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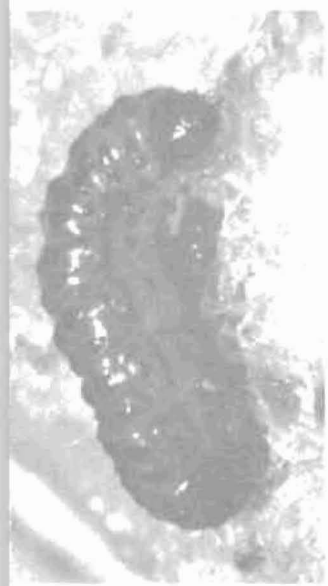

AQUATIC PLANT CONTROL RESEARCH PROGRAM

TECHNICAL REPORT A-85-1

LARGE-SCALE OPERATIONS MANAGEMENT TEST (LSOMT) OF INSECTS AND PATHOGENS FOR CONTROL OF WATERHYACINTH IN LOUISIANA

Volume II: Results for 1982-1983

by

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PO Box 631, Vicksburg, Mississippi 39180-0631

December 1986
Volume II of a Series

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

and US Army Engineer District, New Orleans
New Orleans, Louisiana 70160-0267

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report A-85-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) LARGE-SCALE OPERATIONS MANAGEMENT TEST (LSOMT) OF INSECTS AND PATHOGENS FOR CONTROL OF WATERHYACINTH IN LOUISIANA; Volume II: Results for 1982-1983		5. TYPE OF REPORT & PERIOD COVERED Volume II of a series
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dana R. Sanders, Sr., Edwin A. Theriot		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Engineer Waterways Experiment Station Environmental Laboratory PO Box 631, Vicksburg, Mississippi 39180-0631		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Aquatic Plant Control Research Program
11. CONTROLLING OFFICE NAME AND ADDRESS DEPARTMENT OF THE ARMY US Army Corps of Engineers Washington, DC 20314-1000 and US Army Engineer District, New Orleans New Orleans, Louisiana 70160-0267		12. REPORT DATE December 1986
		13. NUMBER OF PAGES 57
		15. SECURITY CLASS. (of this report) Unclassified
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic plant control
Biological control
Insects
Plant pathogens
Waterhyacinth

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During 1979-1983, a Large-Scale Operations Management Test (LSOMT) was conducted to determine the potential for biological control of waterhyacinth in Louisiana using insects and plant pathogens. This report (Volume II) documents LSOMT results for 1982-1983 and presents final conclusions.

Biocontrol agents were found to be a viable, long-term, low-cost alternative for waterhyacinth control. Primarily due to biocontrol agent

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20. ABSTRACT (Continued).

activity, the waterhyacinth population in Louisiana decreased from an average of 1,250,000 acres in 1974-1978 to 305,000 acres in 1980. This decrease was attributed principally to effects produced by the mottled waterhyacinth weevil (*Neochetina eichhorniae* Warner). By 1983, the plant population had increased to 657,000 acres. This increase was attributed to a decline in the *Neochetina* population following the 1980 reduction in the waterhyacinth population. An increase in the waterhyacinth population had been anticipated, due to the greater reproductive potential of waterhyacinth than of *Neochetina*. However, the 1983 waterhyacinth population was still approximately 50 percent less than the 1974-1978 average, which led to the conclusion that *Neochetina* was still significantly impacting the waterhyacinth population. The 1983 increase in the *Neochetina* population led to a suggestion that the waterhyacinth population might experience another decline during 1984 or 1985. Such a decline would provide evidence of the development of a cyclical relationship between waterhyacinth and *Neochetina* populations, in which the waterhyacinth population declines in the presence of large *Neochetina* populations, redevelops as *Neochetina* populations decline, and then declines as *Neochetina* populations redevelop.

Other conclusions of the LSOMT were:

a. The threshold population level for significant *Neochetina* impacts on waterhyacinth was 3.0 individuals (combined larvae and adults) per plant, followed by a sustained population level of 1.0 individual per plant for 6 months or longer.

b. The waterhyacinth leaf spot fungus (*Cercospora rodmanii* Conway) impacted waterhyacinth at one study area, but failed to become established at another study area. *Cercospora* in the formulation used in the latter case was viable, but not infectious.

c. The Argentine waterhyacinth moth (*Sameodes albiguttalis* Warren) became successfully established at three of four release sites and rapidly dispersed throughout a large portion of southern Louisiana. Its 1983 distribution encompassed a 6,100-sq-mile area, and included all or portions of 13 parishes (counties).

d. Long-term effectiveness of *Sameodes* as a biocontrol agent was not determined because the population was still in the dispersal phase. However, *Sameodes* was observed to produce locally significant impacts on waterhyacinth populations.

PREFACE

This report is Volume II of a two-part series on a Large-Scale Operations Management Test (LSOMT) of insects and plant pathogens for control of water-hyacinth in Louisiana. The LSOMT was sponsored by the US Army Engineer District, New Orleans (LMN), and the Office, Chief of Engineers (OCE), through the Corps' Aquatic Plant Control Research Program (APCRP) at the US Army Engineer Waterways Experiment Station (WES). The OCE technical monitor for the APCRP is Mr. E. Carl Brown.

Volume I, funded by the LMN, described establishment of the various studies and presented preliminary findings for 1979 through 1981. Volume II, funded by OCE, presents findings for 1982-1983 and overall conclusions.

Principal investigators during the study were Messrs. Russell F. Theriot and Edwin A. Theriot, both of the Wetland and Terrestrial Habitat Group (WTHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), WES. Other WTHG personnel assisting in field data collection and analysis included Drs. Dana R. Sanders, Sr., Alfred F. Cofrancesco, Jr., and Patricia A. Perfetti, and Messrs. R. Michael Stewart and Samuel O. Shirley. The assistance of Mr. James H. Manning of the Louisiana Department of Wildlife and Fisheries, Baton Rouge, La., in establishing and monitoring study areas is gratefully acknowledged. Consultative services were provided by Dr. Ted Center and Mr. Wiley Durden, both of the US Department of Agriculture (USDA), Aquatic Plant Management Laboratory, Fort Lauderdale, Fla., and Dr. Gary Buckingham, USDA Quarantine Laboratory, Gainesville, Fla. Special thanks are extended to Mr. Vernon Brou, Edgard, La., who provided records of light-trap collections of *Sameodes* adults. *Cercospora* formulations used in the studies were provided by Abbott Laboratories, Inc., Chicago, Ill. The report was written by Dr. Sanders and Mr. Edwin A. Theriot and was edited by Ms. Jamie W. Leach of the WES Information Technology Laboratory.

The work was conducted under the general supervision of Dr. John Harrison, Chief, EL. Dr. Conrad J. Kirby, Jr., was Chief, ERD, and Dr. Hanley K. Smith was Chief, WTHG. The work was conducted under the direct supervision of Dr. Sanders (1979-1981) and Mr. Edwin A. Theriot (1982), Leaders, Biocontrol Team, WTHG. Mr. J. Lewis Decell was Program Manager of the APCRP.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is the Technical Director.

This report should be cited as follows:

Sanders, D. R., Sr., and Theriot, E. A. 1986. "Large-Scale Operations Management Test (LSOMT) of Insects and Pathogens for Control of Waterhyacinth in Louisiana; Volume II: Results for 1982-1983," Technical Report A-85-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
miles (US statute)	1.609347	kilometres
square miles	2.589998	square kilometres

LARGE-SCALE OPERATIONS MANAGEMENT TEST (LSOMT) OF INSECTS AND PATHOGENS FOR CONTROL OF WATERHYACINTH IN LOUISIANA

Volume II: Results for 1982-1983

PART I: INTRODUCTION

Background

1. The US Army Engineer District, New Orleans (LMN), provided funds in 1977 to the US Army Engineer Waterways Experiment Station (WES) for a large-scale operations management test (LSOMT) of insects and plant pathogens for control of waterhyacinth in Louisiana. An LSOMT is designed to provide research data on promising methods for aquatic plant control, while addressing a specific aquatic plant problem at an operational scale with minimal environmental controls.

2. The WES subsequently developed a test plan for the LSOMT (Sanders et al. 1979) and initiated the LSOMT by establishing a series of field studies to evaluate various combinations of biocontrol agents. Field studies were monitored through 1981, when LMN funding was terminated due to fiscal constraints. A report was prepared for LMN on results of the field studies from 1979-1981 (Sanders, Theriot, and Perfetti 1984).

3. Data for 1979-1981 revealed that effects of various biocontrol agents on waterhyacinth were becoming progressively greater in most study areas. However, maximum potential of the biocontrol agents had not been achieved, and indications were strong that effects would become more pronounced during 1982 and 1983. A decision was made to continue monitoring the LSOMT field studies during 1982 and 1983. Funds for this portion of the LSOMT were provided by the Office, Chief of Engineers, through the Aquatic Plant Control Research Program at WES.

Purpose and Objectives

Purpose

4. The purpose of the study was to determine the effectiveness of various biological agents in controlling waterhyacinth in Louisiana. The purpose of this report was to present both the LSOMT results for 1982 and 1983 and the overall conclusions of the LSOMT.

Objectives

5. Objectives of the study were:

   a. Determine the level of waterhyacinth control provided by various biocontrol agents, when used both alone and in combinations.

   b. Determine the most effective combinations of biological agents for waterhyacinth control in Louisiana.

   c. Develop the framework of an operational system for the routine use of biological agents for waterhyacinth control in Louisiana.

PART II: METHODS

6. All large-scale field studies had been initiated and monitored for at least 1 year by October 1981. Procedures for site selection, application of biocontrol agents, and monitoring of waterhyacinth and biocontrol agent populations were described in Sanders, Theriot, and Perfetti (1984), and the same monitoring procedures were used during 1982 and 1983. Sampling was conducted in April, July, and October of 1982 and in May 1983. *Sameodes* surveys were conducted in October 1982 and in May and October of 1983.

PART III: 1982-1983 RESULTS AND DISCUSSION

7. This part of the report presents the 1982-1983 results and discussion for each large-scale field study. For each study, a summary of findings for 1979-1981 is presented first, followed by the results and discussion for 1982-1983 data. Tables and graphs include data for all sampling periods from 1980 through 1983. No data are included for the *Cercospora* field application rate study because it was terminated in September 1980.

Neochetina, *Sameodes*, and a Spring Application of the Original *Cercospora* Formulation

Summary of previous findings

8. The waterhyacinth population at the Lake Theriot study site remained at 100-percent surface area coverage during 1980 and 1981, but a combination of an expanding *Neochetina* population and *Cercospora* had reduced biomass and plant height by 31 percent in September 1981 as compared with October 1980. *Sameodes* had failed to become established in the study area by September 1981. Abundant *Cercospora* symptoms and an expanding *Neochetina* population at the site in 1981 indicated that this biocontrol agent combination might produce even more pronounced impacts on the waterhyacinth population during 1982 (Sanders, Theriot, and Perfetti 1984).

Results and discussion for 1982-1983

9. A significant reduction in the waterhyacinth population occurred at the Lake Theriot study site during 1982. Surface area coverage of waterhyacinth had decreased to 80 percent by April 1982, and progressively decreased to a minimum of 55 percent in October (Table 1). Mean plant density was 29 percent less in October 1982 than in September 1981. When weighted by percent cover, plant density decreased by 39 percent from September 1981 to October 1982. Mean biomass decreased by 33 percent during the same period. When weighted by percent cover, mean biomass in October 1982 was 63 percent lower than in September 1981, and was 74 percent lower than in October of 1980. Mean plant height was 20 percent lower in October 1982 than in September 1981, and was 45 percent lower than in October 1980. Waterhyacinth covered only slightly more than one half of the study area in October 1982, and individual plants were of the Stage III morphotype, very small, and severely stressed.

10. Decline in the waterhyacinth population at the Lake Theriot study site could not be attributed to abnormal environmental conditions. Winter temperatures were average for the area, dewatering had not occurred, and no herbicide applications had been made. In the absence of extreme environmental conditions, it appeared that biological agents were responsible for the decline in waterhyacinth. Data to support this tenet are presented in the following paragraphs.

11. Pathogen damage. Mean pathogen index values increased significantly during 1982 to a maximum of 5.19 in October (Sanders, Theriot, and Perfetti 1984) (Figure 1). The mean for July 1982 was significantly higher than for

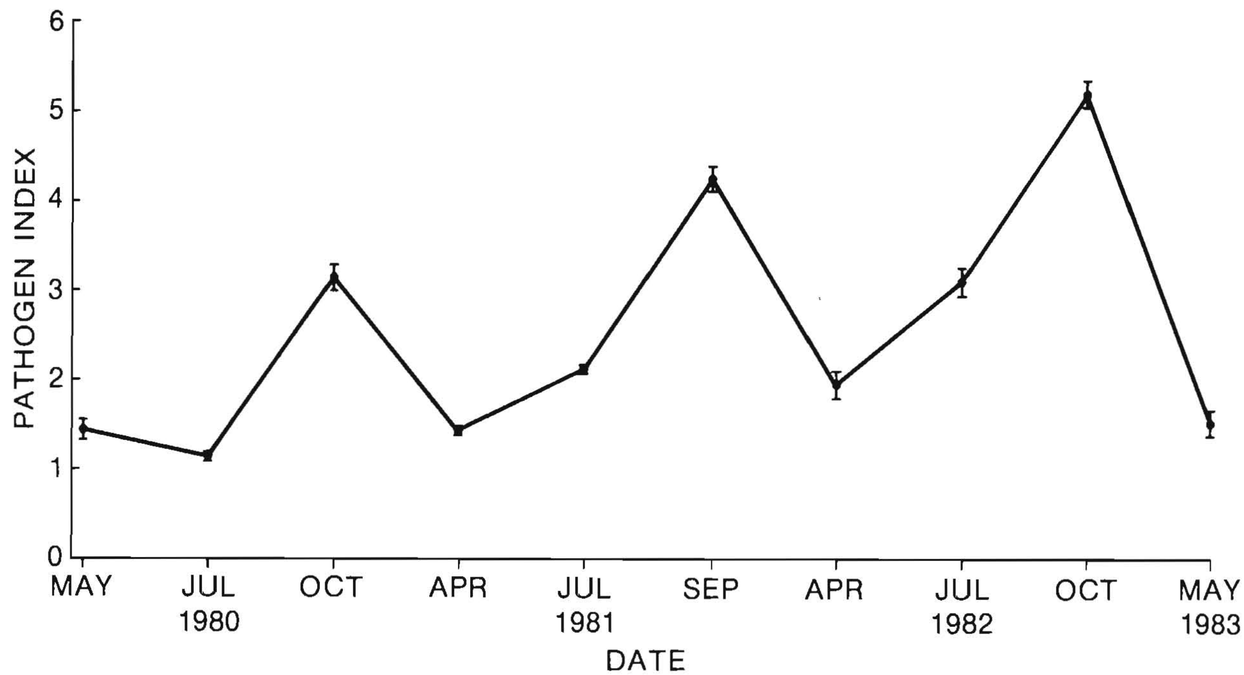

Figure 1. Mean pathogen damage per waterhyacinth leaf at the Lake Theriot study area. Vertical bars represent two standard errors of the means

July 1981, indicating that significant pathogen-induced stress occurred much earlier during the 1982 growing season. The mean value for July was similar to the degree of pathogen damage normally occurring during the fall. The mean value for October 1982 represented the highest value recorded at any study site on any sampling date. Thus, pathogen damage was considered to be an important factor in the decline of waterhyacinth at the study site in 1982.

12. *Cercospora.* Although *Cercospora* symptoms were very abundant at the Lake Theriot study site in 1980 and 1981, no typical symptoms were observed during 1982, and efforts to re-isolate *Cercospora* from waterhyacinth tissues were unsuccessful. Thus, pathogen damage in 1982 was attributed to increased activity by an unidentified group of weak, facultative pathogens normally associated with waterhyacinth in Louisiana. In unstressed waterhyacinth populations, this group of microorganisms normally contributes to the senescence process during the fall. However, the severe stress placed on the waterhyacinth population at the study site by *Cercospora* and *Neochetina* in 1981 weakened the plant population sufficiently that activity by these microorganisms greatly increased during 1982 and occurred much earlier in the growing season.

