975. The presentations by personnel of the U. S. Army Engineer Waterways Experiment Station (WES) were prepared under the general supervision of Mr. W. G. Shockley, Chief, Mobility and Environmental Systems Laboratory (MESL), and under the direct supervision of Mr. J. L. Decell, Chief, Aquatic Plant Research Branch, Environmental Systems Division, MESL.

This report was published with funds provided by the Directorate of Civil Works, Office of the Chief of Engineers (OCE), Department of the Army, Appropriation No. 96X3122, Construction General. Dr. E. O. Gangstad, OCE, was Technical Monitor.

COL G. H. Hilt, CE, and COL John L. Cannon, CE, were Directors of the WES at the time of the preparation and publication of this report. Mr. F. R. Brown was Technical Director.

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Holiday Inn Downtown
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AGENDA

RESEARCH PLANNING CONFERENCE ON THE AQUATIC PLANT CONTROL PROGRAM

Holiday Inn Downtown
Charleston, South Carolina

22-24 October 1975

Wednesday, 22 October

E. O. Gangstad, Chairman

0820	Welcome	LTC D. P. Gregg, CE
0840	Introductory Remarks*	E. O. Gangstad, OCE
0900	An Overview of the Research Program	J. L. Decell, WES
0920	Status of Classification of Aquatic Herbicides	L. W. J. Anderson, EPA
0940	Aquatic Herbicide Tolerance	J. G. Cummings, EPA
1000	Coffee	
1020	Georgia State Certification of Aquatic Pesticide Operations	B. R. Evans, UG
1040	Water-Quality Problems in South Carolina*	J. D. Heriot, DHEC
1100	Status of Florida's Certification Program for Applicators of Aquatic Herbicides	R. F. Dumas, DNR
1120	Aquatic Plant Control in Louisiana*	D. V. Lee, LWFC
1140	Certification of Pesticide Applicators in the States of Texas, Oklahoma, and Arkansas	W. T. Nailon, Jr., CE
1200	Lunch	
1300	Field Trip, Goose Creek Reservoir	J. L. Carothers, CE
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E. O. Gangstad, Chairman

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* Not included herein.

0840	Problems with Submerged Aquatic Plants in the U. S. Army Engineer District, New Orleans*	W. E. Thompson, CE
0900	Reconnaissance Survey of Aquatic Weed Infestations in Lakes and Navigable Streams in Oklahoma	R. Couch, ORU
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0940	Recent South American Field Studies of Prospective Biocontrol Agents of Weeds	G. B. Vogt, USDA
1020	Film—Insects Versus Waterhyacinths*	N. R. Spencer, USDA
1100	Aquatic Weed Problems in Mexico and Texas and Some of the Measures for Their Control	L. V. Guerra, TPWD
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Research Programs
W. N. Rushing, Chairman

1300	Possible Effects of the Introduction of the White Amur into Lake Conway, Florida	K. C. Ewel, UF
1320	Insects Versus Aquatic Plants*	N. R. Spencer, USDA
1340	Aquatic Weed Versus Plant Pathogen, A Study of a Biological Control in Action	K. E. Conway, UF
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1420	Controlled Release Herbicides—Rubber Formulations	G. A. Janes, CBL
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1500	2,4-D in Slow-Moving Water	J. R. Barry, USL
1520	Extensive Degradation of Silvex by Synergistic Action of Aquatic Microorganisms	H. C. Sikka, SURC

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W. N. Rushing, Chairman

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0820	Integrated Control of Waterhyacinths*	W. C. Durden, USDA

* Not included herein.

0840	Coffee	
0920	Waterhyacinths—A Nuisance or a Benefit	B. C. Wolverton, NSTL
0940	Rapid Survey Techniques for Aquatic Plant Management*	L. E. Link, Jr., WES
1000	Large-Scale Field Test with the Monosex White Amur in Florida	J. L. Decell, WES

Summary
E. O. Gangstad, Chairman

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1030	Critique	J. E. Gallagher, AMCHEM
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* Not included herein.

RESEARCH PLANNING CONFERENCE ON THE AQUATIC PLANT CONTROL PROGRAM

INTRODUCTION

The Construction-Operations Division, Directorate of Civil Works, Office of the Chief of Engineers (OCE), arranged for a conference on the Aquatic Plant Control Program to review current operations activities and to afford an opportunity for presentation of current research projects. The conference was held at the Holiday Inn Downtown, Charleston, South Carolina, 22-24 October 1975. A list of attendees is given on pages ix-xiii. The conference agenda is presented on pages xv-xvii. The papers presented at the meeting are published in full herein, except as noted on the agenda. The letter of authority for the conference is presented in Appendix A; an example of the manuals prepared in Georgia for certifying applicators of pesticides, in Appendix B; and the history of the Aquatic Plant Control Program, in Appendix C.

AN OVERVIEW OF THE RESEARCH PROGRAM

by

J. L. Decell*

In collecting my thoughts prior to preparing this presentation, I realized that the speakers on the agenda to follow would present a more detailed overview of the research program. In view of this, I decided to take the liberty of changing the content of my presentation. First, I would like to briefly mention the major areas of research being conducted, and then devote the balance of my allotted time to the subject of the redirection of the Corps' Aquatic Plant Control Research Program.

First, let's briefly touch on the major areas of research. The first category that comes to mind is chemical. Presently, we have a research effort devoted to the determination of the effects and fates of herbicides in the aquatic environment; in addition, we are studying the movement of 2,4-D in slow-moving water. Two closely related efforts in the area of research on chemical control deal with controlled release herbicides. One study addresses the problem of chemically attaching the herbicide to complex polymer compounds, and the other deals with the problem of physically embedding herbicides into rubber formulations.

Many of you, if not all, are familiar with the work being conducted in the next area of research, which deals with the use of biological control agents. There are ongoing studies of the effects of the use of insects on waterhyacinths as well as pathogens for control of waterhyacinths. Some amount of work has been initiated in the search for an insect agent for control of hydrilla as part of the ongoing effort to find new insect enemies of aquatic plants. The best known and probably most controversial biological agent is the white amur fish. Many of you may be aware that we have initiated a very large-scale test for the biocontrol of hydrilla with the white amur. An integral part of this test, a simulation model of the lakes, is nearing completion. This model will allow us to study the possible effects of the presence of the white amur on the lakes' aquatic ecosystem. An additional model relevant to this test is a stocking rate model to be completed this year. This model will allow us to study the aquatic plant population response as a function of time, since we have identified the necessary environmental conditions and have a select size and population of white amur to be stocked. The model data output is a decision-making tool that will be used for the Lake Conway test and future applications of the white amur.

Another area of research, readily identifiable by everyone here, deals with the use of integrated control methods. We are presently conducting tests in Lake Concordia, Louisiana, with several combinations of the previously mentioned pathogens and insects. This study involves the U. S. Army Engineer Waterways Experiment Station (WES), the University of Florida, and the United States Department of Agriculture at Gainesville.

We are conducting a study at the WES that deals with the problem of rapid survey techniques for aquatic plant management. This is not just another remote sensing inventory for aquatic plants. We are attempting to identify equipment and techniques that are within District Engineers' present capabilities and resources. To tell a District Engineer that you have found a method for periodically obtaining an accurate assessment of aquatic plant problems, if he can hire three skilled technicians and buy a $75,000 machine, only serves to convince him that no solution is imminent. Without a major revision in the

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Corps' overall program, he cannot avail himself of this necessary solution in any realistic time frame.

Again, concerning the District Engineer's operational problems, we have an effort under way to produce a mathematical model for use by operations personnel. This model will allow the District Engineer to determine best solutions for identified aquatic plant problems within the inventory of weapons available. In addition, he will be able to attempt various proposed solutions to achieve various levels of control and study these results in order to make a decision *prior* to mobilizing his crews.

In addition to those areas mentioned, there is a renewed interest in mechanical control. Although there will not be any papers presented on this subject this year, there are plans to initiate new work units in the research program for next year. Another area identified for initiation next year will be a category called engineering design. We feel the results of this effort could pay long-range dividends in aquatic plant control. This particular effort is designed to identify aquatic plant control problems that are either magnified or actually created by the design of structures placed in waterways or lakes. More specifically, the problem arises from the fact that the designer had no prior knowledge that an aquatic plant problem existed in the water body. I believe that if the design criteria for future structures to be placed in waterways recognize the existing and potential plant problems, then the resulting structures will actually alleviate the magnitude of the problem.

As I said, you will be hearing a more detailed overview of the research program in the next few days; thus, with your indulgence, I would now like to discuss with you the recent reemphasis on the Aquatic Plant Control Research Program, some things that have happened since that reemphasis, and our view as to the direction the program should take in the future.

In early 1975, the Office of the Chief of Engineers (OCE) directed the Aquatic Plant Control Research Program to become more "operationally oriented." The obvious question came to mind: What does "operationally oriented" mean as it relates to the research to be conducted in the future? In addition, what does this mean in terms of the research program structure and its relation to the operational field units? In general, it simply means that the research program must be structured so that the products of all efforts provide effective, environmentally compatible plant control tools to the District Offices' operational system at an accelerated pace. I would like to point out that this means not only new agents but also the necessary methods and techniques identified for proper use on a continuing operational scale—not an easy task, but a necessary one. How does one begin to address this objective? The first step taken by OCE was to reassign the program from the Planning Division to the Construction-Operations Division. The WES was assigned as lead laboratory for the research program and subsequently was assigned responsibility for management. Administrative shifts? Yes, but the worth of these moves, I think, will be eventually proven in more areas than the administrative. If the decision makers that comprise the managements of both the research and operational segments of the overall program are to begin to focus on common objectives, then it is necessary that the administrative "barriers" be removed. A first step in this direction has been made.

Next, it was necessary that the research program be redirected. But in which direction? Obviously, in the direction of the operational objectives. What impact will this have on the research to be conducted? It is my sincere belief that no negative impacts will result. The redirection of the research program, the turning around to face the glaring operational problems is still being conducted. It is not a one-way street, however. Just as research attempts to positively respond to the user's needs, so must the user attempt to better define his needs to the researcher. In plain English, they must *together* assess the operational problems, agree on a common objective to be reached in a finite time frame, structure an overall plan that meets this objective in a timely manner, and initiate the plan. This procedure sounds oversimplified and somewhat idealistic, but, in reality, each segment of the overall Aquatic Plant Control Program has been following that approach—I believe the missing ingredient has been common objectives. Aquatic plant control is not a common objective. It is the desired result if certain objectives have been met. For the most part, the solutions to most of our aquatic plant problems are site dependent. The public relates to this through their stated value of the aquatic environment. The control techniques used to date have not reflected this dependency in attempting to meet the public's desires. Moreover, we have simply been "putting out brush fires." As you well know, this approach provides no long-range solution. When asked by the public, "What are you doing about it?" operations management can no longer respond with, "We don't have that particular information with us," or "The figures are back in the office." Neither can the research management respond with, "We are conducting research on that problem," or worse, "We determined through research that the complex technical facets of the active system demanded an inordinate effort which resulted in noneconomically feasible and/or too environmentally impactive solutions . . . glop!" I believe that we must be able to show that what is being done in plant control today and tomorrow is part of a very deliberate plan to reach public-related, aquatic plant management objectives within a stated time frame with long-lasting effects. It should be pointed out that such a plan, once initiated, will not relieve us of "putting out brush fires." That requirement will remain until the long-term effects of the plan are evident. Putting out brush fires keeps the temperature of the operating environment at a low enough level that one can efficiently follow through on the overall plan. It is no substitute for the plan itself. The necessary research should be identified as one or more components in the overall plan. When completed, any research component should directly contribute to the operations management's capability to perform the next component function of the plan. Operational management decisions, analysis of research data by the scientist, evaluation of results—all must be made with an eye on the final operational objective as the major consideration.

In redirecting the Corps' Aquatic Plant Control Research Program, new objectives must and will be identified. These objectives will be operational in nature. Plans will be formulated that meet these objectives. These plans will be a product of both operations and research management. Research components within these plans will be identified, and the work will be initiated. There will no doubt be a need eventually for redirection and change in the operational units.

Although there are many who will disagree, it is my opinion that this approach will not degrade the quality of the research. It does not, in my opinion, change the end product of a scientist's efforts; it provides an additional yardstick, graduated in the user's needs, against which the researcher may measure success. The long-term payoff will be made not only in operational effectiveness, but also in scientific knowledge, and will truly achieve an acceptable level of management of aquatic plants.

STATUS OF CLASSIFICATION OF AQUATIC HERBICIDES*

by

L. W. J. Anderson**

ABSTRACT

Commencing in 1976, all pesticide products will be reviewed for classification for either "general" or "restricted" use. After 21 October 1977, "restricted" products can only be used by or under the supervision of Certified Applicators. Aquatic herbicide products will be evaluated on the basis of toxicity to humans and wildlife, formulation concentration, use dilution, and method of application and adequacy of label and labeling. It is anticipated that many aquatic herbicides will not meet the toxicological and use dilution criteria for "general use" classification. Those not meeting the criteria will be classified on the basis of adequacy of label and labeling and consideration of other hazards. Since many aquatic herbicides require specialized skill and equipment, it is anticipated that many, if not most, such products will be classified for "Restricted" use. The pertinent classification criteria are discussed.

INTRODUCTION

The criteria for classification of pesticides are briefly discussed in order to relay some current information with regard to aquatic pesticide regulation and the Environmental Protection Agency's (EPA) progress in implementation of the Federal Insecticide, Fungicide, and Rodenticide Act† (FIFRA), as amended. A brief discussion of certification of pesticide applicators will then follow in order to provide some information on the current status of certification plans.

CLASSIFICATION CRITERIA FOR GENERAL AND RESTRICTED USE PESTICIDES

According to Section 3(d) of the FIFRA, as part of registration, pesticides must be classified as either "general" or "restricted" use; if "restricted," they must be applied by or under the supervision of certified applicators. The parameters to be considered for each product in determining classification are: (1) toxicity, (2) use, and (3) labeling. Certain criteria are used to determine if the pesticide is a candidate for general use. If the criteria for general use are not met, restricted classification is considered. With regard to toxicity criteria, which pertain to the pesticide's active ingredient(s), its formulated concentration, and its final use concentration, the areas of primary concern for aquatic herbicides are dealt with in Section 162.11(C) of the Section 3 Regulations, namely "Criteria for Determination of Unreasonable Adverse Effects" (Section 3 Regulations pp 28283-28284). The definition of an unreasonably adverse effect, according to FIFRA (Section 2(bb)) is:

> "Any unreasonable risk to man or the environment, taking into account the economic, social and environmental costs and benefits of the use of any pesticide."

* Paper has been published in the *Journal of Aquatic Plant Management*, Vol 14, Jun 1976, pp 1-3.

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† Numerical and alphabetical notations in the text refer to sections or paragraphs in the Section 3 Regulations of the FIFRA, as amended, published 3 July 1975 in the Federal Register.

Basic mammalian-toxicological criteria for "general" use classification for newly registered products are as follows.

PARTIAL CRITERIA FOR CANDIDACY FOR "GENERAL USE" CLASSIFICATION, NEW PRODUCTS*

(A) Has an acute dermal LD_{50} greater than 200 mg/kg;

(B) Has an acute dermal LD_{50} greater than 16 g/kg for the formulation as diluted for use as a mist or spray;

(C) Has an inhalation LD_{50} greater than 0.2 mg/*l*;

(D) Is not corrosive to the eye or causes corneal opacity reversible within 7 days;

(E) Is not corrosive to the skin and causes no more than severe skin irritation within 72 hr; and

(F) Causes under conditions of label use, or widespread and commonly recognized practice of use, only minor or no discernible subacute, chronic, or delayed toxic effects on man or other nontarget organisms from single or multiple exposures to the product ingredient(s), their metabolite(s), or degradation production(s).

In addition to these criteria, terrestrial and aquatic wildlife exposure criteria are as follows.

PARTIAL CRITERIA FOR CANDIDACY FOR "GENERAL USE" CLASSIFICATION, PRODUCTS REGISTERED PRIOR TO 21 OCTOBER 75

(A) Occurs as a residue immediately following application in or on the feed of a mammalian species representative of the species likely to be exposed to such feed in amounts equivalent to the average daily intake of such representative species, at levels less than one-fifth the acute oral LD_{50} measured in mammalian test animals as specified in the registration guidelines.

(B) Occurs as a residue immediately following application in or on the feed of an avian species representative of the species likely to be exposed to such feed in amounts equivalent to the average daily intake of such representative species at levels less than one-fifth the subacute dietary LC_{50} measured in avian test animals as specified in the registration guidelines.

(C) Results in a maximum calculated concentration following direct application to a 15-cm layer of water less than one-tenth the acute LC_{50} for aquatic organisms representative of the organisms likely to be exposed as measured in test animals as specified in the registration guidelines.

(D) The pesticide causes, under conditions of label use, or widespread and commonly recognized practice of use, only minor or no discernible adverse effects on the physiology, growth, population levels, or reproduction rates of nontarget organisms, resulting from exposure to the product ingredients, their metabolites, or degradation products, whether due to direct application or otherwise resulting from application, such as through volatilization, drift, leaching, or lateral movement in soil.

Under the "outdoor applications," (Section 162.11(c)(1)(iii)), the maximum concentration allowed for "general use" is less than one-tenth the LC_{50} for aquatic organisms resulting from application to a 15-cm layer of water. For mammalian and avian feed, the maximum residue level criterion (immediately after application) is one-fifth less than the LD_{50} or less than the LC_{50} value

* Other criteria include maximum wildlife exposure levels for terrestrial and aquatic organisms.

respectively, for the test species indicated in the guidelines. The one-fifth safety factor is arrived at from consideration of typical dose response curves for tested species. Such plots indicate that dosages of one-fifth LD_{50} or one-fifth LC_{50} are likely to produce 0.1 and 10 percent mortality, respectively. The aquatic safety factor of one-tenth LC_{50} is obtained by incorporating an additional two-fold safety factor to provide for the general inability of aquatic organisms to escape pesticide exposure.

If these concentration criteria are not met, further consideration for "general" classification will be given with regard to adequacy of the label and labeling to prevent unreasonable adverse effects, as follows.

CRITERIA FOR ADEQUACY OF LABEL AND LABELING, TO ALLOW "GENERAL USE" CLASSIFICATION

(i) To follow label directions, the user of a pesticide product would not have to perform complex operations or procedures requiring specialized training and or experience;

(ii) Failure to follow the use directions in any minor way would result in minor or no discernible adverse effects;

(iii) Widespread and commonly recognized practices of use would not nullify label directions relative to prevention of unreasonable adverse effects on man and the environment;

(iv) The directions do not call for specilized apparatus, protective equipment or material unless they would be expected to be available to the general public;

(v) Following directions for use would result in only minor or no discernible adverse effects of a delayed or indirect nature, such as through bioaccumulation, persistence, or pesticide movement from the original application site, on nontarget organisms.

The basic philosophy behind these criteria is that use of extraordinary methods of application or specialized equipment or both, implies a need for knowledge exceeding that which could reasonably be expected in the general public, hence "restricted use" is warranted.

Since many aquatic herbicides would exceed the one-tenth LC_{50} values based on a 15-cm layer of water, the label criteria become decisive. It seems reasonable to expect that criteria (i), (ii), and (iv) will also not be met by most uses of aquatic herbicides, in which case a "restricted" classification will result. For example, aquatic herbicide applications may require use of specially modified boats, pumping equipment, metering devices and air-blowing devices. In addition, it may be necessary to know general water quality conditions (e.g. pH, alkalinity, hardness, temperature) in order to determine the most appropriate treatment dosage and time of application. If a pesticide has both "general" and "restricted" uses, there are two labeling options:

(1) one product having both general and restricted uses which could only be sold to, and used by certified applicators (even for the general use) (Section 162.10)(j) of Section 3 Regulations) or,

(2) two products (with the same active ingredient(s)): one "general use" label and one "restricted use" label.

It should be noted that since classification criteria are applied to the use conditions of each pesticide, as well as to the active ingredient(s) review must be on a product-by-product basis. It is anticipated that this will be accomplished during the reregistration process commencing in 1976.

CURRENT STATUS OF STATE CERTIFICATION PLANS

According to Section 4 of FIFRA, as amended, EPA is charged with prescribing standards for certification of pesticide applicators of "restricted" products. A governor of a State wishing to certify applicators must submit his State's plans to the appropriate Regional EPA Administrator to gain EPA approval. The "Government Agency Plan (GAP) for Certification of Federal Employees or Applicators of Restricted Use Pesticides," has been developed under the auspices of the Federal Working Group on Pest Management. Originally, this plan was to meet the requirement of qualifying pesticide applicators in the various agencies of the Federal Government to meet the Federal standards. At this time, however, plans for Government Agency qualification are not developed and the future of GAP is uncertain. In any event, GAP plans will have to be in accord with approved State plans.

The concern of Federal applicators is that technically, without a "blanket" Federal Certification, they would have to be certified by each State in which they operate. Practically speaking, however, reciprocity between States and conformity to a common set of EPA standards may obviate the need for multi-State certifications. Some States, within a common region, have developed or are developing certification plans in concert, for example: Idaho, Washington, and Oregon. But, before any reciprocal agreements are established, most states will scrutinize their neighboring States' plans for compatibility. The main difference between State requirements would most likely have to do with demonstrated knowledge of local pest problems and environmental conditions.

Table 1 shows the present (as of 12 March 1976) status of State certification plans. As of now, six States have plans which have been given tentative (1 yr) approval by EPA: Iowa, Georgia, South Carolina, Mississippi, Wyoming, and Washington. The approval is contingent upon enactment and promulgation of proposed legislation and regulations by the State within 1 yr. Other states have submitted plans which are under final EPA review. Some states have not yet submitted plans. Congress passed legislation that extends deadlines until 21 October 1976 for submission of State plans, and 21 October 1977 for certification of pesticide applicators.

Aquatic herbicide application is treated as a separate category under State plans. Demonstration of knowledge of certain areas of basic aquatic biology will be required, as well as specific knowledge of the use of aquatic herbicides, methods of calculating dosage levels, etc. It may be of interest that applications of pesticides for mosquito control are covered under a separate section of state plans, "Public Health Pest Control." One can imagine, however, some crossover between these two aquatic categories, for example, in control programs involving reduction of potential mosquito habitats by control of aquatic weeds.

IMPACT ON AQUATIC PESTICIDE APPLICATORS

Since most aquatic weed control programs are handled by trained, competent personnel through Federal, State, local or commercial entities, difficulties in meeting certification requirements most likely would be negligible. Demonstration of competency in application and general knowledge of basic aquatic biology should pose little problem to those currently operating in this area. It is probable that, for public employees, costs of certification (but not necessarily training) will be waived. Training and certification programs are under way at this time.

Table 1

Status of State Certification Plans. States Are Listed Under the Heading (Step) Which Corresponds to Their Status as of 12 March 1976. Dates Opposite Each State Listed Under the Last Two Steps (7,8) Indicate When the Intent to Approve, or Approval Notice Was Published in the Federal Register

Status of State Certification Plans*

1. Draft State Plan Under Development—2

   Alabama
   Louisiana

2. EPA Review—(Draft State Plan and Legal Authorities)—17

Massachusetts	Kansas	North Dakota
Delaware	Missouri	South Dakota
Vermont	Rhode Island	Utah
Colorado	Nebraska	Ohio
Illinois	Kentucky	Oklahoma
Alaska	Texas	

3. Final State Plan Development—5

California	District of Columbia
New Mexico	Connecticut
Wisconsin	

4. Submission to State Lead Agency Head—0

5. Submission to Governor—2

New York	Arizona

6. Review of Governor Signed State Plan—16

Florida	Guam	Virginia	Virgin Islands
Hawaii	New Hampshire	Nevada	Minnesota
North Carolina	Indiana	Tennessee	Michigan
Montana	Maryland	Maine	Arkansas

7. FR Notice—Intent to Approve State Plan—6

Oregon—11 Dec.	New Jersey—30 Dec.
West Virginia—23 Dec.	Pennsylvania—4 Mar.
Idaho—26 Nov.	Puerto Rico—10 Mar.

8. FR Notice—Approved State Plan—6

Georgia—8 Aug.	Mississippi—11 Feb.
Iowa—16 Sept.	Wyoming—29 Jan.
South Carolina—6 Jan.	Washington—18 Feb.

* TTPI and American Samoa are not included as development of drafts in abeyance pending decision on need.

AQUATIC HERBICIDE TOLERANCE

by

J. G. Cummings*

It might be well to take a moment to consider the history of the Corps of Engineers' (CE) petition, if for no other reason than to acknowledge the persistence and tenacity of Dr. Gangstad, but mainly in the hope that we can expedite such future petitions.

The first question one might ask is, "Why do we need this Environmental Protection Agency (EPA) tolerance regulation under the Federal Food, Drug, and Cosmetic (FFDC) Act to sanction a program which has been ongoing for many years?"

To answer this, we have to look back about 6 or 7 yr when the Federal agencies, which were engaged in large-scale aquatic weed control programs, began to get uncomfortable about their operations. Pressures were being brought to bear from a number of sources:

a. The Federal Working Group on Pest Control began to exert some pressure on Tennessee Valley Authority (TVA), Bureau of Reclamation (BR), and CE to obtain the sanctions of the Federal regulatory agencies.

b. Some departments, notably the Department of Interior (Secretary Hickel), issued directives that only registered pesticide uses could be employed in department programs.

c. Certain local action groups were questioning whether residues contributed to public drinking water supplies were safe. The Oak Ridge, Tennessee, newspaper began an intensive campaign against TVA water treatments. There were lawsuits against Federal agencies because of pesticide treatments in aquatic sites.

d. Proposed amendments to the new Federal Insecticide Fungicide Rodenticide Act (FIFRA) were to make it an offense to use a pesticide in a manner other than described on registered labels.

About this time, the Federal "user" agencies approached the Federal regulatory agencies and pointed out that the use of aquatic herbicides was essential in carrying out their responsibilities (CE navigable waterways). They asked for a mechanism by which sanction of the regulatory agencies could be obtained.

The difficulty was that the Pesticide Amendment of the FFDC Act was designed to set legal residue tolerances for agricultural uses on raw agricultural commodities (rac) (not water), and the FIFRA controlled only the shipment and use of pesticides. After much headscratching, the legal groundwork was laid for a workable procedure. This included finding that drinking water was a processed food within the meaning of the FFDC Act and that a pesticide residue contributed to potable water for intentional use was a food additive within the meaning of Section 409 of the FFDC Act. A tolerance under the FFDC Act became the prerequisite for registration, and the U. S. Departmeni of Agriculture (USDA) issued a notice that registration for aquatic uses would be cancelled unless tolerances were obtained.

The policy was officially endorsed at the highest levels of departmental authority by the Secretaries of Agriculture, Interior, and Housing, Education, and Welfare; they agreed that tolerances for

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pesticides in water should be established under the FFDC Act (rather than under the Public Health Service (PHS) drinking water standards).

Having ascertained that legal tolerances for potable water could be established, the Food and Drug Administration (and later EPA) set about developing the data requirements which would be necessary. Agency spokesmen presented data requirements at national meetings of the professional societies (Weed Science Society of America, American Fisheries Society). In simplest terms, it is this: If the prescribed use is such that there is a reasonable expectation of residues in potable water, fish, shellfish, irrigated crops, or in meat/milk/eggs, it is necessary for the user agency to conduct residue studies to show what levels are to be expected in these commodities. Toxicological data are required to show that the predicted levels are safe.

Fortunately, the Federal agency programs were using pesticides which had toxicological work completed because of existing tolerances on crops. Not so fortunate was the residue data situation. The pesticide manufacturers, who would ordinarily carry this burden, in general declined the task on the grounds that return on research expenditures would not justify the investment. They were in effect saying, "The government is the primary user of aquatic herbicides—it is their responsibility to get the residue data." It should be noted, however, that several manufacturers did make their data available to the petitioning agency and provided valuable advice.

The next question we might ask is, why do we need residue data? The most obvious answer is that the residue information is used to gauge the safety of the use, but the need also derives from certain principles stated in the law (FFDC Act). The first is that the tolerance set for a chemical in a food shall be no larger than is necessary to accomplish the intended effect; secondly, that the tolerance should reflect the residue actually present in the food; and last, that an analytical method to enforce the tolerance must be available. The research required to show the identity and magnitude of residues from agricultural uses on crops are fairly straightforward. The research required to show the level and identity of residues which can result in irrigated crops, fish, shellfish, meat/milk/eggs, and potable water at a given time after an aquatic pesticide use is enormously complicated. Couple this knowledge with the fact that the Federal agencies lacked the considerable experience and expertise necessary in preparing petitions, and you can appreciate the difficulties encountered.

The most important message I would have for any governmental agency which is interested in securing a registration and tolerances for an aquatic use is that the more tightly circumscribed the use, the less residue research is required. For example, the BR petition for 2,4-D tolerances was much more simple to handle than the CE petition because the 2,4-D was used in the western irrigation systems under conditions that excluded consideration of fish, shellfish, and livestock. It is for this reason that the tolerance regulations which have already been issued for use of 2,4-D specifically limit the use to programs under the control of the BR. When sufficient research data are available to support more general use of 2,4-D (under the multiplicity of conditions where 2,4-D can be effectively used), the regulation can be consolidated.

A final word of advice to prospective petitioners for aquatic uses has to do with the restrictions associated with the use. The practicality of such restrictions is an important consideration and, again, depends to a great extent on how closely circumscribed the proposed use is. For example, toxicological considerations may limit the tolerance to some level which requires a holding period before use of the water. Such restrictions presume that the body of water is entirely under the control of the agency. It should also be pointed out that when proposing restrictions (e.g., do not take fish for 2 weeks, or do not use water for domestic purpose for 2 weeks), the user agency assumes the responsibility that such restrictions are practical and can be complied with.

Before, closing, it might be well to clarify the relationship between the tolerances set for pesticide residues in potable water under the Food Additives Section of the FFDC Act and the "Drinking Water Standards" established by EPA under the 1974 Safe Drinking Water Act. The drinking water standards are in general based on maximum permissible contaminant levels of an unavoidable or nonidentifiable source; whereas, the pesticide tolerances are based on a purposeful addition. In order to assure uniformity of the drinking water standards with the pesticide tolerances, both standards and tolerances are referred to the Drinking Water Standards Work Group before publication.

Pesticide	Petitioner	Use	Status
Diquat	CE	Ponds, lakes, slow moving water	Active review
Endothal	Pennwalt	Lakes, ponds, irrigation ditches, canals	Active review
Glyphosate	Monsanto	Irrigation water	Active review
2,4-D	TVA	Watermilfoil, TVA system	Abeyance
2,4-D, Bee	CE	Waterhyacinths, ponds, lakes, slow moving water	Abeyance
Silvex	CE	Waterhyacinths, ponds, lakes, slow moving water	Abeyance
Dichlobenil	Thompson-Hayward	Farm ponds, fish farming, other bodies under control of user	Abeyance
Dalapon	BR	Irrigation ditch bank	Abeyance
Fenac	Amchem	Flowing and nonflowing water, lakes and ponds with low exchange	Withdrawn

Aquatic Pesticides under Tolerance Regulations

altosid	xylene
basic copper carbonate	simazine
copper triethanol amine	2,4-D amine salt
basic copper sulfate	

Published Tolerance Reviews for CE 2,4-D amine, PP1E1046, by EPA, 22 October 1975.

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 180]

[FRL 449-1; PP1E1046/P9]

TOLERANCES AND EXEMPTIONS FROM TOLERANCES FOR PESTICIDE CHEMICALS IN OR ON RAW AGRICULTURAL COMMODITIES

Proposed Tolerance for the Pesticide Chemical 2,4-D

The Department of the Army, Office of the Chief of Engineers [DAEN-CWO-R], Washington,

D. C. 20314, has submitted a pesticide petition (PP1E1046) to the Environmental Protection Agency. This petition requested that the Administrator propose, pursuant to Section 408(e) of the Federal Food, Drug, and Cosmetic Act, the establishment of a tolerance for residues of the herbicide and plant regulator 2,4-dichlorophenoxyacetic acid (2,4-D) in or on the raw agricultural commodities fish and shell fish at 1.0 part per million (ppm). Residues of 2,4-D would result from the application of its dimethylamine salt in water hyacinth control programs conducted by the Corps of Engineers or other Federal, State, or local public agencies in ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, rivers and streams that are quiescent or slow moving. (The Department of the Army has also filed a petition for the establishment of a food additive regulation permitting the use of 2,4-D in potable water. Notice of this filing also appears in today's FEDERAL REGISTER.)

The pesticide 2,4-D is not registered with the Agency under the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended (86 Stat 973), for use against water hyacinths. However, the Corps of Engineers has been granted exemptions from such registration requirements pursuant to Section 18 of FIFRA, as amended, to use 2,4-D to control water hyacinths which impede water flow, reduce recreational use, and provide a habitat for large populations of insects which could pose a hazard to human health. [See FEDERAL REGISTER notices of March 4, 1974 (39 FR 8183), May 30, 1974 (39 FR 18806), October 11, 1974 (39 FR 36637), November 1, 1974 (39 FR 38717), December 9, 1974 (39 FR 42942), and July 10, 1975 (40 FR 29123).]

The Section 18 exemption provision of FIFRA is designed to provide solutions to emergency situations rather than recurring problems. Accordingly, the July 10, 1975, FR document (40 FR 29123) announcing the Agency's decision to grant the Corps most recent request for exemption provided that: "addition specific exemption requests by the Corps of Engineers for use of 2,4-D in moving water beyond calendar year 1975 will not be granted, since, in our estimation, there has been adequate time for the Corps to gather the necessary data to register 2,4-D for this use." Data compiled by the Corps during the course of control programs carried out under the provisions of section 18 have been submitted in support of this petition for tolerance.

The data submitted in the petition and all other relevant material have been evaluated, and it is concluded that the tolerance of 1.0 ppm for fish and shellfish established by amending § 180.142 will protect the public health. In addition, the Agency has concluded that a tolerance should also be established for residues of 2,4-D which may occur in or on raw agricultural commodities irrigated or otherwise in contact with treated water. A somewhat similar problem was addressed in the past when a tolerance was established for residues of 2,4-D in a number of agricultural commodities, resulting from the application of its dimethylamine salt to irrigation ditch banks [40 CFR 180.142(c)]. Based on available data and other pertinent information, it has been concluded that a tolerance of 1.0 ppm should be established for those crops and commodity crop groupings which are listed in § 180.142(c) (citrus, curcubits; forage grasses; forage legumes; fruiting vegetables; grain crops; leafy vegetables, small fruits; and stone fruits; and the individual raw agricultural commodities avocados, cottonseed, hops, and strawberries). Where tolerances are established at higher levels from other uses of the dimethylene salt of 2,4-D on crops included within these commodity groups, the higher tolerances also will apply to residues from the aquatic uses cited above.

For the above reasons, it is proposed that tolerances be established as set forth below. Any person who has registered or submitted an application for the registration of a pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act which contains any of the ingredients listed herein may request, on or before November 28, 1975, that this proposal be referred to an advisory committee in accordance with Section 408(e) of the Federal Food, Drug, and Cosmetic Act.

Interested persons are invited to submit written comments on the proposed regulation to the Federal Register Section, Technical Services Division (WH-569), Office of Pesticide Programs, Environmental Protection Agency, Room 401, East Tower, 401 M St. SW, Washington, D. C. 20460. Three copies of the comments should be submitted to facilitate the work of the Agency and others interested in inspecting them. The comments must be received on or before November 28, 1975, and should bear a notation indicating the subject and the petition document control number PP1E1046/P9. All written comments filed pursuant to this notice will be available for public inspection in the office of the Federal Register Section from 8.30 a.m. to 4 p m Monday through Friday.

Dated. October 22, 1975.

MARTIN H. ROGOFF,
Acting Director
Registration Division

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(Section 408(e) of the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 346a(c)).)

It is proposed that Part 180, Subpart C, § 180.142, be amended by adding the new paragraph (f) to read as follows.

§ 180.142 2,4-D; tolerances for residues.

* * * * *

(f) Tolerances are established for residues of 2,4-D (2,4-dichlorophenoxyacetic acid) from application of its dimethylamine salt for water hyacinth control in ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, rivers and streams that are quiescent or slow moving in programs conducted by the Corps of Engineers or other Federal, State, or local public agencies at 1.0 part per million (ppm) in the crops and crop groupings listed in paragraph (c) above and at 1.0 ppm in or on the raw agricultural commodities fish and shellfish. Where tolerances are established at higher levels from other uses of the dimethylamine salt of 2,4-D on crops included within these commodity groups, the higher tolerances also apply to residues from the aquatic uses cited above.

[FR Doc.75-29047 Filed 10-24-75; 8:45 am]

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[FRL 449-2; PF18]

FOOD ADDITIVE PETITIONS

Notice of Filing

The Department of the Army, Office of the Chief of Engineers [DAEN-CWO-R], Washington, D. C. 20314, has submitted a petition (FAP 6H5104) to the Environmental Protection Agency which proposes the establishment of a food additive regulation permitting the use of the herbicide and plant regulator 2,4-dichlorophenoxyacetic acid (2,4-D) in potable water with a tolerance limitation of 0.1 part per million. These residues would result from the application of the dimethylamine salt of 2,4-D in water hyacinth control programs conducted by the Corps of Engineers or other Federal, State, or local public agencies in ponds, lakes, reservoirs, marshes, bayous, drainage ditches, canals, rivers and streams that are quiescent or slow moving.

Notice of this submission is given pursuant to the provisions of Section 409(b)(5) of the Federal Food, Drug, and Cosmetic Act. Interested persons are invited to submit written comments on the petition referred to in this notice to the Federal Register Section, Technical Services Division (WH-569), Office of Pesticide Programs, Environmental Protection Agency, Room 401, East Tower, 401 M St. SW, Washington, D. C. 20460. Three copies of the comments should be submitted to facilitate the work of the Agency and others interested in inspecting them. The comments should be submitted as soon as possible and should bear a notation indicating the petition number "FAP 6H5104". Comments may be made at any time while a petition is pending before the Agency. All written comments filed pursuant to this notice will be available for public inspection in the office of the Federal Register Section from 8:30 a.m. to 4:00 p.m. Monday through Friday

Dated: October 22, 1975.

MARTIN H. ROGOFF,
Acting Director
Registration Division

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GEORGIA STATE CERTIFICATION OF AQUATIC PESTICIDE OPERATIONS

by

B. R. Evans*

To approach the difficult task of developing a state certification and training program for commercial applicators to meet the Environmental Protection Agency (EPA) regulations, the first step is to define the problem. For example, how many people will probably need to be certified in aquatic pest control, and where are they? Numbers and locations of applicators are essential to organize a training program and to identify the resources necessary to carry it out.

When a State is already licensing pesticide applicators, the task is eased somewhat but often these applicators are only those who apply pesticides for a fee. Since *all* persons desiring to use restricted-use pesticides and who meet EPA's definition of a commercial applicator must be certified, this will include many other groups probably not licensed in most states, such as government agencies, utility companies, and many golf course superintendents (about 500 in Georgia).

Commercial applicators desiring to be certified must pass a written exam based on the EPA general standards which apply to *all* commercial applicators; this exam is concerned mainly with safety, protective equipment, general pest identification, types of application equipment, calibration, and state and Federal laws and regulations affecting their operation. EPA has already prepared an excellent training manual based on the general standards that most states will probably adopt. In addition, the applicator must pass a written exam based on the standards for the category in which he desires to be certified. For example, the EPA standards for Aquatic Pest Control are:

> Applicators shall demonstrate practical knowledge of the secondary effects which can be caused by improper application rates, incorrect formulations, and faulty application of restricted-use pesticides used in this category. They shall demonstrate practical knowledge of various water-use situations and the potential of downstream effects. Further, they must have practical knowledge concerning potential pesticide effects on plants, fish, birds, beneficial insects, and other organisms which may be present in aquatic environments. These applicators shall demonstrate practical knowledge of the principles of limited area application.

While EPA is preparing manuals (an example** is given in Appendix B) for the various categories of applicators, these are currently not available. Since we have begun the training and certification of commercial applicators this fall in Georgia, we have developed our own series of categorical training manuals that have been approved by EPA. The amount of content in a manual that meets the standards is open to broad interpretation. We have taken a very modest view of a minimum of content to initiate the program. The exams in Georgia are based entirely on the training manuals; therefore, the amount of content really defines the burden of the exam.

Since most commercial applicators in Georgia have not been examined before, we will begin at a modest level of knowledge required to pass the exam and upgrade the manuals in future years.

It is expected in the future that attendance at approved training courses or the passing of a written

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** Only the text is presented; illustrations have been omitted.

exam will be necessary for recertification. This will be an opportunity to provide more specific and detailed training that will help to upgrade the industry.

We have found from our evaluation of current courses in progress in Georgia that most commercial applicators are appreciative of training being offered and many desire more. The training and educational value from the certification process is the greatest asset to the applicators and the general public. We need pesticides to control many different pests in our environment, but this must be done without misuse and without endangering the health of man or the environment.

STATUS OF FLORIDA'S CERTIFICATION PROGRAM FOR APPLICATORS OF AQUATIC HERBICIDES

by

R. F. Dumas*

As Florida has one of the greatest noxious aquatic plant problems in the contiguous United States, she also has had the opportunity to be active in the field of aquatic plant control on a massive scale for many years. With the aquatic problem have come many folks to combat it.

The Bureau of Aquatic Plant Research and Control has conducted training sessions throughout Florida over the past 3 yr, attempting to professionalize the field and disseminate the philosophy of aquatic plant management rather than eradication.

To standardize and enhance statewide application techniques, the Bureau has compiled and edited a training and a reference manual from the latest information available. These 100+-page manuals have been completed and are now under review by various experts and by the agency charged with publication. Hopefully, they will be available during the spring of 1976.

Certification of applicators of aquatic herbicides will be carried out by the Bureau of Aquatic Plant Research and Control, Department of Natural Resources, while other certification information will be conducted by the University of Florida Extension Service through the county agents.

Florida has had nearly 600 applicators attend its previous training sessions and does not anticipate any major problems with accomplishing certification of Florida's applicators to meet state and Federal requirements.

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CERTIFICATION OF PESTICIDE APPLICATORS IN THE STATES OF TEXAS, OKLAHOMA, AND ARKANSAS

by

W. T. Nailon, Jr.*

The Federal Environmental Pesticide Control Act of 1972 provided that all pesticides must be classified for either "general" use or "restricted" use by October 1976. The act provided further that those pesticides placed in the "restricted" category may be used only by or under the direct supervision of certified applicators. The law allows 4 yr for development of certification programs by the states for applicators of restricted pesticides. Pursuant to the above requirements, the Environmental Protection Agency (EPA) issued guidelines entitled "Standards for Certification of Pesticide Applicators" in October 1974. These guidelines establish 10 categories for commercial applicators as well as standards of competency for each. The guidelines also cover standards for certifying private applicators and supervision of noncertified applicators by certified people.

The Federal Working Group on Pest Management (FWGPM) is working on a plan for qualifying Federal pesticide applicators for certification, commonly known as the Government Agency Plan (GAP). The primary purpose of the plan is to allow Federal people who may be subject to working in several states to be certified without having to obtain certification in each state in which work is performed. The objective of FWGPM is to develop a plan that will give competency standards for Federal applicators that conform to or at least equal EPA standards and meet criteria of the various states.

STATE OF TEXAS

In keeping with the provisions of the Federal Act which makes certification of pesticide applicators essentially a state responsibility, the Texas State Legislature recently enacted into law the "Texas Pesticide Control Act." This act relates to regulation of labeling, distribution, transportation, storage, use, and disposal of pesticides. It requires state registration of pesticides, licensing of dealers, and licensing and certification of applicators; invests authority and powers in several state agencies in enforcing the provisions of the act; provides for penalties for offenses; and provides for denial and cancellation of licenses, registrations, and certifications.

Since the topic for this discussion relates principally to the certification of pesticide applicators, this aspect of the new Texas law will be covered to attempt to give you some of the principal provisions of the act in this regard. The Texas Pesticide Control Act assigns the Texas Department of Agriculture as the lead agency. With this assignment goes the responsibility for coordinating all activities of state agencies in regulating pesticide use, putting together the state plan for certification of applicators, and submitting the state plan to EPA. That agency also has the responsibility for the coordination and approval of training programs for supervisors and applicators.

The responsibility for certification of applicators has been assigned to several state agencies in Texas, based generally on the license-use categories which are provided by Federal statutes, regulations,

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and guidelines. The Texas Department of Agriculture will certify applicators for:

a. Agricultural pest control (except animal pest control)
b. Forest pest control
c. Ornamental and turf pest control (except as provided in Texas Structural Pest Control Act)
d. Seed treatments
e. Right-of-way pest control
f. Regulatory pest control
g. Demonstration pest control

The Texas Animal Health Commission will certify applicators involved with animal pest control, while the Texas State Department of Health will be responsible for certifying applicators doing public health and health-related pest control. The Structural Pest Control Board will continue to handle the licensing and certification of persons involved in structural, industrial, and institutional pest control. The certification of applicators involved in aquatic pest control will be handled by the Texas Water Quality Board. This category includes aquatic plant control, which is the area of principal concern of this group.

The act provides that each of the above regulatory agencies may classify commercial and noncommercial licenses under subcategories of the principal license-use categories. A fee of not more than $10 may be charged for testing in each category.

Commercial Applicator Licenses

The Texas Pesticide Control Law requires that no person, except an individual working under direct supervision of a certified applicator, may apply restricted-use or state limited-use pesticide for hire or compensation (one who operates a pesticide application business) without a valid commercial applicator license for which a fee of not more than $100 may be prescribed by the regulatory agency. The applicant must pass an examination demonstrating his competence and knowledge of the use and effects of these restricted pesticides in the categories in which he is involved. The applicant must also show evidence of financial responsibility and provide bonding or liability insurance.

Noncommercial Applicator Licenses

Persons who are not engaged in commercial pest control activities and who are not private applicators must obtain a noncommercial license. A noncommercial licensee is defined as a "person or government agency or department which wants to use restricted-use or state limited-use pesticides or to have the authority to demonstrate restricted-use or state limited-use pesticides, does not qualify as a private applicator, and is not required to have a commercial applicator's license." Nongovernmental applicants will be charged a fee of not more than $50. Government entities will be exempt from a license fee. When licenses are issued in the name of a governmental entity, a certified applicator must be employed at all times. Applicants must pass an examination demonstrating competence and knowledge in these pesticides in categories under which they applied. Competence in the use and handling of pesticides will be determined on the basis of these general standards:

a. Labels and labeling comprehension
b. Safety considerations
c. Knowledge of potential environmental consequences under various conditions
d. Knowledge of target and nontarget pests
e. Knowledge of pesticides

f. Knowledge of pesticide equipment
g. Knowledge of techniques
h. Knowledge of state and Federal laws and regulations

Private Applicators Exemption

Private applicators are not required to be licensed or certified. However, the Commissioner of Agriculture is authorized to establish a program for certifying them on a voluntary basis. A private applicator is defined as a person who uses these restricted pesticides for producing agricultural crops on property owned by him or his employer, or under his general control; or who applies the pesticides without compensation other than trading of personal services on property of another person.

Reciprocal Agreements

The new act also provides for the above regulatory agencies to waive a part of all license examination requirements on a reciprocal basis with other state or Federal agencies which have substantially the same standards.

As mentioned previously, the Texas Water Quality Board has the responsibility for administering the program for aquatic pesticide application under the Texas Pesticide Control Act. The tentative proposal is to certify aquatic pesticide applicators in two subcategories, animal and plant. It is proposed that applicators will be certified in research and demonstration as well as regulatory pest control and pesticide use in the control of aquatic pests.

It is planned that training programs to be approved by the Texas Department of Agriculture will be held. Upon successful completion of training and certification, it is proposed that the applicators be issued official identification cards denoting: categories and subcategories of certification, dates of issuance and expiration, and other personal information.

The Texas plan for certification of applicators is presently under preparation. The regulatory agencies mentioned previously are each preparing a draft plan covering the categories for which they are responsible. The proposed plan is scheduled to be put together in the near future and submitted to EPA. In discussions with state people, it is tentatively proposed that the Texas plan will contain provisions for acceptance of the GAP for certifying Federal employees subject to the reservation that it must be either equal to or exceed requirements imposed by the state.

STATE OF OKLAHOMA

Oklahoma is in the process of writing its state plan for certification of applicators. Presently, Oklahoma has a licensing requirement for commercial applicators but does not have enabling legislation to cover licensing and certification of private applicators.

