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STATUS OF BIOLOGICAL CONTROL OF WATERLETTUCE IN LOUISIANA AND TEXAS USING INSECTS

by

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13. ABSTRACT *(Maximum 200 words)*
A series of surveys were conducted in southeastern Louisiana during the spring and summer of 1990 to characterize the assemblage of herbivorous insects impacting waterlettuce. These surveys were considered an important first step prior to the release of *Neohydronomous affinis* in Louisiana, an exotic weevil imported to the United States for the management of waterlettuce. The two most commonly encountered herbivorous insects were the two polyphagous lepidopteran species, *Samea multiplicalis* and *Synclita obliteralis*. Other herbivorous insect species collected included *Draeculacephla inscripta* (leafhopper) and *Rhopalosiphum nymphaeae* (aphid). While these species apparently inflict minimal plant damage they may be important for their role in disease transmission. *Neohydronomous affinis* was also collected from several sites within a 50-mile circle from Lake Verret to east of Lake Beouf. The collection of *N. affinis* was surprising since the closest release of *N. affinis* was in Gainsville, FL, more than

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500 miles away. Populations of *N. affinis* are persisting as indicated by relatively high levels occurring for two growing seasons. Explanations for the presence of *N. affinis* in southeastern Louisiana are unknown. It is probable that it was accidently released from infested plants brought from Florida release areas.

Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP), Work Unit 32406. The APCRP is sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE), and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel was Assistant Manager, ERRAP for the APCRP. Technical Monitor during this study was Ms. Denise White, HQUSACE.

The information presented in this report on the status of biocontrol in Louisiana and Texas was taken from a series of studies undertaken by WES between 1990 and 1991. This report was prepared by Dr. Michael J. Grodowitz of the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), EL, and Drs. William Johnson and Lois Nelson of Nicholls State University, Thibodaux, LA. During the conduct of these studies, Dr. John Harrison was Director, EL, Dr. C. J. Kirby was Chief, ERD, and Dr. Edwin Theriot was Chief, AHG.

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

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Contents

STATUS OF BIOLOGICAL CONTROL OF WATERLETTUCE IN LOUISIANA AND TEXAS USING INSECTS

Background

1. Waterlettuce, *Pistia stratiotes* L., is a free-floating aquatic plant from the Arum family, Araceae. It is characterized by having a relatively short stem where the leaves attach in whorls. The plant has a distinctive light yellow-green to gray-green coloration. The leaves are covered with a fine pubescence and are typically enlarged basally by the formation of aerenchyma cells. This enlargement and the well-developed root system work together to maintain plant buoyancy. While the majority of reproduction occurs vegetatively where daughter plants are produced via stolons, sexual reproduction is now known to occur in the United States (Dray and Center 1990). The plant has one of the highest productivity rates for green plants, and minimal numbers of plants can quickly reproduce and cover an entire water body. In the United States, waterlettuce usually forms dense floating mats where individual plants are highly intertwined, forming an almost impenetrable barrier.

2. Waterlettuce is mainly distributed in tropical and semitropical regions of Africa, southern Asia, southern United States, the southern portion of Central America, and South America, as well as the Caribbean (Holm et al 1977). Its extreme cold intolerance appears to severely limit its distribution in more temperate regions. In the United States, waterlettuce is limited to southern Florida, Louisiana, and Texas. It can be found in most slow-moving or stagnant water bodies, including canals, bayous, streams, ponds, and lakes.

3. The high productivity of waterlettuce and its ability to form large impenetrable floating mats can cause many problems (Holm et al 1977). Navigation is severely curtailed on water bodies containing large infestations of waterlettuce. This, in turn, can reduce recreational uses. Waterlettuce can block water intake valves where industrial and local municipalities receive water supplies. Water losses appear to be higher where waterlettuce infestations occur because of increased evapo-transpiration through the leaf surfaces. Waterlettuce has been shown to impact aquatic or semiaquatic agriculture, including rice (Bua-ngam and Mercado 1975). Distinct changes in water quality have been documented in areas beneath or near waterlettuce mats

(Attiou 1976). These include lowered pH and dissolved oxygen. Such changes in water quality can have a significant impact on local fish populations, particularly under conditions of high temperatures.