13. Factors responsible for the failure of *Cercospora* to persist on the waterhyacinth population during 1982 are unclear. Once established, *Cercospora* populations recur annually on waterhyacinth populations in Florida. Perhaps the specific environmental conditions required for *Cercospora* population development were not present in the study area during 1982. It is also possible that population development of other microorganisms had progressed sufficiently by July 1982 that *Cercospora* development was limited by decreased nutrient availability, and perhaps by antibiosis induced by other microorganisms.

14. *Neochetina.* Mean numbers of both *Neochetina* adults and larvae per square metre were significantly lower for all 1982 sampling dates than for corresponding dates in 1981 (Figure 2). Maximum numbers of *Neochetina* adults in 1982 occurred in October ($26.4/m^2$), while maximum numbers of larvae occurred in July ($90.1/m^2$). When combined means for *Neochetina* adults and larvae for 1981 and 1982 sampling dates were compared on the basis of number per plant and number per kilogram of plant tissue (Figure 3), the *Neochetina* population levels in April and July of 1982 were lower than for corresponding dates in 1981, and were approximately the same in October 1982 as for September 1981. Thus, *Neochetina*-induced stress on the plant population appeared to be less in 1982 than in 1981. However, the *Neochetina* population during 1982 remained sufficiently high to significantly impact the plant population, especially since the plants were already severely stressed at the beginning of the 1982 growing season.

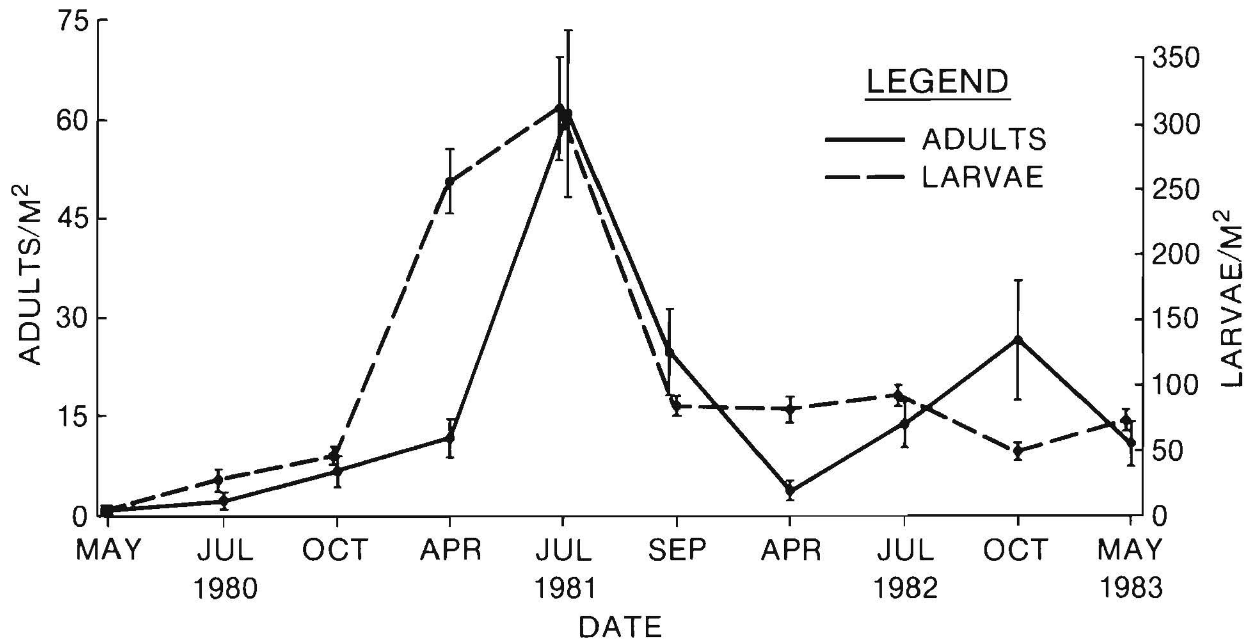

Figure 2. Mean numbers of adult and larval *Neochetina* per square metre at the lake Theriot study area. Vertical bars represent two standard errors of the means

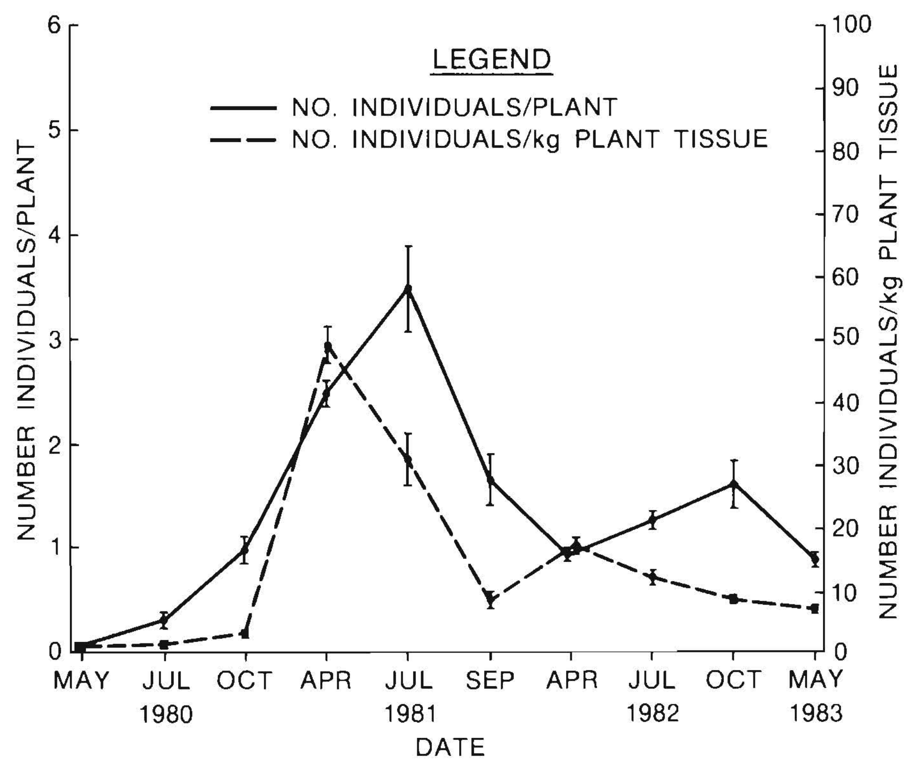

Figure 3. Means of combined *Neochetina* adults and larvae per plant and per unit biomass at the Lake Theriot study area. Vertical bars represent two standard errors of the means

15. Mean index values for adult *Neochetina* feeding scars per leaf were significantly higher in July 1982 than in July 1981, but values for October 1982 were not significantly different than for September 1981 (Figure 4).

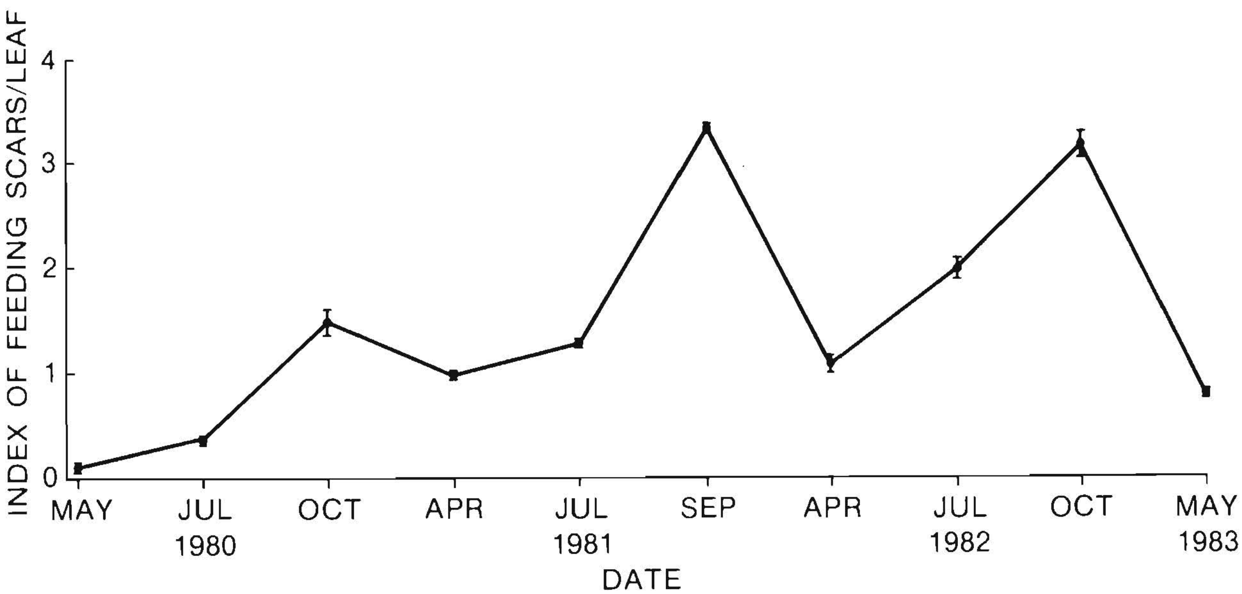

Figure 4. Mean index values for adult *Neochetina* feeding scars per leaf at the Lake Theriot study area. Vertical bars represent two standard errors of the means

This occurred even though the mean number of adults per square metre was nearly five times greater in July 1981 than in July 1982. Adult feeding in July 1982 was largely restricted to the three or four most recently formed waterhyacinth leaves. Older leaves were almost totally destroyed by pathogen damage, and little or no adult *Neochetina* feeding could be detected on these leaves. Thus, *Neochetina* feeding was concentrated on leaves that were suitable. Pathogen damage was much less in July 1981, and more suitable leaves were available for adult *Neochetina* feeding. It is possible that stress effected by adult *Neochetina* feeding was greater in 1982 than in 1981 because feeding in 1982 was concentrated on the more photosynthetically active leaves.

16. *Neochetina* was the principal factor responsible for the decline of the waterhyacinth population at Lake Theriot. A large weevil population developed in October 1980, and the population level remained in excess of 1.0 individual per plant for all sampling dates until May 1983 (Figure 3). Sustained pressure by *Neochetina* during the 1981 and early 1982 growing seasons limited primary productivity sufficiently to significantly stress the waterhyacinth population. To compensate, plants mobilized energy stored in

the rhizomes and root systems, which further weakened them. This was particularly significant in the fall of 1981, and plant regrowth during the spring of 1982 was greatly reduced (as evidenced by decreased surface area coverage, plant density, biomass, and height in April 1982) (Table 1).

17. Other arthropods. Although both *Arzama* and and *Orthogalumna* occurred at the study site in 1982, neither occurred at sufficient population densities to stress the waterhyacinth population (Table 2). *Sameodes* was never found in the study site.

18. Combined effects of biocontrol agents. The decline of waterhyacinth at the Lake Theriot site was effected by a rapidly expanding *Neochetina* population, *Cercospora* activity in 1980 and 1981, and a group of weak, facultative pathogens normally found on waterhyacinth in Louisiana. The waterhyacinth population in 1980-1981 was severely stressed by a combination of *Neochetina* and *Cercospora*, with *Neochetina* serving as the principal trigger factor. The *Neochetina* population remained at sufficient levels in 1982 to exert significant additional stress on the plant population, and additional stress was provided as early as July by weak, facultative pathogens. Pressure on the plant population during 1981 resulted in weakened, stunted plants in 1982, which enhanced the effectiveness of both *Neochetina* and the pathogens during 1982. Since the larval *Neochetina* population and level of pathogen damage in May 1983 remained at levels comparable to that of April 1982, it was expected that biocontrol agents would continue to exert significant pressure on the plant population in 1983.

Conclusions

19. Conclusions of this study were:

a. The waterhyacinth population at the study site declined significantly in 1981 and 1982 due to biocontrol agent activity.

b. A sustained high population of *Neochetina* during 1981 and 1982 was the principal factor triggering the observed decline in the plant population.

c. *Cercospora* developed to population levels that significantly impacted the waterhyacinth population in 1981, but did not contribute directly to observed changes in the plant population in 1982.

d. Impacts of associated weak plant pathogens in 1982 were sufficient to significantly impact the plant population, and their effects were magnified by the weakened condition of the plants during 1982.

e. *Sameodes* did not become established at the study site.

Neochetina and a Spring Application of a Modified *Cercospora* Formulation

Summary of previous findings

20. The waterhyacinth population at the Centerville site remained at 100-percent cover in September 1981, and plant density and height were not significantly different than in August 1980. However, plant biomass was 20 percent lower in September 1981 than in August 1980. *Cercospora* had failed to become established, apparently due to a lack of virulence of the formulation particles. The *Neochetina* population had increased during the summer of 1981, but population levels were lower in September 1981 than in August 1980. The decline in waterhyacinth biomass was attributed to the increased *Neochetina* population during the summer of 1981.

Results and discussion for 1982-1983

21. Waterhyacinth population. Surface coverage of waterhyacinth in the study area decreased to 85 percent in July 1982, increased to 90 percent by October 1982, and was 100 percent in May 1983 (Table 3). Plant density decreased significantly for all 1982 sampling dates as compared to corresponding dates in 1981. Plant density was 28 percent lower in October 1982 than in September 1981, and was 32 percent lower than in August 1980. Plant biomass was 14 percent lower in October 1982 than in September 1981, and was 31 percent lower than in August 1980. Plant height did not vary appreciably during the study. Since these changes in the waterhyacinth population could not be attributed to extreme environmental conditions, it appeared that biological agents were responsible.

22. Pathogen damage. Mean index values of pathogen damage were not significantly different in April and July of 1982 and May 1983 than for corresponding dates in 1981 (Figure 5). Pathogen damage in October 1982 was significantly higher than for September 1981 or August 1980. Thus, increased pathogen damage in October 1982 could have contributed to observed changes in the waterhyacinth population.

23. *Cercospora.* Since *Cercospora* had failed to become established in the study area during 1981 and was not re-isolated from the plant population in 1982, it produced no impacts on waterhyacinth. Instead, pathogen damage was attributed to weak, facultative plant pathogens normally found on waterhyacinth in Louisiana. These plant pathogens produced significant impacts on

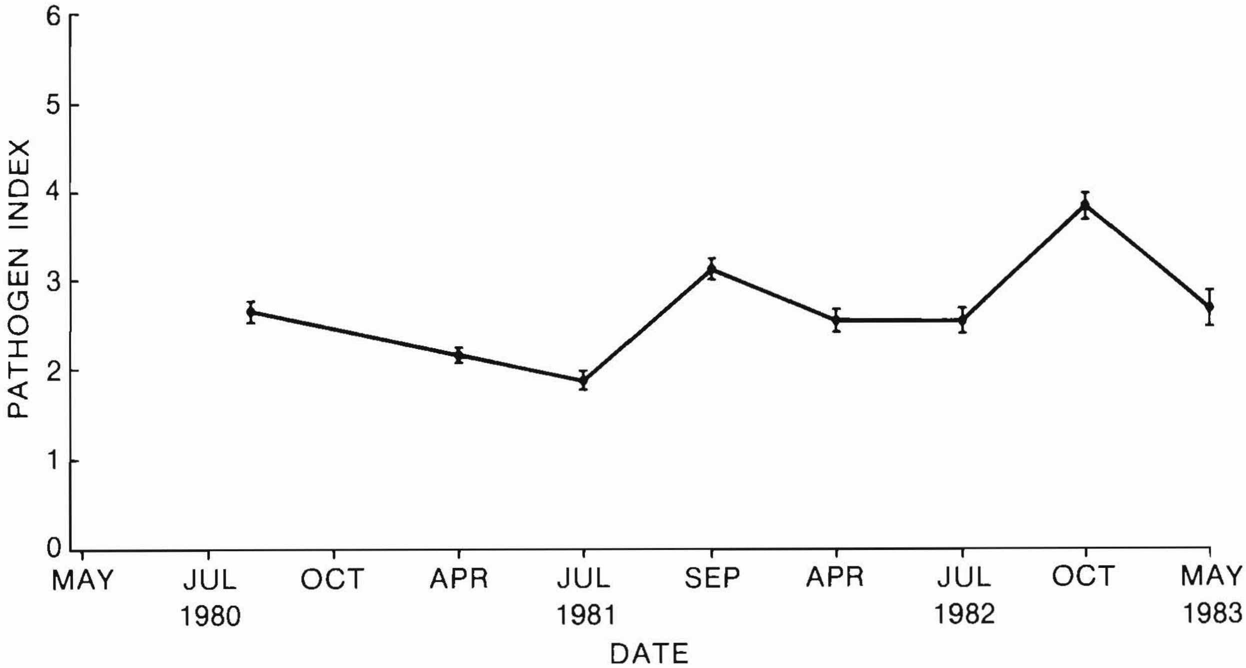

Figure 5. Mean pathogen damage per waterhyacinth leaf at the Centerville study area. Vertical bars represent two standard errors of the means

waterhyacinth only during the fall, and impacts were probably limited to acceleration of senescence. Thus, this group of microorganisms would have produced few, if any, noticeable impacts on the plant population in the absence of other biocontrol agents.

