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The Impact of *Neochetina eichhorniae* (Coleoptera: Curculionidae) on Waterhyacinth in Louisiana

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Abstract

Neochetina eichhorniae was first released in Louisiana during 1974 by the Louisiana Department of Wildlife and Fisheries. This insect species was distributed throughout the State in 1976 and insect populations were well established by 1978. A reduction in waterhyacinth acreage throughout Louisiana occurred. The 1974 population (1.1 million acres) of waterhyacinth in Louisiana was reduced to 301,100 acres by 1980. This four-year study (1980–83) indicated that *N. eichhorniae* effected reductions in waterhyacinth height, density, and biomass at test sites and was a major factor contributing to reduction in waterhyacinth acreage in Louisiana.

Effets de *Neochetina eichhorniae* (Coléoptères: Curculionidés) sur la Jacinthe d'Eau en Louisiane

Neochetina eichhorniae a d'abord été libérée en Louisiane en 1974 par le Department of Wildlife and Fisheries (Departement de la Faune et de la Pêche) de la Louisiane. En 1976, la distribution de cet insecte s'est effectuée dans l'ensemble de l'etat et, en 1978, les populations étaient bien établies. Au fur et à mesure que les populations croissaient, une réduction de l'aire de répartition des jacinthes d'eau a été constatée dans toute la Louisiane. Elle est passée de 1.1 million d'acres en 1974 à 305 000 acres en 1980. D'après notre étude de quatre ans (1980–83), *N. eichhorniae* a causé des diminutions de la hauteur, de la densité et de la biomasse des jacinthes d'eau et a joué un rôle important dans la réduction de la superficie occupée par cette plante nuisible en Louisiane.

Introduction

Waterhyacinth, *Eichhornia crassipes* (Mart.) Solms. (Pontederiaceae), was introduced into the United States at the 1884 Cotton States Exposition in New Orleans, Louisiana, for its decorative inflorescence of blue flowers (Raynes 1964). Since its introduction, waterhyacinth has spread or been distributed throughout a large portion of the United States, particularly in the southeast. Populations have been reported in some western states (Texas to California) and north into Missouri (Godfrey and Wooten 1979). The ability of waterhyacinth to infest a wide range of fresh-water habitats (e.g. lakes, rivers, canals and swamps), and its tremendous growth rate (Penfound and Earle 1948; Center and Spencer 1981) have made it one of the most troublesome aquatic plants in the United States.

Waterhyacinth is capable of both asexual and sexual reproduction. Asexual reproduction, which is more common, occurs by production of vegetatively propagated daughter plants (ramets) that develop on stolons from the parent plant. Once ramets develop, the brittle stolons break and the daughter plants separate from the parent.

Penfound and Earle (1948) reported that 10 plants produced a mat of 655,360 individual plants in one growing season.

Various methods have been employed to control waterhyacinth. Mechanical methods were first employed to prevent downstream movement and to clear navigable waterways. However, chemical spraying with phenoxy herbicides replaced most mechanical operations in the 1950s. Currently, 2-4 dichlorophenoxyacetic acid (2,4-D), a phenoxy herbicide, is the predominant short-term control method employed.

Investigations of biological control began in the early 1960s with researchers exploring areas of South America for candidate biocontrol agents. After 10 years of research, three insect species were identified and approved for use as agents for the biocontrol of waterhyacinth. The first of the three insect species, *Neochetina eichhorniae* Warner (Coleoptera: Curculionidae), was released in Florida in 1972. *N. eichhorniae* was released in Louisiana in 1974 by the Louisiana Department of Wildlife and Fisheries. From 1974–77, 158,000 weevils were dispersed at 492 locations in 39 Louisiana parishes (Manning 1979). *Neochetina bruchi* Hustache and *Sameodes albiguttalis* (Warren) (Lepidoptera: Pyralidae) were released in Louisiana in 1975 and 1979, respectively; however, these species did not become widely distributed.