4. Another economically important problem caused by the presence of waterlettuce is the formation of an ideal mosquito-breeding habitat (Holm et al. 1977). While other floating aquatic plants serve in this capacity, waterlettuce apparently attracts high numbers of species capable of disease transmission. For example, waterlettuce infestations harbor species in the genera *Mansonia* and *Anopheles* (George 1963). Several species in these genera have been shown to transmit the causative agents for malaria, encephalomyelitis, and rural filariasis. However, harborage is not the only manner in which waterlettuce increases population levels of mosquitoes. The elaborate root system of waterlettuce also provides *Mansonia* sp. larvae a means for oxygen uptake. Larvae have pointed air tubes that enable them to pierce waterlettuce roots for oxygen uptake (James and Harwood 1970).

5. Because of the manifold problems associated with waterlettuce infestations and difficulty in treating waterlettuce with herbicides, researchers began to search for viable alternatives to more traditional methods for the control of waterlettuce. One alternative identified was the use of insect biocontrol agents.

6. During the early 1970's, researchers in Argentina identified a potential candidate for biological control of waterlettuce, the weevil *Neohydronomus affinis* Hustache (DeLoach, DeLoach, and Cordo 1976). After completing considerable work on the insect's basic biology and efficacy, these researchers concluded that the weevil was ideal for use as a biocontrol agent.

7. Researchers from the Commonwealth Scientific and Industrial Research Organization imported *N. affinis* into Australian quarantine in 1981 (Harley et al. 1984) and subsequently made field releases the following year. Waterlettuce reductions of 100, 93, and 82 percent were achieved at three reservoirs in only 20 months.

8. Using information on host specificity gained in Australia, *N. affinis* was brought into United States quarantine in 1985. Building upon the host specificity testing done by the Australians, United States testing was finished relatively rapidly, and permission to field test *N. affinis* was subsequently obtained in 1987 (Dray et al. 1990, Habeck and Thompson, In Preparation).

9. The first release of *N. affinis* in the United States occurred at Kreamer Island on Lake Okeechobee (Palm Beach County), FL, during April 1987 (Dray et al. 1990). Approximately 2,300 individuals were released during the period April 1987 through January 1988. Additional releases followed, and to date, *N. affinis* has been released at more than 80 sites throughout Florida (Center and Dray, In Preparation).

10. *Neohydronomus affinis* population dynamics and changes in waterlettuce levels appear to be correlated. For example, at Kreamer Island, only minimal numbers of *N. affinis* occurred for the first 20 months after the initial release. During these 20 months, plant coverage typically remained at between 60 and 90 percent. However, with subsequent increases in the population of *N. affinis* population numbers during January 1989 through May 1990, significant decreases in plant coverage resulted. Currently, waterlettuce coverage remains below 5 percent at this site (Dray et al. 1990).* To date, waterlettuce has been eliminated from three out of the four initial Florida release sites.

Objectives

11. Because of the apparent success of using *N. affinis* in Florida, research was initiated to study the potential use of this species in Louisiana and Texas. Specifically, areas in Louisiana and Texas were surveyed in an effort to qualify the impact native insect species have on waterlettuce infestations before making large-scale releases of *N. affinis*. The following is a summary of the findings from those surveys.

Methods and Materials

12. During the spring and summer of 1990, extensive surveys were conducted in Louisiana and Texas to determine the kinds of native herbivorous insect species impacting waterlettuce populations. The surveys were similar to those conducted in Florida during 1986 (Dray et al. 1988) and were considered an important step prior to the release of *N. affinis* in these areas.

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* Personal Communication, F. A. Dray, United States Department of Agriculture-Agricultural Research Service (USDA-ARS), Aquatic Plant Management Laboratory, Fort Lauderdale, FL.

Louisiana

13. A total of 24 sites in southern Louisiana containing at least some waterlettuce were examined during 1990 and 1991 (Table 1). The sites were located from immediately east of New Orleans, proceeding west to Lake Charles and south to Lacassine Refuge and Pecan Island. All known waterlettuce infestations were examined. Much of the information on waterlettuce sites was obtained from personnel of the US Army Engineer District, New Orleans.

Texas

14. Waterlettuce was less common in Texas. The US Army Engineer District, Galveston, and Texas Park and Wildlife personnel reported only four sites to contain waterlettuce. These ranged from east and south of Austin to just southeast of Houston, TX. The populations were minor with the exception of those located at Brazos Bend State Park.