Legislation is proposed in Oklahoma to combine all previous legislation relating to pesticides and their application and to add authority for certification of private applicators and licensing of retail pesticide dealers. One of the proposed bills which may be considered provides that the act shall be administered by the Oklahoma State Board of Agriculture, the purpose being to regulate registration, labeling, distribution, storage, transportation, use, application, and disposal of pesticides. This proposed act calls for two types of licenses for the various use categories, commercial and noncommercial. Each use category would be subject to separate testing procedures and requirements. Commercial applicator licensees include those engaged in applying pesticides for hire or compensation.

Noncommercial licensees would include those persons, government entities, or businesses requiring the use of restricted-use pesticides and not qualifying as a private applicator. This bill would authorize both testing and license fees but would exempt government entities from the license fee. The proposed bill would also require registration of employees of commercial applicators. Private applicators would also require proper certification before using restricted-use pesticides. Educational programs are being conducted by the Oklahoma Extension Service. Eighty-five hundred persons have attended a pilot training program for private applicators.

STATE OF ARKANSAS

The Arkansas Plant Board is the lead agency for the preparation of the Arkansas plan for certifying applicators. The state plan has been drafted and we understand it was to have been submitted to EPA during the week of 13 October. Detailed information on the Arkansas plan could not be obtained because of its present status. However, the plan is based generally on the 10 categories of applicators as established in the EPA guidelines. It was indicated that Arkansas tentatively proposes to accept GAP for certification of Federal people applying restricted-use pesticides.

FIELD TRIP, GOOSE CREEK RESERVOIR

by

J. L. Carothers*

Insects have been successfully introduced from their native habitat to areas where the host or pest plant had been previously introduced. At the start of a large cooperative effort to find a means of controlling alligatorweed, exploration and investigation were conducted in South America by the Insect Identification and Parasite Introduction Research Branch, Entomology Research Division, U. S. Department of Agriculture. Four species were found to be suppressants of alligatorweed including a flea beetle of the genus *Agasicles*. The beetle was given extensive host specificity tests prior to its introduction and release in 1964.**

Approximately 3,000 beetles were released in 1964 on the Savannah National Wildlife Refuge. An additional 250 beetles were released on the Ortega River in 1965. The beetle population increased and overwintered in sufficient quantities to control most of the floating alligatorweed in a protected cover in 1966.† It was noted that there were two periods of peak beetle population each year. One period was May-June and a second was September-October. From the fall of 1965 through 1967, approximately 20,000 beetles were transferred from Jacksonville to selected and approved locations in Florida, Georgia, Alabama, Mississippi, Texas, South Carolina, and North Carolina through efforts of Mr. C. F. Zeiger and many others.

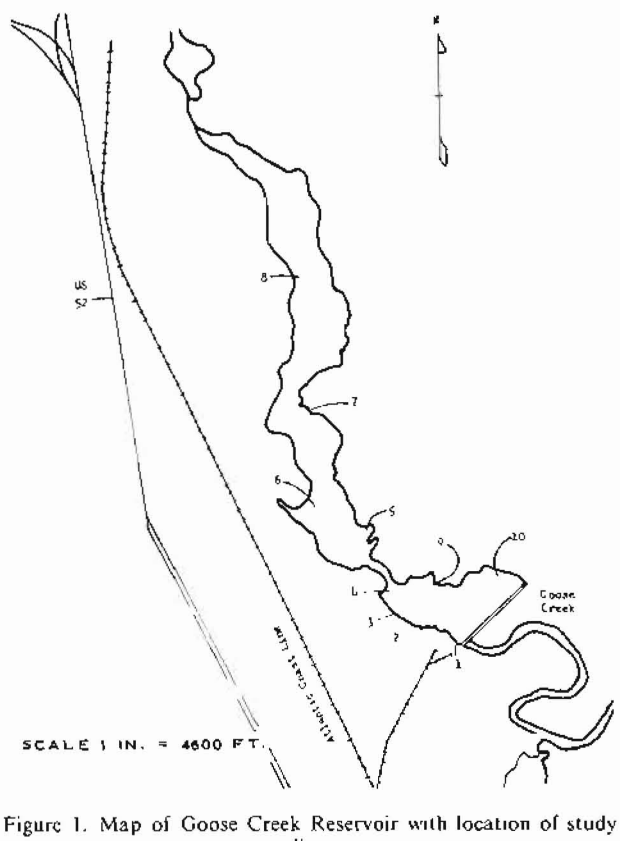

Figure 1. Map of Goose Creek Reservoir with location of study replicates

At each site or location 10 replicates were permanently established to give an indication of response of alligatorweed for the entire area. The distance between each replicate was dependent upon the size of the alligatorweed infestation. Each replicate was individually marked with a stake placed on the bank. The distance from the stake to the outer edge of the floating mat was recorded. Subsequent measurements would allow determination of whether the mat was continuing to increase in size or was being controlled.

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* U. S. Army Engineer District, Charleston, South Carolina.

** W. H. Anderson, "Search for Insects in South America that Feed on Aquatic Weeds," *Proceedings, Southern Weed Conference*, Vol 18, 1965, pp 586-587

† C. F. Zeiger, "Biological Control of Alligatorweed with *Agasicles* n. sp. in Florida," *Hyacinth Control Journal*, Vol 6, 1967, pp 31-34.

Photos were taken of each replication to record the appearance of the alligatorweed as well as to document the extent of the floating mat.

The Goose Creek site (Figure 1) was established 17 September; the second set of observations was made 6 November. Leaf loss and stem damage was so complete on replications 2, 3, and 10 that a separate estimate of the loss due to senescence and webworm damage could not be made. It was also impossible to rate webworm damage in replicate 4.

The alligatorweed flea beetle population was concentrated on the southernmost portion of Goose Creek Reservoir in September 1969. This was evident by the amount of leaf damage and numbers of adults and larvae in that area. Surface vegetation or topgrowth was 98 percent eliminated in replicate 9 (Figure 2a). There was also extensive feeding on the stems. Other plants, including *Polygonum* and *Jussiaea*, were prevalent in the area and account for most of the green foliage in Figure 2a. The extensive damage to alligatorweed made observations on growth stage and vigor difficult to obtain in 1969. In October 1975, the plants had been almost completely eliminated (Figure 2b).

a. September 1969

b. October 1975

Figure 2. Comparison of Goose Creek replicate 9

AQUATIC PLANT PROBLEMS IN PUERTO RICO

by

C. F. Zeiger*

Puerto Rico is the smallest and most easterly of the Greater Antilles (Cuba, Jamaica, Hispaniola, and Puerto Rico). The island is 110 miles long and 30 to 35 miles wide and is composed of diverse terrain types. A mountainous interior accounts for most of the area of Puerto Rico. Steeply sloping mountains extend over 4000 ft above sea level. A coastal plain a few miles wide surrounds the mountains. The climate is subtropical, and a wide variation in rainfall produces several different ecological zones over the island.

Waterhyacinth, *Eichhornia crassipes*, imported into Puerto Rico is the major aquatic plant problem. The waterhyacinth is distributed island-wide in freshwater lakes, streams, and rivers with the majority of the infestations being in the coastal plain areas. There is relatively little infestation in the streams and lakes in the high mountainous interior. The main problem areas are along the north side of the island from Rio Grande to Arecibo. Lesser infestations are in the river systems along the southern part of the island from Naguabo to Ponce and in the southwestern part of the island from Mayaguez through Valle de Lajas to Yauco. The major reservoirs infested are Lago de Loiza, Lago de Cidra, Lago de la Plata, Lago dos Bocas, Lago Coamo, and Laguna Cartagena.

Alligatorweed, *Alternanthera philoxeroides*, was first located in Lago Loiza in June 1968. Since then, it has been located in the vicinity of Mayaguez. A comparatively heavy infestation was noted growing with the hyacinth in the Rio de la Plata in June 1974. It presently is not a problem but has the potential of becoming one.

Several other aquatic plants have been mentioned in the literature reviewed and at a 4 June 1974 meeting in San Juan were considered to be problem plants; these plants included giant smartweed, naiad, coontail, waterlettuce, cattail, algae, and aquatic grasses.

Many of the canals, rivers, and lakes are infested with these plants, some of which are associated with the snail *Biomphalaria glabrata*, carrier of bilharzia (schistosomiasis). Controlling the aquatic plants will in turn assist in the control of the snail and be a definite benefit to public health.

At the present time, there is very little freshwater-oriented activity in the rivers and lakes of Puerto Rico, commercial or recreational, partly because of the heavy hyacinth infestations in rivers, such as the Arecibo and Rio de la Plata. Many of the streams, rivers, lakes, and canals in Puerto Rico are closed to water-oriented use because of bilharzia.

A Preliminary Reconnaissance Report for Puerto Rico has been prepared and approved. The Governor of Puerto Rico has designated the Department of Natural Resources as the local coordinating agency for the Aquatic Plant Control Program. Dr. Leonce Bonnefil, coordinator, representing the Department of Natural Resources visited the Jacksonville District in July 1975 and was furnished information on data required for preparation of the State Design Memorandum and Environmental Impact Statement. The Department of Natural Resources plans for a meeting of all concerned agencies including the Puerto Rico Aqueduct and Sewer Authority and the Puerto Rico Water Resources Authority, who have ongoing Aquatic Plant Control Programs, to draft a work program for the

* Chief, Aquatic Plant Control Section, U. S. Army Engineer District, Jacksonville, Florida.

Aquatic Plant Control Program. The State Design Memorandum and Environmental Impact Statement are being prepared by the Jacksonville District.

Research utilizing biological control methods has been recommended in the Preliminary Reconnaissance Report and approved by South Atlantic Division and Office, Chief of Engineers, U. S. Army. Research using the white amur, *Ctenopharyngodon Idella,* as a control agent was initiated in January 1975 by agreements between the Puerto Rico Department of Natural Resources and the U. S. Army Engineer Waterways Experiment Station. Research using the weevils *Neochetina eichhornia* and *Neochetina bruchi* for waterhyacinth control and the flea bettle *Agasicles hygrophilia* and the moth *Vogtia malloi* for alligatorweed control, as approved in the Preliminary Reconnaissance Report, has not been started.

The waterhyacinth problem in Puerto Rico stems from the rapid growth of the plants completely covering water areas, blocking navigation, and rendering the areas useless for recreational purposes. During heavy rains the plants wash downstream, accumulating at bridges, forming artificial dams and flooding the adjacent upstream areas. In sources of potable water, the plants create bad odors and tastes which must be removed at additional operational and maintenance costs. While it is apparent that the aquatic plant problem does not have the magnitude in Puerto Rico that it does in the southeastern United States, it is felt that there is a definite need and justification for an aquatic plant control program.

RECONNAISSANCE SURVEY OF AQUATIC WEED INFESTATIONS IN LAKES AND NAVIGABLE STREAMS IN OKLAHOMA

by

Richard Couch*

PURPOSE

This report is the result of a reconnaissance survey for Eurasian watermilfoil *(Myriophyllum spicatum L.)* and other aquatic weeds of potential economic importance in Oklahoma.

LOCATION AND SCOPE OF PROBLEM AREA

The entire state of Oklahoma was surveyed in this study. Oklahoma's land area is 69,919 square miles. It has a population of 2,584,000 (1967), which is increasing at an annual rate of 1.5 percent.

Elevation ranges from approximately 5000 ft above mean sea level in the western tip of the panhandle to near 300 ft in the extreme southeastern corner of the state.

Oklahoma is drained by two major stream systems—the Arkansas River system and the Red River system. The Arkansas has 17 large tributaries, whereas the Red has 18. Besides these tributaries, there are 392 named creeks in Oklahoma.

This study represented a first effort at pulling together aquatic weed information for Oklahoma.**

STATE OF PROBLEM

Water has always been a watchword which shaped the destiny of man. Water is equated with food, drink, transportation, recreation, and sanitation. The rise and fall of civilizations have been closely linked with water resources. The availability of good, dependable water supplies is directly proportional to the stability of a civilization.

Oklahoma is one of those states which has abundant water for present-day needs in only a portion of the state. The average annual rainfall ranges from 16 in. in the western part of the panhandle to 54 in. in the southeastern section, resulting in eastern Oklahoma having a surplus of water in most years and western Oklahoma having shortages in most years.

Water is Oklatooa's most important resource. The development of Oklahoma's water capacities has meant more to the healthy economy of the state than any other single factor.

In the early 1930's, Oklahoma had three large man-made lakes—Lake Spavinaw, Lake Overholser, and Lake Lawtonka—for a combined total of 5206 acres. Then came the dust-bowl days of the late 1930's and Senator Robert S. Kerr, a water-resource-minded statesman. As a result of these and other factors, 21 large reservoirs have been built since 1941 having a combined surface area of 375,417 acres. More are authorized and several are currently under construction.

In addition to these large reservoirs, more than 1000 upstream flood detention reservoirs have been built by the Soil Conservation Service since the dust-bowl days. There are 740 private and municipal

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** Personal communication with Mr. Terry Thurman, Oklahoma Water Resources Board, Oklahoma City, Oklahoma.

lakes of 10 acres or more in Oklahoma. Every country has farm ponds, the total in the state being approximately 190,000. These ponds are used primarily for livestock water and irrigation.

This storage of water for power, flood control, domestic and livestock water supply, industry, navigation, irrigation, and recreation has changed the face of Oklahoma. One needs merely to fly across Oklahoma to witness the vast water supply impounded in Oklahoma within the last 30-40 yr. More than a million surface acres are now underwater with more being added each year.*

Water is essential to the development of Oklahoma. Plans are currently under way for equating the unequal distribution of water resources within Oklahoma.[1] Through no real virtue on the part of Oklahomans, water pollution is currently of little consequence. Oklahoma is a young state, slightly less than 70 yr old. Lakes and ponds are even younger, 40 yr at most, with one or two exceptions. Oklahoma is at the stage where plans must be finalized, based on the experience of others, for programs designed to protect and wisely use our water resources.

This paper identifies the existence of aquatic weed problems in certain lakes and streams of Oklahoma. These aquatic weeds have interfered with boating, swimming, fishing (when in excess), and flow of water, and have increased evapotranspiration from municipal and irrigation reservoirs. Interference with navigation and potable water supplies for municipalities are potential problems.

U. S. AQUATIC PLANT CONTROL PROGRAM

The Rivers and Harbors Act of 1965 authorized a comprehensive program for the control of aquatic weeds in the waters of the United States for navigation, flood control, drainage, agriculture, fish and wildlife conservation, public health, and related purposes. The U. S. Army Corps of Engineers was given the responsibility of carrying out this act.

EM 1105-2-26[2] established a procedure for accomplishing the Rivers and Harbors Act charge. In general, an aquatic weed control program is initiated by a Corps of Engineers District whenever reported and/or observed problems seem to justify a need. The district may then request funds for a reconnaissance survey of aquatic weed problems in its area. The reconnaissance survey is limited to readily available data and information. Should the reconnaissance survey indicate a need for a control program, the next step is a detailed planning report called a "State Design Memorandum" to be used to set priorities and request funds for accomplishing a comprehensive aquatic weed control program within the District.

RECONNAISSANCE METHODS

This study was limited by contract definition so that information which was readily obtainable from available literature, consultations with college, university, state and Federal agency personnel, private organizations, and limited field surveys.

The first step was to contact key state officials to solicit their advice and counsel. Mr. Forrest Nelson, Director, and Mr. Terry Thurman of the Oklahoma Water Resources Board, were contacted. They furnished requested information, but more importantly, several contact names.

Mr. Kim Erickson, Assistant Chief of the Fisheries Division of the Oklahoma Department of Conservation, was contacted. He requested a letter detailing desired information which he promised to

* Data extracted from various Oklahoma Water Resources Board publications, Jim Thorpe Building; Oklahoma City, Oklahoma.

send to his field representatives for answering. This was done as requested.

The State Soil Conservation Service (SCS) office was contacted. Dr. Hampton Burns, State Conservationist, supplied valuable data. Also visited was Mr. James Thomas of the SCS office in Tulsa. He, too, supplied helpful information. Dr. George Goodman, Professor of Botany, University of Oklahoma, was contacted concerning his personal experiences with aquatic vegetation in Oklahoma.

A trip to Oklahoma State University (OSU) in Stillwater was conducted for consultation with the following individuals: (a) Dr. Bill Altman, Extension Wildlife Specialist and the person responsible for recommendations pertaining to aquatic weed control in Oklahoma; (b) Dr. Howard Greer, Extension Weed Control Specialist for Oklahoma; (c) Dr. Paul Santelman, Professor of Agronomy and Weed Control Specialist; (d) Dr. Ronald Tyrl, Plant Taxonomist and Curator of the OSU Herbarium.

I visited personally with the following individuals to solicit information and advice concerning aquatic weeds in Oklahoma: (a) Mr. Forrest Nelson, Mr. Terry Thurman, Mr. Zack Williams, and Mr. Bob Kellog of the Oklahoma Water Resources Board; (b) Dr. R. L. Dalrumple of the Noble Foundation in Ardmore, Oklahoma (Dr. Dalrumple, though not currently active, has been, in past years, very involved in aquatic weed research in south central Oklahoma, especially in farm ponds); (c) Drs. John and Connie Taylor of Southeastern Oklahoma State University in Durant, Oklahoma; (d) Dr. Bob Benefield, Mr. John Matthews, and Dr. William Duffer of the Robert S. Kerr Water Quality Research Laboratory in Ada, Oklahoma.

Printed information concerning aquatic weed control in Florida and the Tennessee Valley Authority lakes was requested and received from the following individuals: (a) Dr. Clark Hudson, Department of Natural Resources, State of Florida, Tallahassee, Florida; and (b) Mr. Leon Bates, Terrestrial Ecology Section, Division of Environmental Planning, Tennessee Valley Authority, Muscle Shoals, Alabama.

Dr. Paul Buck, University of Tulsa ecologist, was consulted concerning his experience with aquatic vegetation in Oklahoma.

We contacted Mr. Lou Guerra, director of the statewide noxious weed control program for Texas, and Mr. Ken Whittington, a field representative for Sandoz-Wonder Chemical Company in relation to a report of *Hydrilla verticillata* being discovered in Oklahoma.

Dr. John Taylor was contacted to solicit his advice concerning a planned field survey of southeastern Oklahoma.

I compiled addresses and sent 105 personal letters to reservoir, lake, and city managers having managerial responsibility for municipal lakes and reservoirs in Oklahoma.

Numerous in-state phone calls were made soliciting aquatic vegetation information and data from contacts derived in various ways during the course of the investigation. Included among these contacts were two private weed control companies operating in Oklahoma.

I made a one-day field survey of selected lakes and ponds in the Tulsa vicinity and conducted a tour of south central, central, and southwest Oklahoma lakes infested with Eurasian watermilfoil and other aquatic weeds. The following individuals were involved: (a) Mr. Buell Atkins and Mr. Paul Mace, U. S. Army Engineer District, Tulsa, Oklahoma; (b) Mr. Bill Nailon, U. S. Army Engineer Division, Dallas, Texas; (c) Dr. Ed Gangstad, Office, Chief of Engineers, Washington, D. C.

Considerable time was spent, sandwiched in between the activities described above, conducting a search of the literature. This search included libraries at OSU, Oral Roberts University, and the personal libraries of the persons contacted during the course of the investigation.

An exhaustive search of available information sources has been conducted via letters, phone calls, personal visits, field trips, and the literature. The discussion to follow reflects the results of this effort.

SURVEY RESULTS

Table 1 lists those aquatic plants known to occur in Oklahoma waters. Any of these can be "weeds" in given locations under given circumstances. For example, water star grass *(Heteranthera dubia)* is a problem in some city water supply lakes, such as Spavinaw Lake, because of taste and odor problems caused by the plant.[3] Many farm ponds* are infested with various species, but since most ponds are used primarily for stock watering and irrigation, aquatic vegetation seldom becomes "weeds." Chara and the filamentous algae are most often the problem plants.*,**

Table 1
Aquatic Plant Species Known to Occur in Oklahoma Waters

Family	Common Name	Scientific Name
Haloragidaceae	Eurasian watermilfoil	*Myriophyllum spicatum*
Acanthaceae	Water willow	*Dianthera (Justicia) americana*
Characeae	Chara	*Chara spp.*
Chlorophyceae	Filamentous algae	*Pithophora* and *Spirogyra*
Coratophyllaceae	Coontail	*Ceratophyllum demersum*
Onagraceae	Floating water primrose	*Jussiaea repens*
Pontederiaceae	Water star grass	*Heteranthera dubia*
Nymphaeaceae	American lotus	*Nelumbo lutea*
Nymphaeaceae	Yellow water lily	*Nuphar luteum*
Nymphaeaceae	White water lily	*Nymphaea spp.*
Najadaceae	Pondweeds (sago and others)	*Pontamogeton spp.*
Najadaceae	Southern naiad	*Najas guadalupensis*
Hydrocharitaceae	American elodea	*Elodea canadensis*
Lemnaceae	Common duckweed	*Lemna minor*
Elatinaceae	Waterwort	*Elatine americana*
Lentibulariaceae	Bladderwort	*Utricularia spp.*
Ranunculaceae	Water buttercup	*Ranunculus spp.*
Typhaceae	Cattails	*Typha latifolia*

Eurasian watermilfoil

The most obnoxious weed species in Oklahoma at the present time is Eurasian watermilfoil.[4,5] Table 2 lists the distribution and extent of the infestation of this plant in Oklahoma waters (see Figure 1). It has spread to other locations and increased in acreage since it was first observed in Lake Humphries in 1964. It was in the Wichita Mountains Wildlife Refuge lakes at about the same time, if not earlier. In fact, some have reported it to have been in these lakes and ponds as early as the middle 1950's† and according to deGruchy,[3] it was in Murray County, Oklahoma, prior to 1938.

* Personal communication with Mr. James Thomas, SCS, Tulsa, Oklahoma, and Mr Hampton Burns, State Conservationist, SCS State Office, Stillwater, Oklahoma

** Personal communication with Dr. Bill Altman, Extension Wildlife Specialist, OSU, Stillwater, Oklahoma

† Personal communication with Mr. Gene Bartnicki, Wildlife Biologist, Wichita Mountains Wildlife Refuge, Cache, Oklahoma, and Dr. Paul Buck, Plant Ecologist, Department of Life Sciences, University of Tulsa, Tulsa, Oklahoma.

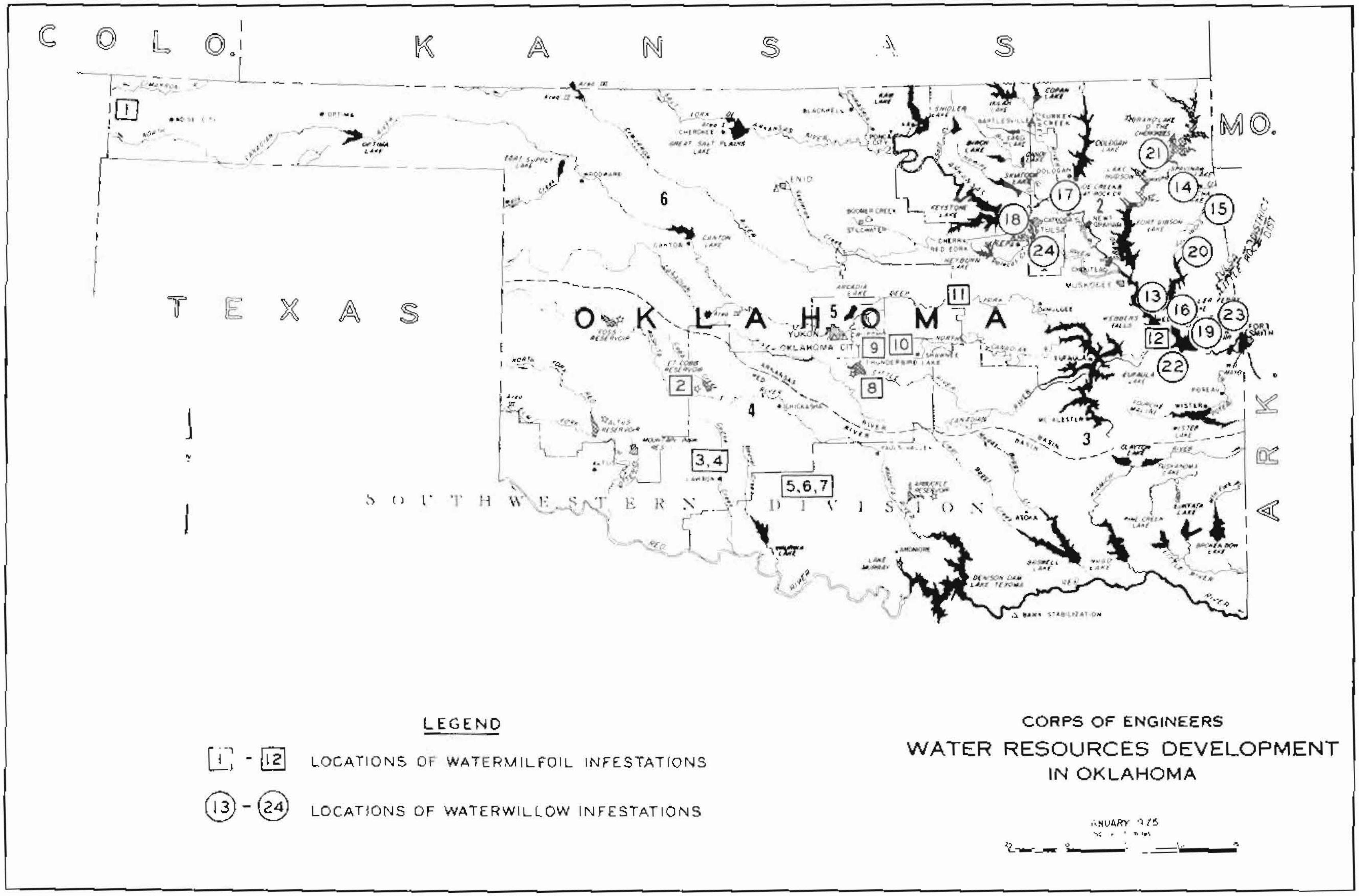

Figure 1. Aquatic weed reconnaissance survey in Oklahoma

Table 2
Known Eurasian Watermilfoil (Myriophyllum spicatum) Infestations in Oklahoma Waters

Lake	Location	Estimated Acres	Year First Observed	Map No.
Lake Carl Etling	Kenton	35	1968	1
Fort Cobb Reservoir	Fort Cobb	1200	1969	2
Wichita Mountains Wildlife Refuge Lakes and Ponds (30)–includes Lake Elmer Thomas	Cache, Lawton, Medicine Park	700	1965 or earlier	3
Lake Lawtonka	Lawton	3	1974	4
Lake Humphries	Duncan	516	1964	5
Clear Creek Lake	Duncan	72	1965	6
Soil Conservation Lakes (2)	Duncan	210	1972	7
Lake Thunderbird	Norman	3642	1973	8
Lake Stanley Draper	Oklahoma City	290	1967	9
Shawnee Twin Lakes	Shawnee	1085	1968	10
Chandler Lake	Chandler	125	1964	11
Robert S. Kerr L&D and Reservoir	Sallisaw	328	1970	12
Total Acreage Infested		8206		
Acreage NOT under jurisdiction of Corps of Engineers or other Federal agency		2336		

Eurasian watermilfoil was likely first introduced into Oklahoma via aquarium dealers. It is now being spread by boats, trailers, fishing gear, birds, and other sources. It can be propagated by seeds, or the more common means of vegetative fragments. Plant fragments can withstand up to 21 days of drying without dying.[6] Its ecological and biological characteristics have been adequately documented.[6,7,8]

Eurasian watermilfoil growth in Fort Cobb Reservoir became so rampant by the early 1970's that swimming, boating, and fishing activities were affected. Evapotranspiration increased in a reservoir that is both hard to fill and hard to keep full. The problem became so serious that an experimental control program was initiated in 1974 using the herbicide 2,4-D.[9] It was a joint effort by the Bureau of Reclamation, Fort Cobb Master Conservancy District, Oklahoma Water Resources Board, Oklahoma State Department of Agriculture, Oklahoma State Department of Health, and the Oklahoma Cooperative Fisheries Unit at OSU. The upper arms of the reservoir were successfully treated in 1974. The program continues in 1975 with the treating of the more infested coves near the dam. In these areas, the water is clearer with the result that the milfoil grows in water up to 15 ft deep.

Lake Thunderbird, another Bureau of Reclamation reservoir, represents a current threat. So far, the infestation has not seriously interfered with water supply from the lake nor with recreation,* but the infestation is young, being first observed in 1973. It may eventually cause problems, especially since this is a clear lake with an average depth of 19.7 ft.

* Personal communication with Mr. Thomas Tucker, Superintendent, Central Oklahoma Master Conservancy District, Rt. 4, Box 275, Norman, Oklahoma.

Lake Stanley Draper is also a relatively clear, shallow lake which maintains a constant level via water pumped from Atoka Lake through 100 miles of pipeline. It is owned and operated by the City of Oklahoma City for municipal water supply and recreation.* The constant lake level and clear water no doubt will enhance the growth of the milfoil population in this reservoir, too.

Shawnee Twin Lakes are operated by the city of Shawnee for municipal water supply and recreation. Both lakes are quite shallow (16.3-ft average depth) and clear. Chandler Lake is another shallow, clear lake, and so are Lake Lawtonka, Lake Humphries, and Clear Creek Lake. These lakes represent the sole water supply sources for the cities they are operated by and for. The impairment of these bodies of water for recreation by the local citizens is serious enough, but the threat of the loss of a municipal water supply or even the reduction of available water supply via evapotranspiration gravely concerns the officials responsible for the operation and management of the lakes.**

The Eurasian watermilfoil infestation in the Robert S. Kerr Reservoir was first observed in 1970. Since this species can be propagated so easily and rapidly,[6,7,8] this infestation poses one of the most serious, present threats—not only to Oklahoma waters, but to the entire McClellan-Kerr Navigation System. The entire system, from Tulsa to New Orleans, could be "sprigged" with the watermilfoil via barge traffic in just a matter of days or weeks. Regarding this infestation, it must be remembered that Eurasian watermilfoil was observed in Watts Bar Lake near Spring City, Tennessee, several years before the pest caused serious problems in Guntersville Lake 150 miles downstream.[7,8] The Tennessee Valley Authority's experience[10] should be heeded. Just because the plants have been in the Kerr Reservoir for 5 yr causing no serious problems does not mean they will never cause problems. Large barge traffic would probably never be seriously hampered, but the infestations represent a "nursery" for plantings at other locations up and down the Navigation System where large growths of the plants could interfere with swimming, boating, fishing, water flow, etc.

Water Willow (Dianthera (Justicia) americana)

Another weed, in northeastern Oklahoma waters principally, is water willow (see Table 3). This plant grows along the shore in water up to 10 ft deep. The lakes with "dense" stands listed in Table 3 have water willow all around their perimeters. Limited mechanical control has been and is currently employed in Spavinaw Lake to keep access channels open. The biology of water willow has been documented previously.[11,12]

Total current confirmed acreage of water willow approximates 1500 acres. Although less prevalent and serious than the watermilfoil problem, it is nevertheless a problem which needs attention. This one could cause navigation and impeded water-flow problems at any time for the Arkansas River navigation channel and its tributaries.

SUGGESTED PLAN OF PROCEDURE

We plan to establish a control program for Eurasian watermilfoil as quickly as a State Design Memorandum, Environmental Impact Statement, and other necessary documents can be prepared. Emphasis should be on a "control program" rather than an "eradication program," because study and

* Personal communication with Mr. J. T. Hart, Superintendent, Reservoir Maintenance, City of Oklahoma City, Oklahoma City, Oklahoma.

** Personal communication with Mr. Raymond Beck, Duncan, Oklahoma; Mr Wes Stucky, Shawnee, Oklahoma; and Mr. Robert James, Chandler, Oklahoma.

Table 3
Known Water Willow (Dianthera (or Justicia) americana) Infestations in Oklahoma Waters

Lake or Stream	Location	Estimated Stands*	Map No.
Greenleaf Lake	Braggs	Dense	13
Spavinaw Lake	Spavinaw	Dense	14
Eucha Lake	Spavinaw	Dense	15
Vian City Lake	Vian	Dense	16
Claremore City Lake	Claremore	Dense	17
Sand Springs Park Lake	Sand Springs	Dense	18
Sallisaw Creek	Sallisaw	Dense	19
Illinois River drainage	--	Moderate	20
Neosho (Grand) River drainage	--	Moderate	21
Lee's Creek drainage	--	Moderate	22
Arkansas River drainage of Sequoyah County	--	Moderate	23
Bixby City Lake	Bixby	Moderate	24

* Dense equals more than 25 percent coverage along shore. Moderate equals less than 25 percent coverage along shore.

experience with the management of plant growth in streams and reservoirs has shown this approach to be the most practical and feasible.

Also needed is a yearly aerial reconnaissance survey of lakes and streams in Oklahoma known to be infested with Eurasian watermilfoil. The purpose of this work would be to monitor the spread of the pest, so control programs could be directed to those areas where most needed. This survey should be a low-cost program utilizing light aircraft, hand-held cameras, and appropriate remote sensing techniques, e.g. infrared, color, and black-and-white photography.

An applied research program[13] must be set up to survey the aquatic vascular flora of the Arkansas and Red River drainage basins of Oklahoma for the following purposes: (a) to describe the distribution of aquatic vascular vegetation in the Arkansas and Red River drainage basins; (b) to relate this distribution to general ecological aspects of the habitat of each collection site and to surrounding land use in an attempt to stereotype aquatic plant species with specific ecosystems.

An applied, experimental research program is needed to determine the most practical, feasible, and economical means of controlling the growth of water willow in the lakes and streams of Oklahoma. Other aquatic plants, e.g. water star grass, should be included in the control program if and when they pose a threat of economic importance.

JUSTIFICATION

Table 2 data show that approximately 2300 acres of milfoil exist in waters not under the jurisdiction of Federal agencies. These waters represent important resources for the cities involved and are essential to the development of the areas cited. Without control programs, the weed infestations represent sources of infestations for other bodies of water, including Federally controlled impoundments.

The local governments have initiated some small control programs in past years but have generally been unable to muster the funds necessary for a thorough job. They would like to have control programs of sufficient magnitude to adequately control the unwanted growth. By so doing, water quality would be improved, recreation enhanced, and economic development improved to the point that the local, state, and Federal economy would be improved.

Federal interest in an aquatic plant control program for Oklahoma would be justified for the following reasons: (a) enhancement of the general economy through improved water quality and quantity for industry, domestic, and irrigation utilization, increased recreational use, and increased lakeside real estate development; (b) prevention of the spread of weed pests into surrounding waterways, particularly Federally controlled reservoirs, streams, and the Arkansas River navigation channel.

STATE AND LOCAL PARTICIPATION

Oklahoma statutes charge the Oklahoma Water Resources Board with the orderly planning, development, and protection of Oklahoma's water resources.[14] This information, coupled with the knowledge that the personnel of the board are leading the control program efforts on Fort Cobb Reservoir, speaks affirmatively to the question of state interest in the control of Eurasian watermilfoil and other obnoxious aquatic weeds in the state. Other state and local agencies are also involved in the Fort Cobb program.

Personal communications with local officials, Messrs. Tucker, Hart, Beck, Stucky, and James, concerned with lakes and reservoirs assure affirmative interest in weed control programs for Oklahoma. Local and state officials are ready and willing to participate in aquatic plant control programs.

CONCLUSIONS

It should be evident from the foregoing data and discussion that Oklahoma has an aquatic weed problem of sufficient magnitude to warrant a control program. Although Eurasian watermilfoil has been in state waters for a number of years, its spread and severity of infestation has intensified in recent years to the point that the time has come for a comprehensive, unified control program. By starting now, perhaps more serious problems may be avoided.

RECOMMENDATIONS

It is recommended that Oklahoma be included in the Aquatic Plant Control Program for the control of Eurasian watermilfoil, water willow, and other obnoxious aquatic weeds as they become economic nuisances, with the understanding and assurance that local and state interests will participate in individual control projects. It is furthermore recommended that assurances required by the authorizing legislature be obtained on a statewide basis. It is also recommended that authority be granted and the necessary funds be made available as soon as possible to prepare and submit for approval a State Design Memorandum.

REFERENCES

1. "Oklahoma Comprehensive Water Plan, Phase 1," Publication No. 60, 1975, Oklahoma Water Resources Board, Oklahoma City, Okla.
2. Office, Chief of Engineers, Department of the Army, "Aquatic Plant Control Program," Engineer Manual 1105-2-26, 27 Jan 1975, Washington, D. C.
3. DeGruchy, J. B. H., "A Preliminary Study of the Larger Aquatic Plants in Oklahoma with Special Reference to Their Value in Fish Culture," Technical Bulletin No. 4, 1938, Oklahoma State University, Stillwater, Okla.
4. Jarman, R., "Eurasian Watermilfoil—A New Menace to Oklahoma Waters," *Proceedings, Oklahoma Academy of Science,* Vol 49, 1970, pp 171-173.
5. __________, "Eurasian Watermilfoil: A New Threat to Oklahoma Waters," *Outdoor Oklahoma,* Vol 26, No. 5, 1970, pp 8-10.
6. "Eurasian Watermilfoil in Fort Cobb Reservoir, Oklahoma," Study Committee Report, 1973, Oklahoma Water Resources Board, Oklahoma City, Okla.
7. Smith, G. E., Hall, T. F., and Stanley, R. A., "Eurasian Watermilfoil in the Tennessee Valley," *Weeds,* Vol 15, No. 2, 1967, pp 95-98.
8. "Control of Eurasian Watermilfoil (*Myriophyllum spicatum* L.) in TVA Reservoirs," Environmental Statement TVA-OHES-EIS-72-8, 1972, Chattanooga, Tenn.
9. "Report on Application and Monitoring Program for Fort Cobb Reservoir," 1975, Oklahoma Water Resources Board, Oklahoma City, Okla.
10. Stanley, R. A. et al., "Program Diversity and Control of Eurasian Watermilfoil in Tennessee Valley."
11. Penfound, W. T., "The Biology of *Dianthera americana* L.," *Amer. Midl. Nat.,* Vol 24, 1940, pp 242-247.
12. __________, "Plant Communities in Oklahoma Lakes," *Ecology,* Vol 34, 1953, pp 561-583.
13. Falter, C. M. et al., "Aquatic Macrophytes of the Columbia and Snake River Drainages (United States)," 1975-697-930, 1974, U. S. Government Printing Office, Washington, D. C.
14. "Annual Report: Oklahoma Water Resources Board," Publication 59, 1975, Oklahoma Water Resources Board, Oklahoma City, Okla.

RECENT SOUTH AMERICAN FIELD STUDIES OF PROSPECTIVE BIOCONTROL AGENTS OF WEEDS

by

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Between January 16 and May 4, 1975, the authors carried out a joint field study in South America to develop information about the biogeography, ecology, and host plant specificity of insects that might be used to control weeds in the Middle South of the United States. In these field studies, we gave priority to three aquatic weeds *(Myriophyllum, Egeria,* and *Alternanthera)* and to three row crop weeds *(Sida, Anoda,* and *Amaranthus).* Cordo also gave special attention to *Eichhornia, Pontederia,* and *Pistia.*

The itinerary included the Río Solimões near Manaus, Amazonas; the narrow littoral of Brazil and Uruguay from the Río Doce at Linhares, Espirito Santo, to the Río Guaíba, Río Grande do Sul, to the Río de la Plata; the upper Río Paraná at Piracicaba, São Paulo; the eastern region of the Provincia de Buenos Aires from Buenos Aires to Necochea and Mar del Plata including the lagoons at San Miguel de Monte and at Chascomus; and the lower Río Paraná and Río Paraguay from Buenos Aires to Corumbá, Mato Grosso. This last region is vast, and the areas visited include campos (prairies), thorn forests, wetlands, and cotton fields of Provincia de Corrientes (eastern Chaco) and of the western Chaco extending through Provincia de Chaco, Provincia de Formosa, and west of the Río Paraguay in Paraguay. Also visited were campos (prairies), wetlands, broadleafed forests, limited thorn forests, and cotton fields of the Paraguayan tributary basin of the Río Tebicuary in Paraguay; and limited peripheral areas of the vast and diverse Paraguayan wetlands of the Pantanal of Mato Grosso. Also covered were the humid region of the upper Río Amazonas near Santa Cruz and Buena Vista, Departamento Santa Cruz; the vast seasonally dry wetlands, the Llanos (plains) de Mojós; adjacent forested alluvial plain of the Río Mamore near Trinidad, also of the Amazon basin, Departamento Beni, Bolivia; and west of the Andes, the very extensive wetlands and some of the uplands of the basin of the Río Guayas between Guayaquil and Santo Domingo. In south Brazil, Uruguay, Paraguay, and Argentina, the authors worked together traveling 5000 miles in an official four-wheel-drive vehicle. Elsewhere Vogt traveled alone or with various cooperators. We failed to extend the itinerary into Córdoba, Tucumán, Salta, and Santa Fé, R. A., as planned because of security restrictions. These drier regions are important centers for Malvaceae, and our studies of *Sida, Anoda, Alternanthera,* and brush suffered because of this omission.

Many of our findings apply to the problems of row crop weeds. Utilization of insects for such purposes will depend on the extent of interest in applying the techniques of manipulative release for biocontrol and the attendant mass rearing requirements.[1] However, both tropical and temperate insect species could be used. In the former case, it would be necessary to match closely the climatic characteristics of the tropical season of insect activity with the growing season in the southern United States. Otherwise, there is little hope for success. This approach, though we believe it has a future, may require much bioclimatic study, life table work, and field exploration to meet the exact requirements. Nevertheless, successful topical application of tropical insects that would be incapable of surviving

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southern United States winters would realize some of the inherent advantages of the "turn it on, turn it off" feature of chemical control methods. Most importantly, such use of winter-sensitive organisms should obviate the troublesome problem of conflicting interest that so often intervenes when exotic organisms are recommended for introduction. Most objections should be invalid if the organism cannot complete its annual life cycle.

Also, it may be desirable to utilize temperate species for biocontrol of weeds in the tropics because of the prospect of a gain in biotic potential.[2] For example, such a strategy might work with *Bactra* on nutsedge.

In the case of South American insects that might be used to control weeds in the southern United States, one important consideration is the possibility that the South American organism will encounter either an ecological homolog or an ecological analog or both when it is introduced. Then the process of competitive exclusion would likely take place, and either the native or the introduced species would be displaced or subjected to a reduced state of coexistence.[3,4] However, this is more likely to occur when there is a mirror-imaging of climate between the region of introduction and the region of origin such as between southern United States and southern South America.

In nature, ecological homologs are allopatric to mostly allopatric species or subspecies that are phyletically closely related, i.e. by common descent. All forms thus have very similar ecological niches, often with almost complete overlap, and the slight differences between niches of the species are mostly a result of evolutionary divergence. Ecological analogs are distantly related allopatric species which have significant overlap of ecological niches, mostly as a result of convergent evolution.

The ecological niche of the phytophagous insect species embraces its total habitat, its parasite-predator complex, all of its food, its seasonality, and its diel periodicity. Through host plant selection, response to humidity, temperature, light pheromones, etc., the behavior patterns determine what portions of the habitat and food supply are sought by the species. Courtship patterns and reproductive behavior contribute to the determination of seasonal activity. Behavior patterns also have much control over susceptibility of a species to its parasite-predator complex. Therefore, behavior patterns give insight into both the realized and potential niche of the phytophagous species. Most behavior patterns can be readily observed in the field.

The potential niche of the species always exceeds the realized niche, often to a very great extent. Its determination usually involves elimination of competitive exclusion and release from parasites and predators; it may be impossible to define without elaborate experimentation.[5] In biocontrol of weeds, the potential niche must also include the possible new host plants an insect agent may encounter in the region of introduction. Some authors include this change under the term "niche shift."[6]

Ecological homologs may be readily recognized forms of naturally occurring polytypic species and super species with contiguous and/or disjunct geographical distributions. The biological attributes of each of these forms apparently are so similar that in nature they cannot exist sympatrically. This is considered to be the situation existing between most of the species of *Agasicles*.[7]

When we consider organisms that occur usually on separate continents and usually in regions that are estimated to have either similar or mirror-imaged climates, we find that probable ecological homologs can usually be recognized by reason of phyletic affinities and by the results of field studies. Ecological nonhomologs are phyletically closely related species that may appear at first to be ecological homologs and then prove not to be. Also, ecological nonhomologs may be naturally occurring, related, sympatric, competing species such as *Disonycha xanthomelas* and *D. collata*. Ecological analogs are less easy to recognize because of the lack of phyletic affinities both in form and behavior. Ecological nonanalogs are distantly related species that may be mistaken as ecological analogs but prove not to be. Also, as naturally occurring sympatric species, ecological nonanalogs may be recognizable as various distantly related species competing for the same host plants. With less closely related and less distantly related species, the determination, homolog versus analog, must rest on more refined knowledge of phylogenetic relationship. With limited knowledge, judgments can only be approximate.

As applied to problems of biological control of weeds, proven ecological homologs and analogs are unsuitable biotic agents for introduction because of probable competitive exclusion. Near ecological homologs and analogs may also be unsuitable. However, probable ecological homologs and analogs and proven nonhomologs and nonanalogs could be successfully introduced biological control agents. Of course, probable homologs and analogs may not prove to be nonhomologs and nonanalogs, and therefore be unusable.

In the strict sense, species with identical ecological niches cannot coexist, and no two species can be ecological homologs.[8,9] In the practical sense, only two (or a few) closely related congeneric species with phyletic relationships can approximate ecological homologs. Also, with ecological analogs, one of the two species being compared often has a much broader ecological niche than the other. For example, one species may utilize numerous host plants other than the one or two it competes for against its analog. In ecological homologs, host plant spectra usually are very similar, at least in the potential sense. But in ecological nonhomologs, significant departures in host plant spectra can occur between the species being compared, e.g. the naturally sympatric *Disonycha xanthomelas* and *D. collata*.

Interpretations and definitions are given above because authors differ widely in applying the terms. Generally, authors give relatively little consideration to phyletic or evolutionary relationships; also, ecological homologs are not distinguished from ecological analogs.[3,6] In addition, many authors restrict the application of the terms to single units of habitats rather than to all units characteristic of a species.[3,4] There has been resistance to considering homologs and analogs of behavior patterns,[10] and most authors exclude behavior from defintions.[6] Usually, authors consider habitat, food, and time in defining niche.[11]

Another consideration is raised by Ayala.[12,13] He criticizes the treatment of "populations of species as if they were genetically homogeneous" and demonstrates the importance of genetic composition of populations in determining coexistence and exclusion by closely related species. Thus, his laboratory experiments show clearly that genetic adjustments (developed in the course of successive generations) between competing sibling (cryptic) species of *Drosophila* allow for successful coexistence. However, all species that he studies are sympatric in nature, at least over parts of their ranges. Four of the six "are found together in the same localities, come to the same baits and share, at least in part, the same foods."

These findings seem to contrast with those of extensive life history and field studies in certain subfamilies of the Chrysomelidae and of leaf-mining beetles, mainly Buprestidae. Vogt* has not detected any evidence of a genetic plasticity that enables closely related specialized phytophagous species to adjust to coexistence. Each and every population segregates ecologically, and closely related species that coexist on the same host plant exhibit some consistent behavioral trait, such as manner of egg placement or mine course pattern, that clearly identifies each biologically. Coexistence seems to be attained by very fine subdivision of niche space and persists as a result of nonextirpative levels of occupation of each species niche. In some systems, the efficient miners select the smaller oak leaves, while the wasteful miners avoid the smaller leaves for oviposition. Possibly elaborate experimentation in extended space and time would show interacting genetic plasticity among these seemingly

* G. B. Vogt, unpublished studies.

noncompeting forms, many of which are cryptic species. In the case of phytophagous insects, it seems from Vogt's studies that cryptic and other closely related species are essentially noncompeting when they are sympatric forms. Therefore, such species are not included here in considerations of ecological homology and analogy.

In less closely related species such as *Disonycha glabrata* (F.), as compared with *D. xanthomelas* and *D. collata* that compete for the same host plants, *Amaranthus* and *Acnida* species, again it seems that it is low levels of niche occupation that enables coexistence.[14] When the three species coexist, they seem to exploit the host plant in the same manner. However, *D. xanthomelas* and *D. collata* both have distinctive host plant spectra that extend beyond the *Amaranthus* and *Acnida* species that constitute the restricted host range of *D. glabrata*. Being more specialized, and presumably the more efficient suppressant, *D. glabrata* sooner or later displaces its two congeners which have their alternative host plants as a resort. Nevertheless, the coexistence of these three species recurs every year on *Amaranthus* and *Acnida* at many sites.