Both the adult and larval stages of *N. eichhorniae* impact waterhyacinth. Adult feeding on the lamina reduces the epidermal surface area, thereby reducing the amount of photosynthate produced. When feeding is heavy, petioles are often girdled and the laminae become desiccated. Larvae feed on the meristematic tissue in the plant crown. This feeding often separates the growing tip from the rhizome and roots.

The purpose of this report is to document the impact of *N. eichhorniae* on waterhyacinth in Louisiana. This research was one part of a Large-Scale Operations Management Test (LSOMT) (Sanders *et al.*, *in press*) conducted in Louisiana between 1979 and 1983.

Methods and Materials

Four waterhyacinth sites in southern Louisiana were examined during a four-year period. Data from the Assumption Parish and Lake Theriot sites are presented in this paper. Sites were sampled in the spring, summer, and fall of each year, and both plant and insect data were collected.

Assumption Parish

The study at this site was actually designed to test different applications of *Cercospora rodmanii* Conway (Hyphomycetes), a fungal pathogen of waterhyacinth. The *N. eichhorniae* population was monitored to determine its background impact. Twelve 336 m^2 plots were established and *Cercospora* application rates of 4×10^4, 4×10^5, and 4×10^6 Colony Forming Units (CFU)/m^2 were each tested in three randomly assigned plots. The three remaining plots were utilized as controls. Each plot was separated by a distance of 0.6 km (0.4 mile).

The percent of the surface covered by waterhyacinth in each test plot was obtained by averaging the visual estimate of three observers prior to sampling. All data were taken from waterhyacinth plants collected from four randomly-located, 0.25 m^2 (0.5×0.5 m) quadrats in each test plot, and samples were placed in plastic bags until examination. Height of the centermost plant in each quadrat was recorded prior to removal of the plants from the quadrat. Plants from each quadrat were placed in a wire basket, allowed to drain for 1 min., and weighed to the nearest gram. The number of mature plants and daughter plants was recorded separately for each quadrat.

Comparisons (Analysis of Variance, GLM, and Duncan's Multiple-Range Test; SAS Institute Inc. 1982) were made for density, biomass, height, and number of daughter plants between plots for each sampling date. Weighted mean values (no./m^2 $\times$ % cover) for density and biomass were calculated for each sampling date, and weighted means were then subjected to the above comparisons.

Five waterhyacinth plants from each quadrat were randomly-selected for assessing pathogen damage. Average pathogen damage/leaf in each quadrat was calculated by summing disease index values (Sanders *et al.*, *in press*) for all leaves on each of five plants and dividing by the total number of leaves. Plot means were determined by summing quadrat means and dividing by the number (four) of quadrats. Mean pathogen damage/test plot was averaged across treatment plots for each sampling date. ANOVA was used to determine whether pathogen damage differed significantly among treatments and sampling trips. Leaf tissue was collected on each sampling trip from selected plants for laboratory re-isolation of *Cercospora*.

The five plants used for assessing pathogen damage were examined for *Neochetina* adults and larvae, and other arthropod species. Mean numbers of *Neochetina* adults and larvae/m^2 were calculated for each quadrat. Resulting means were averaged for each plot and among plots for each sampling trip. ANOVA was used to determine whether mean numbers of *Neochetina* adults and larvae/plant and quadrat varied significantly among sampling trips.

All test plots were sampled in May 1980 prior to application of the formulation. Post-treatment sampling was conducted on 12 July and 30 September 1980. Sampling was discontinued after September due to insufficient numbers of waterhyacinth plants in test plots to obtain valid samples.

Lake Theriot

This site was used to evaluate the impact of *N. eichhorniae*, *S. albiguttalis*, and *C. rodmanii* on waterhyacinth. The site, located in Terrebonne Parish, covered 1.82 ha (4.5 acres). *S. albiguttalis* was released at the site in May 1979 (10,000 eggs) and in June 1980 (1000 eggs). *C. rodmanii* was applied to the site by fixed-wing aircraft on 8 May 1980 at a rate of 35.7 lbs/acre (1×10^6 CFU/g), and sampling was conducted in the spring, summer, and fall of 1980–82, and during May 1983.