24. *Neochetina.* Mean numbers of *Neochetina* adults per square metre were significantly greater in July and October 1982 than for corresponding dates in 1981 (Figure 6). Mean numbers of larvae per square metre were significantly lower in April and July of 1982 than for corresponding dates in 1981. When combined means for *Neochetina* adults and larvae for 1981 and 1982 were compared on the basis of number per plant and per kilogram of plant tissue, the *Neochetina* population was significantly lower in April and July of 1982 than for corresponding dates in 1981 (Figure 7). Combined means were significantly higher in October 1982 than in September 1981 (per plant basis), but were not significantly different when compared on a unit biomass basis. Thus, *Neochetina* populations developed sufficiently during 1981 to significantly impact the waterhyacinth population, but population levels were not sustained during the spring and summer of 1982. Thus, plant biomass and height (Table 3) were not greatly reduced during 1982.

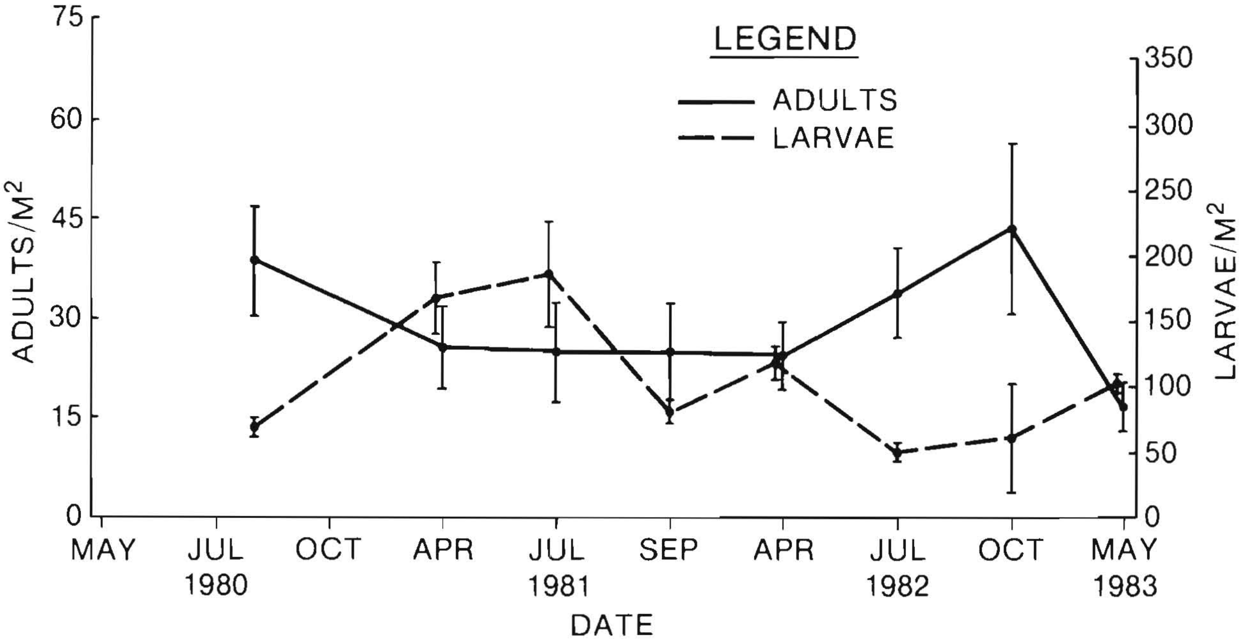

Figure 6. Mean numbers of adult and larval *Neochetina* per square metre at the Centerville study area. Vertical bars represent two standard errors of the means

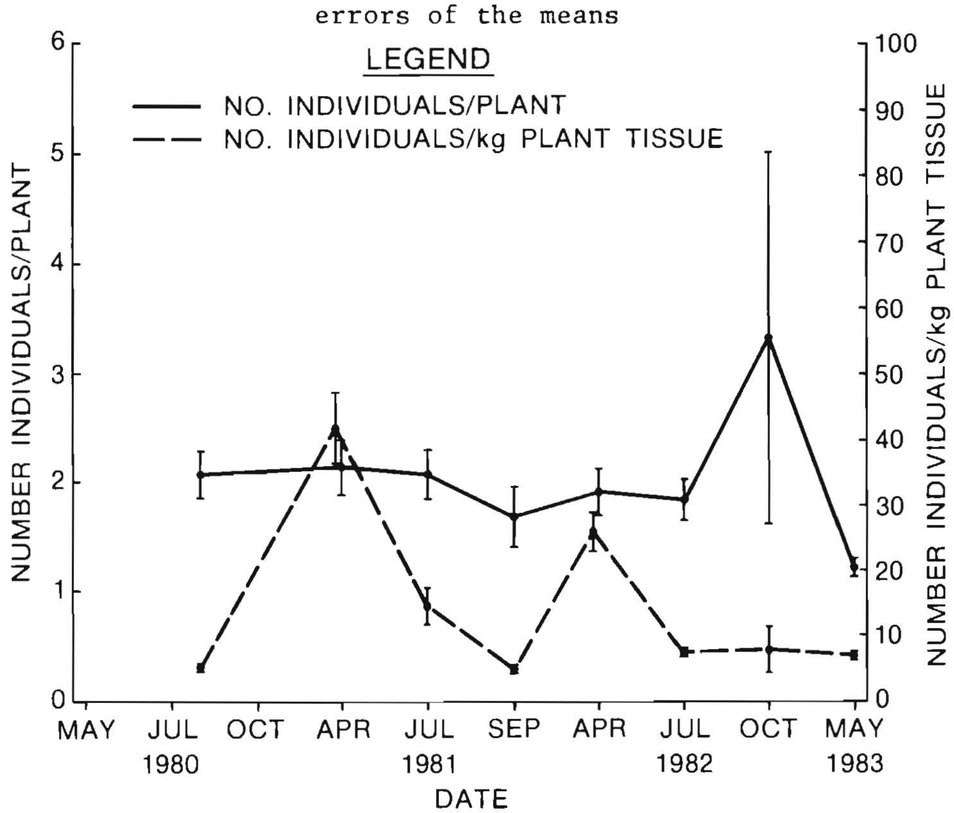

Figure 7. Means of combined *Neochetina* adults and larvae per plant and per unit biomass at the Centerville study area. Vertical bars represent two standard errors of the means

25. Mean index values of adult *Neochetina* feeding scars per leaf were significantly greater in April and July of 1982 than for corresponding dates in 1981 (Figure 8). The mean for October 1982 was not significantly different

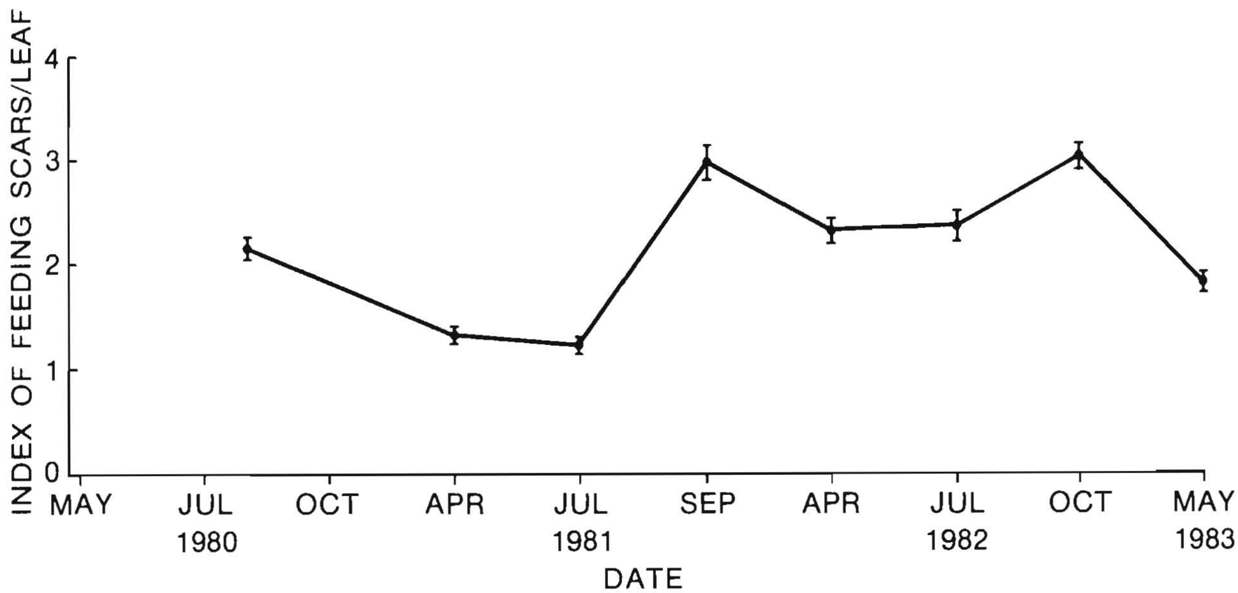

Figure 8. Mean index values for adult *Neochetina* feeding scars per leaf at the Centerville study area. Vertical bars represent two standard errors of the means

than for September 1981. Reasons for increased feeding by *Neochetina* adults in April 1982 are unclear because adult populations were similar in April of both years. Perhaps the difference was due to temporal variations in weather patterns (e.g. periods of colder temperatures in April 1981). Greater adult feeding in July 1982 than in July 1981 was due to the presence of larger numbers of adult weevils in July 1982.

26. Failure of *Neochetina* to produce greater impacts on the waterhyacinth was attributed to a significant reduction in the larval population between July and September of 1981 without a concomitant increase in the adult population in September. This suggested that the relatively large larval population in July 1981 was subjected to environmental conditions that resulted in high mortality rates. However, factors that may have influenced larval mortality are not known. Nevertheless, the *Neochetina* population at Centerville was not sustained at a sufficiently high level to effect a dramatic decrease in the waterhyacinth population.

27. Other arthropods. Neither *Arzama* nor *Orthogalumna* occurred at sufficient population levels to impact the waterhyacinth population (Table 4). *Sameodes* had been released near the study site in 1981 and was found in the general area in 1983, but it was not observed in the study site during 1982 or 1983.

28. Combined effects of biocontrol agents. Although the observed decline in waterhyacinth was attributed primarily to *Neochetina*, pathogen activity also placed additional pressure on the *Neochetina*-stressed population, particularly in September 1981 and October 1982. Failure of *Cercospora* to become established in the study area precluded an evaluation of *Cercospora* and *Neochetina* as a biocontrol agent combination.

Conclusions

29. Conclusions of this study were:

- a. Waterhyacinth biomass and plant density declined in the study area, but the desired level of waterhyacinth control was not achieved.
- b. A moderate-sized *Neochetina* population was the primary factor effecting the observed decrease in waterhyacinth.
- c. Failure of *Neochetina* to develop sustained high population densities limited its effectiveness as a biocontrol agent.
- d. *Cercospora* failed to become established in the study area.

Neochetina and *Sameodes*

Summary of previous findings

30. Surface area coverage of waterhyacinth had been reduced to 60 percent by September 1981. However, plant density, biomass, and height in September 1981 equalled or exceeded values for October 1980. Pathogen damage was low and relatively constant. The *Neochetina* population fluctuated, but was slightly higher in 1981 than in 1980. *Sameodes* did not become established in the study area in 1980 or 1981. Reduction in surface area coverage by waterhyacinth was attributed to effects produced by an expanding *Neochetina* population. Further reductions in the waterhyacinth population were expected during 1982.

Results and discussion for 1982-1983

31. Waterhyacinth population. Surface area coverage of waterhyacinth increased from 60 percent in September 1981 to 90 percent in April 1982, and

remained at that level during the rest of the study (Table 5). Plant density, biomass, and height were similar in October 1982 as in September 1981. The waterhyacinth population at the site in 1982 exhibited the normal pattern of development for waterhyacinth in southern Louisiana (Sanders, Theriot, and Perfetti 1984). Thus, waterhyacinth at Cypress Canal was not significantly impacted by biocontrol agents in 1982.

32. Environmental conditions at Cypress Canal were optimal for waterhyacinth. A dense tree canopy along the canal margin provided reduced summer temperatures and some protection from low winter temperatures. Water flow through the canal varied, but significant flushing periodically occurred. Outflow from an upstream sewage treatment lagoon provided an abundant supply of plant nutrients. Thus, greater populations of biocontrol agents probably would be required to obtain a significant degree of plant control in this system than in a closed system where nutrients are not constantly being added.

33. Pathogen damage. Pathogen damage increased significantly in October 1982 as compared to September 1981 (Figure 9). However, the relatively low value in July 1982 indicated that pathogen damage was not sustained, and was probably related to the pattern of senescence normally occurring during the fall. Since *Cercospora* was not applied in this study, pathogen damage was attributed to a group of weak, facultative pathogens. However, the vigorously

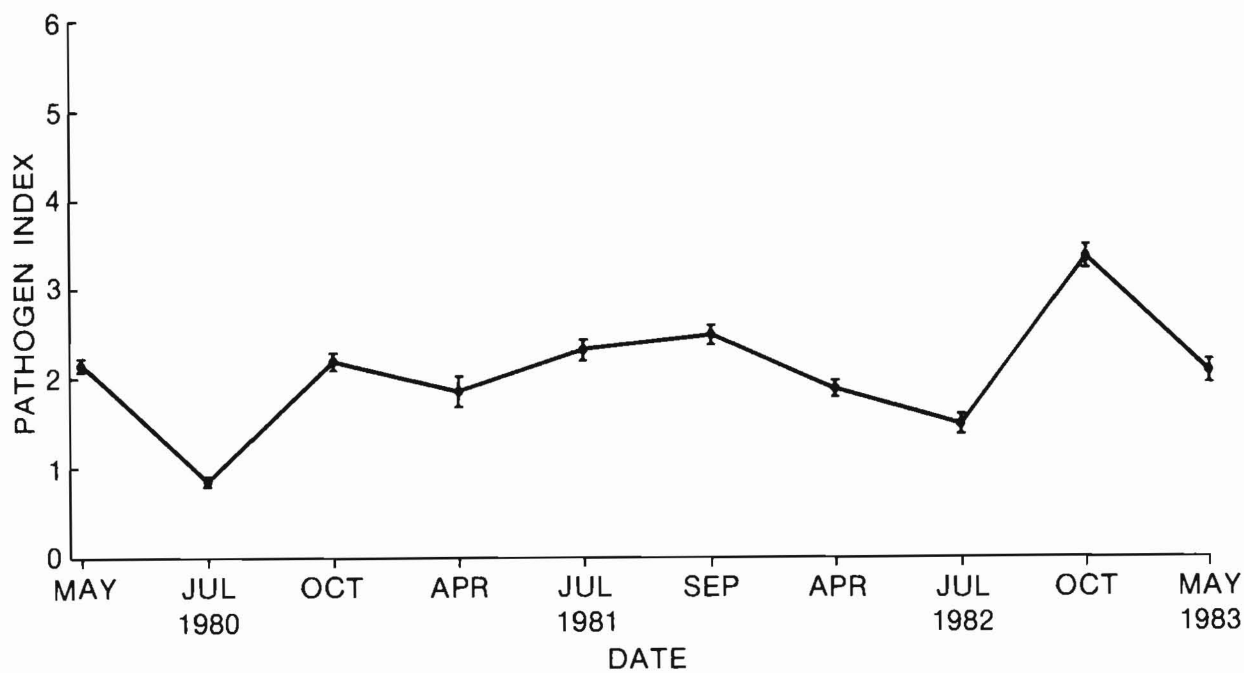

Figure 9. Mean pathogen damage per waterhyacinth leaf at the Cypress Canal study area. Vertical bars represent two standard errors of the means

growing plant population reduced impacts of these pathogens on the waterhyacinth population during 1982.