Finally, there is an intriguing occurrence of what appears to be ecological homologs and analogs of North American insects in the phytophagous fauna of southern South America, some involving weed species such as *Solanum*.[15] Many of these insect species are of genera that are hemisphere-wide in range but are limited to the western hemisphere. A major objective of our South American field studies was, therefore, to further establish the reality of this phenomenon by determining additional host plant relationships and other biological attributes and by detecting additional examples of probable ecological homology and analogy. Hopefully, at the same time, we would detect ecological nonanalogs and nonhomologs that might be useful for the biological control of weeds in the Middle South of the United States. Vogt's (unpublished) recent 2-yr study and earlier field studies in this region provided the basis for comparison that is needed in judging ecological homologs and analogs. Ultimately, there is need to test comparative virulence of the North and South American counterpart insects whether they be probable analogs or probable homologs.

It should be noted further that none of the three species of insects that were successfully introduced from South America into the southern United States to control alligatorweed has encountered an ecological analog or homolog. This was predictable because of the absence of important biotic suppressants of aquatic alligatorweed in the region of introduction and because of the phyletic relationships of the candidate South American insects.[7]

WEED SPECIES OF INTEREST TO THE UNITED STATES

"Sida rhombifolia" L., "S. spinosa" L., "S. acuta" Burm., and "S. varium" St. Hil.

One or more of these four weedy species occurred at virtually every locale visited in South America, north of Azul, Provincia de Buenos Aires (37° latitude). These and several other species occurred in cotton and other cultivated fields in South America, but nowhere was incidence heavy or even appreciable. For the most part, *Sida rhombifolia* and *S. spinosa* occurred as roadside weeds or weeds of fallow fields, turnrows, and pastures.

In more natural situations, these same two *Sida* species also occurred along higher banks of the Río Paraguay together with several other Malvaceae, in thorn forest of the eastern Chaco together with two other indigenous species, and on rocky hills near the Río de la Plata in Uruguay together with several other Malvaceae. Both seemed most at home in these natural drier environments, but *S. rhombifolia* also seemed at home in the humid forest in the Provincia de Corrientes, in the gallery forest at Punta Lara, and in the delta of the Río Paraná near Campana, Provincia de Buenos Aires. These occurrences suggest that these two species may be truly indigenous to southern South America. Elsewhere neither of these plants entered recognizable natural vegetation formations.

For insects, *Sida rhombifolia* is the most universal and usually most acceptable host plant of the four *Sida* species; *S. acuta* is a close second, and *S. spinosa* is fourth in the diversity of insects affecting it. However, most species that attack *S. rhombifolia* will probably accept *S. spinosa* when there is no choice.

About 26 species of insects were found affecting the four species of *Sida*, and an additional 15 insects or so were found when observations were extended to other species of *Sida* and to related Malvaceae of such genera as *Malvastrum, Sphaeralcea, Abutilon,* and *Anoda*. These other malvaceous genera supported many of the same insects as *Sida*. Most of the additional 15 insect species are members of complexes in such genera as *Zygogramma, Calligrapha, Conotrachelus,* and *Pyrgus* (skippers).

A provisional list of the insects found to affect *Sida rhombifolia* and *S. spinosa* in the southern United States and in South America is given in Table 1. Obviously most of the South American insects are represented by probable ecological homologs, i.e. similar to conspecific species, in the southern United States. The notable exceptions are the baridine stem borers, *Zygogramma* and *Calligrapha* leaf beetles, the argid defoliator *Neoptilia liturata* (Konow), and suctorial tingid lace bugs. These are the more promising biocontrol agents for use in the southern United States, but they should first be tested to ascertain whether they will attack cotton and okra to a significant degree. None is reported as a problem on cotton in South America.

None of the cited insects were observed making massive attacks on *Sida* in South America. However, any of these insects introduced into the United States will benefit from circumvention of the specialized parasite-predator complexes that suppress them in South America. Inversely, the predator-parasites of the North American species, e.g. the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) and related chrysomelines, could transfer to introduced *Zygogramma* and *Calligrapha*. Other introduced *Sida* insects could be similarly affected, but it is doubtful that any suppressive effects in the United States would approach those prevailing in South America, unless there is ecological analogy or homology with respect to the parasite-predator complexes.

Since most of the insects listed for the southern United States in Table 1 occur in the Gulf coastal region and do not reach the alluvial plain of the Mississippi River north of Vicksburg, it might be possible to use some of the tropical forms for manipulative release that are listed as having ecological homologs. For example, one or two of the tropical species of *Paragrilus* (Buprestidae) and the tropical hispid are more suppressive insects in South America than are the northern homologs and could prove to be useful. In the case of *Conotrachelus*, we have in *C. erinaceus* LeConte of the southern United States a species that is as suppressive or more suppressive than any of the *Conotrachelus* observed in South America. This insect may have transferred from *Sida elliottii* T. & G. or some other native North American species to *S. spinosa* where it is capable of producing infestations that destroy 70 percent or more of the seeds of a given plant at or near the peak of production in the field.

However, any recommendation to introduce the South American insects of *Sida* must be contingent upon verification of the premise that *S. spinosa* and *S. rhombifolia* are adventive in the United States from South America. That will require additional evidence. There will also be need to consider the possible impact of any introduced insect on other malvaceous species indigenous in the southern United States. This problem points up the desirability of utilizing tropical insects that cannot survive southern United States winters.

Table 1

Provisional List of Insects Affecting "Sida rhombifolia" and "S. spinosa" with an Estimate of Whether or Not an Ecological Homolog Occurs in the Southern United States for Each South American Insect

		Plant Part Attacked	Southern United States	Tropical South America	Temperate South America	Ecological Homolog in Southern United States
Anthonomus	sp. 1	Squares	+	–	–	
	sp. 2	and flower	–	+	+	Yes
Conotrachelus	sp. 1	Seeds	+	–	–	
	sp. 2		+	–	–	
	sp. 3		–	+	+	Yes
Boll worms	sp. 1		+	–	–	
(Lepidoptera)	sp. 2		+	–	–	
	sp. 3		+	+	–	Yes
Lycaenid	sp. 1		+	–	–	
	sp. 2		–	+	+	Yes
Dysdercus	sp. 1		+	–	–	
	sp. 2		–	+	–	Yes
	sp. 3		–	+	–	Yes
Corizus	sp. 1		+	+	+	Yes
	sp. 2		–	+	+	Possibly
Paragrilus	sp. 1	Stem	+	–	–	
	sp. 2		–	+	+	Yes
	sp. 3		–	+	–	Yes
Baridine	sp. 1		–	+	–	No
	sp. 2		–	+	–	No
Loopers	sp. 1	Leaves	+	+	+	Yes
	sp. 2		+	+	+	Yes
	sp. 3		+	–	–	
Skippers	sp. 1		+	+	+	Yes
	sp. 2		–	+	–	Possibly
Zygogramma	sp. 1		–	+	+	No
	sp. 2		–	+	+	No
	sp. 3		–	+	–	No
Calligrapha	sp. 1		–	+	+	No
	sp. 2		–	+	+	No
Sawfly	sp. 1		–	+	–	No
Agromyzid	sp. 1		+	?	?	Yes
	sp. 2		?	+	+	Yes
Hispid	sp. 1		+	–	–	
	sp. 2		–	+	+	Yes
Tingid	sp. 1		–	+	+	No
	sp. 2		–	+	–	No

"Anoda cristata" (L.) Schlecht.

As indicated, we were unsuccessful in gaining access to the regions adjacent to the Andes Mountains near Córdoba, Tucumán, and Salta in Argentina, and Tarija in Bolivia. Herbarium records indicate these drier regions are important centers of *Anoda* sp. prob. *cristata*. However, a very similar, if not the same, species occurs in the vicinity of Buenos Aires. The insects found on this plant appear to be the same species as those affecting the *Sida* growing in the same plant communities. Most notable are the skipper butterfly, a species of *Paragrilus* (Buprestidae), and a tingid.

Prof. Antonio Krapovickas at the Agricultural College in Corrientes, Argentina, considers *Anoda cristata* to be centered in Mexico and Central America. He also considers the form near Buenos Aires and in the Andes Mountains to be closer to a form of *Anoda* indigenous to California, and not *A. cristata* in the strict sense.*

"Sesbania exaltata" (Raf.) Rydb.

This native North American plant occurs as an exotic weed in South America and will be discussed as such in a later paragraph. We concentrated on two species of indigenous South American *Sesbania, S. punicea* (Cav.) DC. and *S. virgata* (Cav.) Pers., which are widespread in alluvial deltas along the narrow littoral of Brazil, in the alluvial plain of the vast Río de la Plata including its large delta, and in the adjacent portions of the eastern and western Chaco. Both of these South American *Sesbania* grow as branching shrubs, sometimes rather large, which is unlike the main stem growth habit of *S. exaltata*. Nowhere in South America was an indigenous *Sesbania* found to be a weed problem either inside or outside cultivated fields.

The four or five specialized insects that are important in the suppression of *Sesbania* are apparently coextensive with the range of these South American *Sesbania* species, which extends from Natal to Buenos Aires to Corumbá, Mato Grosso. These insects include a large stem-boring weevil, *Diplogrammus quadrivittatus* (Olivier); a flower-bud-infesting *Apion*; a defoliating (adult) and root-feeding (larva) weevil, *Eudiagogus episcopalis* (Gyllenhal); and a seed-destroying curculionid, *Rhyssomatus marginatus* Fahrs. Both the *Eudiagogus* and *Rhyssomatus* pupate in the soil.

A single *Diplogrammus* is capable of killing a young plant or a branch of an older plant. It should be especially pernicious to the main stem growth habitat of *Sesbania exaltata*. The adult weevils also feed on the foliage. The host plant specificity of this weevil needs close scrutiny considering that we found a very similar weevil, possibly the same species, infesting an arborescent water primrose, *Ludwigia* (Onagraceae), in the delta of the Río Guaíba near Portô Alegre. Another similar, but clearly distinct, species bores in the stem of a giant *Polygonum* in the delta of the Río Paraná.

No ecological homolog of *Diplogrammus, Rhyssomatus,* or *Apion* is known to occur in the southern United States. There are one to two North American species of *Eudiagogus* that are ecological homologs of the South American species. The North American forms seem to be less important suppressants than their South American counterparts. A more temperate climate in the southern United States may cause this difference.

Near Asunción, on both sides of the Río Paraguay, a very large species of cottony cushion scale was found infesting *Sesbania*. It forms conspicuous colonies that prove fatal to both young and old plants. This is the most virulent insect known to affect *Sesbania*. If it is sufficiently specific, as it may well be, this

* Personal communication, 14 Mar 1975.

insect could be a very useful biocontrol agent for manipulative release, especially if it is unable to survive winters in the United States.

An interesting testing arena for South American *Sesbania* insects against *S. exaltata* exists in Santa Cruz, Bolivia. There, on the grounds of the General Saavedra Agricultural Experiment Station, *S. exaltata* has become established within the past 10 yr, presumably having been introduced with cottonseed from the southern United States. Although no South American species of *Sesbania* is known to us in the Santa Cruz area (basin of the Río Amazonas), the South American *Sesbania* insects have found these exotic plants and are actively suppressing them. *Eudiagogus* and *Diplogrammus* were most conspicuously involved.

Apparently, the aggressiveness of *S. exaltata* is much reduced near Santa Cruz. This becomes strikingly evident in contrast with the Río Guayas basin near Guayaquil, Ecuador, which is situated on the western side of the Andes Mountains. Here *S. exaltata* has become established and is so spectacularly aggressive that it is displacing all natural vegetation in the lowlands of the region. As a result, it threatens an important industry that utilizes a naturally occurring spikerush as a stuffing material for such items as mattresses, furniture, and cushions. Apparently, the basin of the Río Guayas, which is isolated by the Andes, has no indigenous species of *Sesbania*, so the important specialized insect suppressants that are indigenous to the basin of the Río de la Plata are absent.

Nevertheless, extensive defoliation of *S. exaltata* did occur near Guayaquil in isolated colonies of the weed that were beyond its advancing front and in the extensive areas of saline esteros (marshes) where the weed may be exposed to salt stress. Apparently, Vogt was too late in his visit because he was not able to definitely determine what caused the stripping despite an extensive search. Grasshoppers were suspected until a single caterpillar, possibly a fall armyworm, *Spodoptera frugiperda* (J. E. Smith), was found.

The introduction of any South American insect as a control for *S. exaltata* in the United States would involve the dangers inherent in attempting the biological control of a native plant species. Outside cultivated fields, *S. exaltata* may be important to the food chains and an important fixer of nitrogen. Also, two other nonweedy, apparently native species of North American *Sesbania* probably would be attacked. These circumstances indicate that extreme caution must be used in any such introduction. Thus it may be that the species of insect considered for introduction must be a tropical species incapable of surviving winters of the southern United States. Since the five to six species that attack *Sesbania* in South America probably do not meet this requirement, deeper explorations into the Amazon Basin may be indicated if *Sesbania* does in fact extend deeply into that vast region, which may not be the case.

"Solanum carolinense" L.

A weedy species of *Solanum*, distinct but remindful of *S. carolinense*, was observed in the vicinity of Osorio, Río Grande do Sul. It supported both a cassid of the genus *Gratiana* and a lace bug probably of the genus *Gargaphia*. Both these insects, especially the lace bug, showed ability to blight the plant, but both are probable ecological homologs of insects already in the United States. Nevertheless, tropical species in either of these two genera may prove to be more effective suppressants than the native homologs and will be suitable for manipulative release.

In addition, over much of tropical and subtropical South America, there ranges a complex of species of leaf beetles of the genus *Colaspis* that occur specifically on *Solanum* and possibly related genera. These insects develop as root feeders and may be considered prospective biocontrol agents of weedy species of *Solanum*. They have no ecological homologs in the United States, and many of the forms may prove to be tropical. It is obviously important to determine whether they attack cultivated *Solanaceae*. Bosq[16] cites *Colaspis chloritis* Er. adults as damaging potato and eggplant. Normally, this insect develops on *Solanum bonariense*.

Near Buenos Aires a solanaceous weedy plant, identification not at hand, was under very heavy attack by a *Lema* (Chrysomelidae). This species had stripped many plants of foliage and done much excoriation of stem tissue. Along the Gulf states, a comparable species of *Lema* heavily attacks a similar solanaceous plant (*Physalis* sp.).

"Morrenia Odorata" (Hook. and Arn.) Lindl.

At several locations in southern South America, a distinctive eumolpine chrysomelid near *Colaspis* was scarce but occurred only feeding on leaves of *Morrenia*. This was the only insect noted, with the limited attention given this plant. Its development almost certainly takes place as a root feeder on *Morrenia*.

"Amaranthus spinosus" L. and "A. retroflexus" L.

Along the narrow littoral of Brazil between Linhares and São Paulo, *A. spinosus* is the prevalent species. In this region, three species of vittate *Disonycha*, one of which is probably *D. glabrata* (F.), are conspicuously important as suppressants. At Campos, and less evident elsewhere, large numbers of corimelaenid bugs were found on the flower and seed heads. They may have a synergistic effect because high densities of *Disonycha* usually occurred with them, and together they commonly killed the host plant. A mimetic *Lebia* (predator-parasite) that occurred with the vittate *Disonycha* doubtless reduced their effectiveness. We did not find *Amaranthus spinosus* south of São Paulo, Brazil; Encarnación, Paraguay; and Santa Cruz, Bolivia.

In Argentina, Paraguay, and Bolivia, *Amaranthus* is an important to most prevalent weed in cotton and other crops. Near Buenos Aires, *Amaranthus quitensis* H.B.K. (similar to *A. retroflexus*) is a very aggressive weed in cultivated fields. But away from cultivation, e.g. along roadsides and on riverbanks, it is scarce to absent. Southward to Necochea from just north of Buenos Aires, *Amaranthus* was almost free of insects except for a very small colony of *D.* sp. prob. *glabrata* at San Miguel de Monte.

North of Buenos Aires to Santa Cruz in Bolivia, heavy populations of *D.* sp. prob. *glabrata* together with mimetic *Lebia* occurred very locally. From Santa Cruz to Trinidad, Bolivia, a fasciate species (*Phenrica*) replaces the vittate *D.* sp. prob. *glabrata* and showed the same suppressive ability.

However, in the middle Amazon at Manaus, the vittate *Disonycha* occurred to the exclusion of *Phenrica* on *Amaranthus* (but this was not so on *Alternanthera*, Manaus being north of the range of vittate *Disonycha argentinensis*). In northern Argentina and in Santa Cruz, Bolivia, web worms (probably *Loxostege* sp.) and another caterpillar were inflicting very heavy damage that exceeded that done by flea beatles. These Lepidoptera are probably too generalized as to host plant, and *D. glabrata* already occurs in the United States. However, the fasciate species (*Phenrica*) of the Amazon Basin and one or two of the vittate species of the Brazilian littoral and Manaus may be tropical and may be useful in a manipulative release program in cultivated fields in the United States. Also, if the host specificity of the predator-parasite *Lebia* is real, introduced *Phenrica* from South America may be favored in the fields of the United States where no fasciate lebiines occur. A small coreid bug that occurs on the flower and seed heads of *Amaranthus*, less commonly than do the corimelaenid bugs cited previously, may also be involved in synergisms with *Disonycha* and may merit consideration as a biocontrol candidate.

Another tropical species of *Disonycha*, *D. camposi* Barber, occurs to the west of the Andes in the basin of the Río Guayas and in northern Peru. It is closely related to *D. collata* (F.), which ranges from the southern United States to Colombia. *D. camposi* attacks both *Amaranthus* and three species of *Alternanthera* in the alluvial plain of the Río Guayas. It, in turn, is subject to a nonmimetic *Lebia*, even though the flea beetle apparently mimics an *Altica* that occurs in the same habitat and that in turn is subject to a mimetic *Lebia*. Although *D. camposi* is almost certainly a tropical ecological homolog of *D. collata*, it could prove to be a more efficient suppressant of *Amaranthus* in the United States in a manipulative release program, especially if the North American *Lebia viridipennis* Dejean does not attack it. The latter, however, seems unlikely considering the ecological homology between the two *Disonycha* species.

"Alternanthera philoxeroides" (Mart.) Griseb.

Studies were made of *Disonycha argentinensis* Jacoby to further determine its host plant specificity and the extent to which it approaches being an ecological homolog of the native North American *D. xanthomelas* (Dalm.) and *D. collata*, which are proving to be important suppressants of terrestrial alligator weed.[17]

Three new host plants of *D. argentinensis* were discovered, all three widespread throughout much of southern South America. The mesophyte, *Alternanthera kurzii* Schinz., is a host plant in a small area of the eastern Chaco and western Chaco that straddles the Río Paraná-Río Paraguay between the Río Bermejo and Arroyo Empedrado. Usually fasciate *Disonycha (Phenrica)* occurred with *D. argentinenis* in this small approximately 80-km-square area, but elsewhere we found no trace of *D. argentinensis* on this widespread host plant of the Chaco and adjacent regions. Near Santa Cruz and Buena Vista, Departamento Santa Cruz, Bolivia, and near Corumbá, Mato Grosso, *Alternanthera kurzii* supported only colonies of *Phenrica*.

However, near Santa Cruz and Corumbá, both *Alternanthera paronychioides* St. Hil. and *A. pungens* H.B.K. support colonies of *Disonycha argentinensis*. We observed both these mesophytes near Buenos Aires and elsewhere over their very large range without finding either *D. argentinensis* or a specialized galerucid, *"Galerucella" interrupta* Jacoby, that shares these host plants near Santa Cruz and Corumba. *"G." interrupta*, like *D. argentinensis*, ranges south beyond Buenos Aires and west to the Andes (Salta, Tucumán, Córdoba, and La Pampa). Our failure to find either insect on these host plants in the areas south of Santa Cruz and Corumbá is puzzling because no-choice testing indicated that *D. argentinensis* is capable of completing its development on *Alternanthera paronychioides* near Buenos Aires. *Phenrica* is unknown from any host plant south of Corrientes.

Previously, when alligatorweed and *Alternanthera hassleriana* Chod. ex Chod. and Hassler were its only known host plants, the *Disonycha argentinensis* that occurs in the region west of the Río Paraná and the Río Paraguay (Argentina and Bolivia) presented biogeographical problems that suggested the existence of one or two unknown species of *Agasicles*. The discovery of the Amazonian *Agasicles vittata* Jacoby in a very narrow extension of humid climate north of Santa Cruz, Bolivia, plus the additional host plant information about *D. argentinensis* largely dispel these problems. The widespread occurrence of *Alternanthera hassleriana* and Amazonian *Agasicles opaca* Bechyné in the Llanos de Mojós near Trinidad, Bolivia, provide important additional information. Alligatorweed and *Agasicles vittata* are strikingly absent from this vast region of seasonal wetlands within the Amazon Basin.

More extensive and intensive search was made for *Agasicles* both in southern Paraguay and in the interior of Provincia de Corrientes than Vogt was able to do in 1960 and 1961. Still no evidence of *Agasicles* could be found east of the Río Paraguay-Paraná. This absence draws attention to the probable importance of *Disonycha argentinensis*, *Systena* sp. and other biotic suppressants in this region. The *Systena* probably is not as host specific as needed since it also attacks such diverse plants as *Hygrophila*, *Ludwigia*, and *Eclipta*.

We realize now that *D. argentinensis* is not as host specific as *Agasicles* and may not be a panmictic species. Still it is evident from very extensive observations made on this and earlier trips that *D. argentinensis* will not accept *Amaranthus* and chenopodiaceous host plants as do the North American *D. xanthomelas* and *D. collata*. Apparently, we are dealing here with ecological nonanalogs. Therefore, the prospect remains that *D. argentinensis* may be a more efficient suppressant of terrestrial alligatorweed than either *D. xanthomelas* or *D. collata* in the United States. If introduced, the South American insect should displace the North American flea beetles on alligatorweed but not on their alternative host plants.

These three very distinctive species of *Disonycha* were judged to be homologs rather than analogs because of the thread of a common host plant, alligatorweed, and the fact that all three are congeneric species with similar ecologies with respect to alligatorweed. When Vogt first considered *Disonycha collata* on alligatorweed in 1965 in the southeastern United States, he judged it to be an ecological analog of *D. argentinensis*. More refined information now suggests that nonhomolog or nonanalog is the correct judgment.[7]

"Myriophyllum brasiliense" Camb.

This is an indigenous aquatic plant that is widespread over southern South America. Although its occurrence was quite scarce and certainly not adventive at the time of our visit, Cordo notes that in Provincia de Entre Pios the plant is more prevalent and conspicuous during the spring months and gradually gives way to *Ludwigia* as summer advances.

Some insects affecting *M. brasiliense* also affect *Ludwigia* of the same family, Onagraceae. Again, some of the insects affecting these plants in southern South America exemplify the phenomenon of probable ecological homology with insects also affecting these plants in the southern United States (northern hemisphere).

In 1959, Bechyné split off the aquatic genus, *Lysathia*, from the large group of principally terrestrial flea beetles of the genus, *Altica*.[18] *Lysathia flavipes* (Boheman) is a flea beetle that is widespread in southern South America, where it attacks both *Myriophyllum brasiliense* and *Ludwigia peploides* (H.B.K.) Raven. It is also a striking example of an ecological homolog of *Lysathia ludoviciana* (Fall) of the southern United States and Caribbean region. Details of the life cycles match up remarkably closely for the two insects except for the fact that there is no record of the occurrence of *L. ludoviciana* in nature on either *Myriophyllum brasiliense* or the native North American *M. heterophyllum* Michx. However in no-choice testing, *Lysathia ludoviciana* feeds readily upon *M. brasiliense* and develops normally but may suffer reduced fecundity. This may mean the insects are ecological nonhomologs.

In the backwaters of the Rio Solimões near Manaus, *Lysathia* sp. very similar to *L. flavipes* attacks floating *Ludwigia* sp. But in the upper Amazon Basin, in the Llanos de Mojós of Bolivia, no species of *Lysathia* could be found on a widespread floating *Ludwigia* sp. Instead, an apparently specialized acridoid, *Marellia* sp. (Pauliniidae) attacked this plant generally. West of the Andes, another series of related *Lysathia* and *Altica* species attack *Ludwigia* and extend into Central America.

An Argentine hyperine weevil, *Hyperodes Marginicollis* Hustache, that feeds both on the foliage of *M. brasiliense* and bores and pupates in its stem has been under study by Cordo. It seems to be a remarkable ecological analog of the North American phytobiine weevil, *Perenthis vestitus* Dietz, which has a very similar biology and is similarly monophagous. In the United States, this insect attacks both the exotic *M. brasiliense* and the indigenous *M. heterophyllum*, and it is quite apparent that it has transferred to *M. brasiliense* from the native North American host plant. In Argentina, there are several aquatic and subaquatic species that attack *Ludwigia*. In North America, there is also a complex of three to four species of weevils that blight *Ludwigia* and may exemplify more ecological homology and analogy.

Cordo has been studying the *Myriophyllum-Ludwigia* weevil-flea beetle complex in Argentina during the past year and will report on it in detail. Also, when Vogt found *Lysathia flavipes* attacking *Myriophyllum brasiliense* at Piracicaba, he suspected that it was either a sibling species closely related to *L. flavipes* or an example of disjunction in host plant range. However, Cordo had already proved that the *Lysathia* of *M. brasiliense* and of *Ludwigia* in Argentina is a single species. Fifteen years ago, when he studied *L. flavipes* on *Ludwigia*, Vogt was not aware of its ability to attack *Myriophyllum*. Bosq[16] was first to record this apparent small disjunction in the host plant spectrum.

"Egeria densa" Planch. and "E. naias" Planch.

E. densa was prevalent in a tributary of the Río Iguazu near Curitiba in south Brazil, but we failed to find either species in an extensive search that extended from Pôrto Alegre to Río Grande to Chuy to Punta del Este to Colonia to Buenos Aires to Necochea to Chascomus to Buenos Aires to Goya. This region embraces more than half of the herbarium records for southern South America cited in the latest revisionary study of *Egeria*.[19] Also, Burkart[20] reports *E. densa* as common and a pest in the delta of the Río Paraná. We did find *E. densa* in aquaria in the Natural History Museum in Buenos Aires. An attendant told us the plants came from Esteros del Iberá, Provincia de Corrientes.

North of Goya, Provincia de Corrientes, we found *Egeria naias* scarce in a shallow sand-bedded pan lake. Farther north, with the guidance of Prof. Antonio Krapovickas, we found the same plant abundant in a series of sand-bedded pan lakes near San Cosme. In the limited time and with the facilities at our disposal, we found no insects affecting these plants which quite generally were in flower. Effective study of this plant will require much time, a lightweight boat, and other special equipment.

"Eichhornia"

Cordo's field studies found that *Eichhornia crassipes* (Mart.) Solms., *E. azurea* (Sw.) Kunth, and *Pontederia cordata lanceolata* (Nutt.) Griseb. are widespread throughout much of the lower Río Paraná-Río Paraguay basin. *E. crassipes* supports the most diverse fauna of natural enemies followed by *E. azurea* and *P. C. lanceolata*. The frequent occurrence of adult *Neochetina bruchi* Hustache and *N. eichhorniae* Warner on *Eichhornia azurea* indicates the possibility that these weevils can develop on this host plant under certain conditions. The acridoid, *Cornops* sp., was observed attacking *Pontederia cordata lanceolata* and *Reussia rotundifolia* (L.F.) in addition to *Eichhornia crassipes* and *E. azurea*. There was a general absence of *Sameodes (Epipagis) albiguttalis* (Warren) on *E. azurea* and *P. cordata lanceolata* in contrast to its widespread occurrence on *E. crassipes*. The aquatic scarabaeid, *Chalepides luridus* (Burm.), was found at Chaco-í, Paraguay, causing severe damage in a small area of *E. crassipes* and *E. azurea*. Near Resistencia, Provincia de Chaco, along a distributary of the Río Paraná, and very close to it, extensive and heavy growths of *E. crassipes* occur. Since Cordo found only damage of *Neochetina*, he considers the apparent absence of *Acigona, Sameodes, Cornops*, and *Orthogalumna* may indicate their importance as suppressive agents.

In the basin of the Río Guayas, Ecuador, specialized insects of *Eichhornia* are absent, which is contrary to the situation in the basin of the Río de la Plata east of the Andes. Most conspicuously, no presence of the *Neochetina* weevils could be detected. Only occasional, localized, but large, silk-tented mite infestations were seen affecting these plants. As a result, *Eichhornia* may be more aggressive in the Río Guayas. It was quite apparent that there exists in the Río Guayas a larger problem with floating rafts of camalotes dominated by *Eichhornia* than we have seen anywhere in the basin of the Río de la Plata, including the Río Paraguay near Corumbá.

"Pistia stratiotes" L.

Cordo found this plant widespread in the lower Río Paraná—Río Paraguay basin. It attains greater incidence in the western Chaco, possibly due to edaphic conditions. The weevils *Neohydronomus pulchellus* Hustache, *Onichylis cretata* Champ., *Argentinorrhynehus bruchi (Hustache), A. nitens* (Hustache), *A. squamosus* (Hustache), and *Neochetina bruchi* Hustache, and the pyralid, *Samea multiplicalis* Guenée were general in occurrence in northern Argentina. *Neohydronomus pulchellus* was the most ubiquitous and damaging species.[21]

The Brush or Chaparral Problem

Our itinerary was much too late in the season, so we found minimal-to-no insect activity in the open. The season of maximum insect activity in the open we judge to occur in the spring and early summer, i.e. October, November, and early December. Also, we were unable to reach important areas of "monte" (brush) in the drier western areas near Santiago del Estero, Córdoba, Tucumán, Salta, etc. As a result, we saw only a few live stem-boring buprestids (*Psiloptera* sp.), a few trachyderine cerambycids, and some onciderine prunings. No trace of insects that might compare with *Mozena* were seen. In March 1960, pods of *Acacia caven* (Mol.) Mol. were very heavily infested with bruchids along the Río Salado near Santa Fé, Provincia de Santa Fé.

WEED PROBLEMS OF MUTUAL INTEREST TO ARGENTINA AND THE UNITED STATES

One of the objectives of the authors working together was to develop an awareness of exotic weed problems in Argentina and the possibilities of their biocontrol. Such an awareness could lead to cooperative arrangements between Argentina and the United States for solutions of mutual problems.

Amaranthus may be more of a problem in Argentina, Uruguay, and possibly Paraguay than it is in the United States. We observed its weediness at numerous sites. Also, at several locations in Provincia de Entre Ríos, we observed pastures heavily infested with *Carduus* spp., exotics from Europe.

At Punta Lara (south of Buenos Aires), we observed impenetrable thickets of *Rubus* behaving there as a remarkably aggressive weed that monopolizes any opening made in the natural vegetation. *Rubus* is native to North America. Also native to North America is the box elder maple *Acer negundo* L., which has escaped cultivation and aggressively displaces natural vegetation in the gallery forest. Even more aggressive is the Eurasian privet *Ligustrum* sp., which is making heavy inroads into the arborescent vegetation of the preserve at Punta Lara. Prof. A. L. Cabrera of the La Plata Museum concurs that Eurasian privet is a major threat to surviving natural vegetation.*

* Personal communication, 3 Mar 1975.

SOME BIOGEOGRAPHICAL CONSIDERATIONS

The biogeography of *Egeria* and *Myriophyllum* seem principally tied to the temperate to subtropical climates. They are not restricted to the basin of the Río de la Plata. The biogeography of *Sida* and *Anoda* and their insects is not so clearly related to river systems (like *Sesbania*) as it is to human disturbance and to regions of relatively dry climate as in western Argentina.

However, important biotic differences between river basins are clearly indicated by some of our findings. *Eichhornia* and *Sesbania* lack specialized insects in the humid basin of the Río Guayas west of the Andes in contrast to rich faunas in the much larger and more diverse basin of the Río de la Plata west of the Andes. Alligatorweed and *Alternanthera hassleriana* and their flea beetles (six species of *Agasicles* and two species of *Disonycha*) east of the Andes are replaced in wetlands west of the Andes by a very different *Alternanthera halimifolia* (Lam.) Stanl. ex Pittier and a very distinct third species of *Disonycha, D. camposi,* which also attacks *Amaranthus* on moist sites. Obviously, in these examples, it is the high relief of the Andes that is the major separating barrier.

With few exceptions, biotic change does not occur between the basin of the Río Amazonas and the basin of the Río de la Plata in the region of low relief encompassed by the Departamentos Santa Cruz and Beni, Bolivia. Here the closely related *Agasicles opaca* and *A.* n. sp. of *Alternanthera hassleriana* divide geographically by river basin. Similarly, as presently known, *Agasicles vittata* and *A. hygrophila* Selman and Vogt of alligatorweed separate by river basin. This is curious in view of the great ability of *A. hygrophila* to disperse as demonstrated in the southern United States.[22] However, in the case of the fasciate *Disonycha (Phenrica)* versus the vittate *Disonycha,* the biogeography is not determined by river basin. The dividing line between the forms affecting *Amaranthus* cuts across the southern extremities of the basin of the Río Amazonas. Also, the separation between fasciate and vittate flea beetles that affect alligatorweed and other species of *Alternanthera* is blurred by a wide region of overlap that extends rather deeply into both river basins.

While some aquatic plants, such as *Victoria amazonica* (Poeppig) Sowerby and *V. cruziana* D'Orbigny, separate geographically by river basin, others, such as *Phyllanthus* (Euphorbiaceae), *Neptunia* (Leguminosae), *Alternanthera hassleriana,* and alligatorweed, are common to both basins. In the case of the tropical plants, distributions in the basin of the Río de la Plata are confined to the Río Paraguay, some only to its upper reaches.

Another aspect of biogeography and river basins in South America is the extension of so many plant and insect species present in the basin of the Río de la Plata into the small-to-very-small basins strung along the narrow littoral of Uruguay and eastern Brazil. Some of these organisms, e.g. *Agasicles,* have speciated in the process, but many have not.

This field study increased our knowledge of the tremendous diversity of the wetlands of the basin of the Río de la Plata, which are unequaled by any river basin in the western hemisphere, if not in the world. This diversity and the geologic age of the region are the major reasons for considering it as a center of evolution and a source of aquatic organisms. Except in its lakes, distributaries, and the backwaters of its alluvial plain, the basin of the Mississippi River cannot compare with the wetlands of the basin of the Río de la Plata. There is nothing in the basin similar to the wetlands of the western Chaco, eastern Chaco, Esteros del Iberá, Esteros del Santa Lucia, or Pantanal.

We also found that the vast seasonal wetlands, the Llanos de Mojós of the basin of the Río Amazonas, constitute a region of great aquatic diversity that in appearance seems more Paraguayan than Amazonian. Clearly, these wetlands constitute the most important habitat for *Alternanthera* *hassleriana* and *Agasicles opaca* in the basin of the Río Amazonas.

SOME ECOLOGICAL CONSIDERATIONS

In the lower Río Amazonas near Manaus, the annual hydrographic flux may attain 20 m.[23] Here the alluvial flats exposed by the low levels of the Río Solimões during November-January become wet meadows of diverse herbaceous plants including weed species of such genera as *Wedelia, Eclipta Ambrosia, Xanthium, Ludwigia* (scarce), *Hygrophila, Alternanthera, Croton, Echinochloa, Paspalum*, etc. These plants can grow only briefly before rising waters deeply submerge then for 9 to 10 months. This instability of habitat probably precludes most species of specialized insects that might attack these plants. Generally, the natural vegetation at higher levels and on terra firma consists of woody species (trees, shrubs, and lianas) to the complete exclusion of herbaceous species. This absence denies a refuge to many insects that might infest the herbs of the mud flats and exacerbates the instability of that habitat.

However, some herbaceous species do grow, usually scattered among the sedges and grasses that are the dominant components of the extensive floating rafts of vegetation (embalsados) that occur in the backwaters of the Río Solimões. We noted species of the following genera: *Wedelia, Begonia, Hibiscus, Andropogon* (isolated tufts), *Aeschynomene, Neptunia, Utricularia*, and various ferns. Also floating with the embalsado was a scattering of small trees, viz., *Cecropia* and *Montrichardia* (often in colonies). We detected no trace of alligatorweed or of *Alternanthera hassleriana* growing in the embalsados near Manaus, but we found a few stems of *Alternanthera hassleriana* floating among grasses along margins of an embalsado.

Our limited observations of the very extensive embalsados in the basin of the Río de la Plata were made to determine the possible role of alligatorweed and other weed species in the plant communities of established embalsados and the plant succession involved in their formation.

Incipient stages of developing embalsados observed in the Río Santa Lucia near Goya involved species of sedges that apparently became established on thick senescing growths of water fern. *Salvinia auriculata* Aubl. *Eichhornia* clearly was not involved in the initial growth; the sparse alligatorweed showed damage from *Disonycha argentinensis* and did not extend beyond the wet margins of the backwater. We found no evidence of alligatorweed in fully developed embalsados in pan lakes at Santa Teresa and at San Cosme, Provincia de Corrientes; but at the margins of one lake at San Cosme, the few stems of alligatorweed, among grasses and sedges, were under attack by *Disonycha argentinensis* and *Systena* sp. These insects and possibly acid pH and/or salinity are the factors limiting growth of alligatorweed in the embalsado.

Burkart[20] distinguishes three types of floating vegetation composed of macrophytes: (a) the camalote or community composed principally of *Eichhornia azurea* (Sw.) Kunth, *E. crassipes* (Mart.) Solms, and *Pontederia rotundifolia* L.F., (b) the floating cañaverale or community of trailing aquatic grasses, principally *Panicum elephantipes* Nees and *Paspalum fluitans* (Ell.) Kunth; and (c) the embalsado. Burkart reports alligatorweed as one of the few plants that occur occasionally in camalote and canaverale. We have seen this sparse occurrence many times over the years in the basin of the Río de la Plata, especially in its delta.

According to Burkart,[20] the embalsados are structured formations, mattresses with rhizomes, roots, and detritus intermingled. They float and drift about. He cites T. M. Pedersen's observations that the first stage is *Scirpus cubensis* Kunth possibly sprouting on old camalote. Next comes the turf-building *Eleocharis plicarhachis* (Gris.) Svensen and *E. radicans* (Poir.) Kunth together with some

Rhynchospora, Lipocarpha, and *Fuirena.* Together they produce a mat that can be walked on. Later the floating mat looks like turf with black soil covered with flowering plants. It quakes when walked upon.

Camalotes and floating canaverales do not have a substratum that is dense and interwoven. Instead, they are loose associations floating on the water surface. However, in their late stages, they may be the beginnings of embalsados.

Burkart[20] (and Pedersen) lists species of the following additional genera as the flora of the developed embalsado: *Eriocaulon, Habenaria, Eulophia, Utricularia, Hydrolea, Bacopa, Mayaca, Cyperus, Ludwigia, Polygonum, Bidens, Eupatorium, Dryopteris, Imperata,* and small trees of *Cecropia.* Burkart records *Mikania* from camalote, but not from the embalsado. Alligatorweed is conspicuously absent from the list.

In the southern United States, the floating, closely woven mat composed of alligatorweed is the only vegetation formation that approaches the embalsado in structure. There is also a type of camalote composed of a single species, *Eichhornia crassipes,* that grows extensively and a type of canaverale composed of a single species, *Paspalum fluitans,* that is limited in occurrence. However, with the successful introduction of biotic agents from South America[22,24,25] to control alligatorweed, a vegetational succession is occurring in the southern United States that is suggestive of the later stages of the formation of the embalsado. As alligatorweed loses its competitive edge, the floating mats that were once composed exclusively of this species begin to undergo vegetational replacement.[26]

The most important replacement for alligatorweed is *Eichhornia crassipes,* but it does not grow on the mat as do *Utricularia, Limnobium* (near margins of mat), *Hydrolea, Ranunculus, Hydrocotyle, Scirpus* (not *cubensis*), *Cyperus, Eleocharis* (not *radicans*), *Ludwigia, Polygonum, Galium, Bidens, Eclipta, Mikania, Hypericum, Lycopus, Boehmeria,* and *Sacciolepis.* Nine of these genera are listed by Burkart from the South American embalsado. We also found *Bacopa* but only in the replacement vegetation in shallow waters where alligatorweed is rooted to the bottom.

Also, the alligatorweed floating mat, unlike the embalsado, does not hold soil. However, as the alligatorweed undergoes biotic suppression during the growing season, decaying plant material does accumulate, at least for awhile. This material contributes to the substrate needed for the diverse invading flora that normally inhabits swamps, marshes, and pond margins of the southern United States. Apparently, we are still missing the plant species that can hold the mat together as the alligatorweed declines under biotic suppression. There are no counterparts of *Scirpus cubensis* and the turf-forming *Eleocharis (and associated genera). However, some of the genera and species cited by Burkart*[20] *(and Pedersen) as basic to the formation of the embalsado are, as recorded, part of the flora of the southern United States.*[27-29] *Cited as scarce to rare plants are Scirpus cubensis, Eleocharis radicans,* and several species each of *Fuirena* and *Dichromena* (some authors include this genus with *Rhynchospora*). Continued surveillance could reveal the presence of at least some of these plants in the suppressed alligatorweed mat, but it is significant that no evidence of them has been found to date.

In view of the existing floristic lacunae in the suppressed alligatorweed mat and the absence of floating mats of alligatorweed in South America, we believe that alligatorweed and the species involved in its vegetational replacement will be unable to persist indefinitely in a mat formation. This judgment is based on the assumption that the introduced biotic agents will continue to exert the necessary suppression on alligatorweed in the years ahead, which seems likely. It is also based on the assumption that those potential embalsado-forming species of the southern North American flora have already had a good chance to appear in the replacement vegetation of the suppressed alligatorweed mat. However, disappearance of mats from some sites may be a slow process that will vary with location because of differences in hydrographic flux, wind action, and the extent of biotic suppression against replacement species.[26] At many sites south of Vicksburg, Mississippi, *Eichhornia crassipes* will continue to replace alligatorweed mats until it in turn becomes biologically controlled.

CONCLUSIONS AND RECOMMENDATIONS

Regarding row crop weeds that require biotic agents for manipulative release, more than half our findings are probable ecological homologs of species already in the southern United States, though mostly south of Vicksburg, Mississippi. Closer study is needed in both South America and North America to ascertain whether any of them might prove to be ecological nonhomologs and be more possibly suitable for introduction. Of the smaller group of insect species, some are quite clearly ecological nonanalogs. For these more promising biotic agents, there is need to initiate screening tests for host specificity. For insects of Malvaceous weeds, cotton and okra head the list of test plants.

Regarding aquatic and bank-side weeds that require biotic agents for classical biocontrol, our findings on *Myriophyllum brasiliense* indicate that *Lysathia flavipes* is a very near ecological homolog of the North American *L. ludoviciana*. It is doubtful that further study will change this view. Less definitive evidence indicates that the South American weevil *Hyperodes marginicollis* Hustache is an ecological analog of the North American *Perenthis vestitus* Dietz, and, therefore, may be unsuitable as a biocontrol agent of *Myriophyllum brasiliense*. More study is needed to substantiate this view. In regard to *Egeria densa*, there is much need to locate more colonies of this plant and the related *E. naias* and to carry out the demanding and probably slow job of detecting biotic agents.

Regarding terrestrial and bank-side alligatorweed, *Disonycha argentinensis* is quite clearly an ecological nonhomolog or nonanalog and a more specialized possibly more effective agent than the North American *D. xanthomelas* and *D. collata*.[7] To further prove this judgment, there is need to test the South American insect in quarantine on the North American weeds, *Trianthema portulacastrum* L., *Portulaca oleracea* L., and *Stellaria media* (L.) Cyr. Screening for host plant specificity must also include beet, spinach, and wormseed. Whether or not *D. argentinensis* should be introduced largely rests on the results of these tests. The enigma that *Agasicles hygrophila* remains unknown from the interiors of Provincia de Corrientes and southern Paraguay may emphasize the importance of other biotic agents of alligatorweed including *D. argentinensis* and a species of *Systena*.

As indicated above, our findings on *Sida, Sesbania, Egeria, Myriophyllum brasiliense, Solanum, Amaranthus,* and alligatorweed appear to be promising enough to justify continued investigations in South America by the U. S. Department of Agriculture (USDA). The principal region where concentrated studies should be made is southern South America, especially the basin of the Río de la Plata and adjacent regions. These adjacent regions should include the dry regions, mostly of internal drainage, in western Argentina and also Paraguay. The basin of the Río Guaiba in south Brazil is in some ways a Río Parana in miniature.

As emphasis shifts to weed species other than waterhyacinth and alligatorweed, there may be need for better centering of the laboratory, which is presently located near Buenos Aires. Corrientes, R. A.; Asunción, Paraguay; Pôrto Alegre, Curitiba; and Piracicaba, Brazil, are recommended sites.

The topical application of tropical biotic agents could be a method of controlling weeds in cultivated crops. The use of such an approach will require field studies in the more tropical latitudes. There is need for expert advice on the matchability of the growing season in the southern United States with the seasons of tropical climates during which candidate insect biocontrol agents undergo their growth and development.

The mud flats of the Río Solimões near Manaus that are exposed during minimal levels in November-January should be studied more closely for possible insects affecting herbaceous weeds. Such insects will have had to adapt to a very unstable environment that in some respects compares in instability with modern agricultural fields.

The basin of the Río Guayas, Ecuador, needs more study of biotic agents affecting *Eichhornia* and other aquatic weeds. The isolating effect of the high Andes is reflected in biogeographical anomalies.

In the southern United States, further observation is needed of the vegetational replacement taking place in the biocontrolled alligatorweed floating mat. This surveillance is needed to detect evidence of embalsado-forming plant species that could perpetuate the problem of clogged waterways.

ACKNOWLEDGMENTS

Facilities of the U. S. National Herbarium, of the Systematic Entomology Laboratory (USDA), and of the Stoneville Pedigreed Seed Company were important resources needed in the development of the itinerary.

In Brazil, the Institute for Studies of the Amazon Region at Manaus provided technical advice and assistance. Officials of the National University of Parana at Curitiba, of the Agricultural School of the University of São Paulo at Piracicaba, and of the Institute for Sugar and Alcohol Production at Campos provided technical advice and assistance.

In Provincia de Corrientes, Argentina, at the Agricultural University and at Estancia Santa Teresa, we consulted with authorities on *Malvaceae* and *Amaranthaceae*, respectively. We also consulted entomological and botanical collections, authorities at the La Plata Museum and the Buenos Aires Museum of Natural History, and Argentine officials of Instituto Nacional Technologia Agropecuarias at Castelar and at Saenz Pena.

In Paraguay, officials of the Ministry of Agriculture and U. S. Agency for International Development provided technical advice and assistance. At La Paz and the Saavedra Experiment Station, Bolivian officials of the Ministry of Agriculture provided technical advice and assistance. At Guayaquil, Boliche, and Pichelingue, Ecuador, officials of the Ministry of Agriculture and of Instituto Nacional Investigaciones Agropecuarias provided technical advice and assistance.

Sponsorship of these 1976 South American field studies by the U. S. Army Corps of Engineers is gratefully acknowledged. Vogt's salary was continued by the USDA with the understanding that he would divide his time between agricultural and aquatic weeds. Cordo was wholly sponsored by the Corps, and he carried out studies of *Eichhornia, Pistia, Pontederia, Myriophyllum*, and *Ludwigia* that are only briefly reported here.

Four previous field studies in South America, 1960, 1961, 1962, and 1970, were carried out by Vogt. The three earlier ones were sponsored by the U. S. Army Corps of Engineers, while the fourth was a joint undertaking with H. F. Howden of Carleton University, Ottawa, Canada. Most of the results of these field studies remain unpublished, and more than 100 individuals who helped, advised, and made the studies possible remain to be acknowledged.

Very extensive unpublished information on leaf-mining coleoptera has provided important background for these studies. Most of this work was done while Vogt was with the Systematic Entomology Laboratory (Agriculture Research Service (ARS), USDA). He also has the benefit of three very important years (1966-1969) of active association with the Bioclimatic Study Group. This group, which was headed by Norman E. Flitters and the Bioclimatics Study Committee and chaired by the late

L. D. Christensen, operated a large simulated climate facility that was located at the Cotton Insects Laboratory (ARS, USDA), Brownsville, Texas. The very extensive studies of the bioclimatics of closely related allopatric populations of leaf-mining *Pachyschelus* remains unpublished.