Insect and plant collections

15. At each site, waterlettuce plants were removed and carefully examined for signs of damage. Suspect insect herbivores were removed, preserved in 70 percent ethanol, and transported to the US Army Engineer Waterways Experiment Station for identification. If a specific identification could not be obtained, representative specimens were sent to specialists for each major taxon. For the aquatic weevils, specimens were sent to Dr. Charlie O'Brien at Florida Agricultural and Mechanical University at Tallahassee, aquatic Lepidoptera were sent to Dr. Dale Habeck at the University of Florida, Gainesville. For the remaining taxa species, names were given based on information obtained from surveys conducted in Florida.

16. For several sites near Thibodaux, LA, more quantitative estimates of plant status and insect levels were determined for 3 months during the summer and fall of 1991. A total of four replications were taken from each site. For each replication, at both Choctaw and Winn-Dixie sites, two 0.25-m^2 frames were randomly placed adjacent to one another within the site, and all plants that were 50 percent or more within the frame were removed. For the first frame, all plants were counted and their biomass partitioned into above-water, below-water, and total dead material. For the remaining frame, plants were counted and placed into large Belese funnels for extraction of insects. After the plants were totally dry, the extracted herbivorous insects were quantified. Two parameters were calculated from the previously mentioned information--weight (grams)/plant and number of weevils/plant.

Results and Discussion

17. A majority of the sites examined, in both Louisiana and Texas contained waterlettuce that appeared to be damaged by herbivores to some extent. The most common damage gave the plants the appearance of being shredded, i.e., irregularly shaped holes running roughly parallel to the prominent leaf veins. At several sites, the plants had large regularly shaped holes toward the leaf margin. This damage was caused by the most common native insect herbivores, *Samea multiplicalis* and *Synclita obliteralis*. These medium-sized moth larvae appear able to inflict significant damage. *Samea multiplicalis*, the most common, was found at >95 percent of the sites examined (Tables 1 and 2). It was frequently collected in large numbers. Its damage as indicated earlier, gave the plant an appearance of being shredded. *Synclita obliteralis* was less frequently collected, however, at sites where it was found, the plants were heavily damaged. Damage was characterized by large holes in the leaf margin, which are thought to be used as a protective covering for the larvae. These species evidently can both feed and develop entirely on waterlettuce (Knopf and Habeck 1976, DeLoach, DeLoach, Cordo 1979). Both *S. multiplicalis* and *S. obliteralis* were found at sites throughout southern Florida (Dray et al. 1988). Observational data from Florida, Louisiana, and Texas indicate that, while both species can inflict great damage to waterlettuce, they rarely cause significant declines in population numbers.

18. The remaining "important" insect herbivores found on waterlettuce are most likely transient species that do not usually feed on waterlettuce. For example, the two weevil species, *Tanysprrus lemnae* and *Stenopelmus rufinasus*, are known to feed and develop on *Lemna minor* and *Salvinia* sp., respectively.* These weevil species are most likely transient, the most likely reason for their appearance on waterlettuce is that both *L. minor* and *Salvinia* sp. are often found in association with waterlettuce. However, both insect species have been observed to feed on waterlettuce, although damage was relatively minor compared with the two moth species.

19. The surveys also documented that large numbers of *Draeculacephala inscripta* (leafhopper) and *Rhopalosiphum nymphaeae* (aphids) were common. Only

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* Personal communication, Dr. C. O'Brien, Florida Agricultural and Mechanical University, Tallahassee, FL.

minimal feeding damage as a result of these species was observed. These two insect species are of importance because closely related species have been implicated in disease transmission for various plant species (Borror, Delong, and Triplehorn 1981).

20. The most unexpected finding was the collection of *N. affinis* individuals in relatively high densities (>20 individuals/m²) from several sites in southeastern Louisiana during 1990 (Table 1). This was not expected since *N. affinis* was never officially released and limited collecting efforts by other researchers in the past did not reveal the presence of *N. affinis* in this area. The survey sites where *N. affinis* was collected occurred within an approximate 50-mile (80.5-km) circle from Lake Verret to east and south of Lake Beouf. *Neohydronomus affinis* was not collected from any sites west of the Atchafalaya Basin. The relatively high densities of *N. affinis* indicate that the population may have been present in this area for at least 1 to 2 years based on information on population dynamics after initial releases observed at Australia and Florida sites.*