34. *Neochetina.* The mean numbers of *Neochetina* adults were significantly lower in April and July of 1982 than for corresponding dates in 1981 (Figure 10). The number of *Neochetina* adults increased significantly in

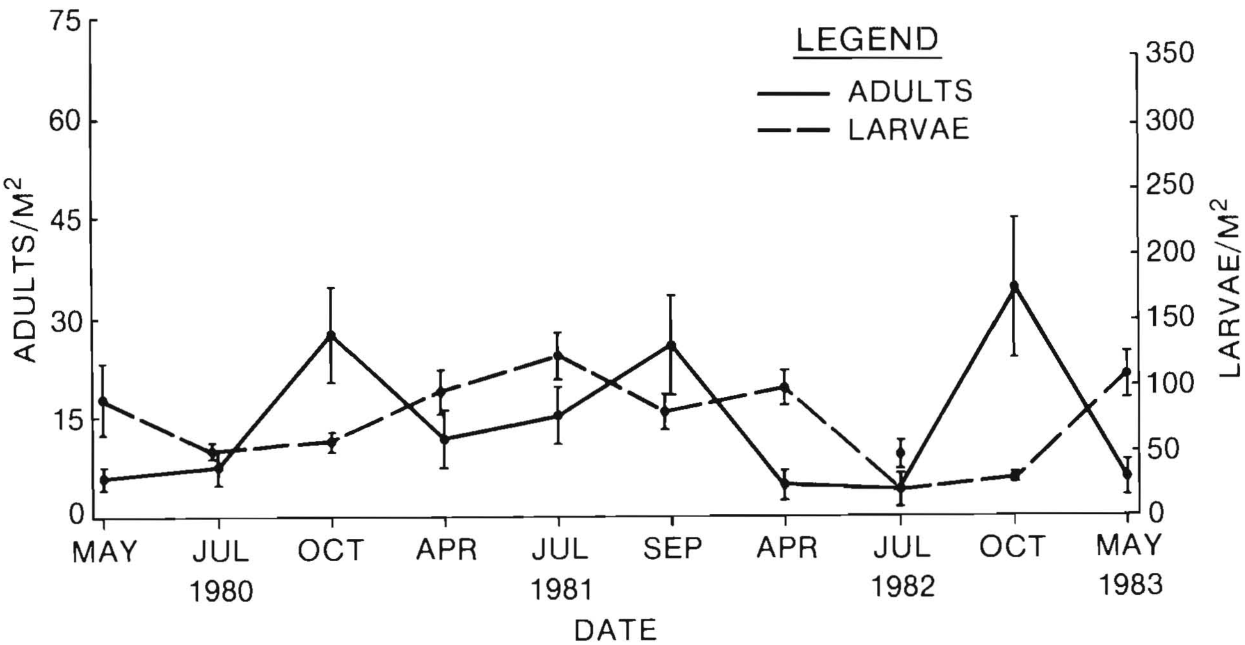

Figure 10. Mean numbers of adult and larval *Neochetina* per square metre at the Cypress Canal study area. Vertical bars represent two standard errors of the means

October 1982, but was not significantly higher than means for October 1980 and September 1981. The mean number of *Neochetina* larvae in April 1982 was similar to that for April 1981, but means in July and October of 1982 were significantly lower than in April 1982, and were much lower than for corresponding dates in 1981. The larval populations in May 1983 and April 1982 were similar. When compared on the basis of number per plant and unit biomass, mean numbers of combined *Neochetina* adults and larvae varied significantly, but in a definite pattern, among sampling dates (Figure 11). Means were annually lowest in spring and highest in fall, when compared on a per plant basis. This was due primarily to high plant densities during spring and low plant densities in fall. The significantly higher insect population in September 1981 than in October 1980 and October 1982 indicated an expanding *Neochetina* population during 1981. However, means for 1982 sampling dates were similar to those for 1980; thus, the weevil population did not continue to expand

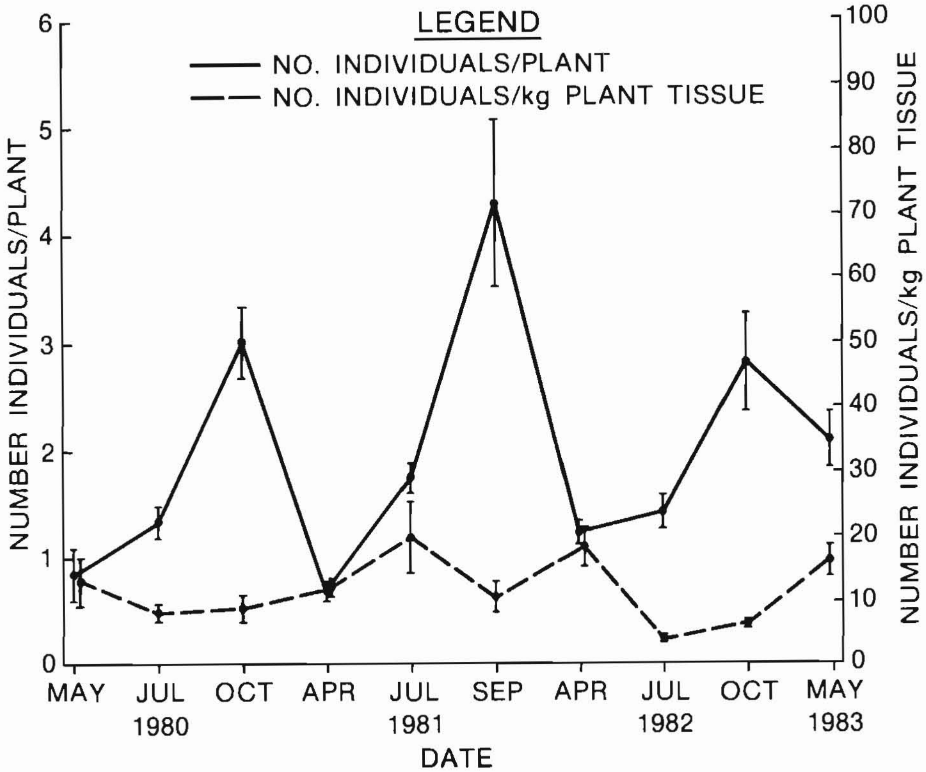

Figure 11. Means of combined *Neochetina* adults and larvae per plant and per unit biomass at the Cypress Canal study area. Vertical bars represent two standard errors of the means

during 1982. Comparisons based on unit biomass of waterhyacinth (Figure 11) revealed that lowest means generally occurred during fall and highest means occurred during spring. This was due to lower waterhyacinth biomass present during the spring. An exception to this general trend was observed during 1981, in which highest means occurred in July. This was the period of the most actively expanding *Neochetina* population.

35. Mean index values of adult *Neochetina* feeding scars per leaf were similar for all 3 years (Figure 12). Lowest values occurred during spring and highest values occurred during fall. The only significant variation in the pattern occurred in July 1982, when the mean value was significantly higher than means for July in 1980 and 1981. This occurred even though the mean number of adults present in July 1982 was significantly lower than the mean for July 1981.

36. Although the waterhyacinth population at Cypress Canal decreased by 40 percent in surface area coverage during 1981, the trend was not maintained during 1982. This was attributed to failure of the *Neochetina* population to

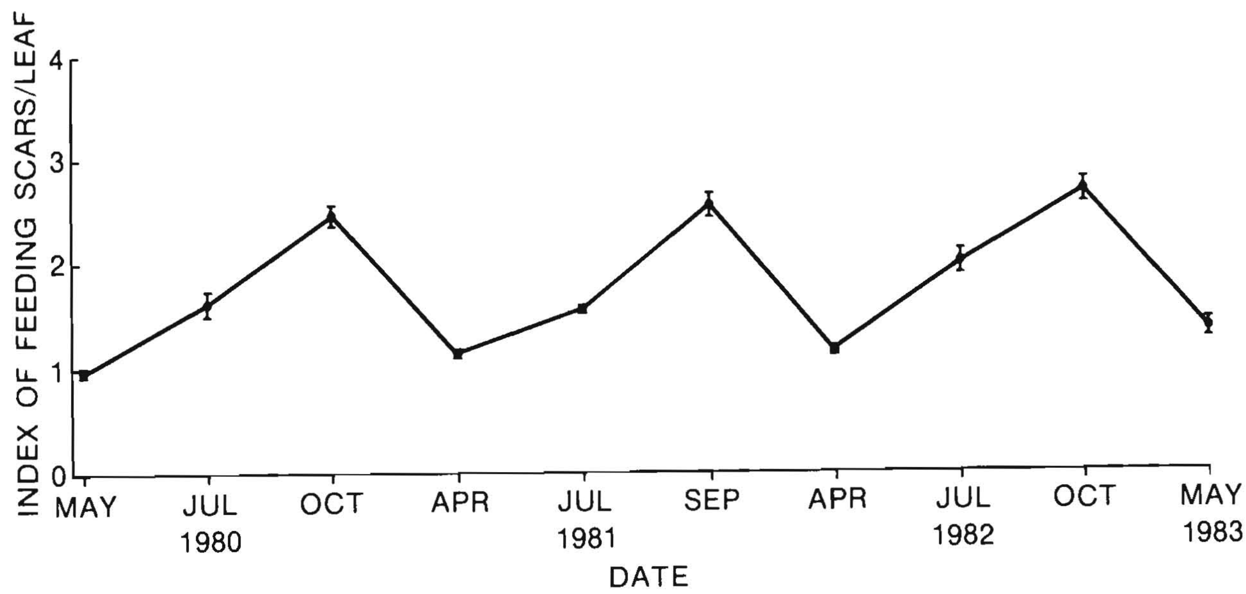

Figure 12. Mean index values for adult *Neochetina* feeding scars per leaf at the Cypress Canal study area. Vertical bars represent two standard errors of the means

maintain the 1981 population levels or expand during 1982. The *Neochetina* population (Figure 10) continued in the synchronous pattern of population development reported in Sanders, Theriot, and Perfetti (1984). When adult populations were high, larval populations were relatively low, and vice versa. Thus, a synchronous pattern of population development is not conducive to development of population levels required to provide the desired level of control. Factors responsible for a continuously synchronous pattern of *Neochetina* population development at Cypress Canal are not known.

37. Perhaps the most critical period of *Neochetina* population development in the Cypress Canal study area occurred between September 1981 and April 1982. Relatively high larval populations were present on both dates, but the adult population in April 1982 was significantly lower than for September 1981 (Figure 10). This pattern had also occurred during the period from October 1980 to April 1981, but the resulting adult population was significantly lower in April 1982 than in April 1981. It was assumed that greater mortality of overwintering individuals occurred in 1982 than in 1981. Another important difference between the *Neochetina* population in 1981 and 1982 was that the larval population increased between April and July of 1981, but decreased during the same period in 1982 without a concomitant increase in the adult

population. This suggested that significant larval mortality occurred between April and July of 1982.

38. Characteristics of the waterhyacinth population at Cypress Canal were not only influenced by the *Neochetina* population, but also by an apparently significant external environmental condition. Cypress Canal periodically received effluent from a sewage treatment lagoon located upstream. This affected the waterhyacinth population in two ways. First, the periodic flow of water from the sewage lagoon tended to concentrate the plant population toward the downstream end of the plot. This condition would have resulted in increased crowding of plants and reduced potential for daughter plant production. Secondly, the high nutrient load afforded optimal conditions for plant growth. During 1980 and 1981, the relatively high weevil populations impacted the plants sufficiently to effect a reduction in the plant population, but surviving plants remained robust. Failure of the *Neochetina* population to expand in 1982, especially during the spring months, afforded the opportunity for waterhyacinth surface area coverage to rapidly increase. Thus, the outflow from the sewage lagoon at least partially offset the effects of *Neochetina* on the waterhyacinth population.

39. Other arthropods. Although both *Arzama* and *Orthogalumna* were present, neither occurred at a sufficient population level to significantly impact the waterhyacinth population (Table 6). *Sameodes* was present in the study area at very low population levels in 1982, but did not impact the plant population.

40. Combined effects of biocontrol agents. Reduction in the waterhyacinth population at Cypress Canal in 1981 was partially attributed to combined effects of *Neochetina* and weak, facultative pathogens normally associated with senescence. Increased activity by *Neochetina* in 1981 stressed the plants sufficiently to enable plant pathogens to produce greater impacts than normally would be expected. Reduced population levels of *Neochetina* in 1982 lessened impacts of pathogens on the plant population, even though pathogen activity was greater in October 1982 than in September 1981. Since *Sameodes* failed to become established until 1982, effects of a combination of *Neochetina* and *Sameodes* on the plant population were not demonstrated.

Conclusions

41. Conclusions of this study were:

a. Waterhyacinth surface area coverage decreased by 40 percent in 1981 as a result of biocontrol agent activity, but significantly increased during 1982 to levels comparable to 1980.

b. *Neochetina* was the major factor responsible for the decline in waterhyacinth in 1981, but failure of the insect population to be maintained or expand in 1982 limited its impacts on the plant population.

c. Weak, facultative plant pathogens contributed to the decline of waterhyacinth in 1981, but their effects in 1982 were indirectly limited by reduced *Neochetina* populations.

d. *Sameodes* became established in the study area in 1982, but did not impact the waterhyacinth population.

e. The degree of control effected by biocontrol agents was limited by outflow from a sewage treatment lagoon located upstream from the study area.

Establishment, Dispersal, and Distribution of *Sameodes*

Summary of previous findings

42. *Sameodes* became established on waterhyacinth in the Cypress Canal area in 1979 and successfully overwintered (Sanders, Theriot, and Perfetti 1984). First found outside the release area in October 1980, the *Sameodes* distribution in October 1980 included 1,230 km^2 and encompassed all or portions of five parishes in southeastern Louisiana. The 1981 *Sameodes* distribution expanded to 2,883 km^2 and included all or portions of nine parishes. Population development was sufficient in some areas to produce noticeable impacts on the plant population. However, *Sameodes* had not become established in the Atchafalaya Basin.

Results and discussion for 1982-1983

43. Although a comprehensive survey for *Sameodes* was not conducted in 1982, *Sameodes* was observed at many sites where it had occurred in 1981. Significant populations were observed by July, which was earlier than had occurred in 1981. This suggested that greater numbers of individuals successfully overwintered during 1981-1982 than in previous winters, and that *Sameodes* populations were expanding.