R. E. Warner, D. R. Smith, and A. B. Gurney of the Systematic Entomology Laboratory (ARS, USDA)have kindly determined, on short notice, weevils, a sawfly, and a grasshopper referred to in the test.

Our colleagues, P. C. Quimby, Jr., and S. H. Kay, have kindly permitted us to cite from manuscripts currently in preparation. P. C. Quimby, Jr., and K. E. Frick have critically reviewed the manuscript and made appropiate suggestions.

Sr M. J. Viana, Museo Argentina de Ciencias Naturales, has kindly determined the weevils of *Sesbania*.

REFERENCES

1. Frick, K. E. and Chandler, J. M., "Culture and Early Release of *Bactra verutana*, A Biological Agent for Purple Nutsedge Control," *Abstracts, Weed Science Society of America*, 1974, pp 66-67.
2. Flitters, N. E., Vogt, G. B., and Robinson, S., "Bioclimatic Studies of Closely Related Allopatric Populations in Leaf Mining *Pachyschelus purpureus* Say (Buprestidae)" (In preparation).
3. De Bach, P., "The Competitive Displacement and Coexistence Principles," *Annual Review of Entomology*, Vol 11, 1966, pp 183-212.
4. Force, D. C., "Ecology of Insect Host-Parasitoid Communities," *Science*, Vol 184, 1974, pp 624-632.
5. Connell, J. H., "The Influence of Interspecific Competition and Other Factors on the Distribution of the Barnacle *Chthamalus stellatus*," *Ecology*, Vol 42, 1961, pp 710-723.
6. Pianka, E. R., *Evolutionary Ecology*, Vol 10, Harper and Row, New York, 1974.
7. Vogt, G. B., McGuire, J. U., and Cushman, A. D., "Probable Evolution and Morphological Variation in South American Disonychine Flea Beetles (Coleoptera: Chrysomelidae) and Their Amaranthaceous Host Plants," ARS Technical Bulletin (In preparation).
8. Savage, J. M., "The Concept of Ecological Niches with Reference to the Theory of Natural Coexistence," *Evolution*, Vol 12, 1958, pp 111-112.
9. McNaughton, S. J. and Wolf, L. L., "Dominance and the Niche in Ecological Systems," *Science*, Vol 167, 1970, pp 131-138.
10. Lorenz, K. Z., "Analogy as a Source of Knowledge," *Science*, Vol 185, 1974, pp 229-234.
11. Schoener, T. W., "Resource Partitioning in Ecological Communities," *Science*, Vol 185, 1974, pp 27-39.
12. Ayala, F. J., "Genotype, Environment and Population Numbers," *Science*, Vol 112, 1968, pp 1453-1459.
13. ______________, "Competition Between Species," *American Scientist*, Vol 60, 1972, pp 348-357.
14. Vogt, G. B., Quimby, P. C., Jr., and Kay, S. H., "Field Studies of Flea Beetles and Their Lebiine Predator Parasites in the Southern United States" (In preparation).
15. White, R. E., "The Identity of *Gratiana lutescens* (Boh.) and *G. pallidula* (Boh.) (Cassidinae:Chrysomelidae)," *U. S. Department of Agriculture Cooperative Economic Insect Report*, Vol 24, No. 10, 1975, p 166.

16. Bosq, J. M., "Segunda Lista de Coleópteros de la República Argentina, dañinos a la Agricultura," *Ingenieria Agronomica,* Vol 14, Nos. 18-22, 1943.

17. Quimby, P. C., Jr., and Vogt, G. B., "Aspects of Alligator Weed in the Mississippi Valley," *Abstract, Proceedings, Southern Weed Science Society,* Vol 27, 1974, pp 280-281.

18. Bechyné, J., "Beitrage zur Kenntnis der alticiden Fauna boliviens," *Beitrage zur Neotropische Fauna,* Band 1 Heft 4, pp 269-388.

19. St. John, J., "Revision of Egeria," *Darwiniana,* Vol 12, 1961, pp 293-307.

20. Burkart, A., "Ojeada sinoptica sobre la vegetación del Delta del Río Paraná," *Darwiniana,* Vol 11, 1957, pp 457-561; Translation by the late Ruth Erikson.

21. DeLoach, C. J. and Cordo, H. A., "*Neohydronomus pulchellus* Hustache, a Weevil Attacking *Pistia stratioles* L. in South America" (In preparation).

22. Vogt, G. B., Quimby, P. C., Jr., and Kay, S. H., "Alligator Weed Biocontrol in the Mississippi Valley," *Abstracts, Weed Science Society of America,* 1975, pp 34-35.

23. Sioli, H., *Tropical River: The Amazon in Studies in Ecology 2: River Ecology,* Vol 461, University of California Press, Berkeley, 1975, pp 461-488.

24. Maddox, D. M. et al., "Insects to Control Alligator Weed," *Bioscience,* Vol 21, 1971, pp 955-991.

25. Brown, J. L. and Spencer, N. R., "*Vogtia malloi* Pastrana, a Newly Introduced Phycitine Moth to Control Alligator Weed," *Environmental Entomology,* Vol 2, 1973, pp 519-523.

26. Vogt, G. B., Quimby, P. C., Jr., and Kay, S. H., "Progress in the Biocontrol of Alligator Weed in the Middle South of the United States" (In preparation).

27. Small, J. K., *Manual of the Southeastern Flora,* Vol 22, University of North Carolina Press, Chapel Hill, 1933, pp 1-1554.

28. Fernald, M. L., *Grays Manual of Botany,* 8th ed., Vol 94, Van Nostrand Reinhold, New York, 1970, pp 1-1632.

29. Correll, D. S. and Johnston, M. C., *Manual of the Vascular Plants of Texas,* Vol 15, Texas Research Foundation, Renner, Texas, 1970, pp 1-1881.

AQUATIC WEED PROBLEMS IN MEXICO AND TEXAS AND SOME OF THE MEASURES FOR THEIR CONTROL

by

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In the central and southern parts of Mexico, noxious aquatic plants have been known to exist since 1890. In these general areas, the plants causing problems have been waterhyacinths, waterlettuce, and Salvinia. At the present time, these plants still exist and continue to create problems. Hydrilla is now present in the water-supply lake for the city of Monterrey.

Waterhyacinths presently create many problems in lakes built for the generation of hydroelectric power, the main problem of these floating plants being they clog up the intakes and thus diminish the amount of water available for generation and the necessary water to cool the generators. Hyacinths have also undermined bridges and low-water bridge pilings; at times they have destroyed the bridges.

CONTROL HISTORY

In 1930, hyacinths created problems in the irrigation district of El Mante in Tamaulipas. These plants had to be removed manually from the discharge areas of the reservoir and from the feeder canals. Later in 1947, radial rotating gates were installed at Rio Santiago to permit the easier discharge of hyacinths from the dam. Manual and some mechanical means have not been able to suppress the luxurious growth of hyacinths in all of the areas.

Some of the submerged aquatics that have historically created problems are *Chara*, *Najas sp.* and *Myriophyllum sp.*

CONTROL METHODS

Four means of control have been carried out in efforts to stabilize the ever-increasing areas of aquatic vegetation. They are:

a. Manual and/or mechanical

b. Physical (drawdowns)

c. Chemical (2,4-D)

d. Biological (white amur, manatee)

Encountered problems are:

a. Manual—very slow, but provides jobs for many

b. Physical—rarely done, water for irrigation too valuable; harvesters create high algae blooms that tend to kill fish.

c. Chemical—too expensive, not knowledgeable enough in their application.

d. Biological—too susceptible to diseases, manatees died. Amurs good feeders provide protein, but have reproduced in a river system, Rio Balsas, and in a lake system, Lago Bodegas, shown in Figure 1.

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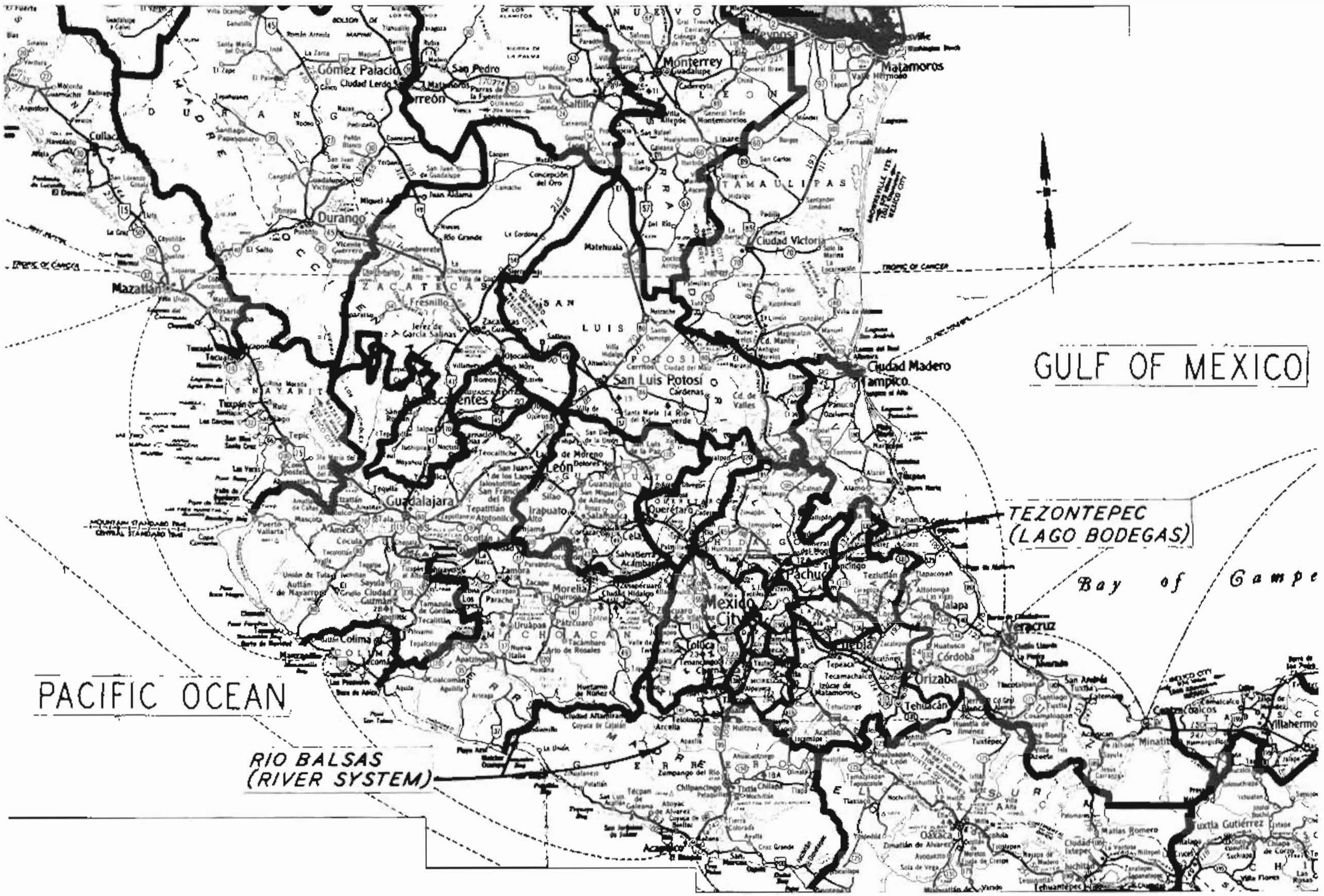

Figure 1. Map of Mexico

White amur is being extensively raised and stocked in many areas of Mexico to maintain some sort of vegetation control and to provide protein for the diets of many of the river-side communities. In the tropical part of Mexico, the amur is extensively stocked in temporary lakes and streams when the lakes and streams fill up during the rainy season (6 months). When the water levels recede, the fishing co-ops, established by the government in many river-side communities, will go in and harvest the fish for market.

PRESENT CONTROL METHODS

Texas has a working agreement with the U. S. Army Corps of Engineers under various contracts with the different District Offices and a research contract with U. S. Army Engineer Waterways Experiment Station (WES) toward the control of hydrilla. Of the nine watersheds in Texas that have waterhyacinth or alligatorweed problems, four are under a control phase and five are on a maintenance level.

Waterhyacinths continue to be the main problem. In many of our maintenance lakes, receding water levels, sunny warm days, and periodic moisture have germinated many hyacinth seeds to produce a new crop every 60-90 days. The extremely shallow water, plus a lot of the brush and some of the remaining timber, make access to these areas very difficult, if not impossible. Aerial application has been considered, but it would be fruitless if the area were not open or available for retouching subsequent growth due to new plants or to those left untreated. The need for some sort of vehicle that would be able to get into these areas is vital and critical.

The areas of the Guadalupe River are relatively clean of hyacinths. A new problem is Elodea that has been released by harvesting machines used on Landa Park. Improper harvesting and lack of proper precautions have resulted in large areas of the beautiful, scenic Guadalupe River being invaded by plants that were cut, but not harvested, and have worked their way down into this river system.

The weed problems in the north coastal area are for the most part under control. There are some occasional outgrowths of waterhyacinths from seed plants, but this requires only periodic treatment measures. Alligatorweed infestation in this general area for the most part is under a biological control program. *Agasicles sp.* (flea beetles) stocked in many areas have done a good job; in other areas, they are still in small numbers, and the eating habits of these colonies are not too noticeable. When large concentrations of flea beetles are noticed in one area, we usually will collect as many as we can and stock them in needed areas. Our usual stocking colony of flea beetles is between 4000 and 5000.

The problem in the Sabine Watershed has, for the most part, been a few isolated cases of waterhyacinths impacting some of the small bayous. A roving crew takes care of these problems as they arise and will usually visit a watershed area about every 2 months. Hydrilla has not shown up on Toledo Bend Lake in this watershed. Alligatorweed, while it is present, does not reach any great magnitude. In some areas of concentration, it does not interfere with water-oriented activities.

A considerable amount of effort is being expended in the Trinity Watershed, primarily toward the control of waterhyacinths. With receding water levels, continued dewatering, and high evapotranspiration rate, waterhyacinths are for the most part in shallow areas difficult to reach. Apparently some sort of all-terrain vehicle with sufficient traction and with a high payload is necessary to avoid the high cost of aerial application. Most usable areas are relatively clean of hyacinths, but constant drawdowns expose seeds to the germinating effect of sunlight, and soon new plants are found in shallow water areas. We have made substantial gains, but the work is difficult and slow.

There has been a small amount of work done on the Neches Watershed. This consisted mostly of spraying small pockets of waterhyacinths and using some experimental chemicals for the control of alligatorweed. Waterhyacinths have been removed mostly from Lake Palestine. The results of the use of Banvel 720 on alligatorweed did produce some immediate "browning," but the results have not yet been fully evaluated. This method of partial control does have some merit, and it will be investigated with intensity at a later date.

In another part of the Neches Watershed, extensive work is being carried out toward the control of waterhyacinths and alligatorweed. This work is on Lakes Rayburn and Steinhagen. This work is being done under a contract with the U. S. Army Engineer District Fort Worth (FWD). The acutal contract work started in mid-July 1975, and to date over 1900 acres of waterhyacinths have been destroyed. The receding water levels, shallow heavy timbered areas, and extensive dewatering for hydroelectric generation make it difficult to treat the nursery grounds where most of the waterhyacinths occur and later float to other parts of the lake. The total cost per acre on these lakes has been $14.50, of which $10.88 is borne by the District. All types of vehicles have been used in the treatment of hyacinths in these two lakes in deep northeast Texas, yet accessibility to the shallow areas seems to be the biggest problem. The factor that is escalating treatment cost is the driving expense.

The Cypress Watershed, principally Caddo Lake, does not have any great problem with waterhyacinths. At the present time, only 23-25 acres of waterhyacinths are on the Texas side. The work that was done 2 yr ago, applying granulated 2,4-D (Aqua-Kleen-20) at the rate of 200-lb total material to the surface acre, proved very successful. The boat roads and fishing access paths that were treated remained open, and a special appropriation to continue this work has been requested. While the cost of materials and application was moderate, the cost-benefit ratio has been very high. All sorts of water-oriented sports, as well as tourism at the lake, have been enhanced by this work.

The South Coastal Watershed is in the southern part of Texas adjoining the border with Mexico. Waterhyacinths exist in some of the resacas or old oxbow lakes. This area is periodically treated with great care as the shores of the lakes are filled with high-priced homes surrounded by gardens and ornamental trees.

HYDRILLA RESEARCH

A small informal research contract (WES 75-6) was granted to the Texas Parks and Wildlife Department in June 1975. This contract was extended to try to establish parameters by which *Hydrilla verticillata* could be controlled or maintained in Lake Livingston, 60 miles northeast of Houston. The main purpose of this contract has been to try out various formulations of herbicides that have been found successful in Florida and other states.

The application of various herbicides was made 15-18 September 1975. Four granulated herbicides were applied from an airboat, but because of the scarcity of hydrilla the test plots were, by necessity, made of 1/2 acre (0.202 ha) and replicated twice. The four granulated herbicides used were Aquathol G, Aqua-Kleen-20, Banvel XP, and Hydeout. All were applied at the rate of 75 lb per 1/2 acre (34.02 kg per 0.202 ha). Table 1 presents the chemical contents of the herbicides.

The liquid herbicides used were diquat, komeen, and cutrine. These were applied in a variety of methods, such as subsurface, midbottom, and bottom placement (Table 2), and both as aqueous and inverted emulsions.

Additionally, a bottom-tuber sampling method was incorporated into the study to determine the

Table 1
Chemical List

Diquat-6,7-dihydrodipyrido (1,2-a: 2', 1' - c) pyrazinediium ion
Cutrine-copper sulfate triethanolamine complex
Cutrine plus—copper sulfate (keleted and sequestered)
2,4-D.B.E.E.—(2,4-dichlorophenoxy) acetic acid butoxyethanol ester
Aquathol—40.3 percent dipotassium salt of endothall
Komeen—8 percent Copper-ethyl nediamine complex
Endothall—7-oxabicyclo (2,2,1) heptane-2,3-dicarboxylic acid equivalent 13.4 percent

Table 2
Plant Drop Measurements Ranked by Herbicide

Material Used	Method	Drop, cm	Plot Open, %
Hydeout	Granulated	17.78	55
1 Diquat, 2 Komeen	Liquid midbottom	13.97	45
1 Diquat, 2 Komeen	Liquid subsurface	10.16	55
Aquathol G	Granular	10.16	25
1 Diquat, 2 Cutrine	Liquid midbottom	7.62	45
1 Diquat, 2 Komeen	Inverted midbottom	7.62	50
1 Diquat, 2 Komeen	Inverted bottom	7.62	45
1 Diquat, 2 Cutrine	Liquid subsurface	6.35	45 (erratic)
1 Diquat, 2 Cutrine	Inverted subsurface	5.84	18
1 Diquat, 2 Komeen	Inverted subsurface	4.57	35
Aqua-Kleen-20	Granular	3.81	15
Banvel XP	Granular	2.54	10

effect of chemical stress on the production of subterranean tubers. A weed biomass study was also incorporated to determine, without bias, the effect of the herbicides on the settling hydrilla. To finalize the study, a fisheries impact study of the herbicidal action on the fisheries aspect was also undertaken. Preliminary findings are discussed below.

Herbicide Evaluating Criteria

Criteria for evaluating the herbicides were based on which herbicide would:

a. Give most rapid "knockdown" of plants.

b. Produce the greatest longevity of weed-free test plots.

c. Produce the least amount of subterranean tubers.

To date the test plots have been evaluated to see which herbicide has produced the most amount of plant "knockdown." The materials are listed in Table 2 by rank according to the material that produced the most plant knockdown as measured from the surface 2 weeks after treatment. Electronic means (illustrated in Figure 2) were going to be used to determine this space, but with the water level receding 3 ft, the hydrilla was compacted to such an extent that true readings could not be obtained. In an alternate method of measurement, a differential reading was taken between the water level and the top of the hydrilla plants. To avoid bias in readings, a simple measurement instrument was designed that would give exact readings.

Tuber Determinations

Usually five turion core samples were taken from each of the test plots. The core sampler was a 1-in. (2.54-cm)-inside-diameter stainless steel tube, 18 in. (45.72 cm) long. Samples were taken from two sides of the test plot equidistant from all sides, and one sample was taken from the approximate middle of the test plot. To date no tubers have been recovered, and so a different size sampler, 2 in. in diameter, that will give us a bigger sample is going to be used.

One of the aims of this phase of the study is to keep a running count of the relative total number and length of the tubers and to ascertain the average mean diameter of same. It is hoped that a growth pattern based on length and the relative mean diameter can be established, enabling these measuring parameters to be applied in relationship to the time in days. Once tubers are being sampled from an area, their growing pattern can be determined and their optimum growth period can be established. Once these parameters have been established and set for a particular area, treatment procedures could possibly be programmed.

These data are being collected and placed in a "Turion Sample Data Sheet" (Figure 3) to be compiled as the work progresses. This information will be useful in determining several factors, such as where and at what depth the most tuber or turion production takes place, the growth in length as well as diameter of the tubers, the number of turions in a physical examination of the core sample as compared with a washed sample, and the total number of turions from a test site and the treated plot. This information will be essential in determining which herbicides or combination of herbicides and what form of application as well as method are best to preclude the subsequent regrowth of hydrilla from subterranean tubers or turions. The period in days in relation to water temperature is necessary to establish the growth patterns of the plants in the various parts of the state. It is hoped that this information will lead to a determination as to when to treat the plant, so the maximum results of the treatment means and procedures can be obtained.

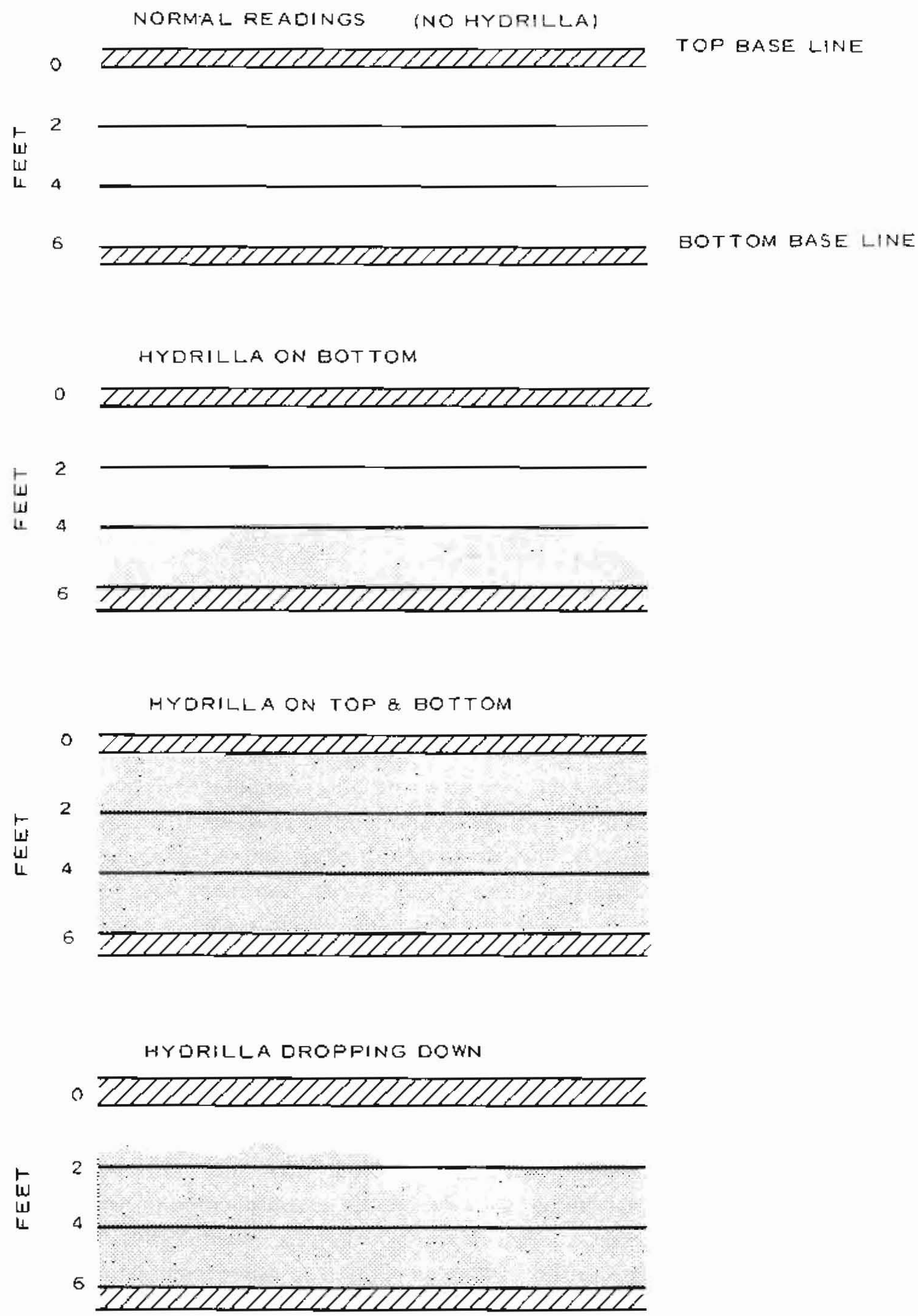

Figure 2. Diagrammatic representation of electronic readings

LAKE LIVINGSTON HYDRILLA RESEARCH
TEST PLOT NO ______

______ DATE

SITE	A	B	C	D	E	TOTAL	
CORE LENGTH (CM)							DAYS SPAN
NO. OF TURIONS							TURION SIZE RANGE (MM)
WASH & SCREEN NO. OF TURIONS							TURION AVG SIZE (MM)
TOTAL FROM SITE							TOTAL/HA.

______ DATE

SITE	A	B	C	D	E	TOTAL	
CORE LENGTH (CM)							DAYS SPAN
NO. OF TURIONS							TURION SIZE RANGE (MM)
WASH & SCREEN NO. OF TURIONS							TURION AVG SIZE (MM)
TOTAL FROM SITE							TOTAL/HA.

______ DATE

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______ DATE

SITE	A	B	C	D	E	TOTAL	
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NO. OF TURIONS							TURION SIZE RANGE (MM)
WASH & SCREEN NO. OF TURIONS							TURION AVG SIZE (MM)
TOTAL FROM SITE							TOTAL/HA.

Figure 3. Turion sample data sheet

POSSIBLE EFFECTS OF THE INTRODUCTION OF THE WHITE AMUR INTO LAKE CONWAY, FLORIDA

by

K. C. Ewel and T. D. Fontaine III*

INTRODUCTION

Considerable interest is currently being shown in the use of the Asiatic grass carp, or white amur (*Ctenopharyngodon idella* Val.), as a biological control agent to reduce the infestations of hydrilla (*Hydrilla verticillata* Royle) that have clogged many waterways in the Southeast. The Office, Corps of Engineers, U. S. Army, has sponsored several laboratory and small-scale field studies of the white amur and is currently planning a large-scale field study in Lake Conway near Orlando, Florida. Studies will begin in January 1976 to determine baseline ecological conditions; the fish will be introduced in the winter of 1977, and the lake will continue to be monitored to determine what effect the fish have on all components of the lake ecosystem.

An effort is currently under way to incorporate the results of the studies being conducted into a predictive model. Ideally, this model will take into account enough of the important relationships among the trophic levels and physical and chemical parameters of the lake to serve as a basis for predicting what effect the fish will have in this lake and perhaps in other lakes also.

A model is now being constructed that uses values and relationships available in the literature to approximate conditions in Lake Conway. When the baseline studies begin in 1976, actual data will be used to alter and expand the model as needed.

MODEL CONCEPTUALIZATION

There are a number of components that most lake ecosystems have in common. It is the detailed composition and operation of these components, plus the effect of external physical forces acting upon them, that distinguish lakes from one another. The model that is used to initiate an effort such as this is, therefore, usually a general one which is then refined according to the specific characteristics of each ecosystem.

The model of Lake Conway as it exists at this early stage is shown in Figure 1. Four general kinds of plant communities are distinguished: (a) native submersed species, such as pondweed (*Potamogeton* sp.), which are predominant around the edges of the lake; (b) hydrilla, which is capable of growing over and shading out the submersed species; (c) phytoplankton, which is concentrated within the top layers of the water and, therefore, also has a shading effect on the submersed species; and (d) algal periphyton, which grows on the surfaces of the hydrilla and other broad-leaved plants. Productivity in the native submersed, hydrilla, and phytoplankton communities is regulated in part by solar radiation and by the availability of phosphorus. Although other elements are certainly critical to plant growth, phosphorus is believed to be one of the main limiting nutrients in aquatic ecosystems.

The periphyton population is considered to be unique, for it is just as dependent on the presence of a

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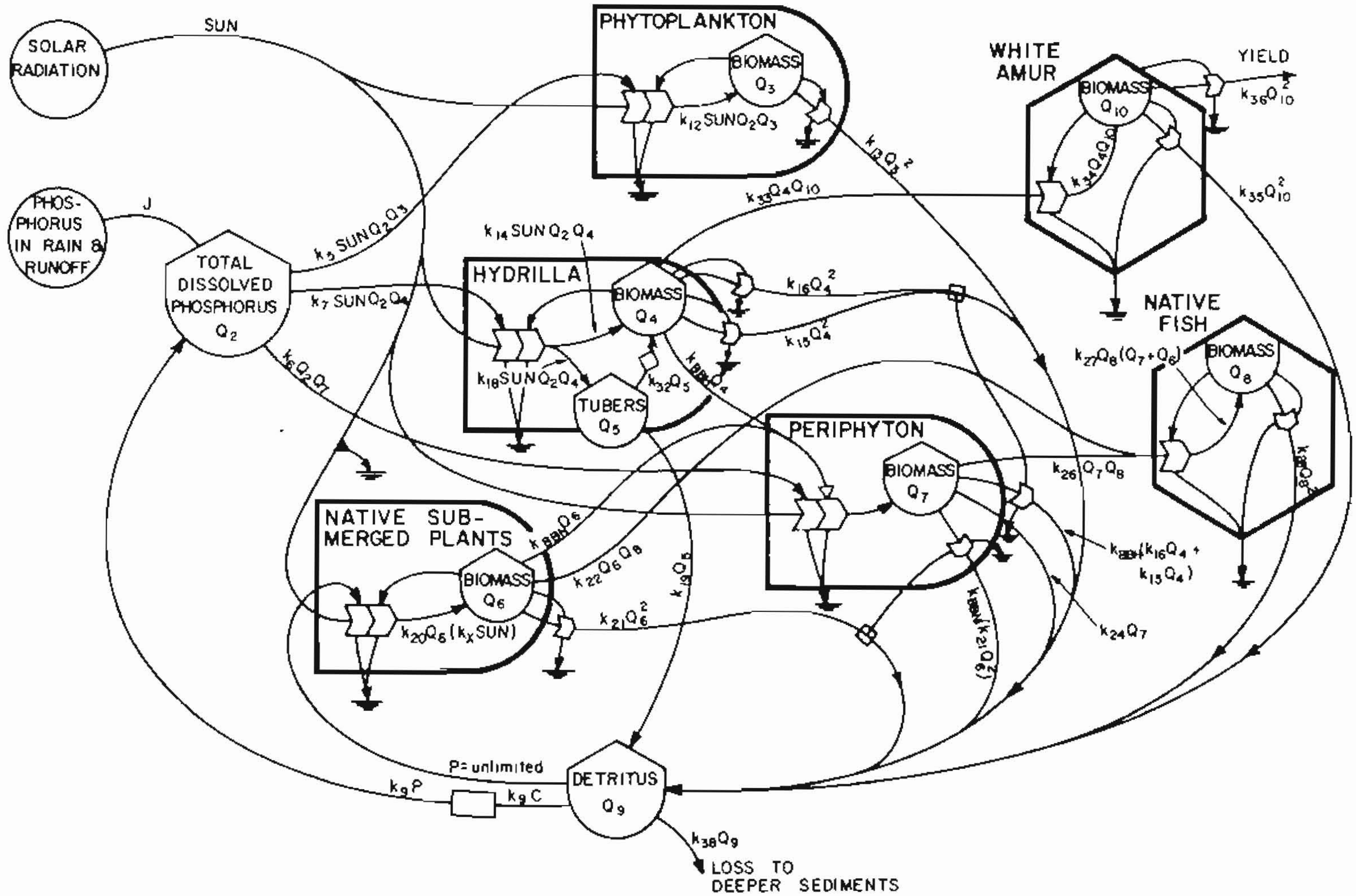

Figure 1. Model of important storages and flows in the Lake Conway ecosystem

substrate (hydrilla and native submersed plants) as it is on phosphorus and sunlight. In the energy flow diagram in Figure 1, this kind of interaction is distinguished by an "open" arrow, indicating an effect rather than an actual flow. Phosphorus and sunlight are actually used by the periphyton population, but its productivity is limited by the amount of substrate. In the equations, therefore, the productivity of periphyton is included as a drain on the phosphorus equation, but phosphorus does not have an influence in the periphyton equation.

Fish use the periphyton and native plants for food. When the white amur is introduced, it is assumed to feed solely on the hydrilla. Sediments form from dying plants, consumers, and waste products and accumulate in a detrital pool from which phosphorus is mineralized.

After the model was conceptualized, differential equations describing these interactions were formulated. These equations were then translated into difference equations, and the model was simulated on a digital computer using the simulation language DYNAMO.

DATA USED IN MODEL

Climatological and Physical Data

Lake Conway actually comprises five interconnected lobes of a single lake system shown in Figure 2. The two southernmost lobes are Lake Conway proper; the lobes are called the South Pool and the Middle Pool and together comprise 304.3 ha. The two lobes of Little Lake Conway total 285.6 ha, and Lake Gatlin covers 27.7 ha.

Precipitation on the lake totaled 10.63×10^6 m^3 in 1973, according to data from the Orlando Weather Station. The drainage area of the lake was determined to be 32.5 km^2 and was estimated to deliver 20.85×10^6 m^3 of runoff, or 50 percent of the rainfall on the area. Solar radiation ranged from 0.67×10^{12} $kcal \cdot mo^{-1}$ in January to 1.19×10^{12} $kcal \cdot mo^{-1}$ in July 1971 over the entire lake.[2]

Phosphorus Budget

The concentration of phosphorus in the rainfall was assumed[3] to be 0.056 $mg \cdot l^{-1}$. The concentration of phosphorus in the lake ranged from the limits of detection to 0.1 $mg \cdot l^{-1}$ total phosphorus, according to actual measurements by the Orange County Pollution Control.[4] An average of 0.02 $mg \cdot l^{-1}$ total phosphorus was assumed for this preliminary model. Phosphorus input is highest in the summer when rainfall is greatest, but an additional peak occurs in the early spring when many residents in the watershed fertilize their lawns. It is assumed that this is the explanation for the threefold increase in the phosphorus concentrations observed in the lake at this time. Phosphorus was also assumed to be mineralized from the sediments at a constant rate (1.53 $gP \cdot m^{-2} \cdot mo^{-1}$).

In this model, phosphorus is removed from the water by three of the plant types: phytoplankton, periphyton, and hydrilla. It is believed that the native submersed plants obtain most of their phosphorus from the sediments. Phosphorus uptake was assumed to be proportional to productivity at the rate of 1 g of phosphorus for each 35 g of carbon fixed.

Hydrilla

Little is known about the dynamics of hydrilla populations in natural situations. Even the standing crop of hydrilla is difficult to estimate because of its habit of forming mats over the surface, giving the appearance of far more biomass than actually present. Productivity was estimated from Westlake's maximum value for submersed aquatic plant productivity.[5] It was assumed that productivity is balanced

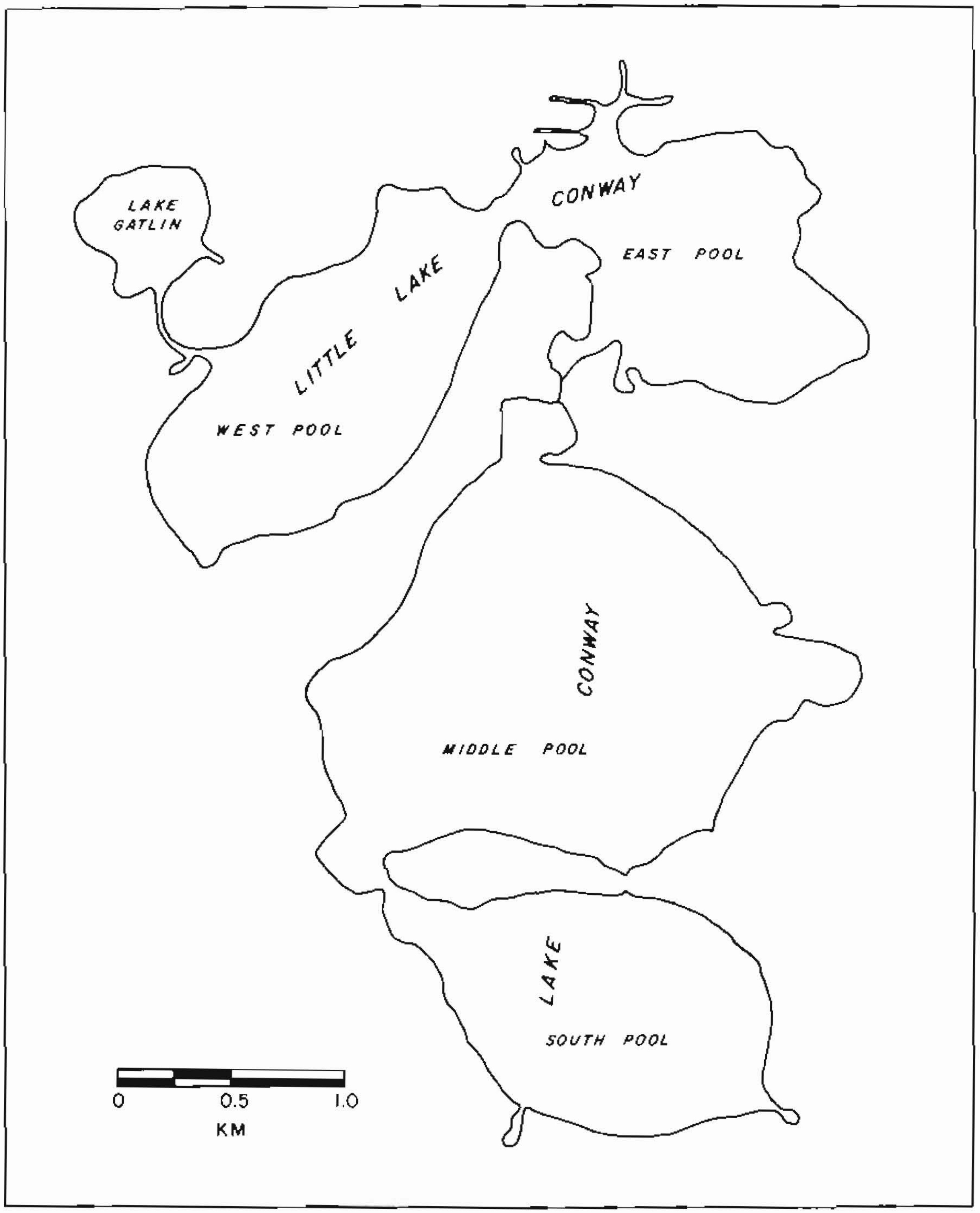

Figure 2. Map of Lake Conway complex near Orlando, Florida

by death and that spraying with herbicides can eliminate most of the standing crop.

Part of hydrilla's productivity is presumed to go into the manufacture and maintenance of tubers and turions which can contribute to the regrowth of hydrilla after its decimation, in this case by herbicides.

Native Submersed Plants

Values determined by Gayle[6] for species such as pondweed in Lake Okeechobee were used to estimate productivity for this compartment in the model. It was assumed that fish consume the plants at a rate equal to one-third the productivity; the rest goes into the detrital pool.

Phytoplankton

The productivity of phytoplankton was estimated[6] to be 1 $gC \cdot m^{-2} \cdot day^{-1}$. Since the lake was assumed to be at steady state conditions, the same amount was estimated to be entering the detrital pool at the same rate.

Periphyton

An estimate for periphyton productivity derived by Wetzel[7] was used. Hydrilla and native submersed plants both influence periphyton productivity since they serve as its substrate. A rate equal to one-third the primary productivity was assumed to be eaten by the fish with the rest going into the detritus. Productivity exceeds the death rate in this compartment because the disappearance of the substrate does not necessarily bring about a decrease in productivity.

Native Fish

The feeding rate of fish was assumed to be 10 percent of the gross primary productivity of the submersed plant and periphyton populations. Steady state conditions were assumed, so that respiration and death were equal to input. The amount of fish present at the start of the study was estimated[8] to be 15.8 $g \cdot m^{-2}$.

White Amur

The white amur was assumed to be stocked at a rate of 100 fish per acre (40.5 per ha), each fish weighing 100 g. These will be monosex white amur and so will not reproduce in the lake. The fish consumes hydrilla at a rapid rate, but only a small proportion (less than 0.2 percent) is judged to be actually assimilated by the fish. The rest is simply short-circuited to the detritus. A large proportion of the white amur population was assumed to be fished each year, and about 10 percent of the standing crop of biomass was assumed to die or be lost as respiratory products each year.

Detritus

The detritus was assumed to consist of two components. A surface component receives all the fresh dead material from which native submersed species take their phosphorus and from which dissolved phosphorus is mineralized. This component gradually, and linearly, settles into a deeper component which is essentially unavailable for such uses by the ecosystem and which was not included in this model.

RESULTS AND DISCUSSION

Equations and Transfer Coefficients

Differential equations describing changes in storages of various components of the model were deduced directly from the conceptual model. They are given in Table 1. Each state variable is listed to the left of the equal sign, and the terms to the right indicate the flows affecting that particular variable. As one state variable changes, such as the phosphorus content of the lake (Q_2), the state variables that it in turn affects, such as phytoplankton (Q_3), will also change, bringing about further change in the lake phosphorus, etc.

Terms capped by a $\frown$ symbol are controlled by irregularly occurring events. Thus, "$\widehat{\text{herb}}$" means that that particular flow is activated whenever herbicide is applied. In this model, the presence of more than 0.28×10^3 $gC \cdot m^{-2}$ of hydrilla triggered the application of herbicide.

Each term to the right of the equal sign is a rate of flow and, in most cases, is expressed as a transfer coefficient (K_x) multiplied by one or more state variables. The transfer coefficient is calculated by setting the entire term equal to a known rate under specific conditions and substituting the values for the state variables under those conditions. In this model, transfer coefficients were assumed to remain constant. They are listed in Table 2. The initial values for each state variable as well as of the flows are given in Table 3.

Simulations

Results obtained by simulation of the model are presented in Figures 3-11. Before discussing them it should be restated that the results shown are of an extremely preliminary nature only.

Four simulations were run. In one case, hydrilla was allowed to grow unrestrained. The results from this simulation are entitled "No Management." Application of herbicide ("Herbicide") was modeled in the second simulation; introduction of the white amur ("White Amur") was modeled in the third; and use of both agents ("White Amur and Herbicide") was modeled in the fourth.

Addressing first the fate of hydrilla under various management schemes (Figure 3), the simulations indicate that highest standing stocks will occur under "No Management" conditions. Standing stocks declined in magnitude when herbicides or the white amur were used. A combination of the two controls ("Herbicides and White Amur") resulted in the lowest standing stock (7 times less than found under undisturbed conditions); the presence of the white amur alone was more successful than herbicide alone (5 and 2.5 times less than "No Management," respectively). None of the management programs completely eliminated the hydrilla, and in all cases hydrilla achieved a dynamic steady state.

Tubers and turions were always manufactured by the plant, the rate depending on the productivity of hydrilla (Figure 4). When hydrilla was under the most stress, these reproductive structures served as growth initiators for hydrilla, allowing it to achieve a dynamic steady state. When no control was used, tubers and turions accumulated rapidly during the time frame used.

Phytoplankton increased when hydrilla was most heavily controlled, reaching more than twice the concentration found under undisturbed conditions (Figure 5). The increased availability of phosphorus seemed to be responsible for this increase. When the white amur or herbicides were used, the concentrations were equal to or slightly less than twice the normal amount, respectively.