21. The *N. affinis* populations apparently had persisted through the fall of 1991. Quantitative estimates were made of plant population levels at two sites and insect population levels at four southern Louisiana sites from July through September 1991 (Tables 3-5). Three of the four sites were known to have *N. affinis* present (Choctaw, Stockyard, and Zero Ranch) based on the 1990 surveys, while *N. affinis* was not collected at the Winn-Dixie site. Insect numbers ranged from 100 to 300 adults/m² at these three sites. Weevil numbers at the Choctaw site remained relatively stable throughout the sampling period. Significant increases occurred at the Stockyard site, about threefold from July to August 1991. This translated to an increase of about one to less than three individuals per plant. *Neohydronomus affinis* adults were not collected at the Stockyard site during the September collection. Similarly, no adult weevils were collected at the Zero Ranch site following the July sampling.

22. The levels of *N. affinis* apparently had little impact on the plant populations. For example, the Choctaw site, which averaged about 200 adult weevils/m², had plants that increased significantly in weight (i.e., about sevenfold; Tables 3 and 4). Similarly, the Choctaw site had an approximate

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* Personal Communication, F. A. Dray, USDA-ARS, Aquatic Plant Management Laboratory, Fort Lauderdale, FL.

sevenfold increase in above-water biomass from July to August (Table 5). This is in contrast to the no-insect site (Winn-Dixie), where above-water biomass remained relatively stable during the July and August sampling (i.e., 4 kg/m^2) with significant increases occurring during the September sampling period of ca. twofold.

23. Based on information on plant and insect population levels gathered at Florida sites beginning in 1987, significant impact because of *N. affinis* did not occur until insect levels exceeded 300 individuals/m^2 for sustained periods.* While such levels were attained at the Stockyard site during the August sampling, numbers of insects were drastically reduced the following month. At no other site did insect numbers exceed 250/m^2.

24. A complicating factor was the presence of native or naturalized insect herbivores found in association with waterlettuce. The most commonly collected species was *S. multiplicalis*. This species averaged approximately 2,000 to 4,000 individuals/m^2 compared with only 300 individuals/m^2 for Winn-Dixie during the July and August sampling period. However, numbers at the Winn-Dixie site increased substantially for the September sampling to approximately 5,000 individuals/m^2. It is unknown why higher total insect herbivores were found at the Choctaw site during the July and August collections; however, this may be related to the proximity of the site to sugarcane fields surrounding the bayou at Winn-Dixie. Pesticide applications in these fields during July and August may have contributed to the lower numbers of *S. multiplicalis* found at the Winn-Dixie site.

25. Reasons for the presence of *N. affinis* in Louisiana are unknown. Possible explanations include: (a) *N. affinis* populations were already established in Louisiana prior to the Florida releases, (b) *N. affinis* migrated from Florida sites naturally, and (c) infested plants from Australia or some other country were distributed into this area. However, little credence can be given to these explanations. For example, past collections by researchers during the early 1960's in the west-Louisiana/east-Texas area did not reveal the presence of *N. affinis*. Hence, it is difficult to believe it was present in the United States prior to its release in Florida. While *N. affinis* can disperse relatively rapidly from original release sites, the large distances covered (i.e., from Florida to Louisiana) in such short time periods are

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* Personal Communication, F. A. Dray, USDA-ARS, Aquatic Plant Management Laboratory, Fort Lauderdale, FL.

unrealistic, especially considering the lack of substantial waterlettuce populations in the panhandle of Florida and the extreme southern portions of Alabama and Mississippi that would aid in their distribution. Similarly, the odds of infested plants reaching Louisiana intact from Australia or South America is low. The most plausible explanation is that plants infested with *N. affinis* from Florida release sites were accidentally distributed into this area. However, even this explanation has little grounds for complete acceptance. For example, the number of release sites with significant population densities of *N. affinis* was still low at Florida sites during 1988 and 1989 (Dray et al. 1990). Infested plants would have had to be transported during this period for insect densities to reach such high levels by summer 1990 in Louisiana. Hence, the odds of removing infested plants from Florida with sufficient densities at that time would be low. Other reasons for the presence of *N. affinis* in Louisiana are being considered.

26. One piece of evidence is important--*N. affinis* appears to be limited in its Louisiana distribution. This distribution is confined to an area between Raceland, LA, and the Atchafalaya Basin. One would think that if *N. affinis* has been in Louisiana for an extended period, its distribution would be more extensive. Such a small range in Louisiana would lend credence to the idea that *N. affinis* has been in the state for only a relatively short time frame. More information is needed on the population dynamics of *N. affinis*.