44. Results of surveys conducted in May and October of 1983 are presented in Table 7. The May survey revealed that *Sameodes* populations had developed in numerous locations 2 months earlier than in 1982 and that relatively large numbers had successfully overwintered during 1982-1983. The observation of *Sameodes* at Centerville inside the Atchafalaya Basin confirmed that the colony released in the area in 1981 had become successfully established. A population found at Lake Verret suggested that *Sameodes* was established throughout the lower portion of the Basin. Whether the population found at Lake Verret represented eastward expansion from Centerville or northward expansion from the Houma area is not known. Nevertheless, these populations represented significant expansion of the range of *Sameodes* in Louisiana. Establishment of *Sameodes* in the lower portion of the Atchafalaya Basin was of significance because the Basin contains large acreages of waterhyacinth and has traditionally been a major problem area. The observation of *Sameodes* at Ester indicated that the colony released in 1981 at Pecan Island (Vermilion Parish) had become established and was dispersing. The observation site was approximately 10 miles* east of the release site.

45. The October 1983 survey (Table 7) revealed two important expansions of *Sameodes* distribution in Louisiana. Populations found at Big Fork, Bayou Sorrel, Duck Lake, and Jeanerette confirmed that *Sameodes* was well distributed in the lower half of the Atchafalaya Basin. The population found near Venice confirmed that *Sameodes* had successfully become established at the southern limits of waterhyacinth distribution in Louisiana. *Sameodes* distribution in October 1983 encompassed a 6,105-km^2 area (Figure 13), including all or portions of 13 parishes.

46. These data indicated that *Sameodes* distribution was continuing to expand in Louisiana. *Sameodes* had become established by October 1983 in areas comprising nearly 75 percent of the total waterhyacinth population in the state. However, *Sameodes* had not become established in the northern half of the Atchafalaya Basin nor in any portion of the state north of Baton Rouge. It is expected that *Sameodes* will continue to expand its range northward to include all of the Atchafalaya Basin and perhaps westward to the Texas border.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

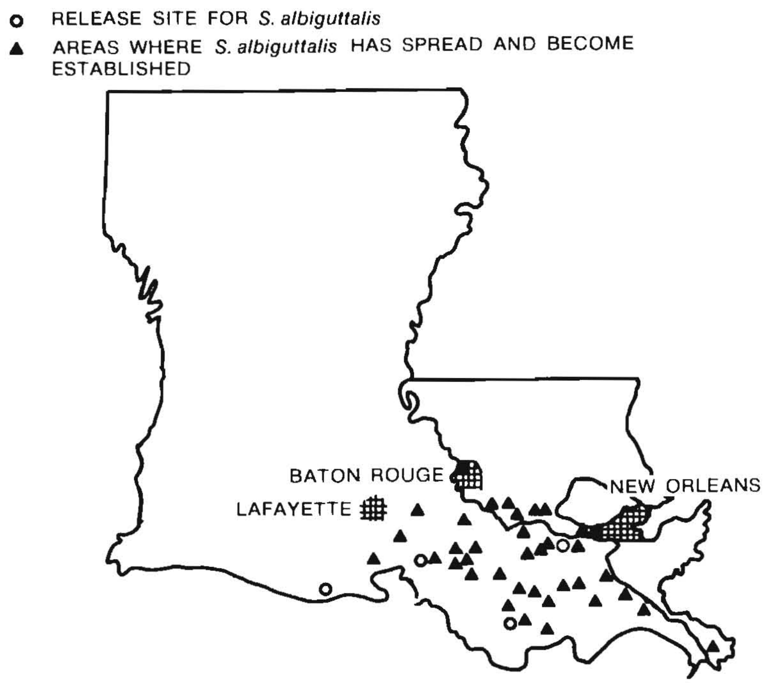

Figure 13. Distribution of *Sameodes* in Louisiana by October 1983

The ability of *Sameodes* to survive in the northern portion of Louisiana is unknown, but it is unlikely that it will naturally spread to waterhyacinth populations in this portion of the state. Waterhyacinth populations north of Alexandria are largely confined to widely separated lakes and reservoirs.

47. Long-term impacts of *Sameodes* on the waterhyacinth population in Louisiana remain to be determined. Waterhyacinth populations in several areas were noticeably impacted by the moths, but no instances were observed in which *Sameodes* significantly reduced the surface area coverage. Environmental influences and life cycle and behavioral characteristics of *Sameodes* may combine to limit its effectiveness as a biocontrol agent. The 30-day life cycle of *Sameodes* affords potential for rapid population development, but the high degree of mobility of adult moths provides potential for significant emigration. As the population rapidly develops at a site and begins to impact the plant population, fewer suitable oviposition sites are available to emerging adults; thus, they migrate to other areas having more suitable plants. It is not uncommon to find dense populations of *Sameodes* at a site in 1 month and none at the same site 2 months later. Thus, *Sameodes* does not appear to exert

sustained pressure on a waterhyacinth population for sufficient periods to effect a substantial reduction in surface area coverage. Effects of *Sameodes* may be enhanced in areas where dense populations of *Neochetina* are also present.

48. Environmental conditions, especially during winter, appear to significantly affect *Sameodes* population development in Louisiana. Whereas peak *Sameodes* populations occur during the spring in Florida (Center 1981), significant populations do not occur in Louisiana until mid to late summer. Since dense *Sameodes* populations do not develop in Louisiana during spring months when waterhyacinth populations consist predominantly of the preferred Stage I morphotype, *Sameodes* has little impact on plant growth during the spring. Most waterhyacinth populations have converted to the Stage III morphotype by the time significant populations of *Sameodes* develop. *Sameodes* does not prefer and seldom is found in large numbers on Stage III plants. Thus, *Sameodes* effectiveness may be limited to impacts on regrowth of Stage I plants following herbicide applications during late midsummer to fall.

Conclusions

49. Conclusions of this study were:

a. *Sameodes* became established on waterhyacinth in southeastern Louisiana and rapidly dispersed to other areas. *Sameodes* distribution in October 1983 encompassed a 6,105-km^2 area, including all or portions of 13 parishes.

b. Ultimate effectiveness of *Sameodes* on waterhyacinth in Louisiana remains to be determined, but its effectiveness may be limited by high winter mortality rates, which precludes development of high population densities during the following spring.

PART IV: GENERAL DISCUSSION

Waterhyacinth Population

50. The waterhyacinth population in Louisiana during 1974-1983 is presented in Figure 14. The population averaged 1.25 million acres during 1974-1978, which was the period during which *Neochetina* was becoming established and dispersing throughout the state. The first noticeable decrease in the waterhyacinth population occurred in 1979, when the population declined to 850,000 acres. However, there was no conclusive evidence that biocontrol agents were contributing to the observed decline, nor that further declines in the plant population could be expected. The waterhyacinth population in October 1980 was 305,000 acres, a 75.4-percent reduction as compared to the average population for 1974-1978. This reduction was attributed to a combination of improved herbicide spray programs, a significant drought during 1980, and effects of an expanding *Neochetina* population (Sanders, Theriot, and Perfetti 1984).

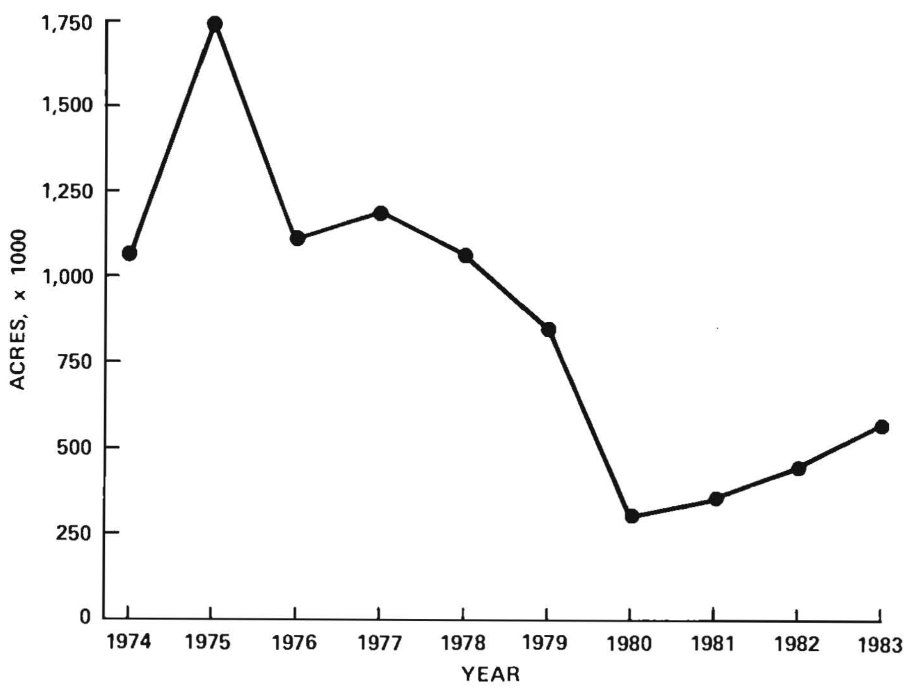

Figure 14. Population of waterhyacinth in Louisiana during 1974-1983 (Louisiana Department of Wildlife and Fisheries 1981)

51. The plant population increased slightly to 340,000 acres in 1981. This was attributed to rapid regrowth of waterhyacinth in some areas where the population had been significantly reduced in 1980. Because waterhyacinth has such great potential for expanding its population level in the absence of external stress factors (e.g. *Neochetina*), it had been anticipated that the plant population would increase during 1981 to levels approaching those of 1974-1978. However, failure of the waterhyacinth population to increase significantly during 1981 following termination of the 1980 drought strongly implicated biocontrol agents as the primary factor responsible for the decline in plant population.

52. The waterhyacinth population increased significantly to 434,200 acres in 1982. This 28.0-percent increase was attributed to reduced *Neochetina* populations in many areas during 1981. Since *Neochetina* is dependent on waterhyacinth for its food supply and reproduction, its population is limited by the available waterhyacinth population. The greatly reduced waterhyacinth population during 1981 caused a significant decline in the weevil population. As the overall *Neochetina* population declined, its impacts on the plant population were reduced, and the plant population increased. The potential rate of expansion of waterhyacinth populations is much greater than for *Neochetina*. Thus, the decreased weevil population allowed the waterhyacinth population to increase significantly in 1981.

53. The waterhyacinth population had increased to 657,000 acres by October 1983 (Figure 14). Although this represented a 51.0-percent increase as compared to the 1982 population, it remained 47.4 percent lower than the average waterhyacinth population for 1974-1978. The increased plant population during 1983 was attributed to failure of the *Neochetina* population to redevelop to a sufficient level to effect another decline in the waterhyacinth population. However, the waterhyacinth population had not redeveloped to pre-1980 levels, which suggested that *Neochetina* was continuing to significantly impact the plant population.

54. Based on observed trends in waterhyacinth population redevelopment during 1982 and 1983, further increases in the plant population could be expected in 1984. However, the *Neochetina* population was significantly increasing during 1983. Sufficient populations of *Neochetina* were present in some areas in 1983 so that the same "swarming" phenomenon observed in 1980 (Sanders, Theriot, and Perfetti 1984) occurred again. Whether *Neochetina* populations

developed sufficiently throughout the major areas of waterhyacinth populations in 1983 to effect another significant reduction in the plant population in 1984 remains to be seen.

Neochetina

Population dynamics

55. A comparison of adult and larval *Neochetina* populations from the three major study areas (Figures 2, 6, and 10) revealed that larval populations are generally lowest in spring, peak in summer, and decline by fall. Adult *Neochetina* populations normally are lowest during spring and peak during fall. At the onset of spring, fewer adults and larvae are usually present than during the previous fall due to winter mortality rates. Surviving adults oviposit and surviving larvae complete their development in spring. Thus, larger numbers of both adults and larvae are usually present by July. Subsequent development of larvae present in July normally leads to further increases in the number of adults in fall. However, larval populations normally decline in fall, suggesting that some external factors may limit reproduction during the middle portion of the growing season. Factors influencing *Neochetina* population development are discussed in paragraphs 66-68.

56. Significant variations in the normal pattern of population development occurred at some study sites. Both adult and larval *Neochetina* populations peaked in July at the Lake Theriot site during 1981. Significant reductions in the waterhyacinth population at Lake Theriot were first observed in 1981. The larval *Neochetina* population also peaked at Lake Theriot in July 1982, but the adult population peaked in October. The same general trend occurred at Cypress Canal during 1981, when the plant population was significantly reduced. Thus, it appears that peak populations of adults and larvae during summer, followed by lower, but significant numbers of both life forms during fall, are most effective in impacting the waterhyacinth population. When larval populations were low during both summer and fall, impacts of *Neochetina* on the plant populations were reduced.

57. When comparing *Neochetina* populations (combined adults and larvae) at the three study sites based on number of individuals per plant and unit biomass (Figures 3, 7, and 11), the number of individuals per plant was usually highest during fall and lowest during spring. This was due largely to

the greater density of waterhyacinth plants normally present during spring than during fall. A significant variation in this pattern occurred at the Lake Theriot site in 1981 when the greatest numbers of *Neochetina* occurred during summer. This resulted in greater impacts of *Neochetina* on the plant population during the summer and fall of 1981, which effected observed reductions in the waterhyacinth population. On a unit biomass basis, the greatest numbers of *Neochetina* normally occurred during spring months when plant biomass was lowest. This pattern varied only at the Cypress Canal site in 1981, when greatest numbers of *Neochetina* per kilogram of waterhyacinth occurred in July. This was attributed to the relatively large number of *Neochetina* larvae present at the site in July 1981, which was a major factor in the observed reduction in the waterhyacinth population.

58. Two major patterns of *Neochetina* population development were observed at the study sites. An asynchronous pattern* of population development (Figure 15) occurred at the Lake Theriot site in 1980 and 1981, while a synchronous pattern of population development (Figure 16) occurred at Lake Theriot during 1982 and at the other two study sites at all times during the study. Although some decrease in the waterhyacinth population occurred at all study sites, greatest reductions were observed at Lake Theriot, where the asynchronous population development pattern existed in 1980 and 1981. Thus, it appears that an asynchronous pattern of population development is more desirable than a synchronous pattern. In an expanding *Neochetina* population, the presence of relatively large numbers of both adults and larvae during one generation increases the probability of higher numbers of both life stages in the subsequent generation. This can rapidly result in sufficient *Neochetina* population levels to impact the plant population, which was the case at Lake Theriot in 1981. In the synchronous pattern, relatively large numbers of one life stage (adults or larvae) in one generation normally lead to higher numbers of the other life stage in the next generation, but not in both. Thus, potential for rapid expansion of a synchronous *Neochetina* population is limited.

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* Refers to the simultaneous occurrence of large numbers of adults of one generation and large numbers of larvae of the subsequent generation.