The native submersed plant population showed interesting responses under different management strategies (Figure 6). Since one of the assumptions of the model was that hydrilla could shade out native species, the native submersed plants were able to compete with the uncontrolled hydrilla for only slightly

Table 1

Differential Equations Used in Model

Lake Phosphorus

$$\frac{dQ_2}{dt} = J - K_5SUNQ_2Q_3 - K_7SUNQ_2Q_4 + K_9P - K_6Q_2Q_7$$

Phytoplankton

$$\frac{dQ_3}{dt} = K_{12}SUNQ_2Q_3 - K_{13}Q_3^2$$

Hydrilla

$$\frac{dQ_4}{dt} = K_{14}SUNQ_2Q_4 - K_{15}Q_4^2 - \overbrace{K_{16}Q_4^2}^{\text{Herb}} + \overbrace{K_{32}Q_5}^{\text{Herb}} - K_{33}Q_4Q_{10}$$

Tubers and Turions

$$\frac{dQ_5}{dt} = K_{18}SUNQ_2Q_4 - K_{19}Q_5 - \overbrace{K_{32}Q_5}^{\text{Herb}}$$

Native Submersed Vascular Plants

$$\frac{dQ_6}{dt} = K_{20}Q_6(K_xSUN) - K_{21}Q_6^2 - K_{22}Q_6Q_8$$

Algal Periphyton

$$\frac{dQ_7}{dt} = K_{BBH}Q_4 + K_{BBN}Q_6 - K_{24}Q_7 - K_{BBH}(\overbrace{K_{16}Q_4}^{\text{Herb}} + K_{15}Q_4) - K_{BBN}(K_{21}Q_6^2) - K_{26}Q_7Q_8$$

Native Fish

$$\frac{dQ_8}{dt} = K_{27}Q_8(Q_7 + Q_6) - K_{28}Q_8^2$$

Detritus

$$\frac{dQ_9}{dt} = K_{37}Q_4Q_{10} + K_{35}Q_{10}^2 + K_{13}Q_3^2 + K_{24}Q_7 + K_{BBH}(\overbrace{K_{16}Q_4}^{\text{Herb}} + K_{15}Q_4) + K_{BBN}(K_{21}Q_6^2) + \overbrace{K_{16}Q_4^2}^{\text{Herb}}$$

$$+ K_{15}Q_4^2 + K_{21}Q_6^2 + K_{19}Q_5 + K_{28}Q_8 - K_{39}Q_6(K_xSUN) - K_9C - K_{38}Q_9$$

White Amur

$$\frac{dQ_{10}}{dt} = K_{34}Q_4Q_{10} - K_{35}Q_{10}^2 - K_{36}Q_{10}^2$$

Table 2
Transfer Coefficients

K_x =	0.8	K_{20} =	0.697
K_{BBH} =	0.8	K_{21} =	0.1
K_{BBN} =	0.5	K_{22} =	0.044
K_5 =	245.9	K_{24} =	0.014
K_6 =	0.125	K_{26} =	0.012
K_7 =	0.76	K_{27} =	0.054
K_{9C} =	6.83	K_{28} =	0.058
K_{9P} =	20.5	K_{32} =	9.13
K_{12} =	74.4	K_{33} =	524.1
K_{13} =	3986.14	K_{34} =	1.06
K_{14} =	11.05	K_{35} =	0.887
K_{15} =	0.35	K_{36} =	146.3
K_{16} =	1.29	K_{37} =	522.6
K_{18} =	0.668	K_{38} =	0.163
K_{19} =	0.533	K_{39} =	0.69

Table 3
Description and Initial Values of Storages and Flows in the Model

Storage or Flow	Description	Initial Value
Q_2	Total dissolved phosphorus	$0.02\ g \cdot m^{-2} \times (3)$
Q_3	Phytoplankton	$1\ gC \cdot m^{-2}$
Q_4	Hydrilla	$329.21\ gC \cdot m^{-2}$
Q_5	Tubers and turions grown by hydrilla	$19.75\ gC \cdot m^{-2}$
Q_6	Native submersed vascular plants	$316.05\ gC \cdot m^{-2}$
Q_7	Algal periphyton	$2106.97\ gC \cdot m^{-2}$
Q_8	Native fish	$189.63\ gC \cdot m^{-2}$
Q_9	Detritus	$526.74\ gC \cdot m^{-2}$
Q_{10}	White amur	$2.37\ gC \cdot m^{-2}$
J	Phosphorus entering through rainfall or runoff of phosphorus	
$K_5SUNQ_2Q_3$	Uptake of phosphorus by phytoplankton	$0.86\ gP \cdot m^{-2} \cdot mo^{-1}$
$K_7SUNQ_2Q_4$	Uptake of phosphorus by hydrilla	$0.49\ gP \cdot m^{-2} \cdot mo^{-1}$
K_9P	Mineralization of phosphorus from sediments	$1.53\ gP \cdot m^{-2} \cdot mo^{-1}$
$K_6Q_2Q_7$	Uptake of phosphorus by algal periphyton	$0.86\ gP \cdot m^{-2} \cdot mo^{-1}$
$K_{12}SUNQ_2Q_3$	Gross primary productivity of phytoplankton	$30.29\ gP \cdot m^{-2} \cdot mo^{-1}$
$K_{13}Q_3^2$	Losses of phytoplankton biomass through respiration and death	$30.29\ gP \cdot m^{-2} \cdot mo^{-1}$
$K_{14}SUNQ_2Q_4$	Gross primary productivity of hydrilla	$180.41\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{15}Q_4^2$	Losses of hydrilla biomass through respiration and death	$180.41\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{16}Q_4^2$	Losses of hydrilla biomass resulting from herbicide regulation	$158.02\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{18}SUNQ_2Q_4$	Production of tubers and turions	$50.04\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{19}Q_5$	Losses of tubers and turions to detritus	$10.53\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{32}Q_5$	Loss of tubers and turions to growth of hydrilla resulting from herbicide application	$180.41\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{20}Q_6\ [K_xSUN]$	Gross primary productivity of native submersed vascular plants	$120\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{21}Q_6^2$	Losses of native submersed vascular plants through respiration and death	$80.33\ gC \cdot m^{-2} \cdot mo^{-1}$
$K_{22}Q_6Q_8$	Losses of native submersed vascular plants to herbivorous native fish	$39.51\ gC \cdot m^{-2} \cdot mo^{-1}$

(Continued)

Table 3 (Concluded)

Storage or Flow	Description	Initial Value
$K_{BBH}Q_4$	Gross primary productivity of algal periphyton on hydrilla	263.37 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{BBN}Q_6$	Gross primary productivity of algal periphyton on native submersed vascular plants	158.02 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{24}Q_7$	Losses of periphyton	27.26 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{BBH}\left(\overbrace{K_{16}Q_4^2}^{\text{Herb}} + K_{15}Q_4^2\right)$	Loss of periphyton biomass resulting from loss of hydrilla substrate	230.45 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{BBN}\left(K_{21}Q_6^2\right)$	Loss of periphyton biomass resulting from loss of native submersed vascular plant substrate	37.93 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{26}Q_7Q_8$	Loss of periphyton to herbivorous native fish	3.03 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{27}Q_8(Q_7 + Q_6)$	Production of native fish biomass	15.8 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{28}Q_8^2$	Mortality of native fish	15.8 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{33}Q_4Q_{10}$	Consumption of hydrilla by white amur	917.85 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{34}Q_4Q_{10}$	Production of white amur biomass	1.86 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{35}Q_{10}^2$	Mortality of white amur	.01 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{36}Q_{10}^2$	Harvest of white amur	1.83 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{37}Q_4Q_{10}$	Egestion of hydrilla by white amur	915.21 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{38}Q_9$	Loss of carbon to deep sediments	85.60 $gC \cdot m^{-2} \cdot mo^{-1}$
$K_{39}Q_6\ [K_xSUN]$	Uptake of carbon associated with phosphorus uptake from sediments by native submersed vascular plants	120.62 $gC \cdot m^{-2} \cdot mo^{-1}$
KgC	Recycle of carbon by sediments	53.73 $gC \cdot m^{-2} \cdot mo^{-1}$
KgP	Recycle of phosphorus by sediments	1.53 $gP \cdot m^{-2} \cdot mo^{-1}$

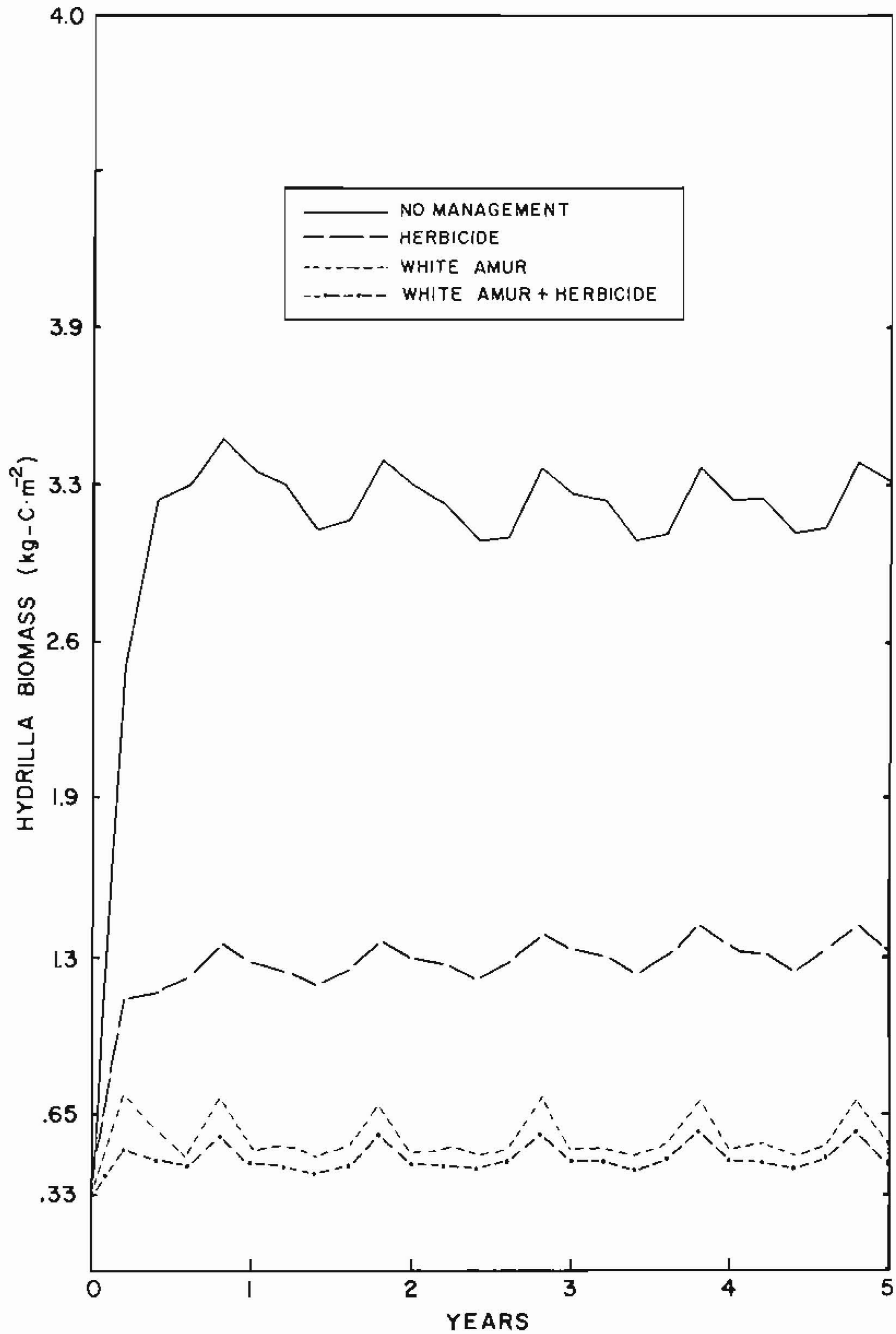

Figure 3. Simulated changes in biomass of hydrilla under four management conditions

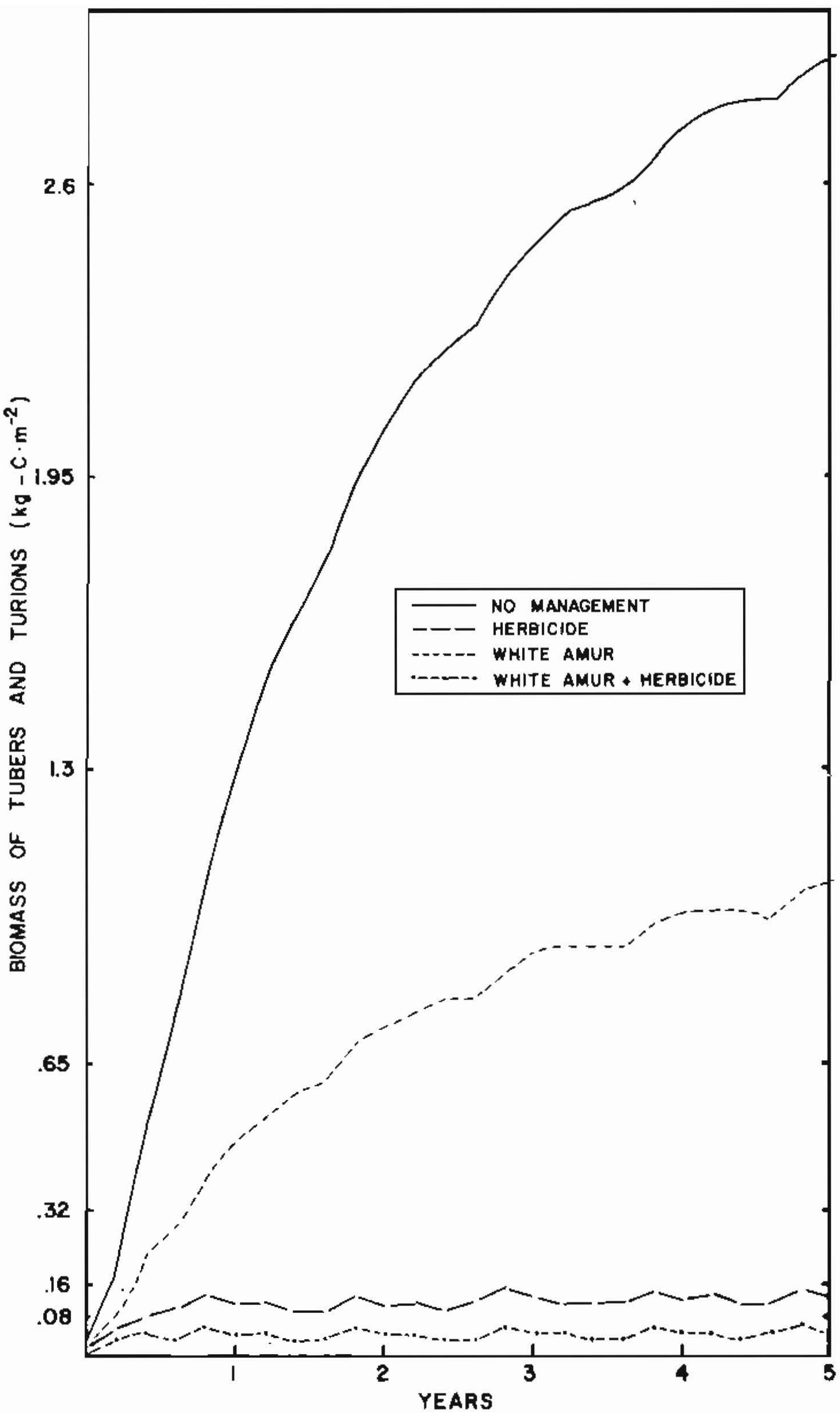

Figure 4. Simulated changes in biomass of tubers and turions under four management conditions

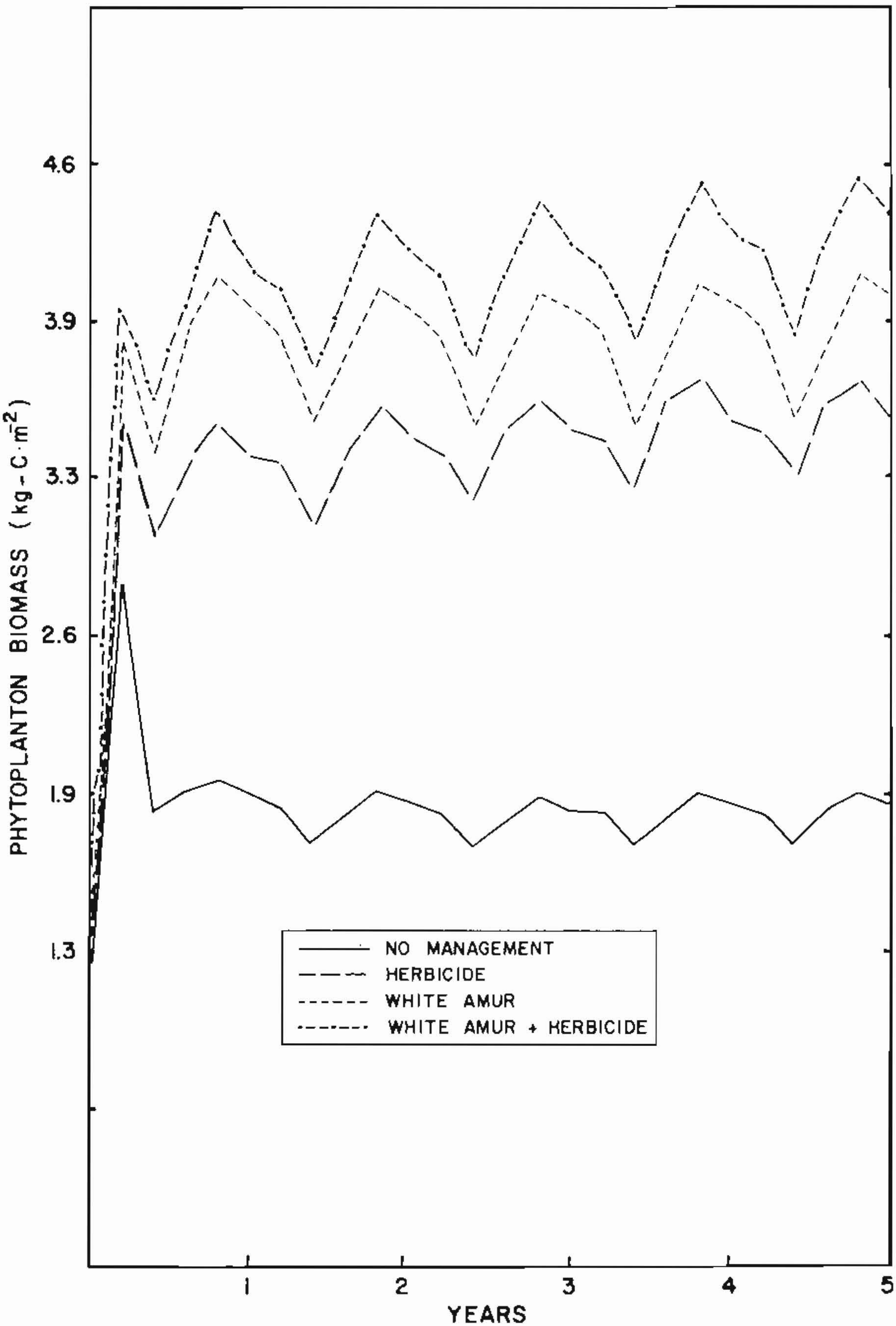

Figure 5 Simulated changes in biomass of phytoplankton under four management conditions

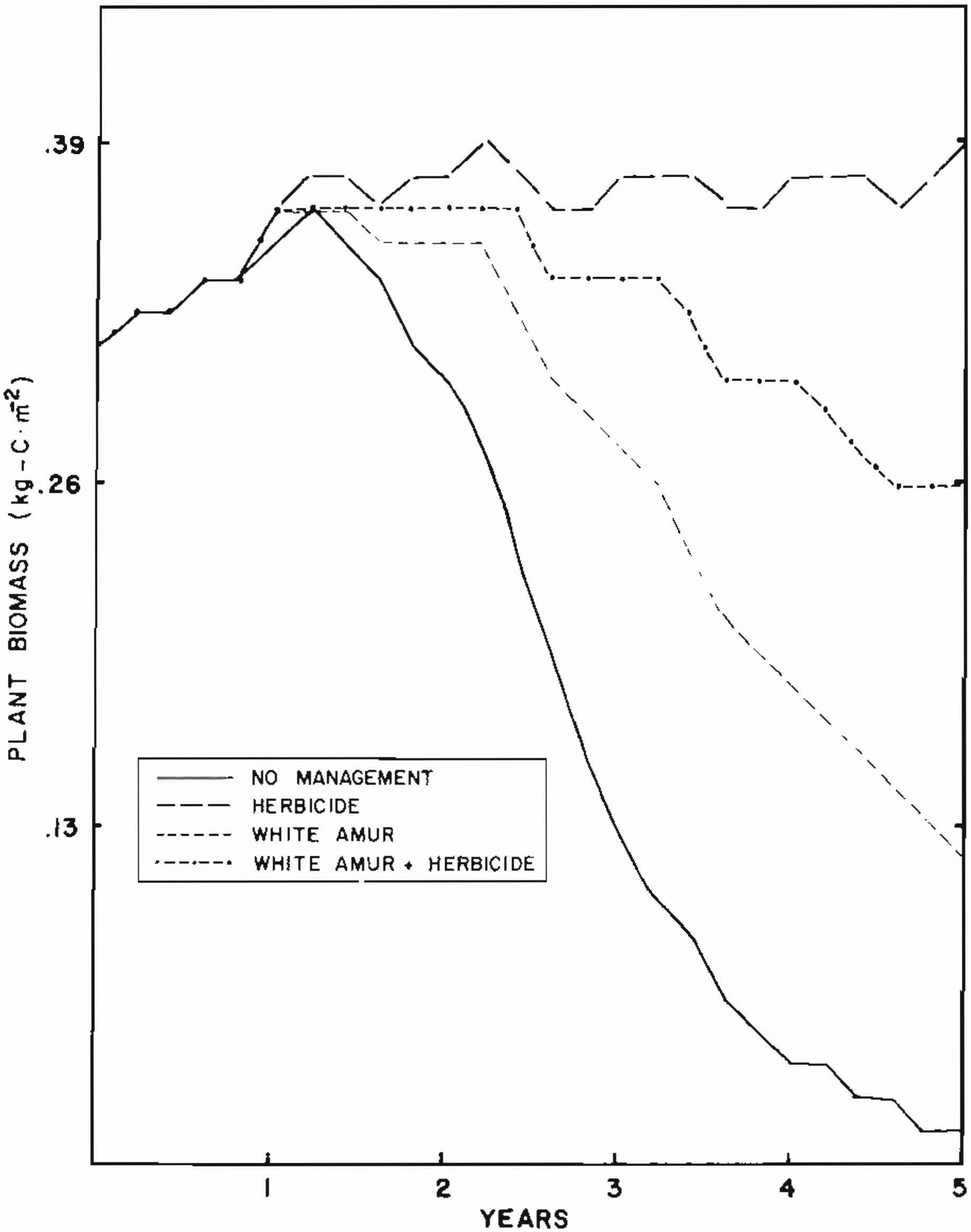

Figure 6 Simulated changes in biomass of native submersed vascular plants under four management conditions

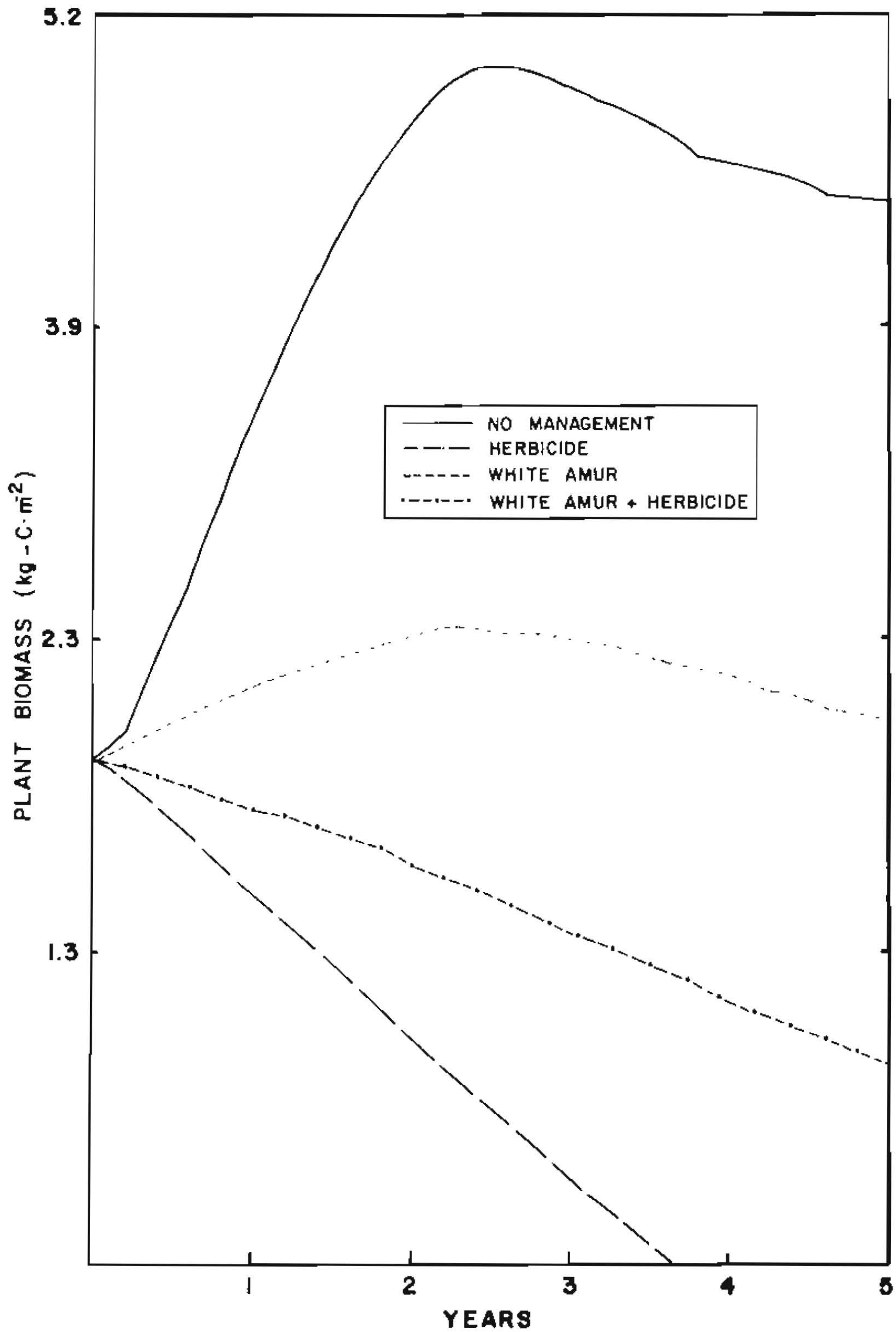

Figure 7. Simulated changes in biomass of algal periphyton under four management conditions

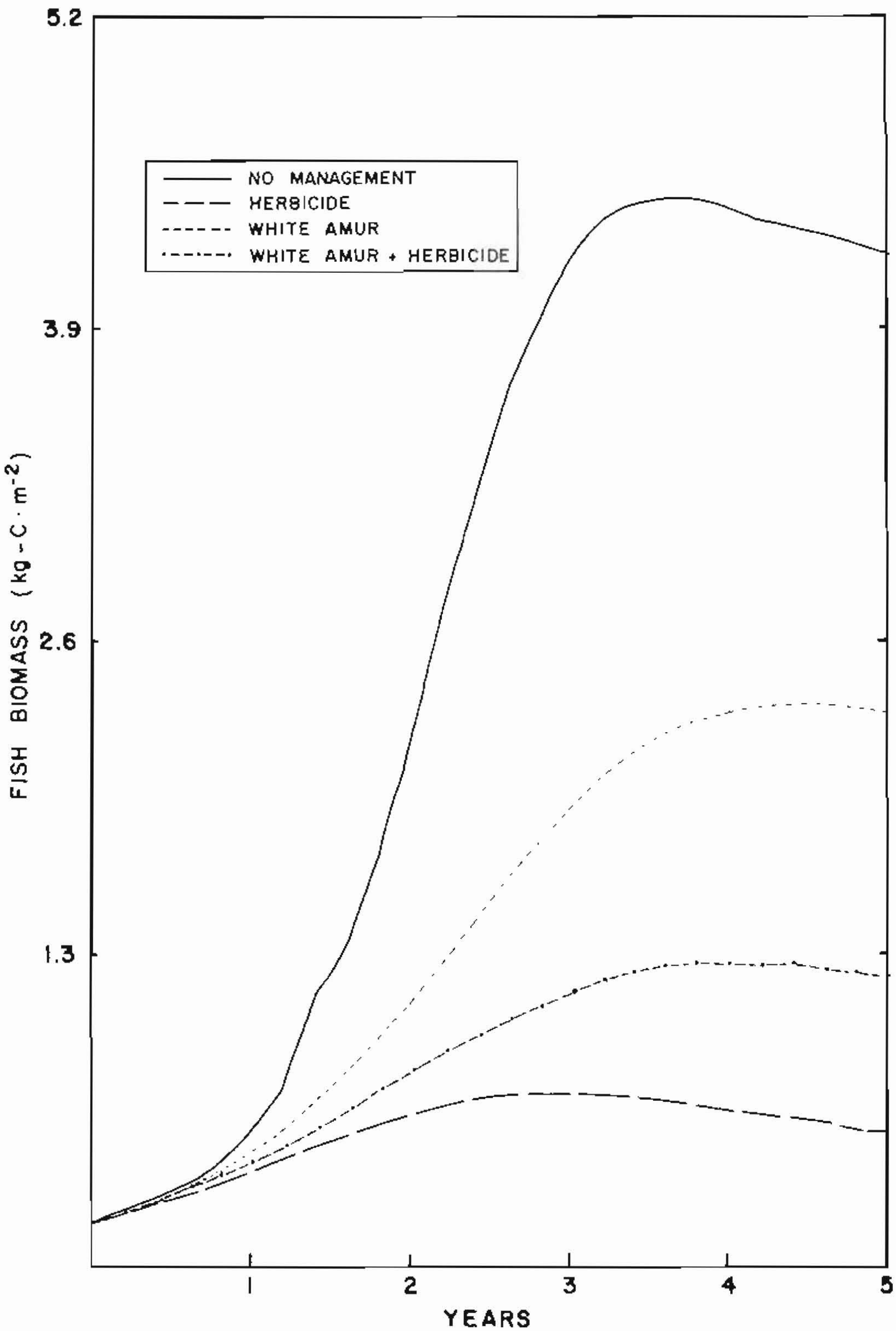

Figure 8. Simulated changes in biomass of native fish population under four management conditions

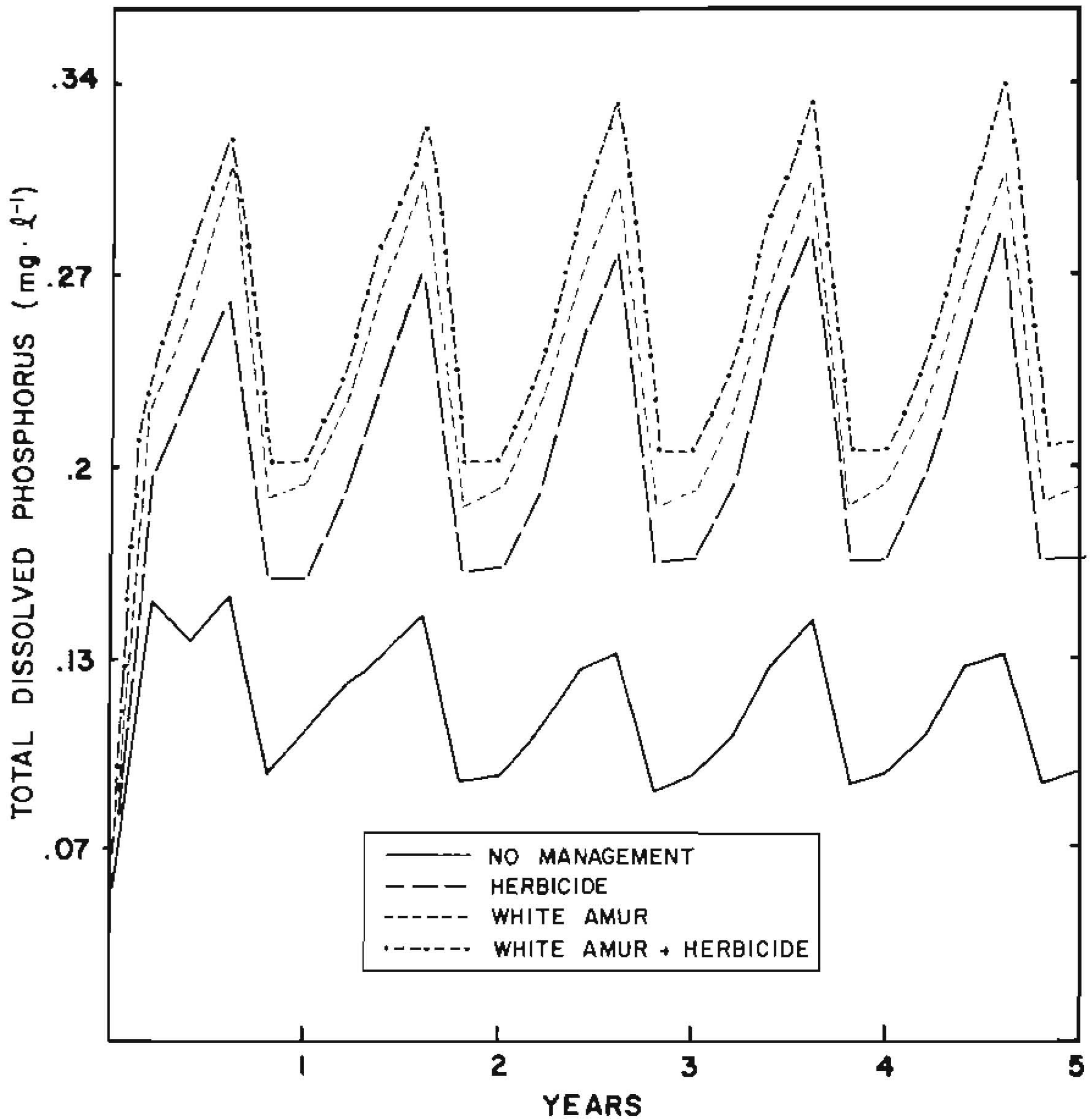

Figure 9. Simulated changes in concentration of total phosphorus in the water under four management conditions

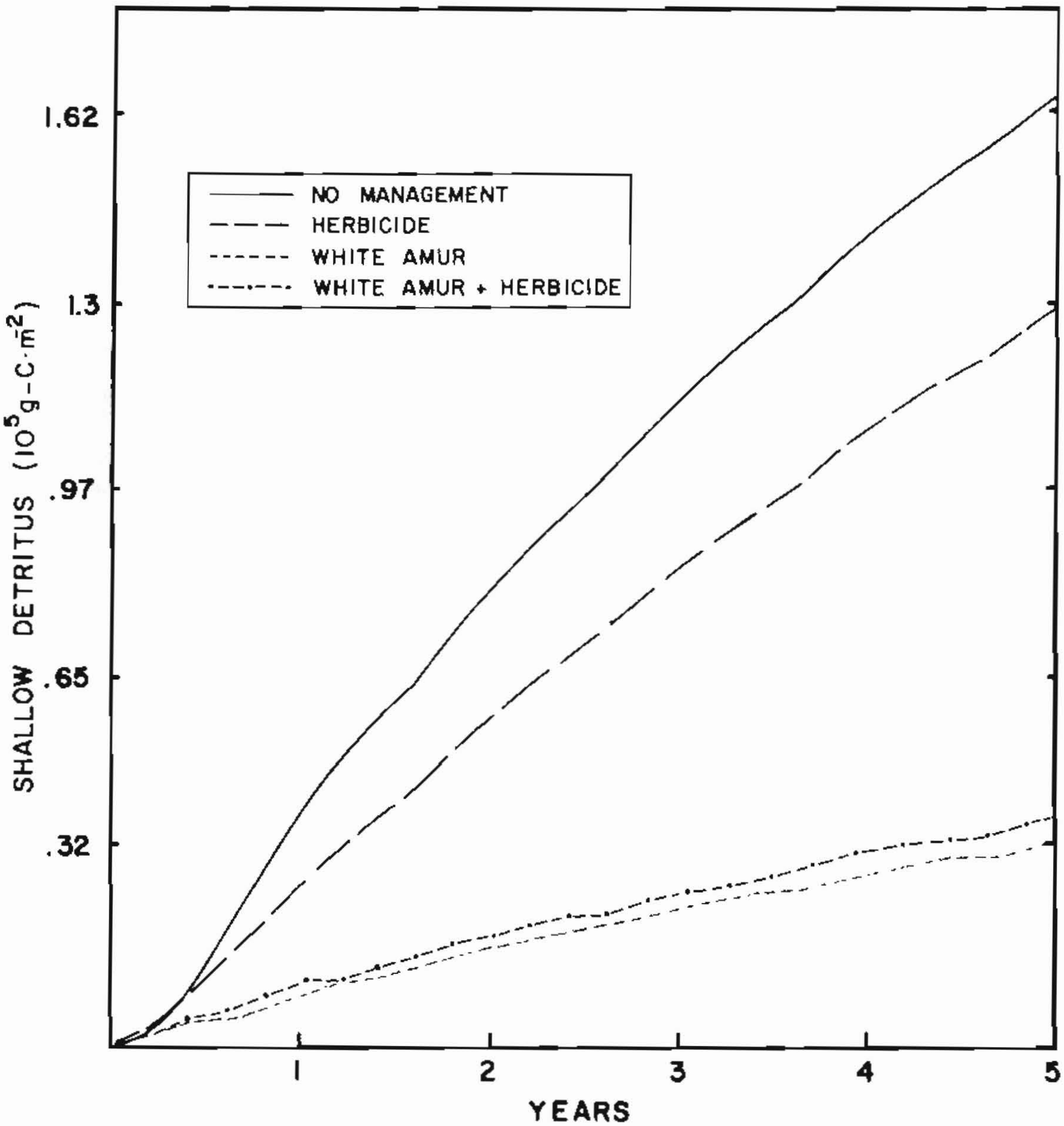

Figure 10. Simulated changes in accumulation of detritus on the bottom of the lake during four kinds of management conditions

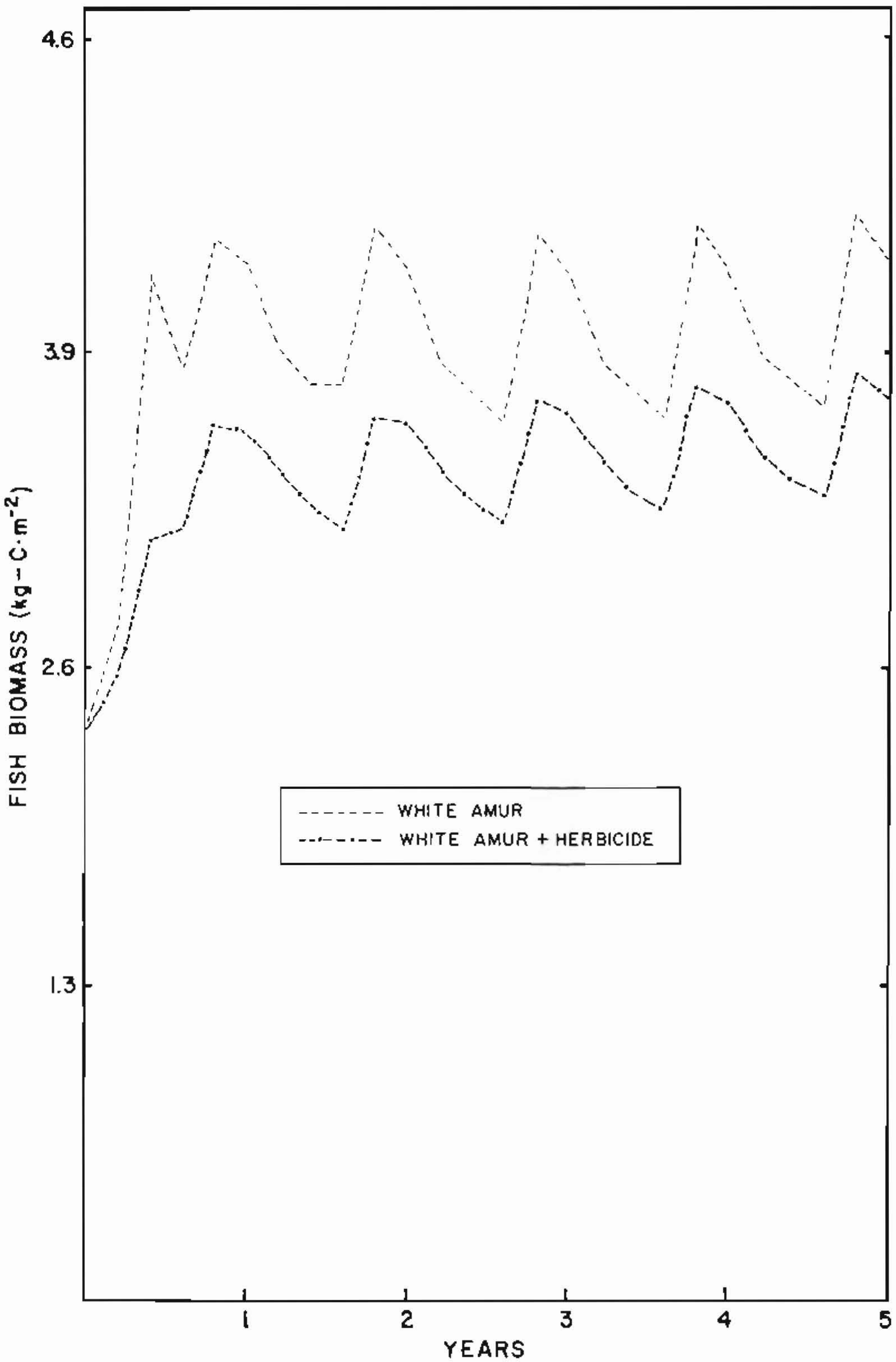

Figure 11 Simulated changes in biomass of white amur under four management conditions

more than 1 yr and then declined in biomass to about one-tenth their original state. When herbicide was applied, native species showed their best growth and seemed to attain a dynamic steady state. Other management schemes proved less favorable.

Algal periphyton showed best development when no management was supplied, hydrilla acting as the main substrate (Figure 7). As management efforts were initiated, decreases in algal periphyton resulted, primarily from decreases in available substrate (either hydrilla or native species).

Native fish also showed best growth when no management was supplied (Figure 8). The supply of periphyton seems to control the fish population in this model, and periphyton is primarily dependent on hydrilla as a substrate. The least amount of growth resulted when herbicide was applied. Intermediate values were achieved for other management schemes. Since all native fish (herbivores, carnivores, and omnivores) were lumped together as one unit in this model, the results obtained depict general trends only. Further work toward a reliable fish submodel is necessary.

When growth of hydrilla was most successfully suppressed, values of phosphorus in the total water column were highest (Figure 9). This cannot be ascribed to faster recycling, since the recycling rate from sediments was set as a constant. Higher total phosphorus values probably resulted instead from a diminished uptake rate caused by a decline in the standing stocks of vegetation. Even when hydrilla is controlled, there is enough of the weed present to exert a shading effect on the submersed vegetation. Only the phytoplankton thrives, but its turnover time is so rapid that its effect on the phosphorus level is only slight. The larger biomass and slower turnover time of the hydrilla population are sufficient to reduce the level considerably when growth is not controlled.

The accumulation rate of the shallow component of detritus was greatest under conditions of no management and least when white amur and white amur plus herbicides were used for weed control (Figure 10). These low values occur because much of the biomass becomes vested in the white amur population.

When white amur was used alone as a management strategy, it achieved a higher standing stock than under conditions of management by both herbicide and white amur (Figure 11), because more food was available for the white amur to eat. As with the native fish component, more work is needed in refining the biomass—number, standing stock, and turnover time relationships of this component.

CONCLUSIONS

A preliminary model suggests that control of hydrilla by the white amur will result in a phytoplankton bloom. However, the population of native fish will be enhanced and the rate of accumulation of organic detritus on the floor of the lake will be decreased.

The extreme generality of the model presented here greatly restricts the usefulness of its conclusions. Variables such as dissolved oxygen, zooplankton, and vertebrates other than fish have been entirely ignored, along with important details in the variables that were included. When a model is first formulated, however, it is important that the number of variables and the relationships among them be as few as possible. Once a model is working predictably, further refinements can be made with greater reliability. It is both interesting and educational to observe the magnitude of change in the results brought about by these refinements.

REFERENCES

1. Water Resources Data for Florida.
2. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, "Climatological Data," Vol 23, 1972, Washington, D. C.
3. Joyner, F. B., "Chemical and Biological Conditions in Lake Okeechobee, Florida, 1969-1972," Report Investigation No. 71, 1974, U. S. Geological Survey.
4. Personal communication with John Bateman, Orange County Pollution Control, National Summary.
5. Westlake, D. F., "Comparison of Plant Productivity," *Biological Review*, Vol 38, 1963, pp 385-425.
6. Gayle, T., *Systems Models for Understanding Eutrophication in Lake Okeechobee*, M.S. Thesis, University of Florida, 1975.
7. Wetzel, R. G., "A Comparative Study of the Primary Productivity of Higher Aquatic Plants, Periphyton, and Phytoplankton in a Large Shallow Lake," *Int. Revue ges. Hydrobiol. Hydrogr.*, Vol 49, 1964, pp 1-61.
8. Barnett, B. S. and Schneider, R. W., "Fish Populations in Dense Submersed Plant Communities," *Hyacinth Const., Journal*, Vol 12, 1974, pp 12-14.

AQUATIC WEED VERSUS PLANT PATHOGEN A STUDY OF A BIOLOGICAL CONTROL IN ACTION

by

K. E. Conway, T. E. Freeman, and R. Charudattan*

For the past 5 yr, plant pathologists have stressed the potential of using plant pathogens to control aquatic weeds. We have made significant progress since last year—in fact, a breakthrough in research. This paper will deal with field testing of a fungal organism for biological control of waterhyacinths (*Eichhornia crassipes* (Mart.) Solms). I (Conway) have been successful in isolating the organism believed to be responsible for the widespread decline of waterhyacinth that occurred in 1971 in the Rodman Reservoir of the Cross-Florida Barge Canal. This organism has recently been described and is now known as *Cercospora rodmanii*. Symptoms of *C. rodmanii* include small punctate spots on leaves and petioles, a progressive burning of the leaf and petiole, a spindly appearance of the petioles, and a root rot.

Last year I talked about some of the preliminary Lake Alice fieldwork at the University of Florida with this organism. Therefore, this will be a progress report on results from Lake Alice. Later, I will present progress in field tests in Rodman Reservoir.

LAKE ALICE

You were informed last year of the procedures we used to produce inoculum and to apply it to the waterhyacinths in Lake Alice. Two sprays of the inoculum were placed on the waterhyacinths in a small pool of Lake Alice on 3 September and 4 October 1974. The pool had an area of approximately 1.7 ha, and the spray coverage from the bank was a 6.4-m arc for an area of 64.42 m^2.

At last year's meeting, I expressed hope that with time we would see greater damage on the plants in the spray area. In the next few weeks, damage not only increased in the spray area but also spread from the spray area to infect all the waterhyacinths in the pool. By late November, conidia were carried by wind currents through the saw grass-cattail barrier surrounding the pool to infect plants in the main part of Lake Alice (Figure 1).

Freezing temperatures occurred in the first week of December. The damage on the plant caused by pathogen and frost continued throughout December and January. The waterhyacinths in the pool at this time were completely brown and appeared to have been killed. Above-average temperatures occurred in the latter part of January and February 1975, and some of the waterhyacinths began sending out offshoots (Figure 2). Evidently, the apical meristem of the plants had not been killed, and the plants were able to resume growth. However, it was apparent that a severe stress had been placed on the waterhyacinths when the plants in the pool area (Figure 3), which were normally 2-3 ft tall, were less than 6 in. high. In comparison with these plants, waterhyacinths in the main lake where the disease was less severe were their normal height of 3-4 ft. Thus, *C. rodmanii* fulfills the purpose of a biological control organism for waterhyacinth by increasing the stress on the plant and not necessarily eliminating the entire population.

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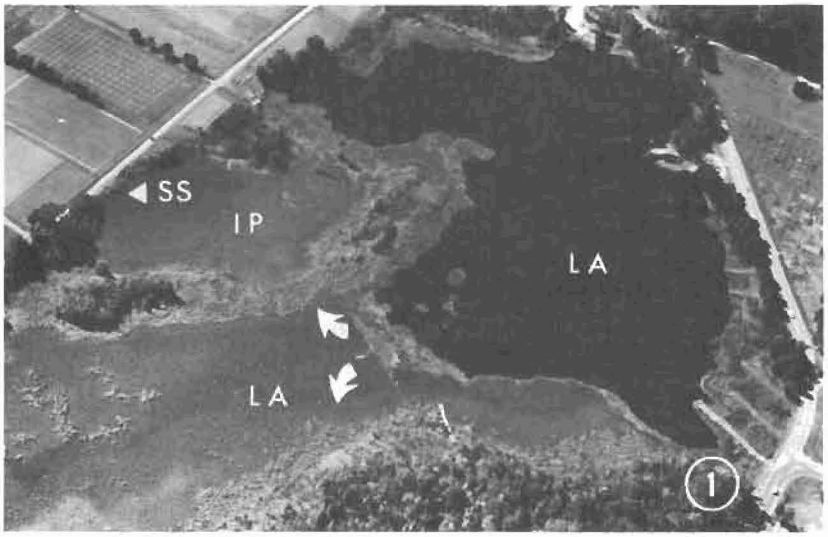

Figure 1. Aerial photo of Lake Alice showing the original spray site (SS), the isolated pool (IP), and the main Lake Alice (LA). Note the dark strips of diseased plants along both sides of the main lake (November 1974)

Figure 2. Regrowth of waterhyacinths in the spray area (18 February 1975)

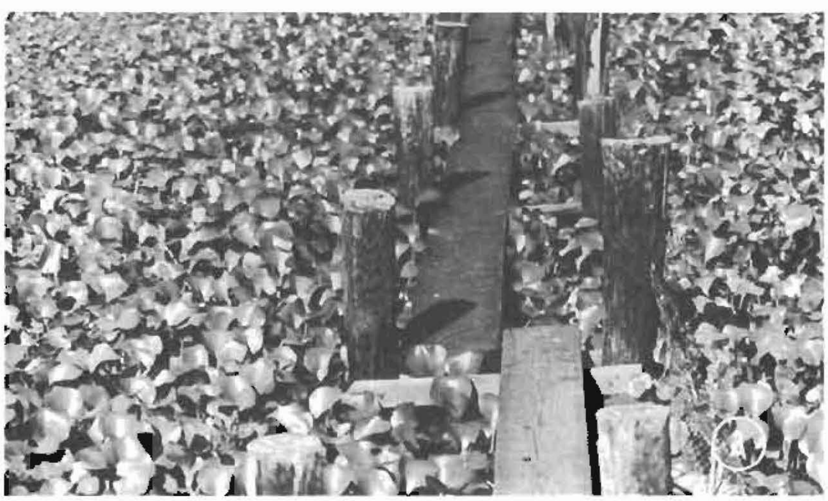

Figure 3. Waterhyacinths in main Lake Alice, 3-4 ft tall (18 February 1975)

We wanted to know what effect infection would have on the plants over a period of time. Four more sprays were applied on the pool area—two in March and one each in May and July.

In April, we were able to determine that most of the small waterhyacinths in the pool were infected again with *C. rodmanii*. However, with the approach of summer the waterhyacinths began their rapid growth phase; by June, the new leaves were outgrowing the disease. The infection of *C. rodmanii* during the summer was confined to the older lower leaves. This condition prevailed throughout the summer until September, when the waterhyacinth growth was slowed by cooler night temperatures. Increased infection was now apparent in the pool area. The waterhyacinths in the pool area showed a general browning by mid-September. This browning has continued into October until definite disease symptoms can be seen on the plants throughout the pool. Damage to the waterhyacinths is approximately 1 month ahead of last year, and we are looking for increased damage this fall and winter.

RODMAN RESERVOIR

Encouraged by the success in Lake Alice last fall, I (Conway) decided to set up some test plots in Rodman Reservoir. A site was chosen behind tree population No. 4 to exclude outside interference with the tests. The purpose of this experiment was to reestablish the disease in the reservoir. Although the disease was very prevalent in 1971, its severity on the waterhyacinth population has lessened each year.