The study area was divided into six areas of uniform size. On each sampling date, a point that served as the center of a circular (7.62 m radius) sampling area was randomly-selected in each area. Locations for five 0.25 m^2 (0.5×0.5 m) quadrats were identified in each sampling area by randomly selecting compass headings and distances (30.48 cm intervals) along the selected compass headings. All waterhyacinth plants in each of 30 quadrats were removed and placed in a plastic bag until examination. All plants in each quadrat were examined for *Neochetina* (larvae and adults), *Sameodes* (larvae and pupae) and other arthropod species impacting the plant.

The first sampling trip was conducted immediately prior to application of the formulation. Waterhyacinth data (percent cover, biomass, density, height, and number of daughter plants) and plant pathogen data were obtained and compared in the same manner as data for the Assumption Parish site. Means for *Neochetina* adults and larvae/m^2 and *Sameodes* larvae and pupae/m^2 were calculated for each sampling date. Mean numbers of *Neochetina* adults and larvae/m^2 were weighted by plant density. ANOVA was used to determine whether calculated means varied significantly among sampling dates.

Results and Discussion

Assumption Parish

Mean values of waterhyacinth parameters measured at this site are shown in Table 1. The percent of surface area covered by waterhyacinth decreased from an average of 89.9% in May 1980 to 33.6% in July and 10.2% in September. Plant density decreased significantly from a mean of 116.7/m^2 in May to 40.5/m^2 in September. When weighted by percent cover, mean plant density declined from 104.8 plants/m^2 in May to 4.1 plants/m^2 in September. Although plant biomass declined in a similar manner, the differences were not significant. When weighted by percent cover, mean biomass declined from 10.6 kg/m^2 in May to 0.6 kg/m^2 in September. Mean plant height increased significantly from 8.0 cm in May to 22.2 cm in July, and showed a non-significant increase to 24.6 cm in September. Daughter plant production declined significantly from a mean of 31.3 plants/m^2 in May to 7.2 plants/m^2 in July.

Table 1. Means for waterhyacinth paramaters monitored during the *Cercospora* field application rate study.

Parameter	April 1980	July 1980	September 1980
Percent cover (%)	89.9	33.6	10.2
Plant density (No./m^2)	116.7 (±8.65)[1]	74.8 (±8.78)	40.5 (±7.59)
Plant density-weighted (No./m^2 * % cover)	104.8	25.2	4.1
Biomass (kg/m^2)	11.8 (±6.36)	6.1 (±1.38)	5.6 (±0.78)
Biomass-weighted (kg/m^2 * % cover)	10.6	2.1	0.6
Plant height (cm)	8.0 (±0.62)	22.2 (±3.03)	24.6 (±4.84)
Daughter plants (No./m^2)	31.3 (±6.04)	7.2 (±2.62)	6.5 (±3.79)

[1] Numbers in parentheses represent two standard errors of means.

Mean pathogen damage/leaf for all treatments, including untreated controls, are presented in Table 2. Mean values for all plots treated with *Cercospora* declined in July as compared to pretreatment values (May), but mean value for untreated controls increased slightly. Pathogen damage increased in all treated plots in September, but too few plants remained in the untreated control plots to allow sampling. Increased pathogen damage in September was not attributable to *Cercospora* because the fungus could only rarely be isolated from samples.

The mean number of *Neochetina* adults increased from 39.4/m^2 in May 1980 to 50.0/m^2 in July 1980, but significantly declined to 28.3/m^2 in September 1980 (Fig. 1). The mean number of *Neochetina* larvae increased from 54.5/m^2 in May 1980 to 97.6/m^2 in July, and then declined to 73.2/m^2 in September 1980 (Fig. 1); the mean numbers of both adults and larvae/plant were higher in September than in May due to the presence of fewer waterhyacinth plants in September.