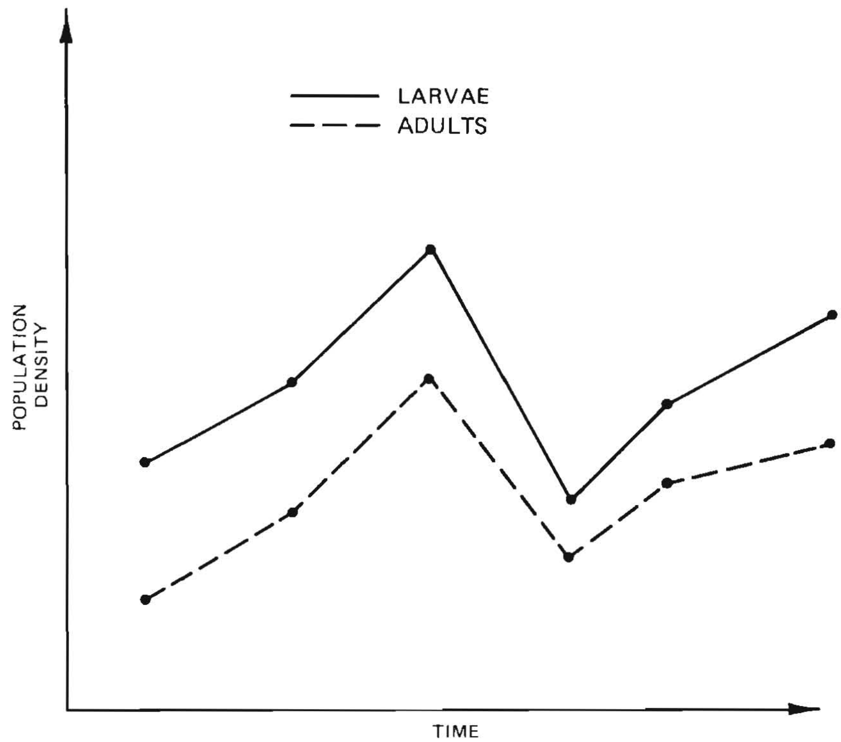

Figure 15. Asynchronous pattern of population development

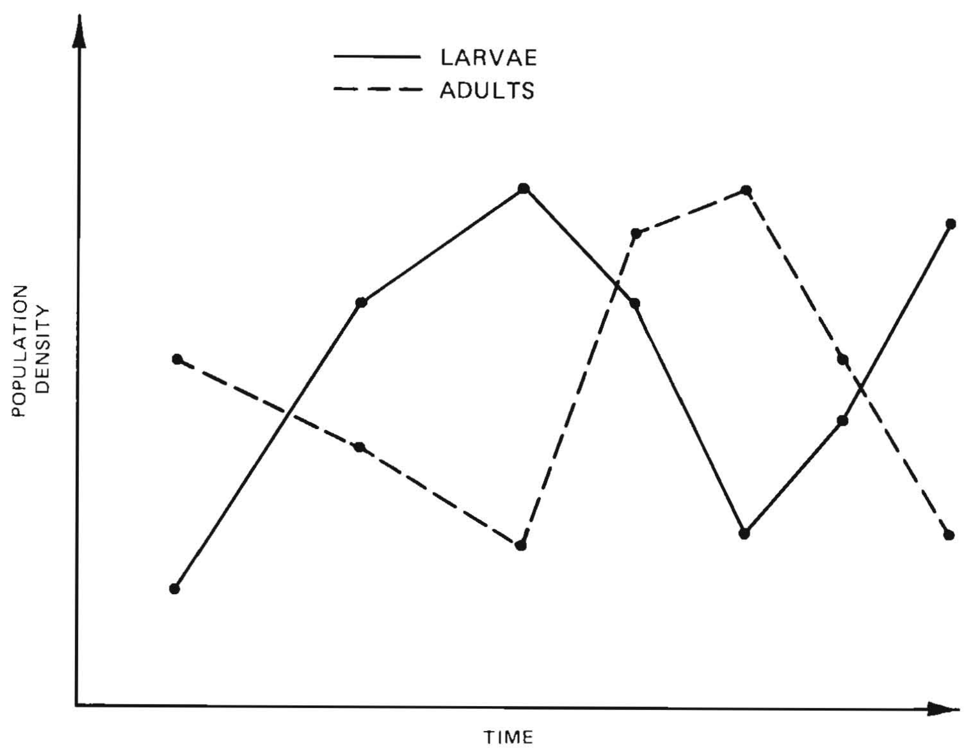

Figure 16. Synchronous pattern of population development

Effects of *Neochetina* on waterhyacinth

59. Specific effects of *Neochetina* on waterhyacinth were presented in Sanders, Theriot, and Perfetti (1984). The net result of these impacts is that *Neochetina* adults and larvae reduce the amount of photosynthate produced by waterhyacinth plants and restrict their translocation to rhizomes and roots. This reduces the amount of stored energy available for plant growth and for initiation of regrowth during the following growing season. Thus, plant vigor is reduced and the plants are more susceptible to various microorganisms normally associated with plant senescence.

60. Critical to manifestation of these effects on waterhyacinth is the initial development of the *Neochetina* population to levels sufficient to trigger these plant responses, followed by sustained populations of *Neochetina* to prevent plant recovery. Generally, the *Neochetina* population level required to exert sustained stress on a weakened plant population is less than that required to produce the initial impacts. This was evident at the Lake Theriot study site. The insect population in 1981 (Figure 3) was sufficient to initiate significant stress on the waterhyacinth population during summer and fall. *Neochetina* populations in 1982 were much lower than in 1981, but the plant population continued to decline. Initial plants produced in April 1982 were fewer, much shorter, and much lower in biomass than those present in April 1981. This reflects less stored energy being available to the initial plants produced during April 1982 than was available in April 1981. Consequently, a reduced insect population, in conjunction with significantly greater pathogen damage, was able to effect significant declines in the waterhyacinth population at Lake Theriot during 1982. Due largely to the synchronous pattern of *Neochetina* population development at Centerville and Cypress Canal, the insect populations never reached a sufficient level to trigger the same magnitude of effects as occurred at Lake Theriot, nor were population levels sustained at sufficiently high levels to exert continued stress by both life stages on the waterhyacinth population.

Threshold *Neochetina* population levels

61. Based on data collected during the *Cercospora* field application rate study, Sanders, Theriot, and Perfetti (1984) tentatively concluded that a sustained *Neochetina* population density of greater than 1.0 individual (combined adults and larvae) per plant effected a significant reduction in the

plant population. They indicated that the threshold level could be somewhat lower, but data were lacking at that time to be more definitive.

62. Data (Figures 3, 7, and 11) from the three study sites described in this report suggested a need for reconsideration of previous conclusions. A combined *Neochetina* population density in excess of 1.0 individual per plant occurred on all sampling dates at Centerville (Figure 7); however, the plant population did not decline appreciably. Combined *Neochetina* population densities in excess of 1.0 individual per plant occurred for all sampling dates from October 1980 to May 1983 (except in April 1982) at Lake Theriot (Figure 3), and values at Cypress Canal (Figure 11) exceeded 1.0 for all sampling dates from July 1980 to May 1983 (except in April 1981). Significant declines in the waterhyacinth population occurred at both Lake Theriot and Cypress Canal. Thus, the threshold for effecting control is probably higher than 1.0 combined individual per plant.

63. The *Neochetina* population at both Lake Theriot and Cypress Canal exceeded 3.0 individuals per plant at least once, followed by population densities of 1.0 individual per plant for two or more subsequent sampling periods. Peak values exceeded 3.0 individuals per plant at Lake Theriot in July 1981 and 4.0 individuals per plant at Cypress Canal in September 1981. Thus, it appears that *Neochetina* produces maximum impacts when the population density exceeds 3.0 individuals per plant at one time, followed by sustained population densities in excess of 1.0 individual per plant for 6 months or more. Goyer and Stark (1984) attributed observed reductions in waterhyacinth populations to the presence of *Neochetina* for several growing seasons, but they reported peak populations of adults of 1.4 individuals per plant immediately prior to a significant reduction in the plant population.

64. When considered on a unit biomass basis, significant reductions in the waterhyacinth population occurred when combined adult and larval *Neochetina* population densities exceeded 15 individuals per kilogram of waterhyacinth during summer or fall months (Figures 3 and 11). Although the *Neochetina* population density at Centerville exceeded 40 individuals per kilogram of waterhyacinth in April 1981 (Figure 7), this was due to the low biomass of waterhyacinth during spring months. The population level dropped to less than 15 individuals per kilogram of waterhyacinth in July, and was approximately 5 individuals per kilogram in September.

65. There is no absolute threshold *Neochetina* population density required to significantly reduce a waterhyacinth population. Threshold levels will vary according to season, plant vigor, duration of high insect population densities, and associated biocontrol agents. The influence of these factors will be discussed in paragraphs 66-68.

Factors influencing *Neochetina* population development and effects on waterhyacinth

66. Factors influencing *Neochetina* population development and effects on waterhyacinth can be divided into two categories:

- a. Intrinsic factors. Intrinsic factors are those that directly relate to the reproductive biology of *Neochetina*.
- b. Extrinsic factors. Extrinsic factors include environmental factors that influence the ability of *Neochetina* to survive and affect waterhyacinth.

67. Intrinsic factors. Two basic intrinsic factors influence *Neochetina* population development:

- a. Generation time. Since *Neochetina* requires approximately 120 days to complete its life cycle (DeLoach and Cordo 1976), no more than 2.5 generations can be produced in one growing season in Louisiana. This limits the potential for population development.
- b. Fecundity. A single adult *Neochetina* female oviposits a total of 200 to 400 eggs. Although a sizable number, it is by no means a high oviposition rate as compared to other insect species, and coupled with the long generation time, reproductive potential is limited.

68. Extrinsic factors. Extrinsic factors influencing *Neochetina* population development and effects on waterhyacinth include:

- a. Factors affecting *Neochetina* population development.
  - (1) Climatic conditions. *Neochetina* survival is influenced by low winter temperatures. Significant numbers of both adults and larvae are killed by extended periods of freezing temperatures during winter months. However, adults appear to be more significantly affected than larvae. Decreased larval populations in fall as compared to summer suggest that either oviposition rates or percentage of viable eggs is reduced during the summer.
  - (2) Available waterhyacinth population. Because *Neochetina* is totally dependent on waterhyacinth as a food source and for reproduction, population development is limited by availability of waterhyacinth. The reduced waterhyacinth population in Louisiana during 1980 and 1981 and the concomitant decrease in *Neochetina* population was thought to be

the principal factor resulting in a gradual, but significant, increase in the waterhyacinth population in Louisiana from 1981 through 1983.

(3) Quality of available waterhyacinth. As waterhyacinth populations become heavily infested by biocontrol agents, both the quantity and quality of the waterhyacinth food source are reduced. Stressed plants contain less stored food, and *Neochetina* individuals must consume larger quantities to obtain their required energy. This may result in smaller individuals of lower vitality, which may lead to decreased fecundity and higher mortality rates.

(4) Predators. Little is known about predators of *Neochetina*. However, large numbers of ants that inhabit waterhyacinth mats probably destroy significant numbers of eggs and some larvae, especially first instars. Larger predators (e.g. insects and birds) may impact the adult *Neochetina* population.

(5) Herbicide spraying activities. When waterhyacinth mats are sprayed with herbicides such as 2,4-D (2,4-dichlorophenoxyacetic acid), all eggs, larvae, and pupae of *Neochetina* are destroyed as the plants die. Thus, *Neochetina* population development is limited in areas where repeated herbicide applications are made annually. Impacts of herbicides on adult *Neochetina* are not well understood.

b. Factors influencing effects of *Neochetina* on waterhyacinth. In addition to intrinsic and extrinsic factors, other factors may influence the effects of *Neochetina* on waterhyacinth. These include:

(1) Degree of confinement of waterhyacinth population. The potential for *Neochetina* effects on waterhyacinth is greatest when the waterhyacinth population is relatively confined. The waterhyacinth population in some areas may be flushed out during periods of high water flow. Since *Neochetina* is usually not highly mobile, the existing insect population may be greatly reduced as plants are carried out of the area. Resulting regrowth of waterhyacinth may be little affected by the remaining insect population because waterhyacinth has much greater potential for population expansion than has *Neochetina*.

(2) Available nutrients for waterhyacinth growth. In areas of abundant nutrient availability for waterhyacinth growth, the threshold *Neochetina* population required to significantly affect the waterhyacinth population may be higher than in areas of limited nutrient availability. This was evident at the Cypress Canal study site, which periodically received effluent from a tertiary sewage treatment pond. Although the waterhyacinth population was reduced in percent cover during 1981, surviving plants were robust and did not appear to be greatly impacted by *Neochetina*. Consequently, the plant population expanded during 1982.

Prospects for control
of waterhyacinth by *Neochetina*

69. *Neochetina* has been demonstrated to be a viable biological agent for control of waterhyacinth in Louisiana. It rapidly became established on waterhyacinth throughout the state, and was implicated as the principal factor resulting in a 75-percent reduction in the plant population in 1980. Although waterhyacinth has steadily increased since 1980, it remains at only 52.6 percent of the average population for 1974-1978. Thus, *Neochetina* continues to exert significant stress on the plant population.

70. The pattern of *Neochetina* population development and its effects on waterhyacinth at Lake Theriot in 1981 and 1982 are probably representative of the role of *Neochetina* in impacting the waterhyacinth population in Louisiana during 1979 and 1980. The *Neochetina* population developed rapidly at Lake Theriot during 1981 and significantly stressed the waterhyacinth population, producing a slight decline in biomass and plant height. This would correspond to the slight decline in the overall plant population in Louisiana in 1979 (Figure 14). Continued pressure by *Neochetina* in 1982 on the already stressed plant population at Lake Theriot resulted in a substantial decline in the percent of surface area coverage of waterhyacinth. This was representative of the significant reduction in the overall waterhyacinth population in Louisiana in 1980 (Figure 14).

71. *Neochetina* is expected to continue to significantly impact the waterhyacinth population in Louisiana. Overall long-term impacts remain to be seen. It is anticipated that the *Neochetina* population will redevelop to levels that will effect another significant decline in the waterhyacinth population. Following the decline in waterhyacinth, the insect population will decline, and the waterhyacinth population will again increase. This natural cycle will be expected to continue unless some catastrophic event results in decimation of the *Neochetina* population. Goyer and Stark (1984) offered the same hypothesis. The magnitude of peaks in the waterhyacinth population growth cycle cannot be predicted, nor is it known whether other biocontrol agents (e.g. *Sameodes*) will contribute sufficient stress on waterhyacinth to produce further reductions in the plant population.

Cercospora

Population development

72. *Cercospora* became established on waterhyacinth only at the Lake Theriot study site. The population first became evident in July 1980 as lesions on the subcanopy, older leaves of scattered plants, especially in portions of the area that were shaded by overhanging vegetation. Lesions were abundant on plants throughout the study area by October 1980, and infected leaves ranged from barely infected to totally dead. Although other plant pathogens were present, their effects were restricted to older leaves. *Cercospora* symptoms were observed only on the third to fifth newest leaves.

73. *Cercospora* symptoms were commonly observed on plants in the study site in April 1981, but the degree of infection was less than observed in the fall of 1980. *Cercospora* symptoms declined in July 1981, presumably due to high daytime temperatures. Very heavy pathogen damage, mostly attributable to *Cercospora*, was observed in September 1981, and it appeared that *Cercospora* development was progressing toward an epiphytotic. Nearly all leaves of observed plants had some degree of *Cercospora* damage.

74. Waterhyacinth plants in most of the study area were visibly stressed in April 1982. They were spindly, Stage III plants of low vigor. Most had extensive necrotic areas on leaves and petioles. However, few apparent *Cercospora* lesions were observed, and the fungus could not be reisolated from damaged plants. No *Cercospora* symptoms were observed in either July or October 1982, nor was *Cercospora* reisolated from diseased plants on either date. It was apparent that the *Cercospora* population had declined either totally or to such a degree that it could no longer be detected. In either case, *Cercospora* was no longer actively impacting the waterhyacinth population.

Impacts of *Cercospora* on waterhyacinth

75. *Cercospora* produced obvious impacts on the waterhyacinth population in 1981. However, the degree to which *Cercospora* affected the plant population could not be determined because *Neochetina* was also impacting the waterhyacinth population.

76. Effects of *Cercospora* on waterhyacinth result in decreased photosynthetic activity, which limits the amount of energy available for both maintenance of growth and reinitiation of growth during the subsequent spring.

Cercospora also produces a phytotoxin, cercosporin, which accelerates tissue necrosis. *Cercospora* effects are similar to those produced by weak, facultative pathogens and saprophytes normally associated with plant senescence. The only significant difference is that its growth rate and infection characteristics enable *Cercospora* to attack more recently produced leaves than the weak, facultative pathogens and saprophytes can infect.