Five sprays were to be applied from the shoreline, one every two weeks. The multiple sprays were felt necessary to begin infection and to increase the inoculum to a high enough level to create an epiphytotic. Spray operations were begun on 28 February 1975 (Figure 4). The next day, the U. S. Army Corps of Engineers began to raise the water level of the reservoir from its winter drawdown depth of 4.67 m to a level of 5.49 m. The water level had risen, and the waterhyacinths were growing and floating free of the shoreline by the second spray date. By the third spray application, the spray plots were moving with the rising water; therefore, one of our objectives of increasing the inoculum in one area could not be achieved.

Figure 4. Application of spray from the shoreline near Paynes Landing behind tree population No. 4 (28 February 1975). Note cypress tree area in the background and the waterhyacinth beneath the trees

In mid-April, damage on the plants due to *C. rodmanii* was present along a gradient from the opening onto the reservoir from tree population No. 4 to our spray site onshore. By this time, there was a definite reduction in plant growth in our plots when compared with the untreated waterhyacinths that surrounded these test areas. In addition to the disease in the tree population No. 4 area, there was also a heavy natural infection of *C. rodmanii* in the main part of the reservoir in the Orange Springs and Blue Springs areas.

During May, the disease in the main reservoir continued to stress and brown the waterhyacinths. On May 30, another spray plot was established in the cypress tree stand in tree population No. 4.

In June, the waterhyacinths in the Orange and Blue Springs areas were completely browned. The symptoms on the plants were typical for *C. rodmanii* damage.

By July, the waterhyacinths in the cypress stand were beginning to brown at the tips of the leaves, and in mid-July the waterhyacinths in our original spray plots were showing the typical *C. rodmanii* symptoms. Waterlettuce was invading soon after the severely infected waterhyacinths died and sank to the bottom. By late July, the waterhyacinths in the cypress stand were also dying out and open water was beginning to show (Figure 5).

Figure 5. Waterhyacinth mats in the cypress tree area under heavy stress by *C. rodmanii*. Notice the open water (July 1975)

On August 7, aerial inspection of the original spray site showed continued browning and dropout of the waterhyacinths. In the cypress tree area, there was now 10-20 acres of open water. By mid-August, the estimate of open water in the cypress tree area exceeded 20 acres. Large mats of waterhyacinth showed typical symptoms, which included many dead plants with floating, spindly petioles and leaves. It was also noted that completely dead plants continued to float until broken apart by wind and water action.

By mid-October, the area of open water was estimated to be 35-40 acres, with an additional 20 acres invaded by waterlettuce. The area now is picturesque (Figure 6).

SUMMARY

The results of our field operations in Rodman Reservoir are encouraging. We are looking for

Figure 6. Spray area in the cypress trees showing open water after diseased waterhyacinths have died out (October 1975)

similar results in the reduction of waterhyacinth in Lake Alice. Currently, evaluation is being given to integrated control using two of our pathogens—*C. rodmanii* and *Acremonium zonatum* in several combinations and with two insects, *Arzama densa* and *Neochetina eichhorniae*. This large field test is being conducted in Lake Concordia, Louisiana, in cooperation with the Department of Plant Pathology, University of Florida (Drs. T. E. Freeman and K. E. Conway), the U. S. Department of Agriculture, Gainesville, Florida, (Neal Spencer and Ted Center), and the U. S. Army Corps of Engineers (WES), Vicksburg, Mississippi. We have to find what factors predispose the waterhyacinth to the disease, when is the best time for spraying, how much inoculum is necessary, and how much area needs to be sprayed to give control of the plants over a long period of time.

ACKNOWLEDGMENTS

The excellent work of Richard Cullen during the laboratory and field phases of these experiments is gratefully acknowledged. Also, thanks are extended to Dave Bowman for his time and interest in the field operations and also for transporting us to our sites. This research was supported in part by the U. S. Army Corps of Engineers Contract No. DACW 73-73-0049, Florida Department of Natural Resources, and by the U. S. Department of the Interior, Office of Water Resources Research and Technology as authorized under the amended Water Resources Research Act.

CONTROLLED RELEASE HERBICIDES—RUBBER FORMULATIONS

by

G. A. Janes*

BACKGROUND

The principal activity of the Creative Biology Laboratory is investigation and development of controlled release systems for biologically active agents. In the simplest terms, this is an endeavor to optimize the use of the active agent and "make a little do a lot." For the past several years, we have examined the potential of using aquatic herbicides in controlled release systems.

The indicated advantages of a controlled release system in the control of pest aquatic weeds are as follows:

a. Long-term effectiveness of a single treatment.
b. Ability to direct application to the desired phytozone.
c. Elimination of the biomass problem connected with acute herbicide applications.
d. Environmental benefits.
e. Economic considerations.
f. Development of new weapons to broaden the range of control.

In an effort to promote and motivate the development of controlled release aquatic herbicides, the U. S. Army Corps of Engineers has funded our contracts to (a) demonstrate chronic toxicity, (b) develop slow release systems (models), and (c) investigate the "chronicity phenomenon."

The "chronicity phenomenon" is the efficacy bonus of chemicals from slow release systems as compared with quantities needed, or used, in conventional applications, where an acute dose is applied. Laboratory studies have shown that ultralow dosages administered continually from slow release systems will control pest aquatic weeds by chronic intoxication. While this takes longer to achieve, the time penalty is not proportional to the reduction in dosage. The concentration/time ratio is not direct, and toxicants have a profound effect on aquatic weeds in a reasonable time even at very low dosages.

During the past year, we have examined a controlled release formula of copper sulfate monohydrate to see if chronic intoxication of pest aquatic plants occurs as it does with 2,4-D BEE, Diquat, and Silvex.

Formulations with a measured release rate of only a fraction of one percent of the total available toxicant per day were evaluated against *Vallisneria americana, Cabomba caroliniana, Lemna* (duckweed), *Myriophyllum spicatum* (Eurasian watermilfoil), and *Eichhornia crassipes* (waterhyacinth) at dosages of 0.06 ppm/day down to 0.0003 ppm/day from the granulated form.

The "chronicity phenomenon" was evident in the test results. Slow release copper exhibited a profound effect on aquatic weeds, and data indicate an effective level of copper ion can be released over a 5- to 7-month period.

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EXPERIMENTAL EVALUATION

Microenvironmental Bioassay

Formulations are prepared at 0.1-g and 0.01-g pellet sizes and suspended from nylon fish line in a 4-l aquarium containing a specific environment. The following elements are present:

a. Soil mixture: 1/3 top soil, 1/3 sand, 1/3 peat moss.

b. Limestone chips (approximately 50 g).

c. Ten mature *B. glabrata* snails.

d. Ten *Lebistes reticulatus* fish (1/2- to 1-in. length).

e. Ten grams of plant material: usually *Elodea canadensis.*

A 10 percent water turnover per day rate is used. All units are aerated, and external temperature held to 72°-75° F. Lettuce is fed *ad libidum* and Tetramin fish food every other day. Mortality observations are made daily, and dead animals are removed.

All pellet dosages are run in replicates of three, and mortality is averaged. Appropriate controls are used. All exposures with new plants and animals are observed until biocidal activity drops off.

In this evaluation, it was noted that many of the compounds tested exhibited significant herbicidal qualities. The following tabulation shows the results obtained with one material (E-14), which appears to demonstrate this potential.*

Month	Plant Type*	0.01-g Mortality, %			0.1-g Mortality, %		
		Snail	Fish	Plant	Snail	Fish	Plant
1	V	94	3	40	100	100	100
2	E	73	0	90	97	3	100
3	E	10	10	100	97	14	100
4	E	63	3	50	80	0	100
5	E	53	14	50	87	0	80
6	E	--	--	--	97	0	95
7	E	--	--	--	14	0	3

* E = *Elodea canadensis* and V = *Vallisneria americana.*

One control aquarium was established for each group of three test aquaria. Control mortality was 1.7 percent on snails, 3.1 percent on fish, 15 percent on *Elodea,* and 10 percent on *Vallisneria.*

"Vallisneria americana"

Three *V. americana* were potted in topsoil and placed on the bottom of a glass aquarium (1 gal) containing 3 *l* of deionized water. After 4 weeks conditioning, E-51 pellets were added at 1, 10, 50, and 100 ppm with respective copper ion contents of 0.175, 1.75, 8.75, and 17.5 ppm. Sixty-day exposures were used at 1- and 10-ppm dosages, 20 replicates at the higher dosages, and 10 jars treated at 0.03-ppm copper ion in solution per day. Observations were subjective, with a 10 rating indicating no observable response and a 0 rating showing complete plant mortality. Temperature was controlled at 70-76° F with

* K. E. Walker and N. F. Cardarelli, "Development of Slow Release Copper Sulfate as a Molluscicide," INCRA Research Report, 1 Jul 1974.

a 14-hr day, 10-hr night Gro-lux light cycle. The following tabulation shows the results.

Day	Mortality at a Given Time (Day),* %					
	Control	Cu++ 0.03 ppm/day	1 ppm	10 ppm	50 ppm	100 ppm
5	2	16	0	8	16	17
10	4	28	13	27	34	41
15	8	43	33	52	47	63
20	9	52	44	67	55	70
25	10	62	58	73	59	74
30	10	77	62	89	61	85
35	10	80	65	93	62	92
40	10	84	68	94	77	96
45	10	86	68	95	85	98
50	9	91	69	100	95	99
55	9	97	72	100	97	99
60	8	100	74	100	100	100

* Average of replicates.

"Myriophyllum spicatum" (Eurasian Watermilfoil)

This experiment was performed in the same manner as that for *V. Americana*. The results are shown below.

Day	Mortality at a Given Time (Day),* %					
	Control	Cu++ 0.03 ppm/day	1 ppm	10 ppm	50 ppm	100 ppm
5	3	10	7	6	9	7
10	6	32	18	14	17	19
15	7	43	29	25	31	37
20	9	50	45	34	41	45
25	6	55	51	47	44	50
30	4	60	33	33	42	52
35	5	63	36	36	44	55
40	6	60	33	40	39	55
45	7	70	37	46	43	65
50	7	70	40	51	53	72
55	7	78	54	57	57	76
60	7	80	74	74	74	79

* Average of replicates.

"Cabomba caroliniana"

This experiment was performed as with *V. americana*, except six replicates were used at each dosage. The results are shown on the following page.

Day	Mortality at a Given Time (Day),* % Control	Cu++ 0.03 ppm/day	10 ppm	50 ppm	100 ppm
5	3	10	23	37	26
10	10	30	33	60	40
15	24	35	50	82	60
20	30	40	66	85	78
25	30	45	80	85	78
30	30	65	90	92	90
35	40	65	93	100	100
40	30	90	100	--	--
45	25	100	--	--	--
50	25	--	--	--	--
55	25	--	--	--	--
60	--	--	--	--	--

* Average of replicates.

The toxicant control dosage used in three experiments was designed to approximate the actual release from the 100-ppm slow release pellet. There is little significant difference among the results achieved with any of the pellet sizes. Perhaps the chronic intoxication rate is being exceeded. Also, there are anomalies in the individual data that need to be examined. However, the results look promising.

FUTURE PLANS

Development efforts for the next year will be directed toward the following goals:

a. Formation of Diquat, Silvex, 2,4-D ester, Endothal, and Fenac into controlled release systems.

b. Determination of the release rates of the biologically active chemicals.

c. Establishment of the tolerance threshold of selected aquatic plants to the chemicals.

d. Recommendation of the formulations for large-scale field tests.

ACKNOWLEDGMENTS

Support of basic research on the "chronicity phenomenon" by Grant No. DACW-73-C-0042 from the Office, Chief of Engineers, U. S. Army, and on the "Slow Release Copper" by the International Copper Research Association, is gratefully acknowledged.

2,4-D IN SLOW-MOVING WATER*

by

J. R. Barry**

This project was sponsored by U. S. Army Engineer Waterways Experiment Station Contract No. DACW 39-74-C-0074. The research was conducted under the supervision of Dr. J. Foret, Dean, U.S.L. College of Agriculture, and the author. Assistant investigators conducting various phases of the work included Dr. L. J. Desselle, Mr. W. Averitt, and Mr. S. J. Langlinais.

The purpose of the study was to determine the effect of application rate, time, and distance from point of application upon 2,4-D residues in slowly moving waters.

PROCEDURE

Site Selection

This study was conducted in a canal system owned and operated by the Southdown Corporation of Louisiana. This particular canal system was chosen because it provided a main canal that served as a common water source for the six lateral canals used as individual test locations. The main canal orignated at Milton, Louisiana, and its water source was the Vermilion River. Each lateral canal used as a test location extended for a distance of at least 6.4 km (4 miles).

Plot Descriptions

The average depth, width, stream velocity, and flow rate for each of the six lateral canals used as test sites are shown in Table 1. The surface velocity measurements made at the time of herbicide treatment varied between 0.1 m/sec (0.32 ft/sec) for canal 1 and 0.32 m/sec (1.05 ft/sec) for canal 6. These velocities were assumed to be suitable for classification as slowly moving waters.

The plots treated at canal sites 1, 2, 3, 4, and 6 consisted of strips 166 m (544.5 ft) long by 3 m (10 ft) wide extending along opposite sides of the canal. The spray applications extended 0.6 m (2 ft) upon the canal bank and 2.4 m (8 ft) into the stream. This left an untreated strip down the center of the canal. The treated area amounted to 0.1 ha (1/4 acre). This application method was selected to simulate an actual treatment situation where fringes of aquatic weeds are to be controlled along both sides of the stream. Under such conditions, it is common to spray as much as 0.6 m of the bank to control encroaching aquatic weeds. Two rates of 2,4-D diethanole amine were applied over the 0.1-ha treated area. Canal sites 1, 3, and 6 received rates equal to 1.82 kg ai/ha (4 lb ai/A), and canals 2 and 4 were treated with rates equal to 3.63 kg ai/ha (8 lb ai/A).

Application procedures for canal site 5 differed slightly from those described earlier for the other canals. At this site a 0.2-ha (1/2-acre) area of the canal was sprayed from bank to bank. The entire spray volume was applied within the canal channel with no bank area treated. The rate of 2,4-D applied at site 5 was equal to 3.63 kg ai/ha (8 lb ai/A). Spray applications were made with a handgun at 125 psi in a water volume equal to 948 ℓ/ha (100 gal/A).

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* This paper will be published as a contract report in 1977.

** Professor of Horticulture, Department of Plant Industry and General Agriculture, University of Southwestern Louisiana, Lafayette, Louisiana.

Table 1
Streamflow Data and Theoretical 2,4-D Residue Levels

Site No.	Cross-Sectional Area* ft²	Cross-Sectional Area* m² (0.0929)A	Avg Surface Velocity ft/sec	(V_{avg})Avg Stream Velocity** ft/sec	(V_{avg})Avg Stream Velocity** m/sec (0.3048) × ft/sec	Q Flow Rate† ft³/sec	Q Flow Rate† m³/sec (0.0283) × ft³/sec	Theoretical 2,4-D Concentration ppb††
1	188.2	17.48	0.32	0.198	0.0603	37.26	1.055	157
2	247.5	22.99	0.30	0.183	0.0557	45.29	1.282	240
3	251.8	23.39	0.55	0.33	0.100	83.09	2.39	118
4	158.5	14.73	0.58	0.348	0.106	55.15	1.56	374
5	119.2	11.07	1.0	0.6	0.182	71.52	2.02	818
6	146.99	13.66	1.05	0.6	0.182	88.19	2.49	201

* Area was compiled by using an average of three planimeter readings.
** Average stream velocity was computed by using the formula $V_{avg} = (0.6) \times$ (avg surface velocity).
† $Q = A \times V_{avg}$.
†† Calculation of theoretical 2,4-D concentration based upon water volume in the treated and channel area of each site at the appropriate treatment rate. These calculations assume complete dispersion of the applied 2,4-D throughout the volume under static conditions.

Sampling

Water samples of approximately 3/4 ℓ in volume were taken from each canal site at the station locations and sampling times shown in Tables 2 and 3. Samples were collected at a distance of 1.53 m (5 ft) from the bank and 0.61 m (2 ft) below the surface of the water.

Table 2
Sampling Station Location and Times of Sampling

Station Location	Time of Sampling
A. Above treated plot	Before treatment and 1/2 hr, 1 hr, 2 hr, 4 hr, 8 hr, 16 hr, 24 hr, 2 days, 4 days, 8 days, 16 days, and 32 days after treatment.
B. Midplot	Same as A.
C. 91.5 m (100 yd) from the lower end of the treated plot	Same as A, except no before treatment sampling.
D. 403 m (440 yd) from the lower end of the treated plot	Same as A, except starting at 1 hr.
E. 805 m (880 yd) from the lower end of the treated plot	Same as A, except starting at 1 hr.
F. 1.6 km (1 mile) from the lower end of the treated plot	Same as A, except starting at 2 hr.
G. 3.2 km (2 miles) from the lower end of the treated plot	Same as A, except starting at 4 hr.
H. 6.4 km (4 miles) from the lower end of the treated plot	Same as A, except starting at 8 hr.

Table 3
Selected Samples (Times and Sites) Analyzed for 2,4-D

Time, hr	Sites*							
	A	B	C	D	E	F	G	H
1/2	X	X	X	–	–	–	–	–
2	X	X	X	X	X	X	–	–
8	X	X	X	X	X	–	X	–
24	–	–	–	X	X	X	X	X
48	X	X	X	X	X	X	X	X

* Keyed to site identifications in Table 2.

Analytical Procedures

The analytical procedures for 2,4-D extraction and analysis were those outlined by Frank and Bartley.*

RESULTS AND DISCUSSIONS

Table 1 illustrates the streamflow rates and other pertinent stream characteristics. Stream velocities ranged from a low of 0.056 m/sec for site 2 to a maximum of 0.182 m/sec for sites 5 and 6. These rates of water movement were assumed suitable to qualify as slowly moving waters.

Also shown in Table 1 are theoretical 2,4-D concentrations for each canal site treated. These figures are based upon the water volume in the treated area plus the adjacent channel area where a static water condition and complete dispersion of applied 2,4-D are assumed. The theoretical 2,4-D levels in all canals exceeded 0.1 ppm, the level established for potable water. However, water sample analyses shown in Table 4 and in Figures 1 and 2 show that the average 2,4-D levels measured were well below 0.1 ppm.

Analysis of variance showed no significant differences due to 2,4-D rates, locations of sampling, and time of sampling. Figure 1 shows the mean 2,4-D levels found for each sampling site.

Although higher levels of 2,4-D were expected in the treatment area and at sampling sites nearest the point of application, these levels were not found to be statistically different from locations above the treated area or at points well below the treated area. The difference in 2,4-D concentration actually measured and in the theoretical levels shown in Table 1 may be at least partially accounted for by the following:

1. In plots 1, 2, 3, 4, and 6 approximately 1/5 of the herbicide was applied to weeds encroaching upon the bank and may not have entered into the stream for sometime after application, if at all. This was not the case at canal 5, where all the 2,4-D was applied over water.

2. Where 2,4-D or other herbicides are applied to floating aquatic vegetation most of the herbicide is placed upon the vegetation and may not enter the water for some time. In many cases, several days are required for the vegetation to sink and for the 2,4-D to contact the water. In addition, part of the 2,4-D would be taken up by the plant and released gradually upon plant decomposition.

* P. A. Frank and T. R. Bartley, "Proposed Monitoring Guidelines for Determining Herbicide Residues in Flowing Water for Use-Registration," Prepared for Interagency Ad Hoc Committee on Use of Herbicides in Aquatic Sites.

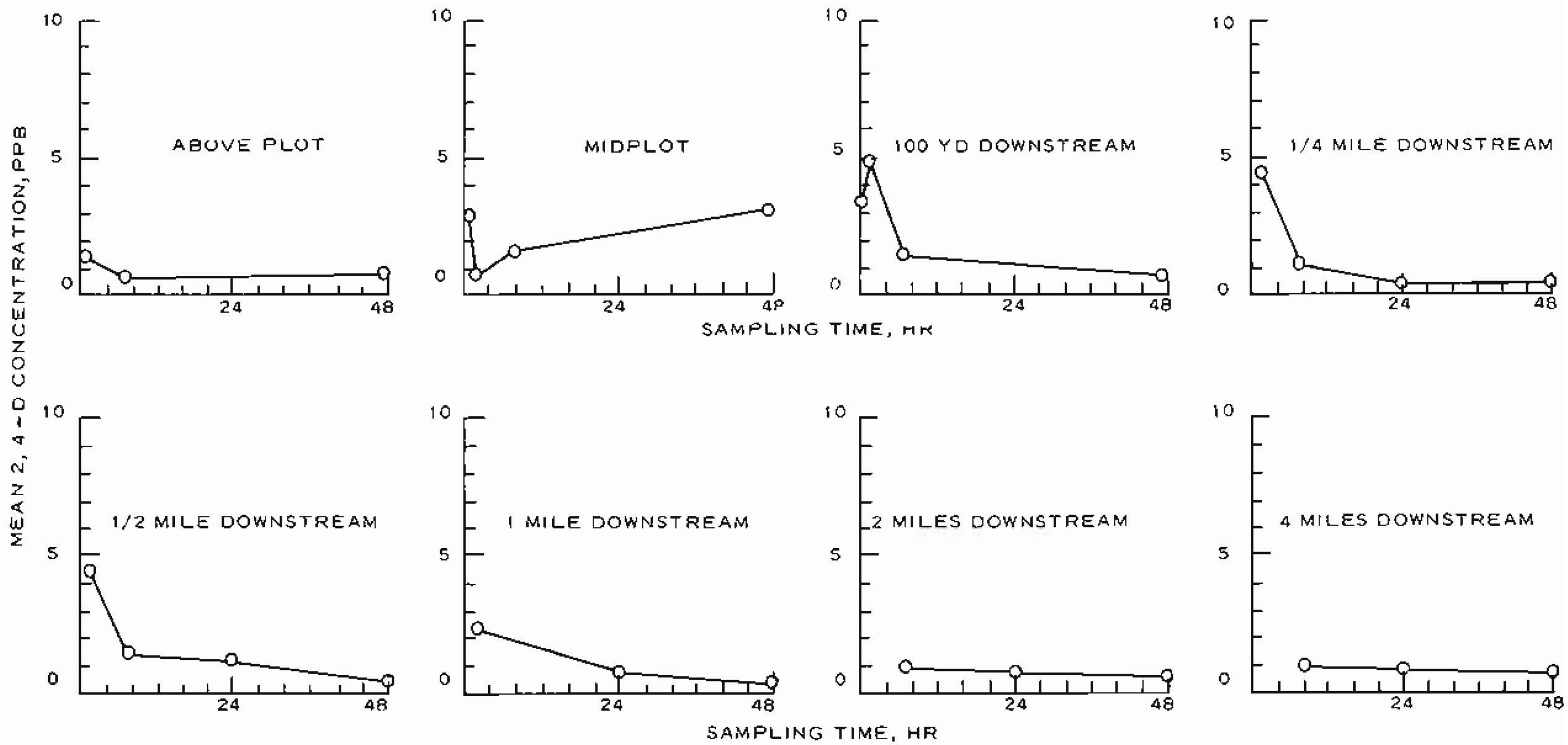

Figure 1. Mean 2,4-D concentration as a function of time for each sampling site

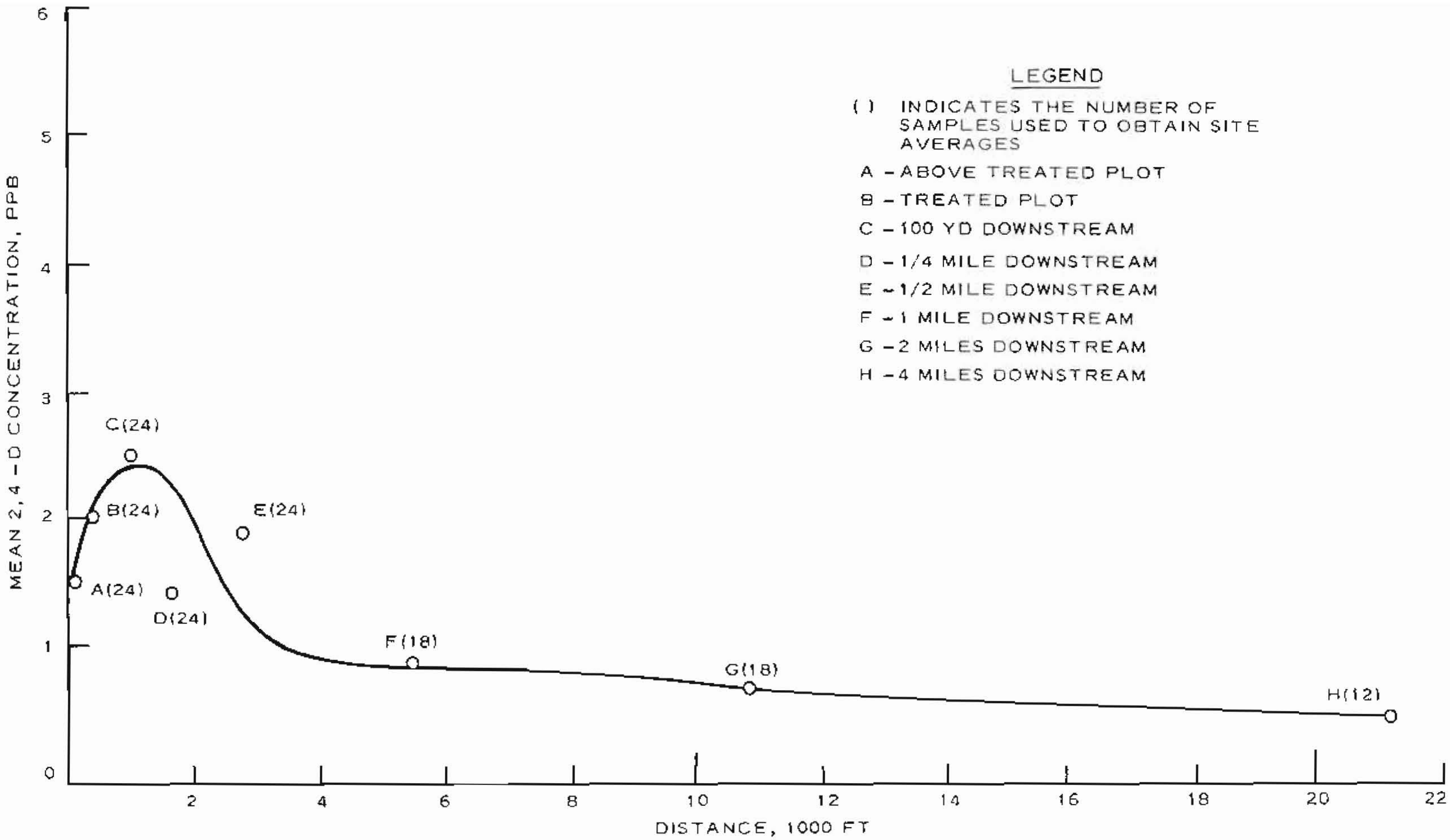

Figure 2. Mean 2,4-D profile based on the average of all times and canals tested

Table 4
2,4-D Concentration for Selected Sampling Sites and Times, ppb

Sampling Sites	Sampling Times After Application, hr	Canal Number and Rate of Applied 2,4-D* 1-I	2-II	3-I	4-II	5-II	6-I
A	1/2	1.42	0.38	14.81	2.07	1.32	0.00
A	2	2.87	0.27	1.03	2.62	1.56	0.32
A	8	2.05	0.30	1.13	0.35	0.00	0.34
A	48	0.57	0.74	0.35	2.60	0.00	0.00
B	1/2	10.41	0.30	3.46	1.62	0.20	1.32
B	2	0.25	0.17	1.39	1.49	0.15	0.23
B	8	1.76	1.54	0.99	2.95	0.13	1.43
B	48	15.81	0.95	0.19	1.13	0.00	0.10
C	1/2	2.13	0.0	0.11	9.98	7.25	1.09
C	2	9.16	1.34	4.90	13.74	0.16	0.11
C	8	0.70	0.24	1.23	3.30	0.0	2.02
C	48	0.0	0.45	0.51	2.60	0.0	0.01
D	2	2.71	8.80	0.17	11.76	0.09	4.06
D	8	2.24	0.00	1.52	2.58	0.09	0.00
D	24	0.59	0.10	0.00	0.49	0.05	0.00
D	48	0.08	0.11	0.17	0.59	0.08	0.58
E	2	4.83	3.94	2.73	8.54	0.98	7.15
E	8	3.82	0.09	2.09	2.78	0.34	0.17
E	24	0.08	0.02	5.32	1.72	0.00	0.90
E	48	0.06	0.17	0.05	0.62	0.00	0.06
F	2	0.94	0.00	0.00	0.88	0.00	10.39
F	24	0.53	0.00	1.04	0.33	1.03	0.00
F	48	0.00	0.28	0.13	0.80	0.18	0.00
G	8	1.33	0.00	1.32	0.22	1.04	1.27
G	24	0.46	0.00	0.28	2.56	0.60	0.16
G	48	1.83	0.50	0.00	1.37	0.10	0.08
H	24	0.00	3.63	0.12	0.17	0.44	0.00
H	48	0.00	0.15	0.00	2.46	0.00	0.00

* I = 4-lb rate and II = 8-lb rate of 2,4-D.

3. The dilution effects resulting from the constant water movement through the treated area would also reduce the concentration of herbicide substantially below the theoretical "high" levels shown in Table 1.

4. The sampling position may not have been ideal to show maximum 2,4-D levels. Dyes indicated irregular movement of surface water. Occasionally patches of dye moved into weeded areas along the banks and remained there for some time before they dispersed into the water and were no longer visible. Most potable water intakes are usually located near the bottom of streams, and it appeared that the dyes moved well above the bottom in the treated areas.

5. The 2,4-D may have become adsorbed on the silt particles in the muddy canal waters and these particles were filtered out of the sample during the analytical procedure. In the streams, these particles would eventually settle out on the stream bottom.

CONCLUSION

Levels of 2,4-D detected in canals treated with 1.82 and 3.64 kg ai/ha and sampled at various downstream locations and times were not significantly different. Concentrations of 2,4-D measured in the canals did not approach 0.1 ppm, the limit approved for a potable water supply.

EXTENSIVE DEGRADATION OF SILVEX BY SYNERGISTIC ACTION OF AQUATIC MICROORGANISMS

by

H. C. Sikka and L. T. Ou*

The herbicide 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) is used for controlling certain aquatic weeds.[1,2] The metabolic fate of silvex in the aquatic environment is of obvious concern because of the potential toxicity of the herbicide and its metabolites to nontarget organisms and their possible adverse effects on man through his drinking-water supplies. Among the factors that determine the fate of a chemical in natural ecosystems, microbial transformation is one of the most important. Reports on microbial degradation of silvex are few. It has been reported that silvex and a structurally similar herbicide, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), are very resistant to microbial degradation.[3,4] The recalcitrant nature of these chemicals was attributed to the number of chlorines attached to the aromatic nucleus and to the presence of chlorine on the meta position of the ring. A soil fungus, *Streptomyces viridochromogenes*, was capable of cleaving the ether linkage and oxidizing the propionic acid moiety of silvex but could not degrade the remaining 2,4,5-trichlorophenol (2,4,5-TCP).[5] A *Brevibacterium* sp. was shown to cometabolize 2,4,5-T to 3,5-dichlorocatechol (3,5-DDC) without any further alteration.[6] In this paper, we report that silvex, a molecule generally considered as recalcitrant, is extensively degraded by the synergistic action of two species of aquatic microorganisms.

A population of microorganisms capable of degrading silvex was developed by an enrichment culture technique using pond water and sediment as an initial source of inoculum. The enrichment medium contained K_2HPO_4, 4.8 g; KH_2PO_4, 1.2 g; NH_4NO_3, 0.5 g; $MgSO_4.7H_2O$, 0.2 g; $Ca(NO_3)_2.4H_2O$, 0.04 g; $Fe_2(SO_4)_3$, 0.001 g; yeast extract (Difco), 2.0 g; and silvex 0.3 g in a litre of distilled water. Silvex degradation was determined by measuring chloride ion release in the medium[7] and by assessing the loss of ultraviolet (UV) absorbance of the supernatant fluid at 288 nm (λ max. for silvex). The individual isolates obtained from the enrichment culture included three species of the genus *Pseudomonas*, an *Achromobacter* sp. and two unidentified gram-negative rods. These isolates were ineffective in degrading silvex when incubated with the herbicide individually or in combination. However, a colony consisting of two bacteria growing together on the agar plate was able to metabolize the herbicide. They were identified to be *Pseudomonas* sp. and *Achromobacter* sp. The culture of *Pseudomonas* sp. plus *Achromobacter* sp. (hereafter referred to as mixed culture) could not utilize silvex as the sole source of carbon but did metabolize the herbicide in the presence of an external carbon source such as yeast extract. When pure cultures of the two bacteria were incubated separately with silvex, no degradation of the herbicide was observed, suggesting a synergistic relationship between the two organisms in attacking the herbicide.

To examine the time-course of silvex degradation, the mixed culture was grown in the mineral medium containing 0.2 percent yeast extract and 300 ppm of silvex on a rotary shaker at 23° C. At various intervals after inoculation, aliquots of cell suspension were removed and centrifuged at 12,000 g's, and the supernatant was assayed for chloride and UV absorbance. We also analyzed the supernatant for phenols[8] and catechols.[9] Additional information on silvex degradation was obtained using the

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herbicide labeled uniformly with ^{14}C in the ring. The mixed culture was grown in the yeast extract-mineral medium containing 300 ppm silvex and 2 μCi of ^{14}C-silvex in a biometer flask.[10] $^{14}CO_2$ evolved from the incubation mixture was trapped in 0.1 N KOH contained in the side arm; the CO_2-trapping solution was removed at appropriate intervals and counted for ^{14}C in a liquid scintillation counter. Aliquots of cell suspension were also removed periodically and centrifuged, and the ^{14}C in the supernatant and cell pellet was determined. For chromatographic analysis, the supernatant was acidified to pH 2 and then extracted twice with ethyl ether. The ether extract was concentrated under a stream of nitrogen, and an aliquot was spotted on thin-layer silica gel plates. The plates were developed in the following two solvent systems: (a) chloroform, and (b) butanol-benzene-water (1:9:10). The radioactive compounds were detected by scanning the chromatograms on a Nuclear-Chicago actigraph and by autoradiography; chromatograms were also examined under UV light to detect possible metabolites. The cell pellet was extracted with 80 percent methanol, and the extract was concentrated under vacuum to remove the methanol. The aqueous solution was acidified, and extracted with ether, and the ^{14}C in the two phases was determined.

The data revealed an extensive degradation of silvex by the mixed culture as indicated by dechlorination and a loss of UV absorbance at 288 nm. Degradation of the herbicide started 18-20 hr after inoculation. After 80 hr, essentially all of the chlorine in the herbicide was liberated as free chloride, and no silvex could be detected in the medium as measured spectrophotometrically (Figure 1a). We did not detect phenols or catechols in the medium after incubation of silvex with the culture. A complete loss of the UV absorbance spectrum (240-320 nm) was noticed after 80 hr, indicating a destruction of the aromatic nucleus. Evolution of $^{14}CO_2$ from the cultures incubated with ^{14}C-ring-labeled silvex provided additional evidence of ring cleavage (Figure 1b). After 100 hr of incubation, about 80 percent of the ^{14}C from the culture solution had disappeared; the decrease in ^{14}C was accompanied by $^{14}CO_2$ evolution and ^{14}C appearance in the cells. Thin-layer chromatographic analysis of the ether extract of the culture medium at different times following incubation did not reveal the presence of any compound other than silvex. This indicates a complete metabolism of the herbicide by the mixed culture. The aqueous phase remaining after ether extraction of the medium contained only traces of ^{14}C. The failure of the culture to accumulate any silvex metabolites suggests that the intermediates were degraded as rapidly as they were formed. Essentially all of the ^{14}C-activity in the cell extract was present in the form of water-soluble products unextractable with ether, which indicates that part of the silvex carbon was incorporated into cellular metabolic intermediates.

In an attempt to accumulate the metabolites produced during silvex degradation, a washed suspension of silvex-adapted cells (2.5 mg dry wt/ml) was incubated in 0.02 M phosphate buffer containing 300 ppm of silvex and 2 μCi of ^{14}C-silvex. After 4 hr of incubation, 93 percent of the bound chlorine was released as chloride in the medium, and 75 percent of the initial radioactivity was evolved as $^{14}CO_2$. Thin-layer chromatographic analysis of the ether extract of the culture medium at various times during the incubation period revealed the presence of a ^{14}C-metabolite (1-5 percent of the initial ^{14}C), which was identified by co-chromatography as 2,4,5-TCP. No other silvex metabolites could be detected in the culture solution during the incubation period. The silvex-adapted cells also readily degraded 2,4,5-TCP as indicated by chloride release and evolution of $^{14}CO_2$ from the culture incubated with uniformly ring-labeled ^{14}C-2,4,5-TCP. The appearance of 2,4,5-TCP in the culture fluid, together with the capacity of the cells for dissimilating it, suggests that it forms part of the pathway of silvex degradation. The cells also extensively destroyed 3,5-DCC as determined by chloride release, suggesting that 3,5-DCC is a likely intermediate in the pathway of silvex degradation. On the basis of these a.

b.

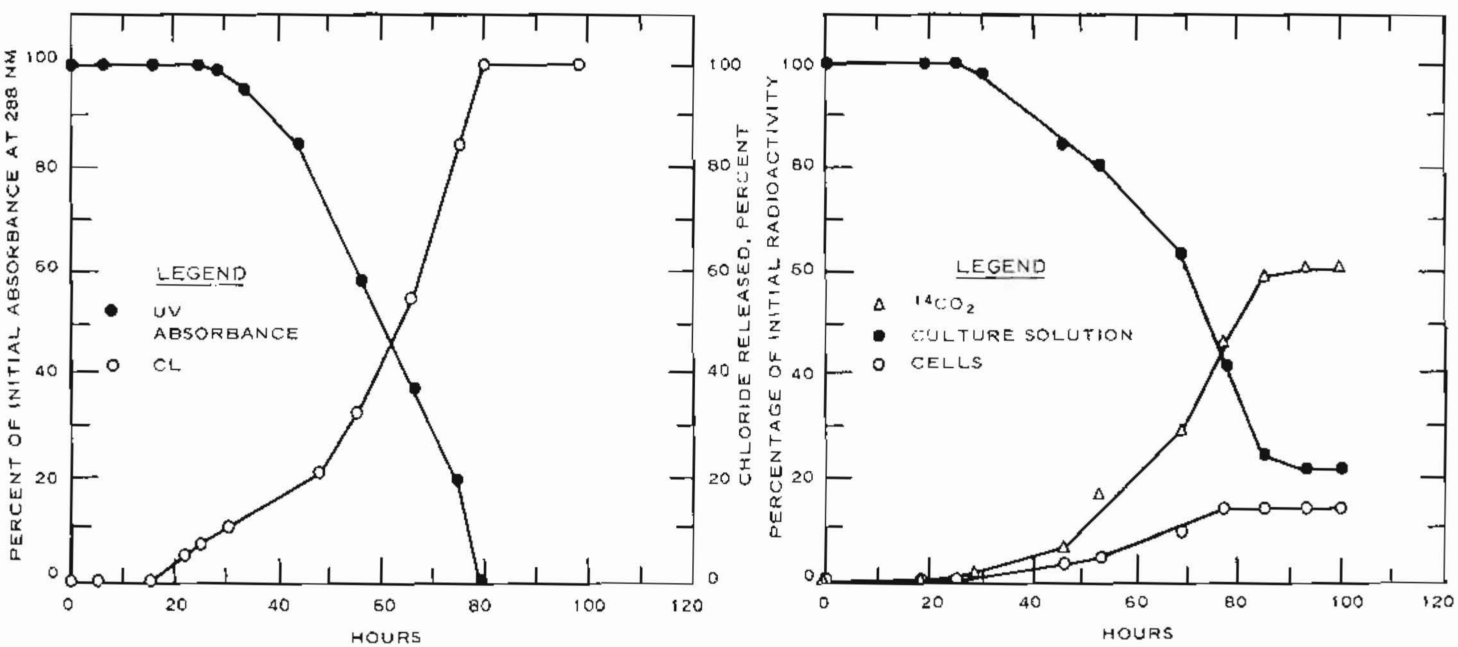

Figure 1. Degradation of silvex by the mixed culture

findings, we postulate that silvex metabolism by the mixed culture involves a cleavage of the ether linkage to give rise to 2,4,5-TCP. The latter is then dehalogenated and the resultant 3,5-DCC is degraded by the pathway previously described.[11]

The *Pseudomonas* sp. or the *Achromobacter* sp. isolated from the mixed culture failed to metabolize silvex or 2,4,5-TCP when the washed cells of each organism were incubated separately with the chemicals; neither did the organisms degrade the chemicals when the cells of the two organisms were mixed in different proportions. Presently, we cannot offer an explanation for the inability of individual or intentionally mixed cultures of the two bacteria to metabolize silvex or 2,4,5-TCP. It is likely that the organisms underwent some changes during their isolation from the mixed culture which may have resulted in a loss of their ability to degrade the chemicals.

The findings of this study have ecological significance for two reasons. First, the investigation has shown that silvex, an environmentally important and supposedly recalcitrant herbicide, is extensively degraded by the action of aquatic microorganisms. In our preliminary studies, we have observed that these organisms also disrupt the aromatic ring of 2,4,5-T. Prior to this work, no organisms had been reported to be capable of effecting ring cleavage of silvex or of a structurally similar molecule. Secondly, the data presented herein demonstrate the significance of a synergistic relationship between microorganisms in the decomposition of recalcitrant molecules. The inability of pure cultures of microorganisms to degrade a chemical cannot be taken as proof that the substance is resistant to microbial attack; it may, in fact, be readily destroyed by the combined action of two or more organisms. A synergistic relationship between microorganisms has also been noted in the degradation of cycloparaffinic hydrocarbons[12] and other pesticides.[13-15]

ACKNOWLEDGMENT

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REFERENCES

1. Blackburn, R. D., *Weeds*, Vol 11, 1963, pp 21-24.
2. Frank, P. A., Hodgson, R. H., and Comes, R. D., *Weeds*, Vol 11, 1963, pp 124-128.
3. Alexander, M. and Aleem, M. I. H., *J. Agr. Food Chem.*, Vol 9, 1961, pp 44-47.
4. Burger, K., MacRae, I. C., and Alexander, M., *Soil Sci. Soc. Amer. Proc.*, Vol 26, 1962, pp 243-246.
5. Bounds, H. C. and Colmer, A. R., *Weeds*, Vol 13, 1965, pp 249-252.
6. Horvath, R. S., *Bull. Environ. Contam. Toxicol.*, Vol 5, 1971, pp 537-541.
7. Iwasaki, I., Utsumi, S., and Ozawa, T., *Bull. Chem. Soc. Japan*, Vol 25, 1952, p 226.
8. Loos, M. A., Roberts, R. N., and Alexander, M., *Can. J. Microbiol.*, Vol 13, 1967, pp 679-690.
9. Arnow, L. E., *J. Biol. Chem.*, Vol 118, 1937, pp 531-537.
10. Bartha, R. and Pramer, D., *Soil Sci.*, Vol 100, 1965, pp 68-70.
11. Tiedje, J. M. et al., *J. Agr. Food Chem.*, Vol 17, 1969, pp 1021-1026.
12. Beam, H. W. and Perry, J. J., *J. Gen. Microbiol.*, Vol 82, 1974, pp 163-169.

13. Gunner, H. B. and Zuckerman, B. M., *Nature*, Vol 217, 1968, pp 1183-1184.
14. Bordeleau, L. M. and Bartha, R., *Soil Biol. Biochem.*, Vol 3, 1971, pp 281-284.
15. Pfaender, F. K. and Alexander, M., *J. Agr. Food Chem.*, Vol 20, 1972, pp 842-846.

INTEGRATED CONTROL OF WATERHYACINTHS WITH FOUR BIOLOGICAL AGENTS

by

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As we have heard, one of the areas of endeavor in the Aquatic Plant Control Research Program is the use of biological agents for the control of waterhyacinths. The personnel of the Waterways Experiment Station (WES) are conducting an in-house project at Lake Concordia, Louisiana, involving the integrated effects of four biological agents—two insects and two plant pathogens—which have shown promise in affecting the growth and spread of waterhyacinths. This project is being conducted in cooperation with Mr. Neal Spencer and personnel of the U. S. Department of Agriculture (USDA) Biocontrol Laboratory, Gainesville, Florida, and with Drs. Ed Freeman and Ken Conway of the University of Florida Department of Plant Pathology, also at Gainesville. The WES personnel set up the study plots and are providing support in the periodic weighing of the plants and evaluation of the effects of the agents. The USDA and University of Florida people are assisting in evaluating the biological aspects of the agents used.

PURPOSE OF STUDY

The purpose of this study is to determine the relative effects on waterhyacinths of four biological agents alone and in combination. It is hoped that the project will shed some light on the desirability of using an integrated approach for management of waterhyacinths. We should be able to determine from this study whether to proceed with using the subject agents in a large-scale operations management test with the ultimate objective of providing an operational tool for use by agencies concerned.

THE STUDY SITE

The study site is in the upper or eastern end of Lake Concordia. This lake is an oxbow left by the Mississippi River about 30 km west of Natchez, Mississippi, near Ferriday, Louisiana. Covering approximately 405 ha, the lake is surrounded by areas of extensive farming of cotton, corn, and soybeans. The lake is under the jurisdiction of the Louisiana Wildlife and Fisheries Commission, whose permission and generous support I would like to acknowledge. Lake Concordia is one of several oxbow lakes along the western edge of the southern Mississippi River that are used extensively for sportfishing and other recreational activities. Waterhyacinths are rather abundant on the lake and are generally kept in control, at least around the docks and fishing areas, by 2,4-D spraying by the Louisiana Wildlife and Fisheries Commission.

SITE SETUP

The plots used in this study are the same 2- by 2-m aluminum ones that were used in the program we

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conducted on evaluation of the CO_2 laser for control of waterhyacinths. (This program is described in an earlier report.*) The plots are constructed of 4-in. aluminum pipe welded together in a square. Each plot has upright aluminum rods for supporting an 18-in.-high chicken wire fence for containing the plants. A small, nylon-mesh net is attached to the underside of the plots for holding the plants when the plots are lifted out of the water for weighing. The site setup is composed of 64 aluminum plots arranged in eight rows of eight plots each, tied along cables running between available cypress trees. In the early spring of this year, small individual waterhyacinth plants were collected in the near vicinity and placed in each plot. The plants were not counted, but a sufficient number were put in each plot to barely cover the water surface. The plants were allowed to establish themselves and begin normal growth before any treatments were introduced.

TREATMENT OF WATERHYACINTHS

The biological agents used in this study are the waterhyacinth weevil, *Neochetina eichhorniae*; the moth, *Arzama densa*; the fungus, *Cercospora*; and the zonate leaf spot fungus, *Acremonium zonatum*. The treatment design is from Cochran and Cox, Experimental Designs, and is a 2^4 factorial in an 8 by 8 quasi-latin square. The design is such that we have 16 treatment combinations, including the controls, each occurring four times in the experiment, i.e. four replicates of all possible combinations of the four agents plus four controls.

The insects were placed on the plots on 10 June 1975. In the case of the waterhyacinth weevil, 50 adults were placed on each plot that received that treatment; 150 larvae of the *Arzama densa* were placed on each plot to get that treatment. The plant pathogens were placed on appropriate plots on the evenings of 24 and 25 June. The method used to apply these involved growing the fungus in laboratory culture, then mixing the cultures with water, and actually spraying the mixture onto the plots. Each plot to receive these agents received a 15-sec shot of each fungus-water mixture on each of the two evenings.

DATA COLLECTION

The data collection scheme involves principally the weighing of each plot and measuring of plant height at 2-week intervals along with a visual evaluation of each plot by cooperating scientists; the numbers of flowers are also recorded. Color prints (35mm) are made of each plot at each weighing.

The weighing apparatus consists of an aluminum frame attached to two boats, an electronic winch, and a lifting cage. With this setup the operators straddle the plots, lift them out of the water, drain them for 1 min, and then record a gross weight through the use of electronic gadgetry involving a load cell and an automatic counter. Empty plots were weighed at the beginning of the experiment; net weights are obtained by subtracting these from the gross weights of each plot.