Lake Theriot

Mean values of waterhyacinth parameters measured at this site are shown in Table 3. Percent cover of this study area by waterhyacinth remained at 100% throughout the 1980 and 1981 growing seasons. Percent cover by waterhyacinth declined from 80% in spring 1982 to 55% in fall 1982. Numerous other plant species were beginning to establish in the site by October 1982. However, a break in the floating barrier during winter 1982, allowed waterhyacinth from the adjacent marsh to re-invade the study site, and percent cover of the site by waterhyacinth was 90% in May 1983. Mean plant densities decreased throughout the growing season of each sampling year. Values were higher in spring 1980 (201.0/m^2) than in the spring of subsequent years. However, higher daughter plant densities in spring 1981 through 1983 suggested that the waterhyacinth population at the site was not as far along in seasonal development as was the waterhyacinth population in May 1980. It is speculated that plant densities would have been similar among the different years if the spring surveys had been

Table 2. Means of pathogen damage/leaf during *Cercospora* field application rate study. Means were calculated from three replicates of each treatment rate except where indicated.

Treatment rate[1]	April 1980	July 1980	September 1980
10^4	3.26	2.92*	7.71+
10^5	3.22	2.89	6.95
10^6	3.15	3.06	7.35
C	3.42	3.60	-†

[1] Treatment rates expressed as number of colony forming units (CFU)/m^2.
* Based on two replicate plots.
\+ Based on one replicate plot.
†Too few plants remained to allow sampling.

conducted at more similar times of the growing season. However, because percent cover of waterhyacinth in the study area decreased significantly during 1982, weighted plant density values (number of plants/unit area in relation to the entire study site) showed that the waterhyacinth population decreased in number during the 1982 growing season (Table 3). Mean weighted plant densities were 31, 47, and 61% lower in April, July, and October 1982 samples, respectively, than in samples taken at comparable times in 1981. Mean biomass values showed the typical pattern of maximum biomass production during late summer months before a reduction in the fall. However biomass values showed a continual decline in waterhyacinth production in comparisons made between similar sampling dates of consecutive years. Peak biomass at the site was 30.4 kg/m^2 in 1980, 13.2 kg/m^2 in 1981, and 9.0 kg/m^2 in 1982. Furthermore, by weighting biomass values by percent cover estimates, it was shown that peak biomass in 1982 (July) was 79% lower than that of 1980 (July). Mean plant heights showed a similar decline throughout this study.

Mean pathogen damage (Fig. 2) decreased slightly during early summer of 1980 and then increased significantly during late summer and fall. Means of pathogen damage during subsequent years showed a progressive increase throughout each growing season,

Table 3. Plot means for waterhyacinth parameters monitored at the Lake Theriot study area.

Parameter	May 1980	Jul. 1980	Oct. 1980	Apr. 1981	Jul. 1981	Sept. 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 (No./m^2)	201.0 (±16.06)[1]	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 (No./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 (±)
Daughter plants (No/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)

[1] Numbers in parentheses represent two standard errors of means.