Factors influencing
Cercospora population development

77. Factors influencing *Cercospora* population development can be divided into two types: factors influencing population establishment and factors influencing the rate of population development.

a. Factors influencing population establishment. Although *Cercospora* became successfully established at Lake Theriot, applications at two other locations resulted in failure of establishment for the following reasons:

   (1) Effects of *Neochetina*. *Cercospora* in the original formulation applied at Amelia failed to become established on waterhyacinth due to the impacts of an extremely dense *Neochetina* population (Sanders, Theriot, and Perfetti 1984). Feeding by adult weevils on waterhyacinth leaves effectively destroyed the stomata through which *Cercospora* infects the leaves. Substomatal chambers where *Cercospora* mycelium proliferates were also destroyed, eliminating the high humidity needed for hyphal development.

   (2) Formulation modification. The *Cercospora* formulation applied at Centerville was modified by Abbott Laboratories in an effort to produce a more suitable formulation for marketing purposes. The modified formulation was drier, had larger numbers of viable propagules, and had fewer contaminants than the original formulation. However, the viable propagules lacked infectivity; thus, *Cercospora* failed to become established. Lack of infectivity was attributed either to loss of virulence of stock cultures or to procedures used in the formulation process.

b. Factors influencing the rate of population development. The rate of *Cercospora* population development may have been influenced by climatic conditions, quality of waterhyacinth, and/or antagonistic effects produced by other microorganisms.

   (1) Climatic conditions. The major climate factor influencing *Cercospora* development in southern Louisiana appeared to be high summer temperatures, which inhibited growth of *Cercospora*. Thus, population peaks occurred during spring and fall, with the greatest population peaks occurring during fall.

(2) Quality of waterhyacinth plants. *Cercospora* population development occurs most rapidly on the large, Stage III waterhyacinth morphotype, especially during fall months when photosynthetic activity is reduced and the senescence rate increases. The larger plant leaves during fall provide increased surface area for the infection process, and the amount of stored energy available to *Cercospora* is maximal during fall. *Cercospora* does not develop as rapidly on the small, Stage I morphotype commonly found during spring. Leaf surface area is reduced and, although photosynthetic activity is high during spring, most of the photosynthate is rapidly mobilized for daughter plant production.

(3) Antagonistic effects of other microorganisms. Although not demonstrated in this study, certain microorganisms normally found on waterhyacinth in Louisiana may produce antibiotics that limit growth of *Cercospora* mycelium. This could have been partially responsible for failure of *Cercospora* to develop to significant population levels at Lake Theriot during 1982.

Prospects for *Cercospora* as a biocontrol agent

78. Although *Cercospora* became established on waterhyacinth at Lake Theriot and population development was sufficient to impact the plant population in 1981, prospects for its use as a biocontrol agent are not promising. The original formulation applied at Lake Theriot was suitable for establishing a *Cercospora* population, but it had several properties that made it unsuitable for commercial use. These included:

a. Relatively low numbers of viable propagules. The relatively low number of viable propagules per gram of formulation necessitated application of large quantities of inoculum to achieve the desired treatment rate.

b. High moisture content. The high moisture content of the original formulation resulted in a short shelf life. Thus, the original formulation could not be stored for long periods.

c. High contaminant level. The original formulation contained other microorganisms capable of utilizing the carbon source used for *Cercospora* production. This, together with the high moisture content of the formulation, combined to produce a short shelf life of the formulation.

d. Variable-sized formulation particles. The original *Cercospora* formulation consisted of variable-sized formulation particles, which could pose some application problems.

Accordingly, Abbott Laboratories modified the original formulation to produce a formulation that consisted of high numbers of viable propagules, low moisture content, reduced contaminants, and uniform particle sizes.

79. The resulting modified *Cercospora* formulation had the desired characteristics of a good commercial product, but it was not acceptable for field use. Although the number of viable propagules was much greater than in the original formulation, the propagules were not infectious (Sanders, Theriot, and Perfetti 1984). Since the original formulation lacked the desired characteristics of a commercial product and *Cercospora* in the modified formulation lacked infectivity, *Cercospora* will not be a useful biocontrol agent unless further formulation modification results in propagules that are infectious.

80. It had been anticipated that the *Cercospora* population established at Lake Theriot would disperse to waterhyacinth populations in the area adjacent to the study site, but this did not occur. Thus, *Cercospora* is not an aggressive pathogen and will only be effective in areas where it is directly applied, assuming that the problems associated with the formulation can be resolved. Should this occur, *Cercospora* could be recommended for use as a biological agent for control of waterhyacinth in Louisiana.

Sameodes

Establishment and dispersal

81. *Sameodes* successfully became established on waterhyacinth at three of four sites where it was released. Although populations did not become established at the actual release sites, they developed in adjacent areas. This is the typical pattern of *Sameodes* establishment. Adults are highly mobile, and those emerging from released larvae will seek preferred oviposition sites. Factors influencing selection of oviposition sites are poorly understood, but oviposition usually occurs on Stage I plants. If Stage I plants are not available to emerging adults, they often emigrate from the release site.

82. Dispersal of *Sameodes* was rapid in the area between New Orleans and Houma. *Sameodes* populations were found in nine parishes on both sides of the Mississippi River by October 1981. Migration appeared to occur primarily in a westward direction from the Cypress Canal release site. There was no evidence in 1981 that *Sameodes* had become established in the Atchafalaya Basin or west of Lafayette where releases had been made earlier in 1981. However, *Sameodes* populations were observed in the general area of both 1981 release sites during 1982, indicating that the released colonies had become established and

overwintered. *Sameodes* was successfully established in 13 parishes in southern Louisiana by October 1983, including the southern half of the Atchafalaya Basin. The 1983 distribution included areas in which approximately 75 percent of Louisiana's waterhyacinth population occurred.

Future anticipated dispersal

83. *Sameodes* should continue to disperse to waterhyacinth populations in the remainder of the Atchafalaya Basin. Should this occur, it is also expected that *Sameodes* will disperse to waterhyacinth populations in the area between the Atchafalaya Basin and Alexandria. Dispersal in western and northern Louisiana may be limited by the discontinuity in waterhyacinth populations. If so, efforts will be required to effect establishment in these areas.

Impacts of *Sameodes* on waterhyacinth

84. *Sameodes* populations have been observed to produce noticeable impacts on waterhyacinth populations in some areas of Louisiana. However, there have been no documented cases in which the moths have significantly reduced the surface area coverage of waterhyacinth in an area. Noticeable impacts have included "brown-out" areas in an otherwise healthy waterhyacinth population and small areas of open water in waterhyacinth mats.

85. Feeding activity by *Sameodes* larvae impact waterhyacinth in four principal methods:

- a. Consumption of stored energy. Larval feeding in petioles and, to a lesser degree, in the rhizome results in consumption of significant quantities of energy that would otherwise be available for use in plant growth or daughter plant production.
- b. Disruption of translocation. Larval feeding destroys vascular tissues in waterhyacinth petioles, which disrupts translocation of water and nutrients. Since larval feeding is most intense on newer leaves that are most actively photosynthesizing, disruption of translocation often results in destruction of these leaves. Thus, total productivity of the waterhyacinth plant is reduced, and the plant crown is often destroyed.
- c. Waterlogging of plants. Extensive tunneling of bulbous petioles by larvae decreases plant buoyancy and the plants float lower in the water. This increases susceptibility of the plants to necrosis. In extreme cases, the plant may be completely destroyed.

d. Limitation of reproductive capability. Larval tunneling often destroys apical meristems of infested plants. When this occurs at the time of initiation of inflorescence, the degree of flowering is reduced. More significantly, larval tunneling at the base of petioles often destroys lateral meristems from which stolons are produced. Since daughter plants are produced on these stolons, *Sameodes* is capable of limiting asexual reproduction of waterhyacinth. This could be the single most important impact of *Sameodes* on waterhyacinth.

86. Long-term impacts of *Sameodes* on waterhyacinth in Louisiana remain to be seen. Since *Sameodes* does not normally remain on a given waterhyacinth population for several successive generations, its impacts may be limited primarily to effecting a reduced rate of asexual reproduction. This effect is very subtle and difficult to demonstrate. Its ultimate effectiveness may be limited by external environmental factors discussed in paragraphs 87-89.

Factors influencing *Sameodes* population development and effectiveness as a biocontrol agent

87. Development of *Sameodes* to large population levels and its potential effectiveness as a biocontrol agent will be influenced by both intrinsic and extrinsic factors.

88. Intrinsic factors. Intrinsic factors involve characteristics of the life cycle and biology of *Sameodes*. These include:

a. Generation time. Since *Sameodes* has a 30-day life cycle (Center 1981), it is possible that eight or more generations may occur in a single growing season in Louisiana. Thus, *Sameodes* has the inherent capability of rapidly developing to large population levels.

b. Fecundity. A single adult female may oviposit 300 or more eggs. Coupled with the short generation time, the potential for *Sameodes* to develop to large population levels is enhanced.

c. Feeding stages. Only the larva of *Sameodes* feeds on waterhyacinth. This limits the potential effects on waterhyacinth to plant parts that are utilized as food sources by the larvae.

d. Preference for oviposition on Stage I plants. Since adults oviposit preferentially on Stage I plants, effects of *Sameodes* are largely restricted to waterhyacinth populations where Stage I or Stage II plants predominate. Most waterhyacinth populations consist of the Stage III morphotype during the summer and fall. Thus, *Sameodes* effectiveness is limited during this portion of the growing season.

89. Extrinsic factors. Extrinsic factors include the following environmental characteristics that impact *Sameodes* population development and effectiveness:

a. Climatic conditions. Several climatic conditions impact *Sameodes* population development:

(1) Low winter temperatures. Low winter temperatures influence the overwintering capability of *Sameodes* in two ways. First, significant mortality of individuals occurs during extended periods of freezing temperatures. Secondly, extended periods of freezing temperatures destroy the petioles of waterhyacinth plants, which decreases buoyancy. As plant buoyancy decreases, petioles containing larvae and pupae become waterlogged, and the *Sameodes* drown. This may be the most significant factor limiting *Sameodes* population development in Louisiana. *Sameodes* populations are reduced to such low levels by spring that several generations are required to achieve population levels comparable to those occurring during the previous fall. By this time, most waterhyacinth populations have converted to the Stage III morphotype, and are not as susceptible to *Sameodes* damage.

(2) High summer temperatures. Ambient temperatures in waterhyacinth canopies sometime exceed 35°C during the hotter summer months. This effectively limits the reproductive ability of *Sameodes*. Reproduction during these months may be largely restricted to shaded areas.

b. Quality of waterhyacinth plants. In addition to their preference for Stage I waterhyacinth plants as oviposition sites, *Sameodes* is usually found on healthy, vigorously growing plants. As the *Sameodes* population and resulting impacts on the plants increase, adults are more likely to emigrate to other waterhyacinth populations. This tends to limit the degree of *Sameodes* population development at specific locations.

c. Predators. Although its natural predators do not occur in the United States, *Sameodes* is susceptible to predation by some species of insects in Louisiana. Ants that colonize waterhyacinth mats may destroy *Sameodes* eggs and some first instar larvae. Adult *Sameodes* may be captured by dragonflies and other large insect predators. Impacts of dragonflies may be reduced by the nocturnal habit of adult *Sameodes*.

d. Herbicide spraying activities. Herbicide spraying activities may either enhance or restrict development of a *Sameodes* population. Herbicide applications to a waterhyacinth mat on which large numbers of *Sameodes* larvae and pupae are present will result in the death of most individuals. On the other hand, herbicide applications may benefit *Sameodes* population development by destroying an extensive mat of Stage III plants, which are not commonly utilized by *Sameodes*. Regrowth from remaining plants is usually the bulbuous-petioled, Stage I morphotype normally preferred by *Sameodes*. This is most likely to occur in Louisiana during the summer and fall when *Sameodes* populations are highest.

Prospects for control of waterhyacinth by *Sameodes*

90. *Sameodes* has significant potential as a biological agent for control of waterhyacinth in Louisiana. It has been demonstrated to overwinter in southern Louisiana, although significant mortality of overwintering individuals occurs. The greatest potential for *Sameodes* as a biocontrol agent may be its ability to restrict daughter plant production, especially during summer and fall, on waterhyacinth regrowth following herbicide applications. Failure of *Sameodes* to overwinter in large numbers is expected to limit its impacts on waterhyacinth during spring months when most waterhyacinth populations consist predominantly of the preferred Stage I morphotype. The tendency for *Sameodes* to emigrate from areas of high population densities may prevent development of sufficient populations to significantly reduce the surface area coverage of waterhyacinth in most areas. However, it may prove to be an effective management tool in combination with other biocontrol agents.

Other Potential Biocontrol Agents

91. Other potential biocontrol agents include insect species currently present on waterhyacinth in Louisiana, insect species not currently present, and a complement of microorganisms that are capable of inflicting additional damage on already-stressed waterhyacinth populations.

Other insect species currently present

92. Two other insect species currently present on waterhyacinth in Louisiana are *Arzama* and *Orthogalumna*. Both species are widely distributed on waterhyacinth in the state and have the potential for inflicting significant damage when high population densities are achieved.

93. *Arzama.* *Arzama* larvae are very large and feed voraciously on waterhyacinth. The relatively long larval stage of the life cycle affords a single individual the opportunity to feed on several plants during its development. However, high population densities are seldom observed due to the highly mobile adults and a complement of predators and parasites that attack this native moth (Baer and Quimby 1980). Nevertheless, *Arzama* may contribute to the total stress induced by biocontrol agents on waterhyacinth in some areas.

94. *Orthogalumna.* The Argentine waterhyacinth mite may occur in large numbers in isolated instances. When this occurs, the mite is capable of reducing productivity of infested leaves, and the functional life of individual leaves may also be reduced. However, effectiveness of the mite is limited by its extremely low degree of mobility. Thus, some portions of a waterhyacinth population may be severely infested, while nearby plants are not infested.

Insect species not currently present

95. The Chevroned waterhyacinth weevil (*Neochetina bruchi* Hustache), a close relative of *Neochetina eichhorniae*, was released at a few locations in Louisiana during the mid-1970's. However, it failed to develop to large population densities and was never widely distributed in the state (Manning 1979). No *N. bruchi* were found at any location during the LSOMT. Because *N. bruchi* produces similar impacts on waterhyacinth as *N. eichhorniae*, it should be released throughout Louisiana. Theoretically, *N. bruchi* has greater potential as a biocontrol agent in Louisiana than *N. eichhorniae* because it has a slightly shorter life cycle and can withstand slightly colder temperatures. Both characteristics should enhance the ability of *N. bruchi* to develop to high population densities in Louisiana.

Other microorganisms

96. Foret, Barry, and Theriot (1980) listed a group of microorganisms found on waterhyacinth in Louisiana in 1977. Some of these microorganisms probably represent the complement of weak, facultative pathogens and saprophytes associated with waterhyacinth senescence. In the absence of stressed waterhyacinth plants, these species produce few, if any, impacts on the plant population. However, some combination of these species may significantly impact waterhyacinth when other factors (e.g. *Neochetina*) have effected a stressed waterhyacinth population. Such was the case at Lake Theriot when the waterhyacinth population in July 1982 was severely stressed by *Neochetina*. Since most of these species are ubiquitous, similar effects may occur throughout the state.

Combinations of Biocontrol Agents

97. Although relatively little data resulted from the LSOMT on combined effects of combinations of biocontrol agents, two potential agent combinations

merit discussion. These include: *Cercospora* - *Neochetina* and *Neochetina* - *Sameodes*.

Cercospora - Neochetina

98. Reduction in waterhyacinth biomass and plant height at Lake Theriot in 1981 was attributed to this combination of agents. Although it was impossible to partition the effects of each agent on waterhyacinth, both species occurred at high population densities in September. This suggested that *Cercospora* and *Neochetina* can be used in combination to effect a decline in the plant population. However, *Cercospora* failed to become established at the Amelia site, apparently due to the lack of suitable infection sites resulting from intense feeding by adult *Neochetina* (Sanders, Theriot, and Perfetti 1984). Thus, use of this combination of agents may be contingent on applying the *Cercospora* formulation at a time when the adult *Neochetina* population is relatively low. This would ensure availability of sufficient infection sites (stomata) to allow establishment of *Cercospora*. Failure of *Cercospora* to persist at Lake Theriot in 1982 was apparently not due to effects produced by the *Neochetina* population because *Neochetina* population levels were lower in 1982 than in 1981 when *Cercospora* populations were highest. The future of *Cercospora* as a biocontrol agent will be dependent on resolution of formulation problems.