In addition to the data collected above, the plots are inspected periodically by visiting entomologists, plant pathologists, and WES personnel, who make their qualitative evaluations of the effect of the various agents on the waterhyacinth plants. This information has not yet been organized and coordinated, so I will limit my comments to the general types of damage that the different agents caused to stress the plants. The Neochetina feeding spots are by now familiar to everyone. The weevil

* K. S. Long and P. A. Smith, "Effects of CO_2 Laser on Water Hyacinth Growth," Aquatic Plant Control Program Technical Report 11, Nov 1975, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

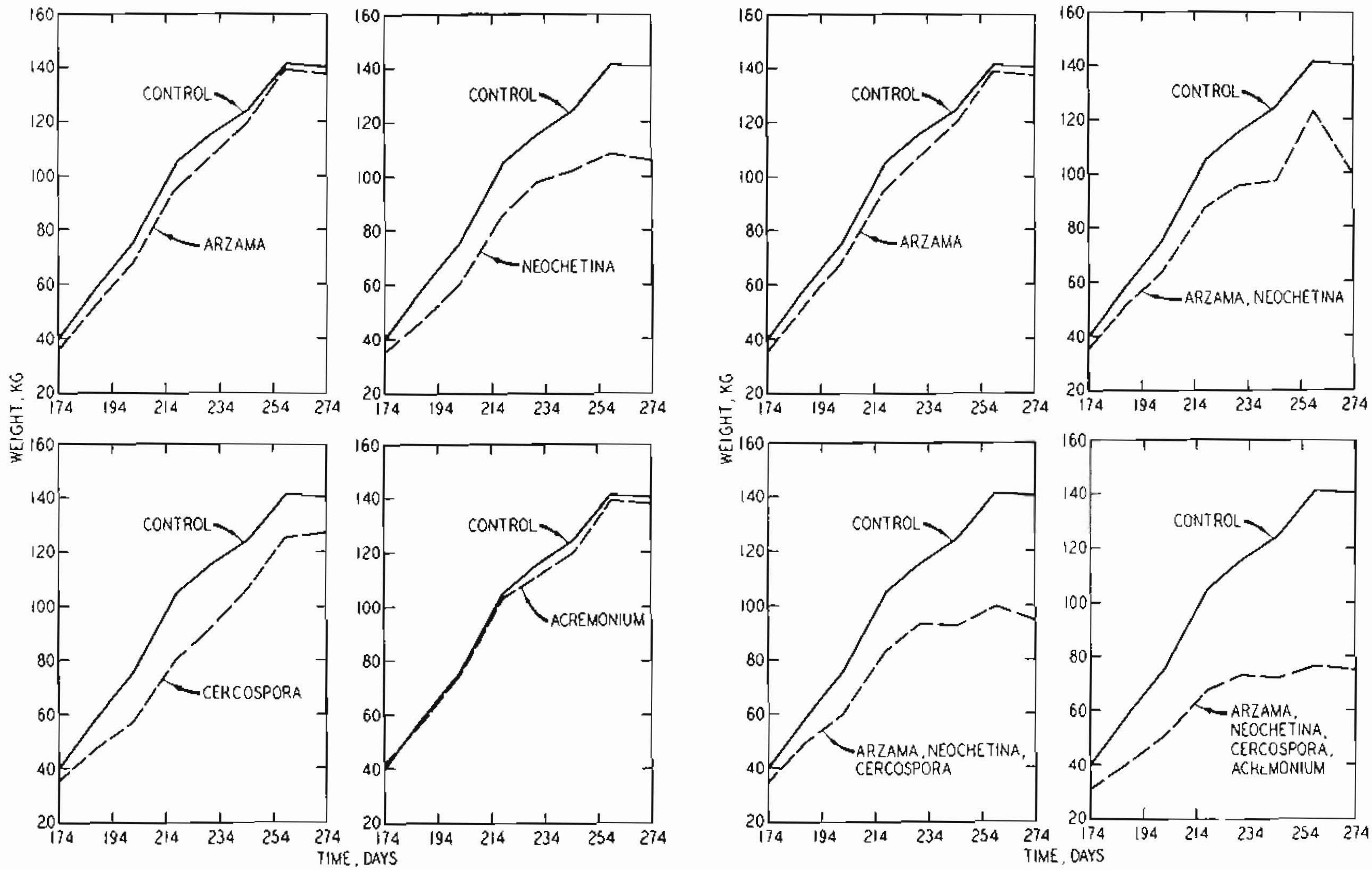
larvae tunnel the leaf petioles and cause damage. The larger Arzama larvae also tunnel the leaf petioles and cause considerable damage. The observed destructive effects are typical of these two plant pathogens.

RESULTS

The data generated in this study have not yet been subjected to critical analysis, but there are trends in the biomass figures which appear significant and which I would like to show. Figure 1a shows graphically the plot weight data versus the separate biological agents, i.e. control and Arzama, control and Neochetina, control and *Cercospora*, and control and *Acremonium*. Note that of the two insects, Neochetina appears to have the greater effect on waterhyacinth growth, and of the two pathogens, *Cercospora* has the greater effect. Figure 1b shows graphs of the control plots versus one, two, three, and four agents, respectively. As mentioned, no statistical analyses have been run, and these particular graphs were chosen simply to make a point of the trends we are seeing in the data. Other combinations could have been used just as well. Note that these data were taken from the actual plots containing the various combination of agents and not derived by adding the data from plots containing the individual agents. It is not known at this time just what that would show. These data show information obtained through 1 October 1975. We are continuing the study through the winter with less frequent field data collections and plot evaluations to determine the effects of frost and freezing on the plants and on the biological agents. Plans are to publish this information by June 1976.

PROBLEMS

As in any field test, it is impossible to have the controls on this experiment that are obtainable in the laboratory. Therefore, we have experienced several problems in this study involving organisms other than the control agents which were introduced. Some cross contamination of the test agents has occurred, but this seems to be minimal. The major problems have been contamination of some of the plots with the spider mite, with a species of spider which is probably a predator of Neochetina, with some fungi other than the test species, and with terrestrial crop insecticides inadvertently sprayed on the plots from airplanes working in nearby fields. It is hoped, however, that with the expertise of workers involved and with the proper experimental design, we can separate the effects of these contaminating factors from the effects of the introduced test organisms.



a. Plot weight data versus separate biological agents

b. Control plots versus one agent, two agents, three agents, and four agents, respectively

Figure 1. Integrated control of waterhyacinths, Lake Concordia, Louisiana, 23 June - 30 September 1975

WATERHYACINTHS—A NUISANCE OR A BENEFIT

by

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Waterhyacinths, *Eichhornia crassipes* (Mart.) Solm., grow profusely throughout the subtropical and tropical regions of the world, obstructing waterways and interfering with navigation, fishing, aquatic recreation, and other uses of waterways. Efforts to control this plant have been difficult because of its phenomenal growth rate.

The characteristics that make the waterhyacinth a nuisance become desirable attributes when the plants are used in a controlled biological system for pollution removal.

The NASA National Space Technology Laboratories, as a result of searching for economical solutions to upgrading the effluent quality of its sewage and chemical waste treatment lagoons, began investigating the potentials of waterhyacinths and other vascular aquatic plants for pollution control.[1-4]

The NASA Vascular Aquatic Plant Program, supported by the NASA Office of Applications, is being conducted at the National Space Technology Laboratories. During the initial phase of this program, successful demonstrations have been carried out in laboratory and field tests using waterhyacinths in controlled waste treatment lagoons for the reduction of total suspended solids and DOD_5 levels and the removal of nutrients and other pollutants from industrial and domestic sewage wastewaters. Waterhyacinth, because of its rapid growth rate (8-16 tons of biomass per acre per day in sewage lagoons), demonstrates a remarkable capacity for absorbing and/or metabolizing or concentrating chemical pollutants. Additionally, plants harvested as part of the controlled biological waste treatment process can be converted to useful products, such as animal feed, methane gas, fertilizer, and other raw materials. Animal feed and fertilizer can be produced from plants grown in domestic sewage free of toxic heavy metals, while methane gas can be produced from plants grown in any type of chemical or sewage wastewaters.

As part of the pollution removal process of waterhyacinth waste treatment systems, a program of periodic harvesting and disposal of plant material is necessary to optimize the pollution removal process. The harvested plants possess valuable protein, nutrients, and other minerals that can be recycled.

Freshly harvested waterhyacinths contain approximately 95 percent water by weight. Economical transportation and utilization of the harvested plants in the form of waterhyacinth meal for animal feed, organic fertilizer, and soil conditioner, etc., require reduction of the moisture content to suitable levels. Mechanical dewatering is undesirable because large amounts of the nutrients are lost when the juices are pressed out of the plant. A drying process that evaporates the moisture down to approximately 5 percent moisture content leaves a quality product that can be ground and stored with no deterioration of the waterhyacinth meal. To accomplish drying, large quantities of thermal energy must be used to evaporate the excess moisture content of the plants. Since drying cannot be economically accomplished using conventional drying equipment, a specialized solar drying system was designed specifically for waterhyacinths. This system will be placed into operation during April-May 1976.

Waterhyacinths, when grown in nutrient-rich sewage, were found to contain from 20 to 25 percent

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crude protein during peak growth periods. Results from animal feed experiments conducted with sewage-grown waterhyacinths demonstrated that dried water hyacinth meal can be used as a preformed protein and mineral supplement in beef cattle feed.

When waterhyacinths are grown in warm enriched sewage, their growth rate (8-16 tons per acre per day) cannot be matched by any other known plant. The massive quantities of waterhyacinths that can be produced while cleaning up sewage can also be converted to methane through bioconversion. NASA studies have demonstrated the potential of waterhyacinths to produce sufficient biomass to generate from 3500 to 7000 ft^3 of methane while producing over 0.5 tons of fertilizer per acre per day from the bioconversion process.[5]

The ability of waterhyacinth and other vascular aquatic plants to absorb and concentrate traces of heavy metals at a predictable rate demonstrates the potential applications of these plants in continuous biological heavy metal monitoring systems.[6-8] These plants also have potential utilization as safety filters and leak detectors in continuous monitoring of radioactive substances in nuclear power plant thermal effluents.

REFERENCES

1. Wolverton, B. C., "Waterhyacinths for Removal of Phenols from Polluted Waters," NASA Technical Memorandum TM-X-72722, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.
2. Wolverton, B. C., McDonald, R. C., and Gordon, J., "Waterhyacinths and Alligatorweeds for Final Filtration of Sewage," NASA Technical Memorandum TM-X-72724, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.
3. Wolverton, B. C., Barlow, R. M., and McDonald, R. C., "Application of Vascular Aquatic Plants for Pollution Removal, Energy and Food Production in a Biological System," NASA Technical Memorandum TM-X-72726, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.
4. Wolverton, B. C. and McDonald, R. C., "Waterhyacinths for Upgrading Sewage Lagoons to meet Advanced Wastewater Treatment Standards, Part 1," NASA Technical Memorandum TM-X-72729, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.
5. Wolverton, B. C., McDonald, R. C., and Gordon, J., "Bioconversion of Waterhyacinths into Methane Gas, Part 1," NASA Technical Memorandum TM-72725, 1975 National Space Technology Laboratories, Bay St. Louis, Miss.
6. Wolverton, B. C., "Waterhyacinths for Removal of Cadmium and Nickel from Polluted Waters," NASA Technical Memorandum TM-X-72721, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.
7. Wolverton, B. C. and McDonald, R. C., "Waterhyacinths and Alligatorweeds for Removal of Lead and Mercury from Polluted Waters," NASA Technical Memorandum TM-X-72723, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.
8. Wolverton, B. C. and McDonald, R. C., "Waterhyacinths and Alligatorweeds for Removal of Silver, Cobalt, and Strontium from Polluted Waters," NASA Technical Memorandum TM-X-72727, 1975, National Space Technology Laboratories, Bay St. Louis, Miss.

LARGE-SCALE FIELD TEST WITH THE MONOSEX WHITE AMUR IN FLORIDA

by

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During the recent redirection of the Corps' Aquatic Plant Control Research Program, it was felt that past and present research efforts should be critically viewed in the light of the new program approach. In short, we were striving to answer the question: What research, if any, has matured to the point that it could be tested on a large scale? Why such a test? To collect the data required to assess the feasibility of using a control agent on an operational scale. Why a large scale? So that the results might be confidently extrapolated to the operational scale when supplemented by deterministic model predictions.

On 19 February 1975, a meeting was held at the Waterways Experiment Station to review past research in an effort to determine the most promising results in terms of operational potential. Representatives of the South Atlantic Division (SAD), Jacksonville District, OCE, U. S. Fish and Wildlife Service, U. S. Department of Agriculture, and others were present. As a result of this meeting, the consensus was that the white amur fish presented the most potential for large-scale testing. The considerations which resulted in our choice of this particular biocontrol agent are worth mentioning.

First, we biased our research so that primary consideration was given to biological control agents. It is our belief that proper biological control offers the most promising long-term permanent solution to many of our Nation's aquatic plant problems. No doubt, chemical control will always be used to some degree. Although chemicals are presently the only predictable low-priced method of aquatic plant control, they are at best only a temporary solution. We view their use as a method of maintaining control until the use of biological or integrated techniques are perfected and operational. Thus, in the future, the use of chemicals would hopefully be minimal.

Second, the white amur presented the most potential in terms of predictability. Our approach was to determine the scope of an effort needed to assess the environmental impact of its use and once assessed, to judge whether or not the fish should be used as a weed control tool, and if so, on what scale. If after the collection of the necessary data and the analysis of the modeling results, the conclusions indicate that the fish should not be used, then the issue will be laid to rest.

Third, research funded through the Fish and Wildlife Service's Fish Farming Experiment Station at Stuttgart, Arkansas, had resulted in the development of a technique for spawning a monosex population of white amur. A by-product of this research was approximately 35,000 monosex white amur. We felt that by using the monosex population, the risk of reproduction would be greatly minimized—not eliminated—only minimized. For, while these fish are all females, they are reproductively functional and able to reproduce.

As a result of this meeting, we decided to present the general concept of such a test to interested agency representatives in Florida. Florida was chosen for several reasons.

First, Florida has the most intense continual aquatic plant problems. Because of this, Florida state

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agencies devote more resources to research on aquatic plant problems than do agencies of other states. This was felt to be an advantage because of the possible benefits to be derived from this technology base. Second, Florida and the Corps' Jacksonville District have a rapidly spreading problem with the submerged aquatic plant hydrilla. This species, unchecked, could well replace the waterhyacinth as the number one aquatic plant pest in the southeastern United States. Third, the white amur, through small pond studies in Florida, had been proven effective in controlling hydrilla. On 20-21 May 1975, a meeting was held in Jacksonville, Florida, to discuss the concept.

In the presentation of the concept, it was proposed that before anyone could pass judgment on the white amur as an environmentally compatible, operationally effective weed control tool, at least the following questions must be addressed.

a. What questions need to be answered to assess the feasibility of using the white amur?

b. What type of relations, both environmental and operational, would be necessary to answer these questions?

c. What type of data would have to be collected to generate the relations?

d. How do we design a comprehensive test, including field data collection, to provide these data?

In response to question *a* above, we suggested that the following were good examples of questions that need to be answered.

a. What is the effect of the white amur on hydrilla?

(1) How do we measure the effect?

(2) Does the hydrilla population stabilize?

(3) How do we determine the proper stocking rate of white amur to maintain the desired hydrilla population level?

(4) How do we maintain a sufficient stocking rate for this stabilization?

b. What is the effect of white amur on the ecology of the lake?

(1) Water quality.

(2) Game fish.

(3) Aquatic macrophytes.

(4) Zooplankton and phytoplankton.

(5) Benthos organisms.

c. What happens to the white amur with time?

(1) Numbers.

(2) Size.

(3) Biomass.

(4) Dietary habits.

d. What are the operational requirements for using white amur for aquatic plant management?

(1) Spawning and raising white amur.

(2) Constraints on introduction—environmental, political, climatic.

(3) Factor or factors that should be monitored so operators will know what they must do to maintain the system.

(4) Restocking time interval and numbers for maintaining sufficient stocking rate.

(5) Long-range data collection requirements.

e. What waters of the SAD (for instance) are amenable to plant control using the white amur?

As an example of some of the types of relations that might be generated as a basis for answering these questions, those shown in Figures 1-6 were hypothesized.

Initial criteria for a test site were proposed and discussed. Generally, these first criteria were:

a. Between 1000 and 5000 acres.

b. Significant areas at various depths, ranging from 30 cm to at least 5 m (to determine the depth constraints, if any, of the hydrilla-amur interaction).

c. At least one inlet with a permanent stream discharging into it (to determine effects, if any, of temperature variations on habits on the white amur).

d. A significant and stable population of game fish (i.e. maintained without periodic restocking).

e. An assemblage of the common aquatic plants.

f. Fairly high use rate of water-oriented recreation (to determine the reactions and response of the surrounding community).

The balance of this meeting was devoted to discussions pertaining to the identification of data to be collected as well as possible sites. As a result of this meeting, an agreement was reached that such a project was needed if the present concerns over the possible effects of the white amur's presence are to be answered.

In late May 1975, a meeting was held with Dr. Earle Frye, Director of the Florida Game and Freshwater Fish Commission (FG&FWFC), and COL Emmett Lee, then District Engineer, Jacksonville District, to discuss the proposed test concept. Dr. Frye informed us that the decision as to whether or not a lake could be stocked for the test would have to be made by the FG&FWF Commissioners. The concept of the test was presented at the June Commissioners' meeting. The Commission recommended that a presentation of the proposed test and stocking be placed on the agenda for its July meeting, at which time they could legally rule on the stocking. They also suggested that we meet with the FG&FWFC staff members and recommend a test site during the July meeting. Subsequently, we met several times with Mr. John Woods, Chief, Fisheries Division, and his staff; the Lake Conway, Little Lake Conway, Lake Gatlin chain near Orlando, Florida, was selected for the test (Figure 7). This three-lake chain (Figure 8) consisting of five distinct lakes totals 1820 acres. Depths in the lake system range up to 35 ft. The perimeter is almost completely developed, and the lake is used extensively for recreation. In July, the site proposal and test concept were presented to the Commissioners, and they ruled unanimously to permit the stocking and directed Dr. Frye to transmit a letter granting permission. This letter was issued on 4 September 1975.

Subsequently, the test design was begun. Several meetings were held with potential contractors to determine the level of detail and scope for the data collection phase of the program. From these meetings, a list of data to be collected and the frequency of the collection were identified in Table 1.

A data collection referencing system consisting of transects and submerged buoys has been established (Figure 9). A draft of the test plan has been written, including a security plan for the lake system. The lake system was evaluated for potential escape routes, and fish barriers were designed to be constructed prior to the stocking. Drawings of these barriers are shown in Figures 10-12.

Basically, the overall test is designed to:

a. Establish relations pertaining to the response of the various parts of the aquatic ecosystem to the presence of the white amur.

b. Provide the capability to extrapolate the results of this test to other aquatic ecosystems in a meaningful way.

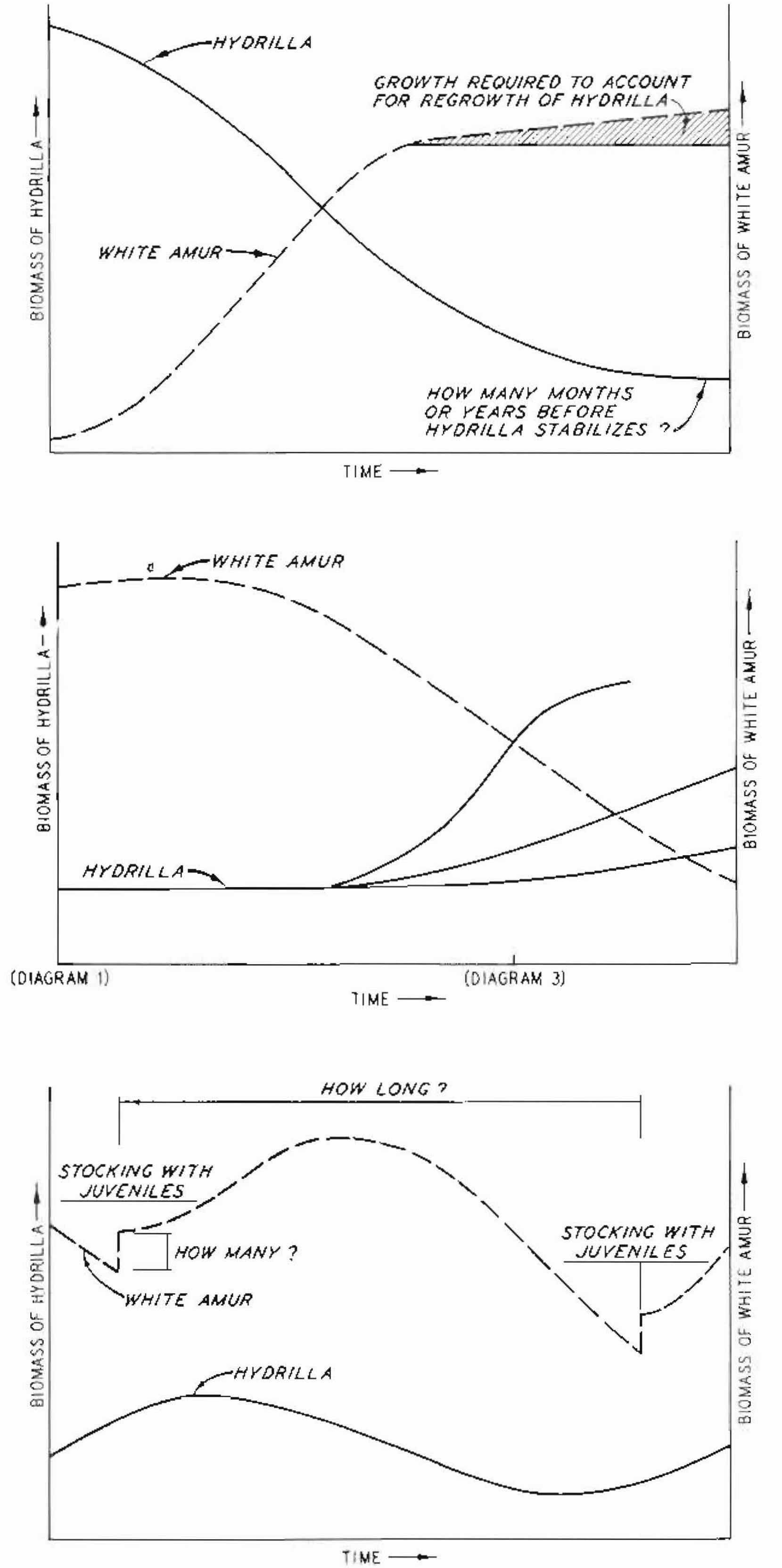

Figure 1. Hypothesized relationship for biomass of hydrilla and white amur with time

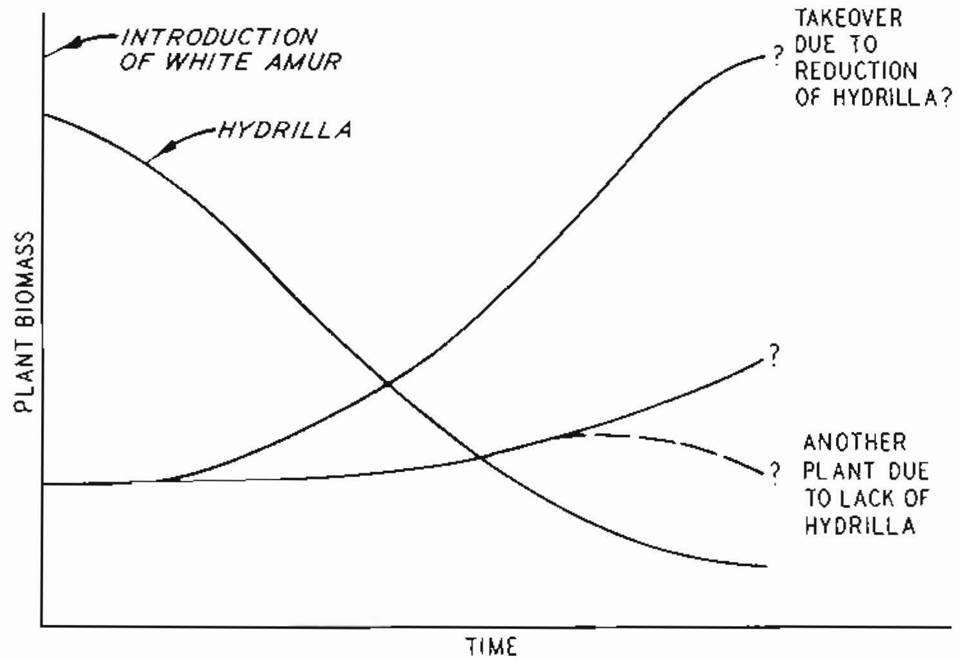

Figure 2. Hypothesized relationship of biomass of hydrilla and other plants with time

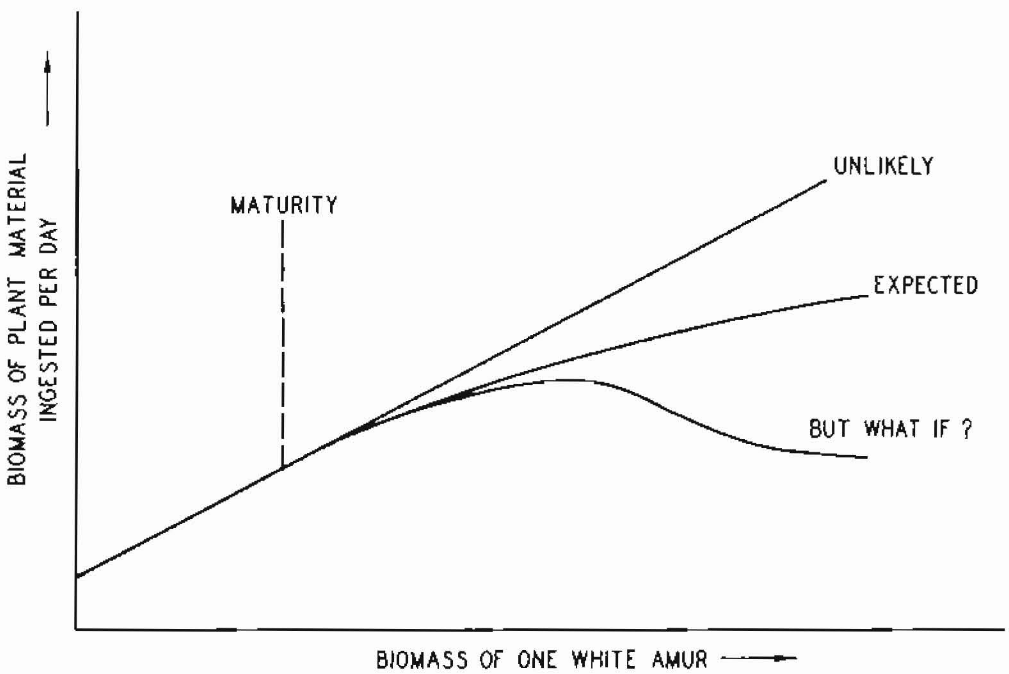

Figure 3. Hypothesized biomass of one white amur ingesting hydrilla

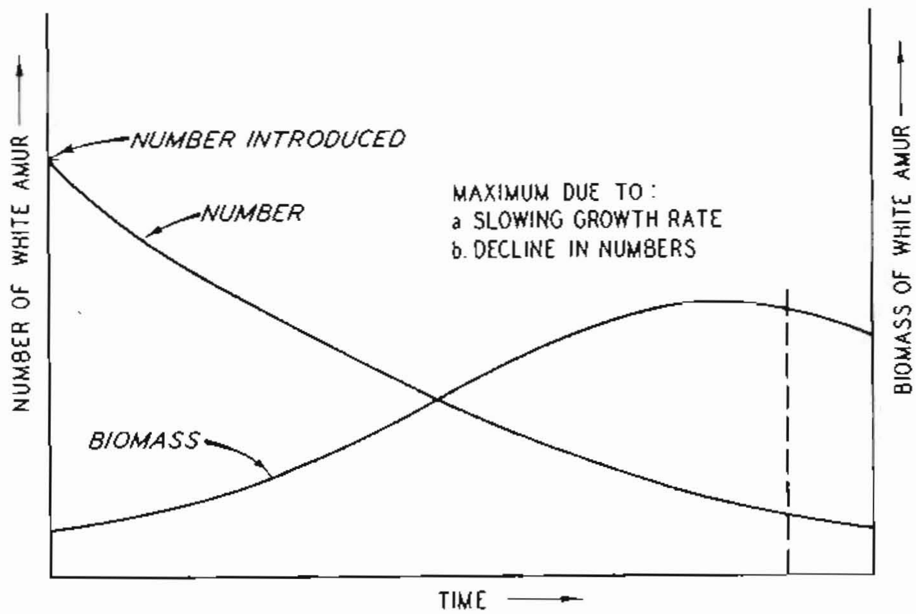

Figure 4. Hypothesized numbers of white amur with time

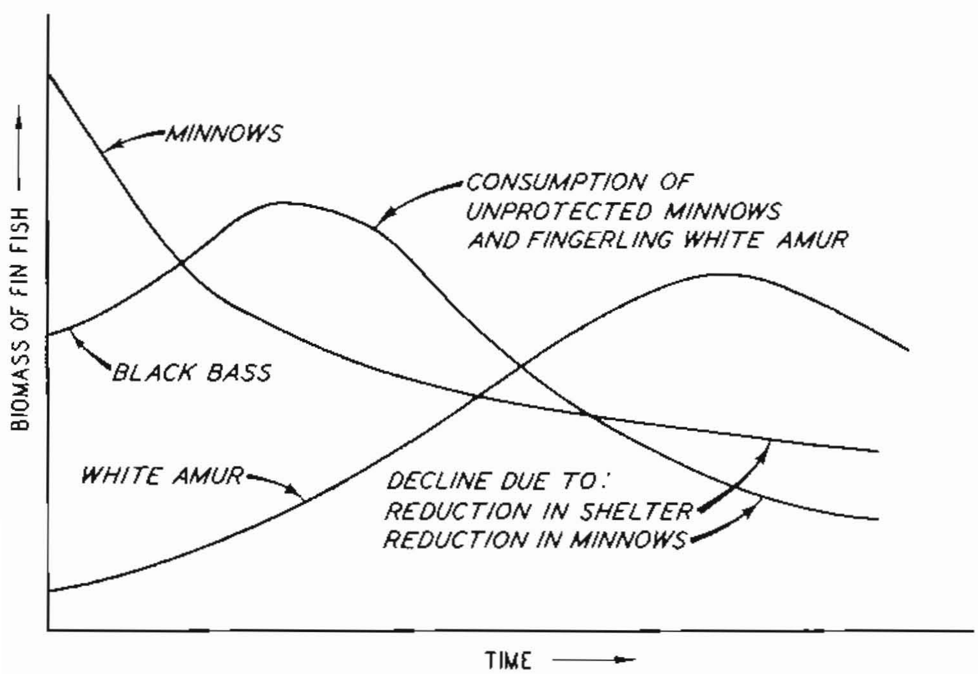

Figure 5. Hypothesized biomass of all fish with time

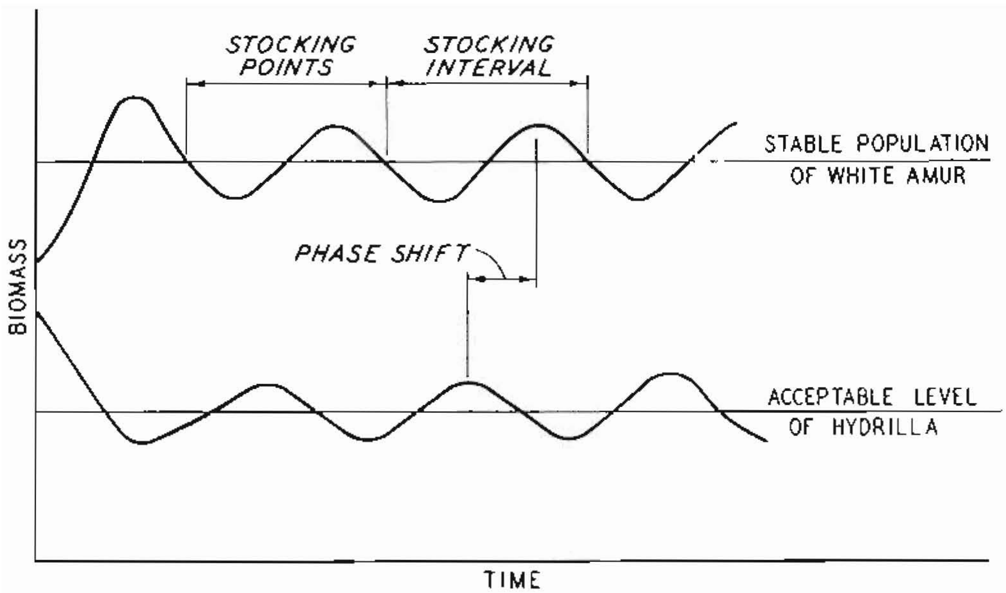

Figure 6. Hypothesized cyclic relationship of white amur and hydrilla biomass with time

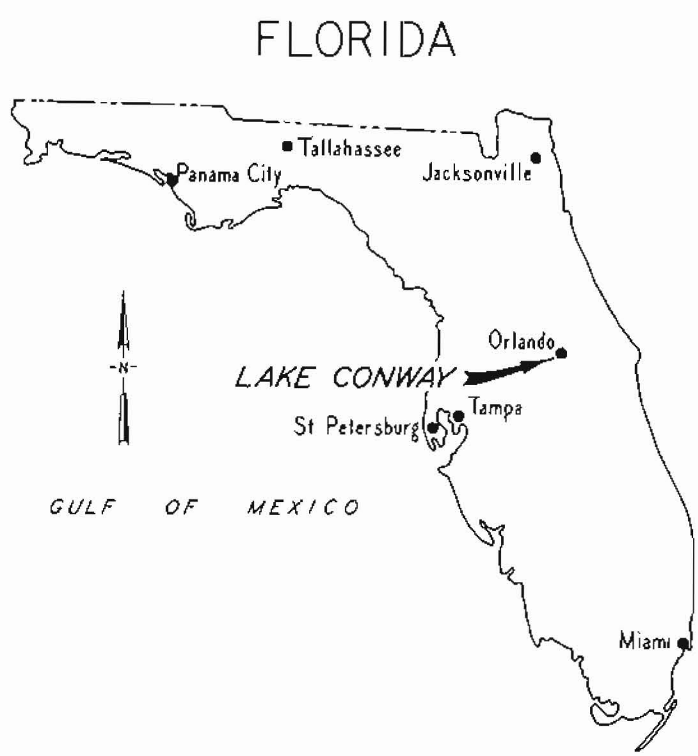

Figure 7. Vicinity map of Lake Conway area

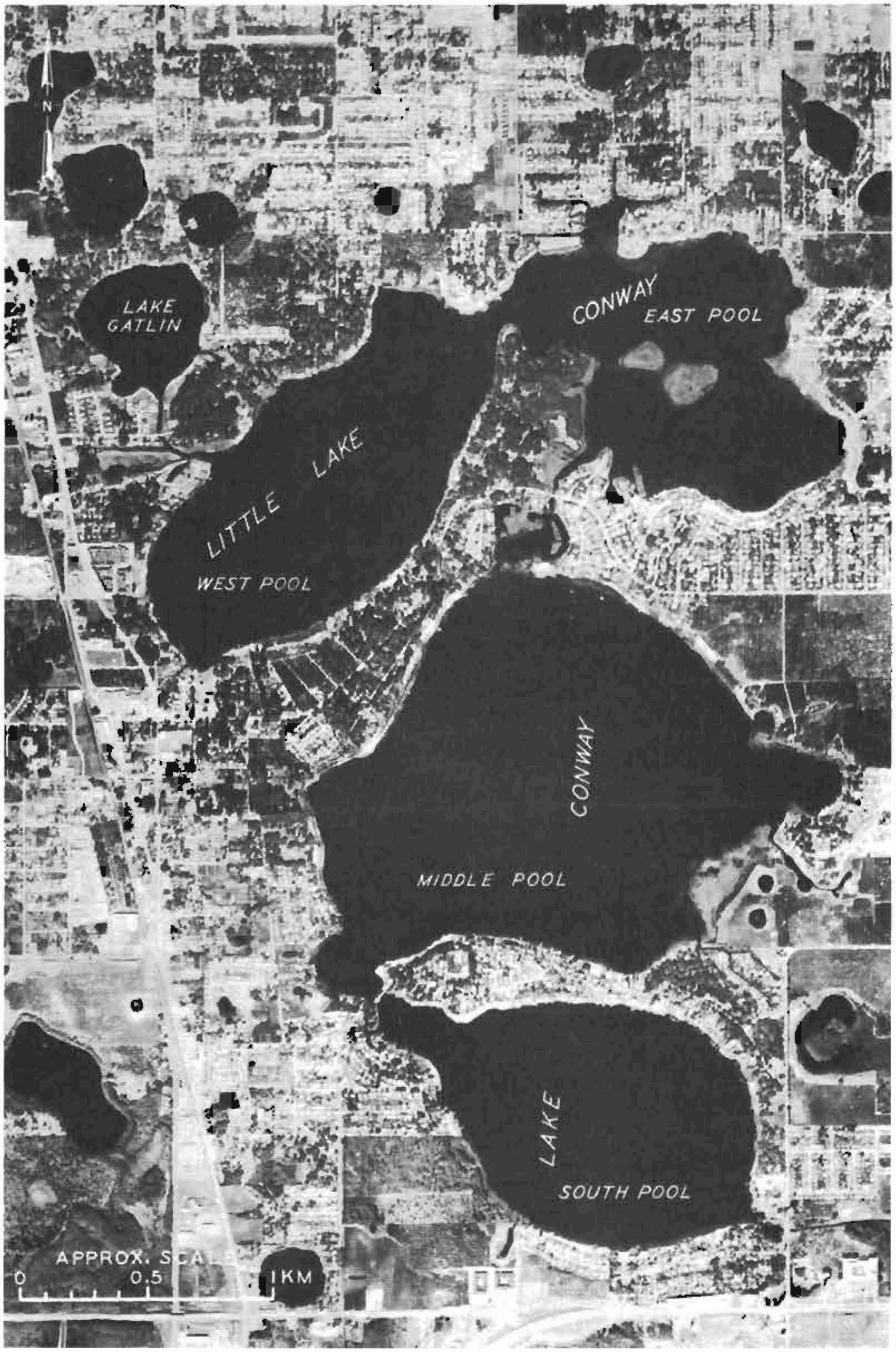

Figure 8. A aerial mosaic of Lake Conway System

Table 1

Summary of Data Collection Program for Large-Scale Operations Management Test—White Amur

Work Unit	Factor No.	Family Name	Sampling Factor Name	Interval	Data Source, Comments
A	1	System usage and values	Fishing	--	Fish and game agencies
			Hunting	--	Fish and game agencies
			Recreation: swimming, boating, skiing, (others)	--	Park and recreation agencies
			Aesthetic	--	Park and recreation agencies, public hearings
			Commerce (transport)	--	Chambers of commerce, transporation agencies
			Consumption: domestic, manufacturing, irrigation, livestock	--	Chambers of commerce, public utilities, agricultural sciences
			Beach and shore	--	Chambers of commerce, parks and recreation agencies
	2	General system qualities (hydrography)	Geographic location	--	Maps
			Perimeter description	--	Maps, on-site inspection
			Bottom topography	--	Maps, on-site inspection survey
			Beach and shore topography	--	Maps, on-site inspection, survey
			Water elevation (seasonal variation)	--	Maps, on-site, literature, records
			Water inflow and circulation	--	Maps, on-site survey
			Shore vegetation	--	On-site inspection
			History (as deemed relevant)	--	Literature, interview, records search
	3	General site qualities (basin)	Backshore topography	--	Maps, on-site, survey
			Backshore land use	--	Maps, on-site, survey
			Drainage basin: general climate, general topography, general hydrography, geology, soils, land use management practices (nutrient sources) (sediment sources), urban/industrial functions, history (as deemed relevant)	--	Maps, on-site inspection, survey, literature and records, interview
B	4	Meteorology	Wind speed	*	Continuous or periodic recorders, not less than about twelve readings per 24-hr cycle, all factors
			Wind direction	*	↓
			Air temperature	*	↓
			Relative humidity	*	↓
			Solar radiation	*	↓
			(Reflected radiation)	*	↓
C	5	Water quality	Turbidity	Mo	Secchi disk on-site and lab sample on-site, or
			Temperature	*	Monthly continuous recording, various depth intervals
			Conductivity	*	Monthly bulk sample, or continuous on-site recording

(Continued)

* Sampling frequency to be determined.

Table I (Concluded)

Work Unit	Factor No.	Family Name	Sampling Factor Name	Interval	Data Source, Comments
C	5	Water quality	pH	*	Monthly bulk sample, or continuous on-site recording
			Transmissivity	*	
			Dissolved oxygen	*	
			Color	*	
			Total phosphorus	Mo	Lab analysis of bulk water sample
			Ortho-phosphate	Mo	
			Total organic nitrogen	Mo	
			Nitrate-nitrite	Mo	
			Ammonia	Mo	
			Hydrogen sulfide	Mo	
			Calcium (Ca Co_2-HCO)	Mo	
			Chlorophylls (A)	Mo	
			Phaeopigments	Mo	
			Heavy metals	Mo	
			Pesticide residues	Mo	
			Total suspended solids	Mo	
	6	Sediment quality	Total phosphorous	Bi	Lab analysis of bulk sediment sample
			Ortho-phosphate	Bi	
			Total organic nitrogen	Bi	
			Nitrate-nitrite	Bi	
			Ammonia	Bi	
			Total organic (combustible)	Bi	
			Sediment particle size	Bi	Soil screen
D	7	Zooplankton	Count, by spp or life form	Mo	Bulk samples; net or screen samples
	8	Phytoplankton		Mo	Bulk samples; net or screen samples
	9	Benthos		Bi	Bulk samples; net or screen samples on-site survey for crustaceans, amphibians, etc.
	10	Periphyton		Mo	Inspection of plants and other fixed underwater surfaces
E	11	Fish	By species:		
			abundance	Mo	Field observation, capture
			size distribution	Qt	
			sex distribution	Qt	
			spatial/areal distribution	Mo	
			feeding activity	Mo	
			food habit	Mo	Observation, stomach analysis
			reproductive activity	Mo	Observation, examination
			(other behavior)	*	(as appropriate)
F	12	Aquatic mammals (and related types)	By species		
			population density	Mo	Observation, trapping, tagging
			area distribution	Mo	
			age distribution	Mo	
			sex distribution	Mo	
			habitat preference	Mo	
			food preference	Mo	Observation, stomach analysis
			feeding activity	Mo	Observation
			reproductive activity	Mo	Observation, examination
	13	Waterfowl, birds	By species: (as for mammals)	Mo	(As for mammals)
G	14	Aquatic vascular plants	Height profile	Mo	Profilometer, fathometer, meter stick
			Area coverage	Mo	Compass and tape survey
			Biomass, species	Mo	Bulk volume at specified depths
			Species composition	Mo	Taxonomic survey } voucher specimens
			Phenology	Mo	Visual observation } voucher specimens

* Sampling frequency to be determined.