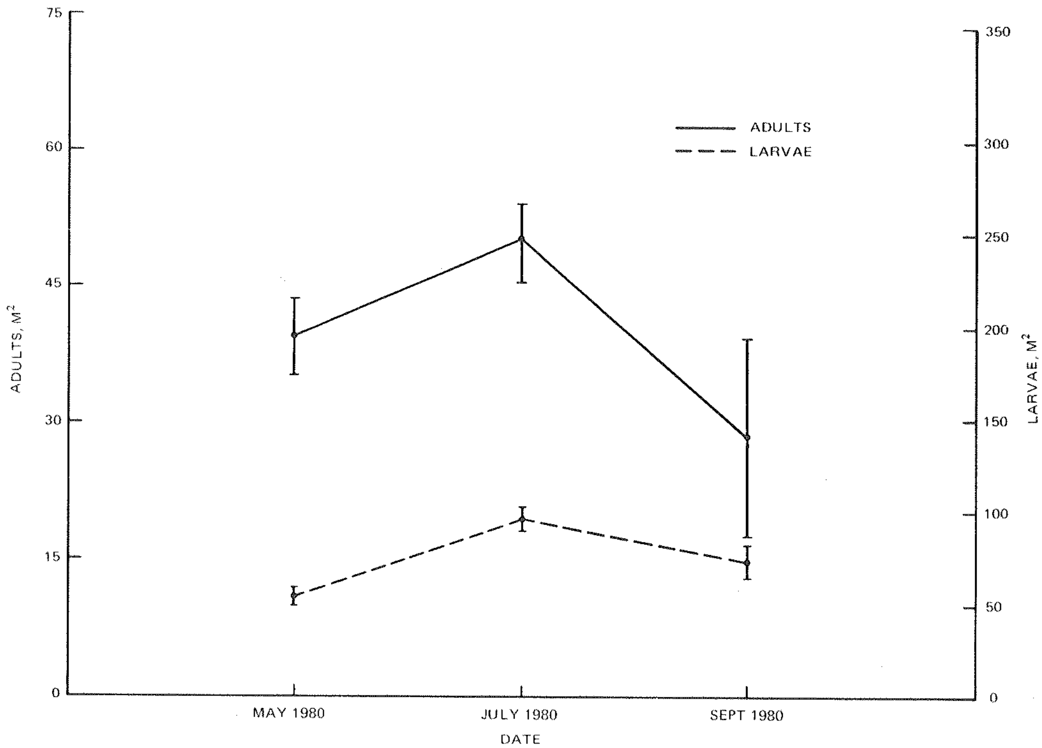

Fig. 1. Mean numbers of *Neochetina* adults and larvae/m^2 at Assumption Parish site. Vertical bars represent 2 SD of the means.

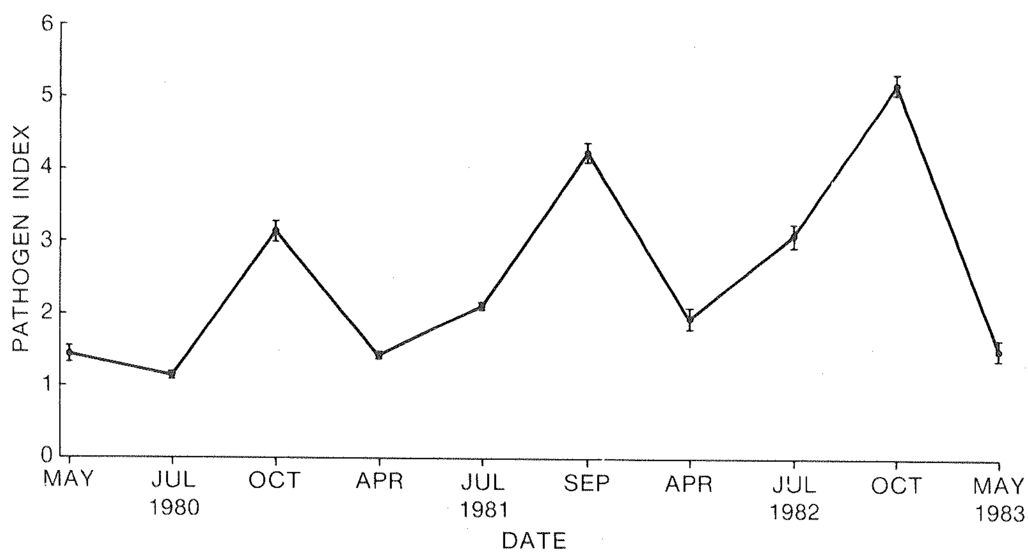

Fig. 2. Mean pathogen index values/leaf for the Lake Theriot site. Vertical bars represent 2 SD of the means.

and values for each sampling period through October 1982 were significantly higher than values from the same period of the previous year (Fig. 2). *Cercospora* was re-isolated from waterhyacinth tissues on all post-treatment dates prior to May 1982. Pathogen damage continued to increase in 1982, even though *Cercospora* could not be re-isolated from plant tissues after September 1981.