Neochetina - Sameodes

99. *Neochetina* and *Sameodes* may function as an effective biocontrol agent combination under some, but not all, conditions. Since *Sameodes* normally does not occur at high population densities on Stage III plants, the greatest likelihood for this combination of agents to provide control of waterhyacinth is on populations consisting of Stage I plants. Combined feeding of *Neochetina* larvae and adults and *Sameodes* larvae may limit production of daughter plants and effect a reduction in plant biomass and surface area coverage. In addition, regrowth of waterhyacinth in areas where population reduction has been effected by *Neochetina* is susceptible to infestation by *Sameodes*. In this case, *Neochetina* would serve as the trigger factor to reduce the waterhyacinth population, and both species would repress regrowth.

Prospects for Biocontrol of Waterhyacinth in Louisiana

100. Prospects for biocontrol of waterhyacinth in Louisiana are excellent. The significant reduction in the waterhyacinth population, which has already occurred, was attributed primarily to effects of *Neochetina*. *Sameodes* has become established throughout areas containing 75 percent of the state's waterhyacinth population, and should provide significant additional stress on the plant population in the future. Should problems associated with the production of a commercial *Cercospora* formulation be resolved, *Cercospora* could also be effectively utilized.

101. Combined effects of *Neochetina*, *Sameodes*, *Arzama*, *Orthogalumna*, and the group of weak, facultative pathogens normally associated with waterhyacinth senescence in Louisiana should prevent the waterhyacinth population from achieving pre-1980 levels. The addition of *Neochetina bruchi* to this complement of organisms could elicit a further reduction in the waterhyacinth population in the state.

102. The ultimate level of control that will be provided by biological agents remains to be seen. It is expected that a natural cycle will develop, in which the plant population declines in response to biocontrol agent activity, and then redevelops to some level following an associated decline in biocontrol agent populations. Definition of this natural cycle could be effectively used in planning and conducting herbicide spray programs to obtain the maximum possible level of control.

PART V: OVERALL CONCLUSIONS AND RECOMMENDATIONS

Conclusions

103. Overall conclusions of the LSOMT were:

a. The waterhyacinth population in Louisiana decreased by 75 percent in 1980, and gradually increased in subsequent years to approximately 50 percent of the 1974-1978 average (1.25 million acres) by October 1983. This decline was attributed principally to effects produced by *Neochetina*.

b. Waterhyacinth populations at two of three principal study areas declined in surface area coverage, biomass, and plant height during the study. *Neochetina* was the primary factor effecting the reduction in waterhyacinth.

c. *Neochetina* is most effective as a biocontrol agent when the population develops in an asynchronous pattern, in which adult and larval populations peak simultaneously.

d. Sustained *Neochetina* populations of 1.0 individual (combined adults and larvae) per plant for 6 months or more following a peak of 3.0 individuals per plant or greater appeared to represent the threshold for effectively reducing the waterhyacinth population.

e. Large-scale applications of *Cercospora* resulted in effective establishment of *Cercospora* at only one of three study sites. Failure of successful establishment at one site was attributed to intensive feeding damage of waterhyacinth by *Neochetina*, and failure of establishment at the other site was attributed to lack of infectivity of *Cercospora* propagules in the formulation.

f. *Cercospora* developed to significant population densities at Lake Theriot in 1981 and contributed to the observed decline in waterhyacinth. However, it failed to occur at effective levels at the site during 1982.

g. Failure of *Cercospora* to disperse from the study site to adjacent waterhyacinth populations confirmed that it is not a strongly aggressive plant pathogen.

h. *Sameodes* became established on waterhyacinth at three of four release areas and rapidly dispersed throughout much of southern Louisiana.

i. *Sameodes* was distributed in a 6,105-km^2 area by October 1983, including all or portions of 13 parishes. The area of distribution encompassed approximately 75 percent of the waterhyacinth population in Louisiana, including the southern half of the Atchafalaya Basin.

j. Long-term effectiveness of *Sameodes* remains to be determined, but its effectiveness as a biocontrol agent may be limited by significant winter mortality, which reduces the population to very low levels by spring.

k. A group of weak, facultative pathogens associated with waterhyacinth senescence may contribute significantly to the decline of waterhyacinth populations when the plant populations become severely stressed by other biocontrol agents.

l. Biocontrol agents, particularly *Neochetina* and *Sameodes*, are expected to continue to provide a significant degree of control of waterhyacinth in Louisiana. A natural cycling of both waterhyacinth and the biocontrol agents is expected to develop, in which the plant population increases for a 2- to 3-year period, and then declines following redevelopment of the biocontrol agent populations. However, magnitudes of peaks in the plant population remain to be determined.

Recommendations

104. Recommendations for use of biocontrol agents for waterhyacinth control in Louisiana are listed below:

a. *Neochetina eichhorniae* should be applied to waterhyacinth populations in any area of the state where it is not currently established. Particular emphasis should be placed on releases in the northern areas.

b. Since *Neochetina eichhorniae* populations are significantly affected by herbicide spraying activities, studies are needed to establish management procedures that will provide the maximum possible level of waterhyacinth control when biocontrol agents and herbicidal control measures are used in consort.

c. *Neochetina bruchi* should be released on waterhyacinth populations throughout the state. This species has a shorter generation time, can tolerate colder temperatures, and can provide greater stress on waterhyacinth during certain seasons of the year than *Neochetina eichhorniae*. It may be especially effective in northern portions of the state.

d. *Sameodes* should be released in all portions of the state where it is currently absent. Particular emphasis should be placed on releases in northern and western Louisiana.

e. Unless problems associated with the *Cercospora* formulation can be resolved, it should not be considered for future use as a biocontrol agent.

103. Detailed guidance for these activities will be provided at a later date to the New Orleans District in a guidance document.

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Table 1

Plot Means for Waterhyacinth Parameters Monitored at the Lake Theriot Study Area

Parameter	May 1980	Jul 1980	Oct 1980	Apr 1981	Jul 1981	Sep 1981	Apr 1982	Jul 1982	Oct 1982	May 1983
Percent cover	100.0	100.0	100.0	100.0	100.0	100.0	80.0	70.0	55.0	90.0
Plant density, #/m^2	201.0 (±16.06)*	100.7 (±6.97)	53.7 (±5.80)	110.7 (±10.53)	110.7 (±9.12)	66.3 (±5.23)	95.2 (±12.21)	83.1 (±7.69)	46.9 (±5.30)	93.5 (±8.07)
Plant density--weighted, #/m^2 * % cover	201.0	100.7	53.7	110.7	110.7	66.3	76.2	58.2	25.8	84.2
Biomass, kg/m^2	19.5 (±1.36)	30.4 (±1.60)	19.2 (±1.64)	5.7 (±0.63)	12.8 (±1.27)	13.2 (±1.13)	5.0 (±0.49)	9.0 (±0.97)	8.9 (±1.24)	11.5 (±0.85)
Plant biomass--weighted, kg/m^2 * % cover	19.5	30.4	19.2	5.7	12.8	13.2	4.0	6.3	4.9	10.4
Plant height, cm	31.2 (±1.94)	70.6 (±9.84)	77.1 (±3.27)	16.8 (±0.99)	39.2 (±2.34)	52.9 (±3.23)	11.3 (±0.84)	34.1 (±2.56)	42.5 (±3.76)	36.5 (±4.23)
Daughter plants, #/m^2	17.6 (±4.76)	0.8 (±0.71)	3.5 (±2.32)	32.8 (±8.14)	6.5 (±2.25)	2.1 (±0.92)	29.3 (±5.06)	3.9 (±2.12)	4.0 (±1.87)	28.3 (±5.85)

* Numbers in parentheses represent two standard errors of the means.

Table 2

Mean for *Arzama* Larvae and Mean Index Values for *Orthogalumna* at the Lake Theriot Study Area

	May 80	Jul 80	Oct 80	Apr 81	Jul 81	Sep 81	Apr 82	Jul 82	Oct 82	May 83
Arzama larvae*	2.6	0.4	0.9	0.0	0.0	0.5	0.0	0.0	0.0	0.0
*Orthogalumna***	0.1	0.7	0.6	0.0	0.0	0.0	0.0	0.3	0.0	0.0

* Larvae per square metre.
** Index of *Orthogalumna* tunnels per leaf.

Table 3

Plot Means for Waterhyacinth Parameters Monitored at the Centerville Study Area

Parameter	Aug 1980	Apr 1981	Jul 1981	Sep 1981	Apr 1982	Jul 1982	Oct 1982	May 1983
Percent cover	100.0	100.0	100.0	100.0	100.0	85.0	90.0	100.0
Plant density, #/m^2	54.9 (±6.49)*	91.9 (±9.53)	101.6 (±15.48)	52.5 (±9.10)	66.9 (±6.85)	48.4 (±6.07)	37.6 (±5.63)	96.3 (±5.43)
Plant density--weighted, #/m^2 * % cover	54.9	91.9	101.6	52.5	66.9	41.1	33.8	96.3
Biomass, kg/m^2	21.5 (±1.46)	4.7 (±0.44)	14.7 (±1.25)	17.3 (±1.21)	4.5 (±0.75)	12.2 (±0.87)	14.8 (±0.99)	17.8 (±1.43)
Biomass--weighted, kg/m^2 * % cover	21.5	4.7	14.7	17.3	4.5	10.4	13.3	17.8
Plant height, cm	70.6 (±3.50)	18.6 (±1.87)	54.0 (±7.28)	70.2 (±6.31)	8.4 (±3.11)	61.1 (±6.85)	69.1 (±9.99)	35.0 (±3.64)
Daughter plants, #/m^2	4.7 (±1.88)	43.7 (±4.49)	6.0 (±2.19)	3.1 (±1.79)	13.3 (±3.54)	2.5 (±1.12)	1.3 (±1.45)	31.7 (±3.93)

* Numbers in parentheses represent two standard errors of the means.

Table 4

Mean Number of *Arzama* Larvae and Mean Index Values For *Orthogalumna* at the Centerville Study Area

	Aug 80	Apr 81	Jul 81	Sep 81	Apr 82	Jul 82	Oct 82	May 83
Arzama larvae*	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
*Orthogalumna***	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1

* Larvae per square metre.

** Index of *Orthogalumna* tunnels per leaf.

Table 5

Plot Means for Waterhyacinth Parameters Monitored at the Cypress Canal Study Area

Parameter	May 1980	Jul 1980	Oct 1980	Apr 1981	Jul 1981	Sep 1981	Apr 1982	Jul 1982	Oct 1982	May 1983
Percent cover	100.0	100.0	100.0	80.0	75.0	60.0	90.0	85.0	90.0	90.0
Plant density, #/m²	112.5 (±12.89)*	43.5 (±4.25)	28.5 (±2.79)	148.9 (±12.37)	80.7 (±5.57)	25.2 (±2.87)	83.9 (±8.68)	35.7 (±5.77)	22.4 (±1.19)	53.5 (±5.56)
Plant density--weighted, #/m² * % cover	112.5	43.5	28.5	119.1	60.5	15.1	75.5	30.3	20.2	48.2
Plant biomass, kg/m²	7.8 (±0.89)	7.8 (±1.16)	10.9 (±1.44)	8.5 (±0.69)	8.1 (±0.86)	10.9 (±1.33)	6.1 (±0.87)	12.9 (±1.56)	9.9 (±0.94)	6.9 (±0.88)
Plant biomass--weighted, kg/m² * % cover	7.8	7.8	10.9	6.8	6.1	6.6	5.5	10.9	8.9	6.2
Plant height, cm	23.1 (±1.30)	51.1 (±4.80)	56.3 (±2.75)	21.1 (±1.11)	42.3 (±2.16)	65.3 (±5.62)	12.6 (±5.02)	77.7 (±6.03)	71.9 (±19.83)	54.5 (±6.76)
Daughter plants, #/m²	13.2 (±4.94)	13.7 (±4.20)	2.3 (±1.58)	60.7 (±11.94)	11.6 (±5.26)	13.7 (±3.91)	14.1 (±7.07)	7.5 (±2.56)	13.7 (±3.21)	6.3 (±3.92)

* Numbers in parentheses represent two standard errors of the means.

Table 6

Mean Number *Arzama* Larvae and Mean Index Values for *Orthogalumna* at the Cypress Canal Study Area

	May 80	Jul 80	Oct 80	Apr 81	Jul 81	Sep 81	Apr 82	Jul 82	Oct 82	May 83
Arzama larvae*	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
*Orthogalumna***	0.0	0.0	0.6	0.0	0.2	0.6	0.0	0.2	0.3	0.0

* Number of larvae per square metre.
** Index of *Orthogalumna* tunnels per leaf.

Table 7

Locations of *Sameodes* Occurrence During 1982-1983 Surveys

July 1982

St. John the Baptist Parish
Roadside canal at intersection of Interstate 10 and Interstate 55

Ascension Parish
Roadside canal paralleling US Highway 61 near Sorrento

St. Charles Parish
Cypress Canal near Lake Salvador

Lafourche Parish
Bayou Des Allemands at US Highway 90 intersection

May 1983

St. John the Baptist Parish
Roadside canal at intersection of Interstate 10 and Interstate 55

St. Charles Parish
Marsh canal on northeast side of Lake Salvador

Lafourche Parish
Bayou Des Allemands at US Highway 90 intersection

Assumption Parish
East side of Lake Verret near Pierre Part

Terrebonne Parish
(1) Roadside canal along Louisiana Highway 315, 2 miles north of Theriot
(2) Miners Canal, south of Lake Hatch (near Theriot)

St. Martin Parish
Canal inside and parallel to Atchafalaya Basin levee near Centerville

Vermilion Parish
Roadside canal along Louisiana Highway 82 near Ester

October 1983

St. John the Baptist Parish
Roadside canal at intersection of Interstate 10 and Interstate 55

St. Charles Parish
(1) Roadside canal paralleling US Highway 61, 4 miles east of Norco
(2) Canal at Paradis
(3) Roadside canal paralleling Louisiana Highway 3127 north of Lac Des Allemands

(Continued)

Table 7 (Concluded)

October 1983 (Cont.)

Lafourche Parish
- (1) Roadside canal paralleling Louisiana Highway 24, 1.0 mile east of intersection with Louisiana Highway 56
- (2) Roadside canal paralleling Louisiana Highway 24, 1.0 mile west of intersection with Louisiana Highway 1

Jefferson Parish
- (1) Roadside canal paralleling US Highway 90, 3 miles west of Avondale
- (2) Roadside canal paralleling Louisiana Highway 301 at Barataria

Plaquemines Parish

Roadside canal paralleling Louisiana Highway 23 near Venice

Terrebonne Parish
- (1) Roadside canal paralleling Louisiana Highway 315, 1.0 mile south of Theriot
- (2) Roadside canal paralleling Louisiana Highway 57 at Dulac
- (3) Roadside canal paralleling Louisiana Highway 20, 1.0 mile west of Donner

Iberville Parish

Roadside canal paralleling Louisiana 404, 0.5 mile east of Shell Oil Road

St. Martin Parish
- (1) Roadside canal paralleling US Highway 90, 2.0 miles east of Morgan City
- (2) Canal inside and paralleling Atchafalaya Basin levee at Centerville
- (3) Big Fork (Atchafalaya Basin)
- (4) Bayou Sorrel (Atchafalaya Basin)
- (5) Duck Lake (Atchafalaya Basin)

St. Mary Parish
- (1) Canal at Charenton flood gate near Jeanerette
- (2) Edge of Catahoula Lake along Louisiana Highway 96, east of Catahoula