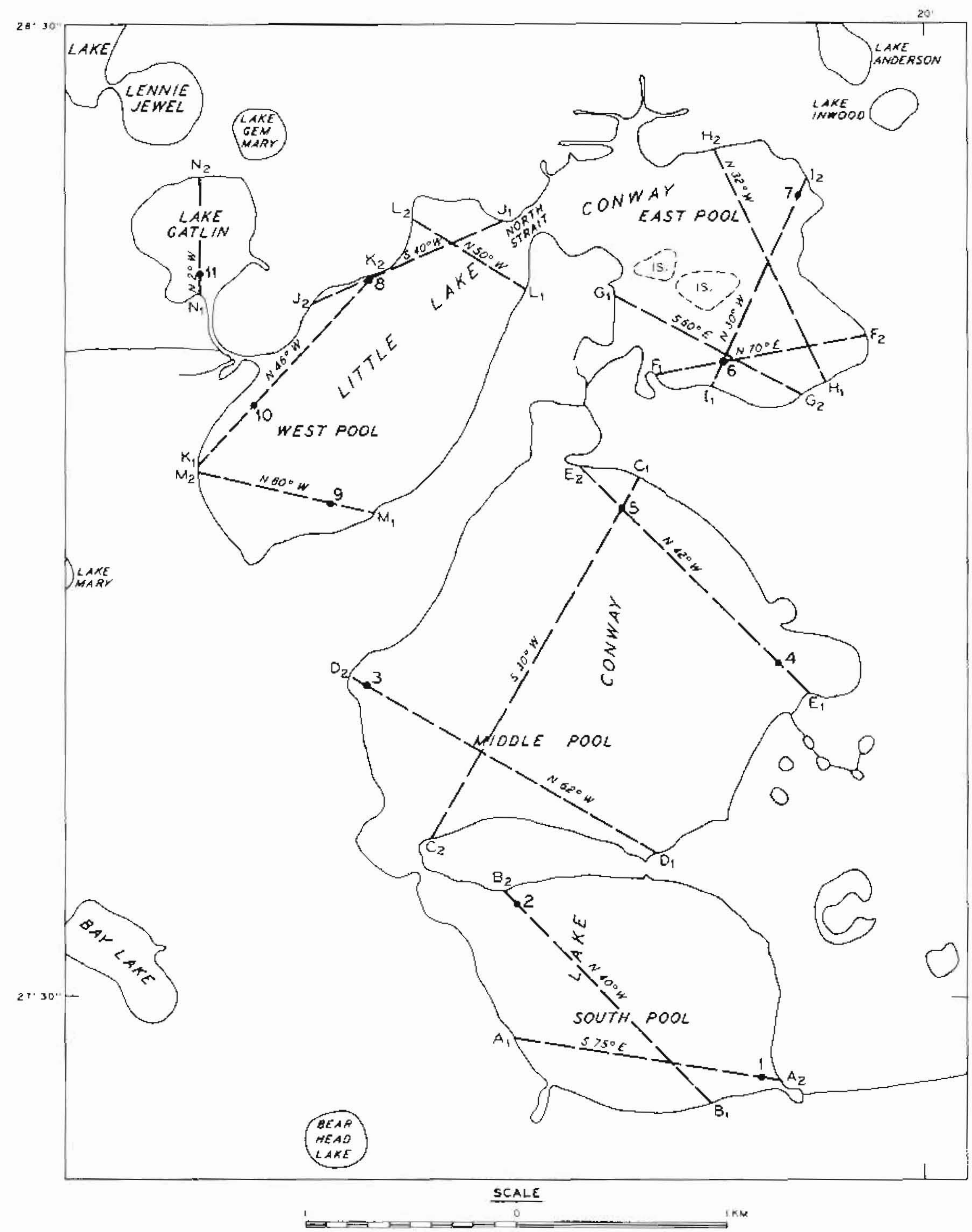

Figure 9. Diagram of Lake Conway System showing transects and sampling points for data collection

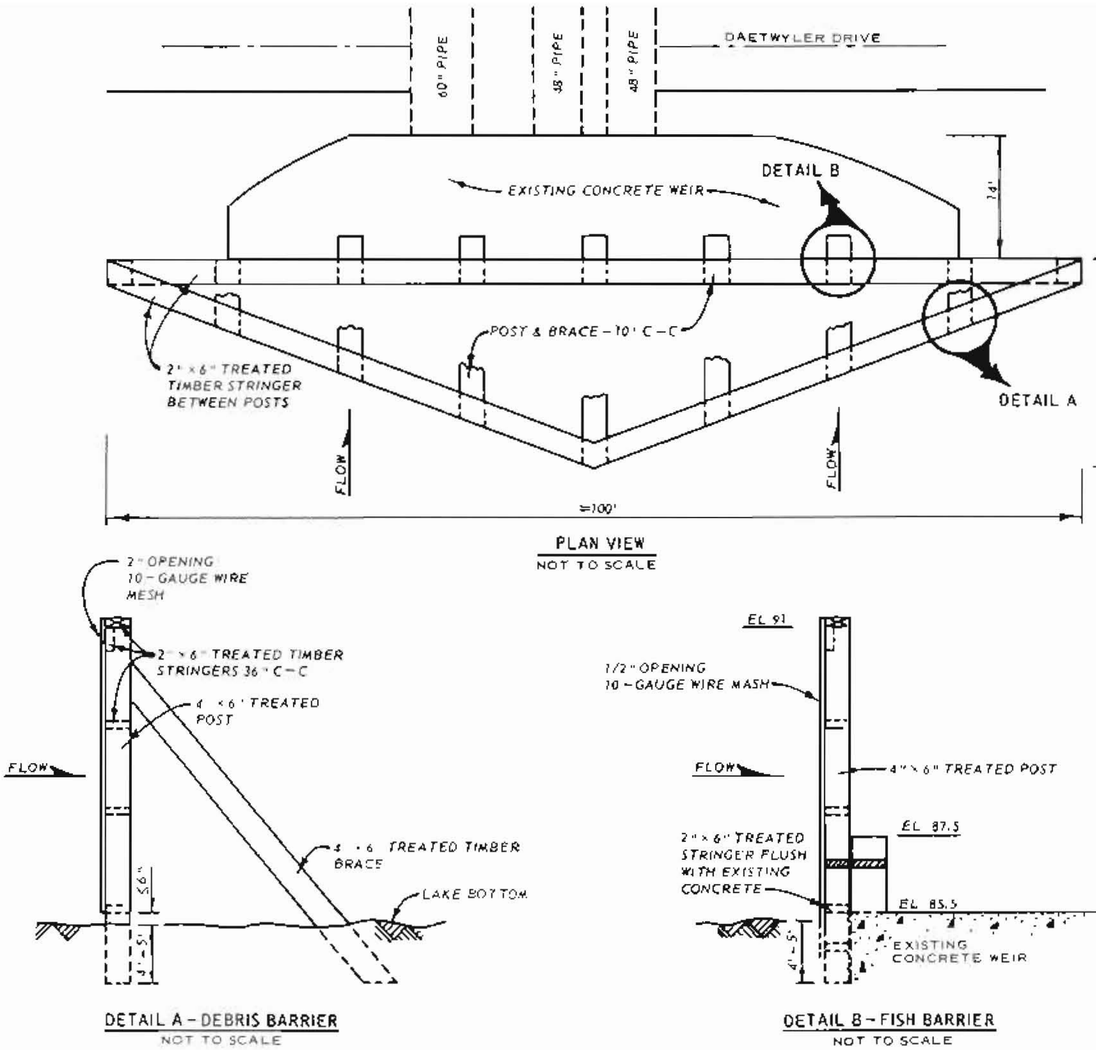

Figure 10. Barrier control structure—outlet control structure, location 1

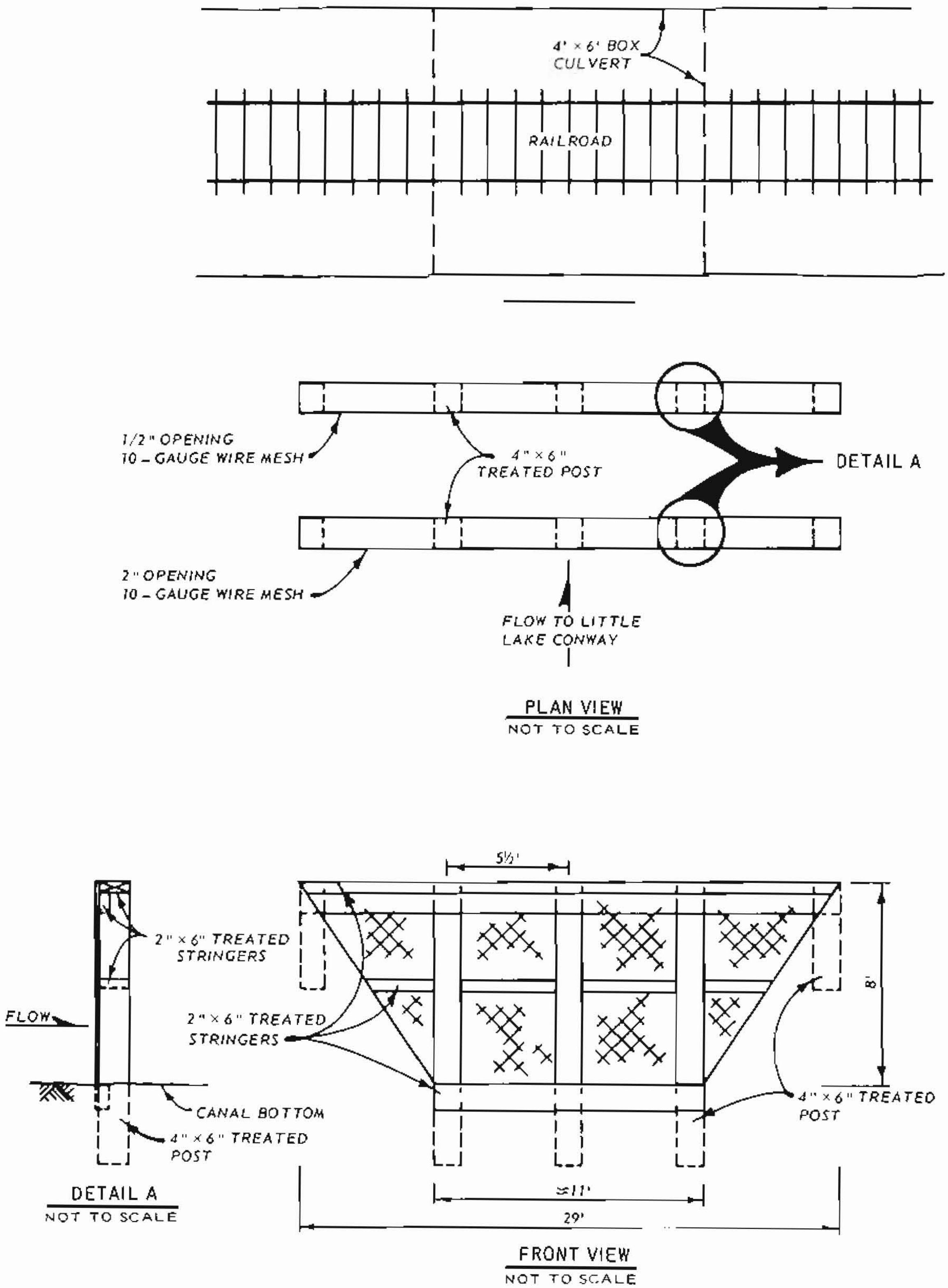

Figure 11. Barrier system—inlet canal from Lake Jessamine, location 2

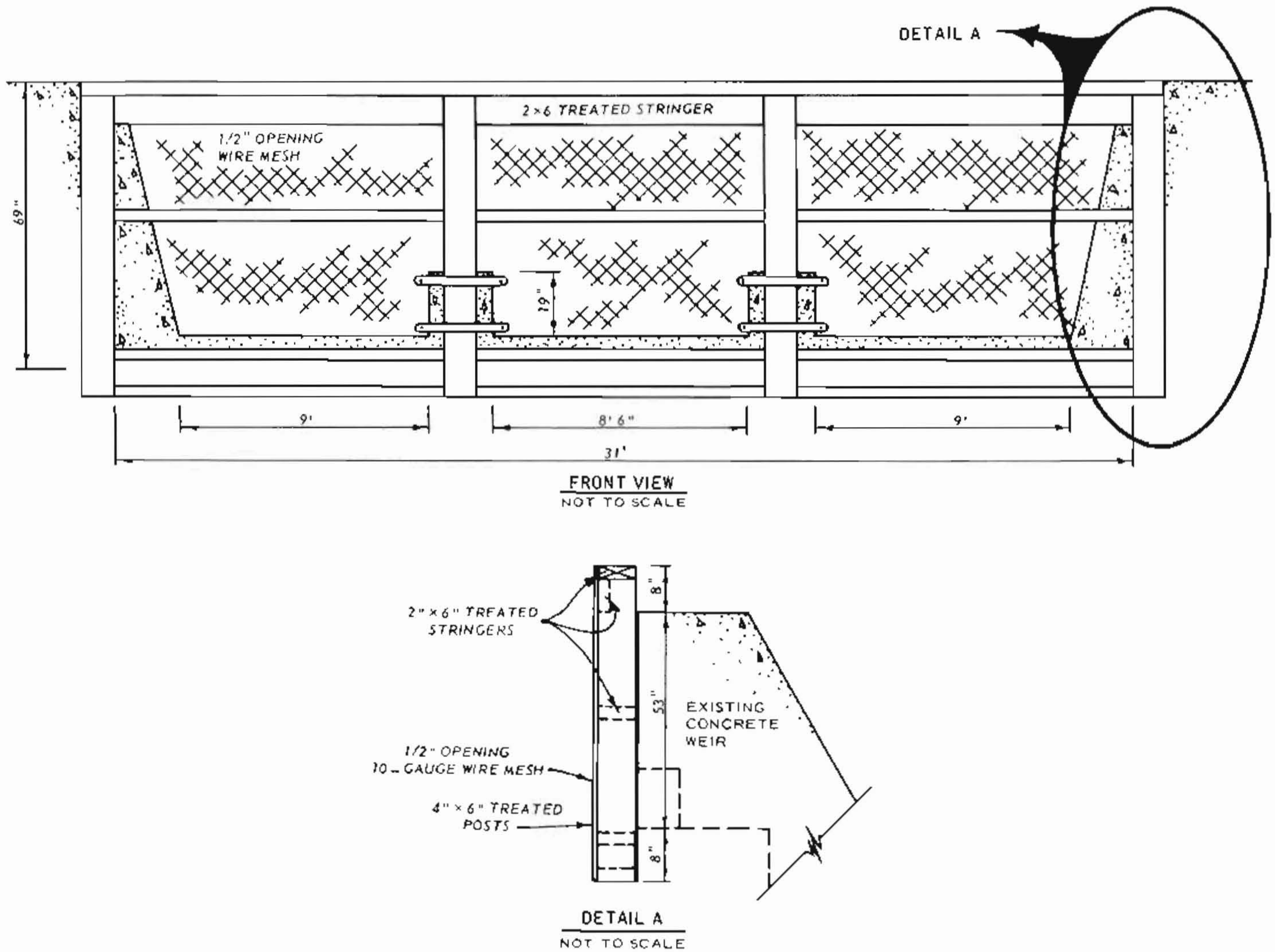

Figure 12. Barrier system—Lake Mare Prairie, location 3

c. Furnish a basis for determining the feasibility of using the white amur on an operational scale, through a better understanding of the response of the ecosystem to the amur's presence.

At the present time, three significant milestones have been scheduled as follows: baseline data collection—January 1976-March 1977; stocking of white amur—Spring 1977; and continuous monitoring of data groups—Spring 1977-1980.

An integral part of the overall test is the modeling effort. At present, the following three major models are under various stages of development.

a. White amur stocking model.

b. Ecosystem response model.

c. Operations model.

I would like to mention each of these briefly.

The stocking model is intended to provide the capability for determining, on a rational basis, the size and number of white amur to be stocked for a given identified problem area when given specified environmental parameters.

The ecosystem response model is structured to provide a means of simulating the response of the aquatic ecosystem through the modeling of the interactions existing among these components.

The operations model is intended to provide the user with a method of specifying a problem condition or assumed projected conditions and of obtaining the identification of realistic equipment-agent-technique solutions that are cost-effective within the user's resource constraints. Given these solutions, the user could choose the most acceptable and then use his selection as the resource base for structuring a management plan for operations activities.

All of these models are deterministic. They are intended to display responses for a given specified set of conditions. The majority of the relations within the models are based on presently available data. However, an adequate amount of data is not available. These missing data identify gaps in the technology base. Laboratory studies or measurements are being planned or are being initiated to collect these needed data.

At the present time three significant milestones have been scheduled (Figure 13). The stocking size and numbers of fish to be used for the Conway test will be determined through the use of the stocking model and the ecosystem response model. After stocking the lakes, the subsequent data monitored will be compared with the predicted response curves. The model will be continually updated with the use of these data. An extensive sensitivity analysis has been conducted and will periodically be reconducted so that system responses measured during the test can be explained with respect to the basic relations or their interactions. Once validated, the model with the knowledge of the sensitivity to environmental ranges should provide a useful tool for management. Coupled with the ecosystem model predictions, management decisions will thus be based on consideration of possible ecosystem responses.

MILESTONES

BASELINE DATA COLLECTION — JAN 76-SPRING 77
STOCKING OF WHITE AMUR — SPRING 77
CONTINUE MONITORING OF DATA GROUPS — SPRING 77-1980

Figure 13. Milestones for large-scale operations management test with the white amur

WRAP-UP COMMENTS

by

W. G. Shockley*

Like Justin Wilson—I "garantee," I have learned more than I wanted to know about a lot of things. I learned what "bot boudin" is. I learned that you can compress learning, training, and certification into an "instant expert" process. I learned that you can put pesticide in contact lenses—is this to get those pink elephants that you see some mornings?

Seriously though, a lot of *good basic* research is being done, but there is much more to do. As Neal Spencer said, "We can control some of the weeds, at some of the places, some of the time, but we cannot control all of the weeds, at all of the places, all of the time." There is plenty of room for a variety of treatment methods to be used in aquatic plant control.

One of the big problems is technology transfer. You can have all the good research in the world, but it is useless unless you can translate this into terms that a technician in a boat can understand and use. As Lewis Decell said, "The Corps of Engineers is trying to fight a bear with a switch."

In the field of agriculture, one of the best ways to get a farmer to adopt new practices, or chemicals, or what have you, is to set up a demonstration so that he can see with his own eyes the effects of the new ideas. We hope to do the same in the field of aquatic plant control through the use of large-scale demonstration projects such as the one we are starting at Lake Conway. We hope that there will be more like it in years to come.

It also seems evident that future research should be conducted in a variety of areas, but more emphasis needs to be placed on translating the research results into operational practices so the man in the field can select the right method and the right tool for his particular problem.

This meeting has been an interesting one and very rewarding. I hope to see you all again this time next year.

* Chief, Mobility and Environmental Systems Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

CRITIQUE

by

J. E. Gallagher*

One can use the current cliché "you've come a long way baby" with reasonable accuracy in evaluating the current Corps meeting. The Corps is very much involved in aquatic weed control research and this 10th year of annual reports shows that a lot of long-range progressive thinking has gone into its research planning.

This planning has shown the Corps able to be flexible in its support of research programs as well as in its operational policy. These are flattering words but well deserved. I am sure that the science of aquatic weed control would not have been able to show progress without the financial support of the Corps over the past 10 yr.

The section on biological weed control is showing signs of maturity and reality. Neal Spencer's comment that "biological weed control can be effective in some places some of the time, but not in all places all of the time," puts this control agent in true perspective in terms of what must come—an integrated plant management control program. The fact that the program is continuing and expanding to include the use of pathogens as well as insects is encouraging. Finally, the survey work of Mr. Vogt indicates the validity of going back in the past to look for solutions of the future.

The awareness of the present was shown by the inclusion of the discussions of state certification programs. The Corps' operational unit will have to be closely tied into state certification for smooth operation. The continuing evaluations of local and regional problem status, as reported on by Lee, Guerra, and others, help keep the real world in focus. No matter how far out the research program may reach, the prime objective is to help the man in the field. The man up to his waist in the morass of aquatic vegetation needs every bit of help he can get, and I am sure that he appreciates having the Environmental Protection Agency (EPA) representative show a better understanding of his needs.

The promises of the future, as evidenced in the work reported by National Aeronautics and Space Administration (NASA), the remote sensing project headed up by L. E. Link, and the aquatic ecosystem model being developed by Dr. Ewel, should ultimately make operational programs easier. The conversion of a problem to a resource will certainly justify management programs using all control methods if it can be shown just how much impact those methods have in the environment.

Perhaps the most encouraging part of the conference had to be the section pertaining to the Corps' image building. I have felt that the low-key concept was not an effective way of getting the job done. The public has to become aware of the good that the Corps does; now that you plan to make the general public aware of how and why you activate programs, I believe that you will find far more support for your programs.

Furthermore, the utilization of relatively complete ecosystem, as in the case of the Lake Conway project, holds great promise. We never, in the past, could answer any impact questions except those involving the short-term effect, and that was frequently not adequate. The opportunity to document the long-term effects, possibly with a predictability factor, should be of immense value. The Corps is in the best position with its many facilities, which are complete environment systems, to set up more of these

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* Research and Development, AMCHEM Products, Inc., Ambler, Pennsylvania.

long-range projects designed to produce broader spectrum aquatic ecosystem models capable of answering the effect questions in advance.

I have to say, "A very excellent meeting certainly attacking the problems of the day," but I would be less than accurate if I implied that the meeting addressed all of the problems. Let me suggest some directions, as I see it, for action to be taken.

First, in spite of the necessity of all that has been discussed, the key problem is still essentially being ignored. We have to find ways of reaching the reinfestation source of the major aquatic weed problems. Lou Guerra graphically pointed out the difficulties in reaching these back areas, and Bill Thompson showed some of the frustration and futility of current programs when he commented on the fact that the hyacinth acreage in Louisiana had increased "only slightly" after the expenditure of 1-1/2 million dollars.

I am sure that among the Corps people there is an awareness of this need. Priorities and value judgments sometimes come into play in the choice of where need is most pressing. We are a politic people and do react to the loudest squeal of the wheel. I would like to see some long-term studies with the slow-release materials as part of our action program to minimize reinfestation. Since you are now partially committed toward work in this area, I believe that you should expand this work. The mechanics of placement could be worked out, and we do have knowledge of application timing. We do need more, but the important effort is to initiate the action and begin to document the data.

Second, I believe that the Corps should think about adding a staff member at the OCE level who will be responsible for coordinating Corps' label petitions. This man will have to become knowledgeable of product registration both at the national and the state level. He would be expected to organize the data collection from operational and research programs in a manner that would provide acceptable inputs for label petition and environmental impact statements. The time has come for the Corps to become proficient in the ways of the EPA world. The most important use of the research funded by the Corps is the generation of data that will provide the tools for operation programs.

Third, begin to set up more concrete liaison with other Federal and state agencies with the objective of jointly funding research of mutual benefit. Here, I am thinking of studies such as the bluegill metabolism work done by the group under Dave Stalling at the Fish Pesticide Laboratory in Missouri. In view of the fact that the aquatic weed problems are subject to control with nonproprietary compounds, this is the only effective means of providing necessary high-cost data. The Corps should not have to bear the cost of these studies alone. There is a large list of expensive long-term studies that will eventually be required of all pesticides in use.

Fourth, maintain the integrated control concept and expand this to include different environments. Now that we are almost at the stage of having a use label for hyacinths and milfoil, we must begin to collect data and show proof positive that the aquatic plant management programs do not adversely affect the environment. We will never be able to convince those opposed to pesticides until we can produce the documented long-term evidence. A strong complete case history will help move programs ahead with minimum resistance.

Finally, accelerate your program of providing educational manuals—everyone is doing it, but a Corps problem-solving manual will be of most direct benefit to your regional operations. Don't stop publishing the annual research report.

APPENDIX A

LETTER OF AUTHORITY FOR THE CONFERENCE

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D. C. 20314

REPLY TO ATTENTION OF: DAEN-CWO-R 19 September 1975

SUBJECT: Interagency Construction-Operations Meeting, Aquatic Plant Control Program

1. Arrangements have been completed for a Construction-Operations Meeting on operations activities for the Aquatic Plant Control Program to be held in the Charleston District, 22-24 October 1975.

2. The agenda for this meeting is planned to provide professional presentation of current research projects, review of current operation activities, and review research proposals, Inclosure 1.

3. This letter is our invitation to attend and participate in the discussions. Reservations for rooms should be made by each participant at the Holiday Inn, in Charleston, South Carolina, P.O. Box 310 29402. The inclosed post card should be mailed before October 1, 1975.

FOR THE CHIEF OF ENGINEERS:

2 Incls
as

RICHARD M. EDWARDS
Acting Chief, Construction-Operations Div.
Directorate of Civil Works

APPENDIX B

TRAINING MANUAL FOR CERTIFICATION OF COMMERCIAL APPLICATORS OF PESTICIDES IN GEORGIA

by

B. R. Evans

TRAINING MANUAL FOR CERTIFICATION OF COMMERCIAL APPLICATORS OF PESTICIDES IN GEORGIA

by

B. R. Evans

This training manual is intended to provide you with the information you will need to meet the standards of the Environmental Protection Agency for pesticide certification and to prepare you to take an examination given by the State Department of Agriculture based on this manual. It is not intended that this training will provide you with all the information you need for effective aquatic pest control.

An excellent reference* is available in which specific recommendations are made for control of specific kinds of weeds. The status of each herbicide is also indicated as to whether it is "recommended" or whether it is "suggested" for use. Included among this information is data on rate of application appropriate to the treatment method chosen for control, as well as remarks which relate to water quality and restrictions regarding time intervals during which water should not be used for specific purposes to avoid environmental hazards.

Various other reference materials are available to provide information on the biology and control methods for other aquatic pests which belong to the animal kingdom.

AQUATIC WEED GROUPS

There are several distinct differences in growth habits among aquatic weeds As a result, aquatic weeds may be divided into four groups, with certain similarities within each group.

a. *Algae.* There are several forms of algae, including filamentous algae (example, *Pithophora* sp.) and the so-called branched algae which includes musk grass (*Chara* sp.).
b. *Floating weeds.* Floating weeds are seed-bearing plants which float free on the water's surface, never become rooted in the soil, and are propagated by sexual and asexual means.
c. *Emersed weeds.* Emersed weeds are always rooted in the soil, with some leaves and flowers emergent above the water surface. The leaf form may differ for the plant portions which are above and below the water. These plants are seed-bearing, persistent, and somewhat difficult to control.
d. *Submersed weeds.* Submersed weeds are rooted in the soil, as are emersed weeds, but the whole plant is covered by water. However, the flowering portion of the plant may emerge above the water surface.

OTHER AQUATIC PESTS

Several warm-blooded pests, such as muskrat and nutria, inhabit the aquatic environment. Occasionally, population numbers of these animals may cause them to become pests requiring control. Commercial applicators responsible for control must be familiar with pertinent regulations and potential hazards to the environment as a result of control efforts.

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* Photos or line drawings of examples of each of the four classes of aquatic weeds, along with a text including a description of the plant and its habitat, distribution, and relative importance, are contained in the publication entitled "Aquatic Weed Identification and Control Manual," published by the Bureau of Aquatic Plant Research and Control, Florida Department of Natural Resources.

SPECIFIC REQUIREMENTS

Specific requirements of commercial applicators in the aquatic pest control category relate generally to a practical knowledge in three areas which may be defined as water use situations, secondary effects of pesticides upon organisms in the aquatic environment, and the principles of limited area application.

Water Use Situations

Habitats for aquatic weeds involve various proportions of water and soil from intermittently wet ditches to ditches which always hold standing water, to streams, to stock ponds, to farm ponds, to lakes, and to intermediate habitats. For purposes of this discussion, however, we can confine our attention to three types of water use situations.

Static water. Static water can be defined as water confined for considerable periods of the year, or totally confined within a known area with no movement of water to downstream locations. If a herbicide is applied to weed control, there is no reason to expect that any appreciable downstream effect may occur except overflow resulting from unusual storm conditions. Water impoundments such as stock ponds, and in some cases farm ponds, will fit into this category.

Limited-flow water impoundments. This type refers primarily to farm ponds, lakes, and ditches. Ditches may be intermittently wet and dry, depending upon local climatic conditions. However, herbicides applied to habitats such as ditches may present some hazard to downstream locations, due to movement of the applied pesticide following an influx of water from surrounding areas. The purpose of the ditch is to drain the surrounding land area, so considerable amounts of water must pass through the ditch area. In addition, many farm ponds may be characterized as having limited flow since there nearly always is an overflow pipe and an emergency overflow channel (spillway). The overflow pipe is designed to permit passage of a continuous and relatively well-defined amount of water at all periods of the year. The emergency spillway is provided to permit outflow of water from the pond at periods of the year when storm incidence may cause excess amounts of water to accumulate in the pond. In such cases, pesticide applications to limited-flow water areas may be found in small amounts in waters downstream from the application site. It is conceivable that larger amounts of pesticides from a treated area may be found downstream in the event of sudden rain storms which interrupt or come immediately after pesticide application.

Moving water. Moving water is characterized as water found in small streams, creeks, streams and rivers where there is always some detectable movement. Applied pesticides may be found in downstream locations in varying amounts away from the area of original application. Such situations present the greatest potential for concern as an environmental hazard.

Secondary Effects of Pesticide Applications

Improper application rates. Proper application of herbicides to aquatic situations involves equipment calibration and calculation of appropriate water volumes in order to determine correct dosage rates. There are several well known and proven methods of equipment calibration and water volume calculation to determine pesticide application rates. Environmental hazard can result from the improper application rate.

a. Static water. If application rates are too low in a static water situation, desired kill of pests may not be accomplished. However, the water supply may be contaminated and unsuitable for use by livestock or as an irrigation supply. In the event of excessive application rates, damage to the fish populations may result, either from direct toxicity or an excessively rapid kill of plant materials which may result in oxygen depletion in the water, leading to suffocation of the fish population. Excessive application rates might also exclude livestock from use of the water for a period of time and would rule out the use of water supplies for irrigation for an indefinite period of time. However, little effect would probably be observed as far as downstream hazards are concerned, since little or not outflow normally occurs.

b. *Limited flow water.* Improper application rates could result in contamination of downstream water used by municipalities or communities for domestic water supplies. The hazardous condition would exist whether limited-flow water sources were treated with an application rate too low to accomplish a desired kill of vegetation or if the rate were excessive. It is conceivable that excessive rates might result in a too rapid rate of kill of vegetation which could lead to oxygen depletion and subsequent suffocation of the fish population. This might further complicate contamination of downstream water supplies used as domestic waters, due to bacterial contamination resulting from decomposition of killed fish.

c. *Moving water.* Herbicide application to moving water is a common practice in the southeastern United States. Since there is little or no way to control downstream effects or environmental hazards, application of such pesticides to moving waters may lead to at least temporary contamination of downstream water supplies which may be used for domestic consumption. In addition, the pesticide, though applied locally for pest control, is certain to move to other areas of the stream and affect various aquatic organisms.

Faulty application. There are two major hazards involved in faulty application of pesticides: (a) possible contact of applied pesticide with nontarget organisms with resultant damage; and (b) failure to apply the pesticide to the target pest resulting in no kill of the desired pest. For example, it would be hopeless to apply granular herbicides in fast-moving water, whereas they might work quite well in static water impoundments and limited-flow water situations. All currently registered herbicides employed for aquatic weed control are rated limited or not at all toxic to fish, birds, insects, and other aquatic organisms, so long as proper application rates and techniques are employed. Other pesticides' labels should be carefully observed to ensure that the aquatic environment is not unduly contaminated as a result of pest control efforts.

Limited Area Application

Aquatic weeds may occur in the whole body of water as submersed weeds or may appear to cover the whole surface of the water as floating weeds. Conversely, the same weeds or other pests may occur only in limited areas within a body of water, whether it is a static, limited-flow, or moving body of water. "Limited area application" implies the advantage of improved safety to aquatic species, specifically the fish population. If pesticides that are potentially toxic to the fish population are applied to a limited area, the fish population can move to untreated water areas and escape potential toxic effects. Also implied in this concept is that the application of a minimal amount of pesticide tends to reduce the potential effect upon downstream environments in the event of spillover from the treated body of water.

There are essentially three areas in the body of water which may be treated—the surface, total water column, and "bottom acre-foot."

Surface-applied treatments. Contact pesticides are generally applied to control floating weeds. Generally only one-fourth to one-third of the surface area of the body of water is treated at a time in order to reduce the possible hazard of oxygen depletion resulting from too rapid kill of large masses of vegetation in the water, which may affect the fish population.

Total water column treatments. In this application technique, frequently employed with emersed weeds and often with algae treatments, the whole body of water (including the water column from the bottom of the water impoundment to the surface) is treated. The entire volume of the body of water is calculated, and the chemical is added to reach a specified dilution in the total water column. An alternative is to calculate the entire water body and then treat only one-fourth or one-third of the total water column, based on surface area, confining the treatment to selected sections of the pond where the pest infestation may be more intense. Specific application techniques include injection directly into the water with the undiluted chemical, or some dilution of the chemical sprayed or cast upon the surface of the water. With either method, further dispersal throughout the water column is dependent upon water currents. Aquatic granules are formulated to provide rapid sink to soil-water interfaces to control emersed and submersed weeds.

Bottom acre-foot treatments. This is a specialized application technique which is intended primarily for control of submersed aquatic vegetation. A boat carrying application equipment drags a hose or boom just above the lake or pond bottom. The chemical is dispersed through nozzles, and specific gravity of the chemical causes the treatment to remain near the bottom in the proximity of the rooted, submersed weeds. Fish can move out of this water level and avoid any direct contact with the chemical until chemical residues are diluted or dissipated.

APPENDIX C

HISTORY OF THE AQUATIC PLANT CONTROL PROGRAM

by
E. O. Gangstad

Prepared for the

Interagency Research Advisory Committee
Expanded Project for Aquatic Plant Control

Holiday Inn Downtown
Charleston, South Carolina

October 1975

HISTORY OF THE AQUATIC PLANT CONTROL PROGRAM

by

E. O. Gangstad*

INTRODUCTION

This is the tenth meeting of the Research Advisory Committee of the Expanded Project for Aquatic Plant Control, as authorized by the Rivers and Harbors Act of 1965. A great deal of research and extended control operations have been accomplished during the past 10 yr. The program of this meeting serves to emphasize the changes that have taken place. This group met at the Gaido Motor Hotel in Galveston, Texas, 13-14 October 1966. Mr. Guscio, Mr. Raynes, and Mr. Blakeley, who are with us today, attended that meeting. In 1965, there were five research programs underway, i.e., (1) The Department of Agriculture (Crops and Entomology), on herbicides and insect control, (2) The U. S. Fish and Wildlife Service, on the effects of herbicides on fish and benthic organisms, (3) The Federal Water Pollution Control Administration, Public Health Service, on the toxicity of pesticide residues, (4) Auburn University, on the environmental effects of herbicide treatment, (5) and the University of Southwestern Louisiana, on the effects of synergistic agents on herbicide control.

NEW RESEARCH PROJECTS

In 1968, research on the application of a carbon dioxide laser for control of aquatic plants was initiated at Redstone Arsenal, Alabama, with supporting research at Athens College, Alabama; research on controlled-release herbicides was begun at Edgewood Arsenal, Maryland, with supporting studies at Akron University, Ohio. A field model of the laser was built and field tested by the Waterways Experiment Station (WES) (1970-1974), but the results do not justify field application. Exploratory studies on controlled-release herbicides have been extended with a research contract at Wright State University, but we do not have a successful field application at this time.

In 1969, studies on the use of herbivorous fish for control of submersed aquatic weeds at Auburn University were extended to include applied studies in Florida at the Fort Lauderdale Research Center, with supporting studies on the development of a monosex white amur at the Fisheries Research Station at Stuttgart, Arkansas. Currently we are involved in a large-scale test program at Lake Conway, Orlando, Florida, coordinated by WES.

In 1970, we initiated additional studies on the residues of 2,4-D in fish and shellfish at the Pesticide Research Laboratory at Columbia, Missouri, with supporting studies at Warm Springs, Georgia. Additional studies on the residues in water and their effects were undertaken at Northwestern University, Louisiana, Syracuse University Research Corporation, New York, and Virginia Polytechnic Institute, Virginia. Endothall and diquat were added to the list of herbicides for detailed study.

* Prepared by Dr. E. O. Gangstad, Botanist, Office, Chief of Engineers, Construction-Operations Division, Washington, D. C

INTEGRATED CONTROL OF ALLIGATORWEED

Examination of experiments initiated in 1971 indicated that a treatment with low rates of 2,4-D (1 to 2 lb/A), coordinated with *Agasicles* feeding damage, results in the deterioration of subsurface mats of alligatorweed. The constant pressure on the surface alligatorweed growth, when using the integrated method, appeared to deplete the subsurface carbohydrate reserves in alligatorweed stems. Herbicidal treatment, followed by release of alligatorweed flea beetles, is more effective than using beetle populations that have overwintered. The optimum time for a large beetle population to feed on alligatorweed is when regrowth from herbicidal treatment is 6 to 8 in. Feeding damage, prior to or after that stage of growth, decreases the control effect. The integrated control in laboratory and small field plot experiments has yielded a higher reduction of floating alligatorweed mats than is attainable with either agent used alone.

CONTROL OPERATIONS

The Aquatic Plant Control Program is a cooperative program with states, costs shared 70-30, as work in kind on a reimbursable basis. In Florida, the 1966-70 annual cost was $329,100 of which the non-Federal cost was $88,700. Benefits of the program are very favorable. The cost-benefit ratio varies with different situations from 1:7 to 8:0 with an overall average of 3:3. In Louisiana, the program is cooperative with the Louisiana Wildlife and Fisheries Commission; the total annual cost for the 1966-1970 period was $649,600 of which the non-Federal cost was $136,500. The annual benefit has been estimated at $2,941,000 with a cost benefit ratio of 4:1. The program in the State of Texas is cooperative with the Texas Parks and Wildlife Commission. The average annual benefit of the program is estimated to be $194,000, with an average annual cost of $29,650 and a cost-benefit ratio of 6:7. Other programs are active in New York, Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Arkansas, and Oklahoma to a limited degree.

ALLIGATORWEED CONTROL

Insects have been used successfully as a form of biological control to suppress alligatorweed (*Alternanthera philoxeroides*) (Mart.) (Griseb) in Florida and other southeastern states under the Corps' aquatic plant control program in cooperation with the Division of Entomology Research of the United States Department of Agriculture. The alligatorweed flea beetle (*Agasicles hygrophilia* Selman and Vogt) was the first host-specific insect to be introduced. Other insects, alligatorweed thrips (*Amynothrips andersoni* O'Neill) and a stem-boring moth (*Vogtia malloi* Pastrana) are also host specific and have been introduced for alligatorweed control. Infestations of alligatorweed are reduced to a maintenance status in most situations in the southeastern states where these insect controls have been released. Acreage of infestation and chemical treatment for 1963-1973 period are summarized in Table 1.

1966 RESEARCH ADVISORY COMMITTEE MEETING

The Research Advisory Committee met in a conference room at Gaido Motor Hotel, Galveston, Texas, 13 October 1966, with the Southwestern Division and Galveston District as host. COL J. E.

Table 1
Table Acreage of Infestation and Chemical Treatment of Alligatorweed for 1963-1973*

	Infestation		Treatment	
	1963	1973	1963	1973
South Atlantic Division				
Jacksonville, Fla.	2,597	Minor	50	None
Savannah, Ga.	1,838	Minor	50	None
Wilmington, N. C.	428	3,220	100	235
Charleston, S. C.	30,430	29,710	750	750
Mobile, Ala.	4,831	225	50	109
Lower Mississippi Valley Division				
New Orleans, La.	55,880	36,275	19,605	4000
Vicksburg, Miss.	None	200	None	200
Southwestern Division				
Galveston, Tex.	1,200	8,400	1,200	300
Total Acreage	97,186	78,030	21,805	5594

* Estimate of acreage by field crews.

Unverferth, District Engineer, Galveston Division, opened the meeting, welcoming the Committee to the Southwestern Division and Galveston District. Those present were:

Name	Representing	From
J. R. Griffith, Chairman	LMVD, Corps of Engineers	Vicksburg, Miss.
F. J. Guscio, Member	SAD, Corps of Engineers	Atlanta, Ga.
G. H. Jones, Member	SWD, Corps of Engineers	Dallas, Tex.
F. L. Timmons, Member	ARS, U. S. Department of Agriculture	Laramie, Wyo.
H. P. Nicholson, Member	Federal Water Pollution Control Administration	Athens, Ga.
A. B. Montgomery, Member	Bureau of Sport Fish Wildlife	Atlanta, Ga.
L. E. Horsman	OCE, U. S. Army Engineers	Washington, D. C.
Hal Blakeley	OCE, U. S. Army Engineers	Washington, D. C.
J. J. Raynes	SAD, Corps of Engineers	Atlanta, Ga.
COL J. E. Unverferth	GD, Corps of Engineers	Galveston, Tex.
A. B. Davis, Jr.	GD, Corps of Engineers	Galveston, Tex.

HERBICIDE RESEARCH

According to Dr. Timmons, ARS, USDA, 100 new chemicals were tested in 1969, 62 in 1966, and

33 in the last 3 months. The overall activities on alligatorweed in last year's tests were not as good as the silvex treatment used as a standard. There is one new formulation of 2,4-D that shows promise in the greenhouse and test tanks. Also, the use of 6 lb of ametryne and 0.25 lb of 2,4-D per acre has shown some promise for control of alligatorweed, but preliminary field tests did not equal the results obtained in greenhouse tests. Tests with silvex and 2,4-D in varying quantitites were conducted in Florida, Georgia, South Carolina, and Louisiana. Generally, silvex inhibited regrowth longer than 2,4-D. Retreatment apparently should be made when there is from 5 to 10 percent regrowth, as this accomplishes effective control with fewer treatments. ARS is of the opinion that vigor and type of alligatorweed growth at the time of initial treatment appear to be the most important factors in determining susceptibility to herbicidal treatment. Water quality, depth of mat, and other physical and chemical phenomena are the causes of control variations and at times contribute more to plot-to-plot variations than the variations between chemical treatment. The 1966 treatments duplicating 1965 treatments have not been as effective on alligatorweed as results obtained from treatments in past years.

Dr. Timmons also reported that the shelf life of silvex is a determining factor in the effectiveness of the material on alligatorweed and that silvex will consistently control alligatorweed. Three esters of silvex tested in 1965 and 1966 produced about equal control. The addition of diglycolic acid at 25 lb per acre resulted in a slight increase in the activity of 2,4-D. Paraquat incorporated in floating granules gave good control with two applications of 6 lb per acre. At the Savannah Wildlife Refuge, a 125-acre impoundment had been drained, then treated 4 weeks later with 6 lb of silvex per acre, and subsequently reflooded. This procedure resulted in excellent control of alligatorweed. In biological control studies, the thrip is under quarantine in the ARS California Laboratory and is ready for distribution when clearance is obtained. Laboratory studies have been initiated on the stem-boring phycitided moth in South America. In persistence studies, 70 percent of the diquat disappeared in 30 min and 70 percent of the paraquat disappeared in 12 hr, indicating the persistence difference to be insignificant. Dr. Timmons also advised that there were 19 herbicides currently registered for use in some type of aquatic situations bearing the label statement, "Do not contaminate potable water."

FISH AND WILDLIFE RESEARCH

Mr. Montgomery, U. S. Fish and Wildlife Service, reported that the alligatorweed in the North Carolina test areas has been eradicated and virtually eliminated from all test areas. Water samples collected in 1966 from the areas treated in 1965 were normal, and that study indicated little, if any, long-range, harmful effect on fish and bottom organisms (benthic populations). Also, there was an increase in the fish population in 1966 over 1965. Observations and sampling will continue into next year and probably be phased out, barring some unforeseen occurrence. In tests in Louisiana ponds, 95 percent of the fish were killed in one of the three ponds treated (Jones Pond). Fish killed were principally sunfish and gizzard shad. It is thought that a chemical reaction rather than the toxic effects of silvex caused the kill in this pond. No fish kill was obtained at the other ponds treated. Further evaluations will be needed to determine, if possible, why the kill occurred.

RESIDUE RESEARCH

Dr. Nicholson, Federal Water Pollution Control Administration, stated in his report that persistence of silvex in the Louisiana ponds for the first treatment was about the same as that found in the tank studies made at the laboratory in Athens, Georgia. In the second treatment, there was an unexplained show of silvex (as an acid) from the third through the seventh week. Results of the third treatment were about the same as the first treatment. Fish samples taken 12 weeks after treatment showed the highest concentration of silvex. Other tests at the Louisiana ponds showed that the pond soils were about the same (29-37 percent silt), cation exchange capacity about the same, pH constant at 6.0, with some variation in organic matter between the three ponds.

ECOLOGICAL STUDIES

In the Auburn University research activities reported by Mr. Raynes, growth studies established in August 1964 were continued in 1966 in plastic pools to determine the effects of treatment combinations consisting of 2,4-D and silvex. Also, studies were made to discover the effects of treatments of several species of aquatic plants with diuron and liuron (two different substituted urea herbicides) on fish production. At 10 lb per acre, the diuron eliminated all aquatic plants with the exception of a few dwarfed sprigs of alligatorweed. It was also found to be highly toxic to fish in this series of pools. Liuron, at the rate of 10 lb per acre not only was not as effective in eliminating aquatic plant but also did not appear to have drastically affected the fish populations. In pools treated with diquat, the recovery of chemicals in residue studies indicated that some chemical degradation had occurred. Recovery of paraquat from bottom muds of pools treated in 1962 indicated that some chemical degradation had occurred; however, recovery of paraquat from bottom muds of pools treated in 1962 indicated that little, if any, appreciable degradation had occurred. Studies on alligatorweed control on Jim Woodruff Reservoir were also continued.

There is an estimated 5000 acres of Eurasian watermilfoil in the Spring Creek Arm of Jim Woodruff Reservoir. Light penetration studies indicate that the high-water conditions in this arm are favorable for growth of the plant to depths of 15 ft.

CHEMICAL RESPONSE STUDIES

Research at the University of Southwestern Louisiana described by Mr. Parkman revealed that during the past year fieldwork on plots of alligatorweed and submersed species, especially *Elodea*, has been continued. These and other subjects will be comprehensively discussed in the annual report to be submitted about 1 November 1976. At the time of this report, no certain method exists for the control of alligatorweed, i.e., no commercial product that in a single application will eliminate at least 95 percent of the alligatorweed growing under aquatic environment. Observations indicated that environmental conditions control not only the activity of the herbicide but possibly the age of the alligatorweed plant itself. In old stands the new growth is fairly well controlled, whereas the oldest or lignified layers are hardly susceptible to treatment. It has been generally believed that the roots do not play a major part in the uptake of 2,4-D compounds. However, findings this year show that under certain conditions chlorophenoxy herbicides may be absorbed by the alligatorweed roots much more readily than by the leaves. Variances of as much as 2.0 units in the pH of cellular constituents have been noted between treated (phenoxy herbicides) and untreated plant materials. Studies are under way to trace the extent of the pH change in the living tissue of the alligatorweed and to that end plan the use of chemicals which may or may not accelerate the activity of the phenoxy herbicides. Some 60-odd chemical compounds are to be tested as synergistic agents and will probably be screened during this winter. This screening of chemicals is not to be confused with the work done by Dr. Lawrence at Auburn. The primary objective at Auburn was testing hundreds of chemicals for herbicidal activity, whereas this screening is for the purpose of discovering compounds which will accelerate or promote herbicidal activity. Also the forthcoming report will describe a series of experiments tracing the extent of penetration of herbicidal compounds into the alligatorweed in order to determine if there is some correlation between the hydrogen-ion concentration of the cellular constituents and the amount of herbicide which has progressed along the stem of the alligatorweed.

CROP RESIDUE STUDIES

Dr. Timmons reported that he has interested Dr. Paul R. Miller, Epidemiological Investigations, ARS, in doing research on *Alternaria* (red spot) and in collecting samples of the diseased plants on a trip scheduled for November. This is one of a complex of organisms widely distributed along the East Coast which affects many field crops. No known organism is specific for alligatorweed, and its use as a control agent is doubtful. A 3-yr research contract for the study of herbicide residues in irrigated crops was initiated by ARS. These studies will include identification of the herbicide and metabolites. Acrolein, used for aquatic plant control, and copper sulphate, used for algae control, are currently under study. Silvex and 2,4-D will be investigated during the second year. Two more herbicides may be studied. Another 2-yr research contract for determining the fate of herbicide compounds and metabolites in edible crops has also been initiated. In addition, either silvex or 2,4-D will be tested in static water situations in all states to determine the fate of the compounds under varying environmental conditions. It was noted that the annual use of 2,4-D in the United States is 30,000,000 lb per year.

INTERAGENCY AD HOC COMMITTEE ON HERBICIDES

The Interagency Ad Hoc Committee on Herbicides was discussed. It is in reality a subcommittee of the Interior and Agriculture Weed Control Committee, often referred to as the Interagency Committee on Weed Control. One of the purposes of the Ad Hoc Committee is to obtain clearances for herbicides to be used in aquatic situations. The parent committee's responsibilities include reviewing all herbicide and pesticide work, surveying current research investigations, determining needed research and safe residue tolerances, and making recommendations to the Interior and Agriculture Weed Control Committee. It was the consensus that the Research Advisory Committee should establish and maintain coordination with these committees. Following this discussion, a motion was made by Mr. Guscio and seconded by Mr. Griffith that the Research Advisory Committee request its U. S. Public Health Service member to ascertain the steps that are required to obtain approval for use of silvex for control of aquatic weeds in raw water sources of potable water. The motion passed unanimously.

PANAMA CANAL RESEARCH PROPOSAL

The Panama Canal Company had proposed (according to Dr. Timmons) a contract with ARS for research at Ft. Lauderdale, Florida, for the control of *Elodea* with financing of $25,000 per year for 2 yr. Such programs would actually require about $40,000 per year instead of the $25,000 proposed. We indicated that ARS would not use present personnel engaged in the expanded project research without the concurrence of the Research Advisory Committee. The opinion of this committee was that cooperative work with the Panama Canal Company should be deferred and considered under the new program. No objection was interposed to the work being done as a separate item outside of the current Expanded Project.

PROBLEMS NEEDING RESEARCH

In discussing the continuing research objectives and need for other research, Mr. Guscio emphasized that the research performed under this program must be continuously focused on the need of control operations and problems of controlling specific species of aquatic plants. It was indicated that current needs for the project exist for determining the environmental fate of 2,4-D and silvex in water and soils, reviewing other esters of silvex and their metabolites, determining effects of field dosages on fish and wildlife, perfecting biological control of waterhyacinths, and obtaining a literature survey on the ecology, plant physiology, and biological control of Eurasion watermilfoil and sea lettuce with a view for determining and initiating needed research on these aquatics. As noted, $300,000 was proposed to be added to the FY 1967 funds to be used to provide a start on this research program

Two problems peculiar to water supply and aquatic plants present in the South Atlantic Division were discussed. The first problem involved the Edisto River in South Carolina which supplies the water for the city of Charleston. The junction of this river's North Fork and South Fork is 58 miles upstream from the water supply intake. The 27-mile portion of the North Fork from Orangeburg, South Carolina, downstream to the juncture with South Fork has been approved as a flood control project; plans provide for the removal of all logs, stumps, fallen and leaning trees, and the eradication of about 250 acres of alligatorweed. Much of the weed will be physically removed, and the remainder is planned to be treated with herbicides. Since silvex has not been cleared for operational use, 2,4-D was to be used with additional treatments as required. However, the Charleston District is concerned with possible effects that 2,4-D might have on this drinking water supply. It is in need of standards or guidelines since neither the state nor the Public Health Service has any overall policy on the use of 2,4-D in drinking water sources.

The second problem is concerned with a stream used for recreational boating, recently impounded to form a 600-acre water supply reservoir for the city of Punta Gorda, Florida. The reservoir was formerly treated under the expanded project with 2,4-D for waterhyacinth control. However, the waterhyacinths cannot be treated now due to the lack of clearances for herbicides in potable raw water supplies. The reservoir is virtually covered with waterhyacinths. No problems concerned with water supply and treatment have been expressed to date, but numerous complaints regarding the waterhyacinth obstructions to navigation have been received from the boating public. The Florida State Health Department has given very limited clearance for the use of 2,4-D in this reservoir.

These problems were singled out to show the Jacksonville District's need for guidance, the growing concern over the use of 2,4-D, and the lack of knowledge regarding its use in raw water sources for potable water. During discussion of these problems, it was stated that the Food and Drug Administration was making a comprehensive study on 2,4-D. This study was believed to be nearing completion; however, the date which the report was to be made public is not known. A motion was made by Dr. Nicholson and seconded by Mr. Montgomery that the Committee Chairman approach FDA seeking preliminary release of its forthcoming report on 2,4-D in view of the critical need of the Corps of Engineers for the use of 2,4-D to control certain widespread obnoxious aquatic plants. The motion was passed unanimously. It was agreed that the request should be made by the Chief of Engineers for the Committee.

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

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At the request of the Recreation Resources Management Branch, Construction-Operations Division, Directorate of Civil Works, Office, Chief of Engineers, a conference was held in Charleston, South Carolina, to review current operation activities and new research proposals, and to afford an opportunity for presentation of current research projects.

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