Mean numbers of *Neochetina* adults and larvae collected at the Lake Theriot site during this study are shown in Fig. 3. Numbers of adult weevils increased throughout the growing season during 1980, but obtained levels of only 6.7 adults/m^2 by October. The maximum number of larvae collected during 1980 was 44.8 larvae/m^2, also in October. Mean numbers of both adults and larvae were significantly higher in April 1981, with mean values reaching 11.7 adults/m^2 and 257.9 larvae/m^2. The *Neochetina* population continued to increase throughout early- to mid-summer. By July, the mean number of adults was 61.9/m^2. Larvae also showed a significant, but less dramatic increase to 312.8/m^2. Numbers of adults and larvae had decreased by September 1981,

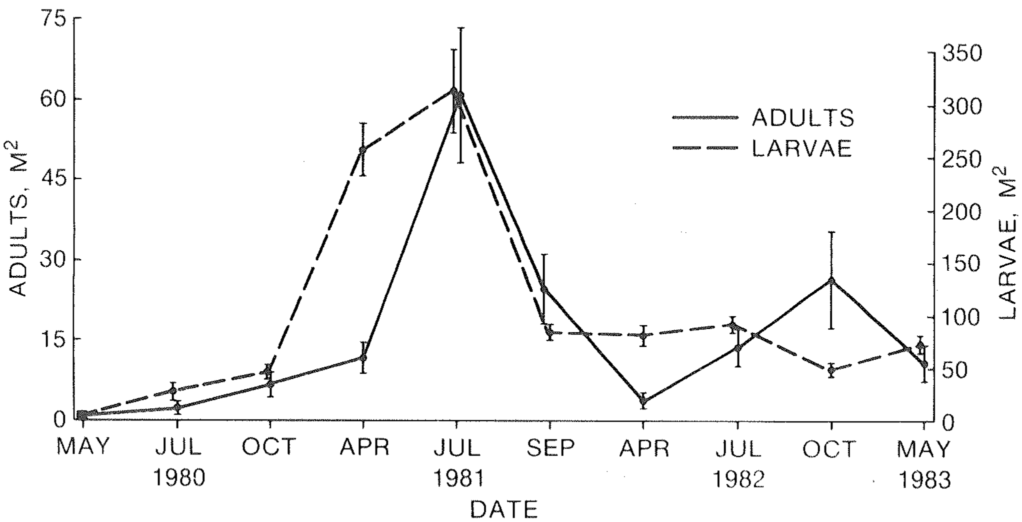

Fig. 3. Mean numbers of *Neochetina* adults and larvae/m^2 at the Lake Theriot site. Vertical bars represent 2 SD of the means.

to 24.8 and 83.2/m^2, respectively, and numbers of *Neochetina* never again attained levels as high as during the first portion of the 1981 growing season. Numbers of *Neochetina* larvae remained at the September 1981 level into summer 1982, but decreased significantly to 50.0 larvae/m^2 by October 1982. Density of *Neochetina* adults increased throughout the 1982 growing season, attaining a seasonal maximum of 26.4 adults/m^2 in October. Numbers of adults declined to 10.4 adults/m^2 by May 1983.

Other arthropod species did not attain levels sufficient to significantly damage the waterhyacinth population. *Sameodes* was never collected in any samples, nor was evidence of its presence ever found during the study.

Waterhyacinth populations at both sites showed a significant reduction in production during the study. Reductions occurred during different years for each site and appeared to be linked to the establishment and development of the *Neochetina* population. When data collection began, a well-established *Neochetina* population was found at the Assumption Parish site, while the *Neochetina* population at the Lake Theriot site was not yet well-established.

Although data for only one growing season were taken at the Assumption Parish site before the waterhyacinth mat dropped out, significant reductions in percent cover, plant density, and number of daughter plants were recorded. Plant height increased from May to September (1980); however, the increase was only to a height of 24 cm, which is much smaller than the average height recorded at the other study sites (Sanders *et al.*, *in press*). This size reduction demonstrates the reduced fitness of the waterhyacinth population and indicates that the plants were stressed prior to the start of data collection. The *Neochetina* population present at the site in 1980 was not significantly larger than the *Neochetina* populations in healthy waterhyacinth infestations; however, our observations indicate that the weevil population was capable of destroying both the meristematic and photosynthetic portions of most plants. Because *Cercospora* was only rarely re-isolated from waterhyacinth tissues from the site, the role of this pathogen was considered non-significant in effecting the observed reduction. This view is emphasized because the high pathogen value at the site (Table 2) may otherwise unjustly implicate the role of *Cercospora*. The pathogen damage index values, as assessed in this study, represented a cumulative impact of all microorganisms. During fall months, these values were always high at all study sites, due to the deteriorating condition associated with normal senescence (Sanders *et al.*, *in press*). At the Assumption Parish site, pathogen damage values were high throughout the year because of an otherwise severely stressed waterhyacinth population, and not because of significant *Cercospora* infectivity.

Obviously, some factor had stressed the waterhyacinth at the Assumption Parish site prior to our study initiation in May 1980. Comparison between this site in 1980 and the Lake Theriot site in 1982 reveal certain similarities. At these times, both sites had waterhyacinth populations that were below normal in plant height, biomass, and density. Also, other aquatic plant species were beginning to compete with waterhyacinth for surface area dominance at both sites. Although one can only speculate as to the reason for the prior reduction in fitness of the waterhyacinth population at Assumption Parish, the Lake Theriot site offers evidence that a large *Neochetina* population during the first part of the growing season can inflict such a reduction.

The waterhyacinth population declined in percent cover, biomass, density, and plant height at the Lake Theriot site after the spring and summer peak in the *Neochetina* population. The weevil population expanded significantly in April 1981 and maintained relatively high levels. Examining the relationship of the number of *Neochetina* individuals (both larvae and adults)/kg plant tissue, we found that insect values were extremely high in April 1981 (49 individuals/kg) and July (32 individuals/kg). This four- to five-month sustained impact was apparently sufficient to reduce the ability of waterhyacinth to store food and produce new growth.

Goyer and Stark (1984) conducted a *N. eichhorniae* study during 1979 and 1980 at sites near Whitehall and Morgan City. Their findings were very similar to our results from the Assumption Parish and Lake Theriot sites. They found a reduction in percent cover, biomass, density, daughter plant production, and height and waterhyacinths were completely absent from the bayou at Morgan City, Louisiana by 1981.

The Louisiana Department of Wildlife and Fisheries estimates the waterhyacinth acreage in Louisiana annually at the end of each growing season. Fig. 4 depicts the estimated waterhyacinth acreage from 1974 through 1983 and some general trends can be observed. The acreage of waterhyacinth remained high through 1978, while the insect population was developing. A slight reduction in waterhyacinth acreage was observed in 1979. A swarming of *Neochetina* occurred in the south-central portion of the State adjacent to the Atchafalaya Basin in August 1980. The waterhyacinth population decreased drastically in 1980 to a level of 121,946 ha (301,100 acres). This represented a 75% reduction in waterhyacinth acreage from the 1974–78 average of 1.25 million acres. The waterhyacinth acreage gradually increased to a level of 243,000 ha (600,000 acres) in 1983, which was still 50% lower than the 1974-78 average.

Although the impact of *Neochetina* on the waterhyacinth population is significant, environmental factors assist and enhance the impact of the insects. During and prior to the establishment of *Neochetina*, environmental factors (e.g. extreme cold) occasionally reduced the waterhyacinth acreage; however, the growth capability of waterhyacinth was such that, after one growing season, the waterhyacinth acreage was again near or at its maximum.

Fig. 4. Total acreages of waterhyacinth in Louisiana during 1974–83. Data provided courtesy of the Louisiana Department of Wildlife and Fisheries.

When *Neochetina* population levels become large enough to impact the plants, they reduce the ability of waterhyacinth to store food or produce growth. This impact also makes the plants more susceptible to environmental stress. Plants subjected to environmental stress do not recover in one growing season when impacted by large insect populations.

The increase in waterhyacinth acreage for 1981 through 1983 is predictable since *Neochetina* is host-specific to waterhyacinth and a reduction in waterhyacinth, the food source of *Neochetina*, effects a reduction in the *Neochetina* population. We predict that an oscillating pattern will occur in the waterhyacinth acreage in Louisiana, but the eventual amplitude of the oscillations remains a question.

Acknowledgments

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