Future Directions

27. In the immediate future, the distribution of *N. affinis* in the United States waterlettuce range, specifically in Louisiana and Texas, will be enlarged. This will be accomplished by moving infested plants from Florida and Louisiana to areas where *N. affinis* is not currently present. Greenhouse-reared individuals will be used to supplement such range extensions whenever possible. Efforts will also continue to monitor *N. affinis* populations dynamics and correlate these with shifts in waterlettuce infestation levels. This is currently being accomplished in Louisiana and will continue. A release of *N. affinis* was made in southeast Texas at Lake Dunlap during September 1991, and limited observations will continue to be made on the insect's population dynamics. Additional releases are now being considered.

28. In October 1990, *Namangana pectinicornis* was officially released from United States quarantine facilities. Releases were made at several sites

during 1991. *Namangana pectinicornis* is a relatively large moth capable of inflicting large amounts of damage on waterlettuce (Thompson and Habeck, In Preparation). Greenhouse studies have indicated that it is highly effective in producing damage. Future plans include releasing *N. pectinicornis* at several south Florida sites, with subsequent monitoring of population levels and efficacy. If this species proves to be effective at initial Florida release sites, larger scale range extensions will be attempted in Florida and then in Louisiana.

Summary

29. Diverse assemblages of native insect herbivores, similar to those found in Florida, feed on waterlettuce in Louisiana and Texas. These include the moth species, *S. multiplicalis* and *S. obliteralis*. While these species can inflict large quantities of superficial damage, they do not appear to be capable of reducing population densities. Two native weevil species, *T. lemnae* and *S. rufinasus*, commonly collected from waterlettuce, are known to feed and develop on *L. minor* and *Salvinia* sp., respectively. These species are most likely transient on waterlettuce because it grows in association with *L. minor* and *Salvinia* sp. While these species have been observed to feed on waterlettuce, they inflict only minor damage. The exotic weevil species *N. affinis* was collected from several sites in Louisiana at relatively high population densities. This is surprising since this species was never officially released in Louisiana and the closest release sites were in the Gainesville area of Florida. Population densities of >70 individuals/m^2 indicate that the species has been present for at least several years. Reasons for its presence are unknown but are probably due to infested plant material arriving from Florida. Population dynamics are currently being monitored in an effort to assess impacts.

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Table 1

Sites in Louisiana Examined for Presence of Insect Herbivores Damaging Waterlettuce during 1990 and 1991

Site	Location	*Neohydronomous affinis*	*Samea multiplicalis*	*Synclita obliteralis*	*Draeculacephala inscripta* (leafhopper)	*Rhopalosiphum nymphaeae* (aphid)
Bayou Folse	On Bayou Folse road, 2 miles* off Willow Road-Old Hwy. 90 near Raceland, LA	N	Y	N	N	N
Stockyard	Small drainage ditch behind Raceland, LA, Stockyards on Hwy. 308, leads to Lake Boeuf	Y	Y	Y	Y	N
Hwy. 14 Slough	4 miles north of eastern boundary of Lacassine Refuge in Louisiana	N	N	N	N	N
Lake Arthur Slough	North 6 miles east of Lake Arthur, LA, small slough	N	Y	N	N	N
Pecan Island	Bayou off of Hwy. 82 leading to Pecan Island, LA	N	Y	N	N	N

(Continued)

* To convert miles to kilometers, multiply by 1.609347.

Note: An "N" indicates that no specimens were collected while a "Y" indicates the collection of at least one individual.

Table 1 (Continued)

Site	Location	*Neohydronomous affinis*	*Samea multiplicalis*	*Synclita obliteralis*	*Draeculacephala inscripta* (leafhopper)	*Rhopalosiphum nymphaeae* (aphid)
Little Prairie	1 mile north of Little Prairie, LA, on Hwy 82	N	Y	N	N	N
Esther	6 miles southeast of Esther, LA	N	Y	N	Y	N
Halpin Canal #1	Extreme southern end of Halpin Canal off Lake Beouf, LA	N	Y	N	Y	N
Halpin Canal #2	Halpin Canal off Lake Beouf, LA	N	N	N	Y	Y
Foret Canal	Foret Canal off Lake Beouf, LA	Y	Y	N	Y	N
No-name Canal	No-name canal off Lake Boeuf, LA	N	Y	Y	Y	N
Bayou L'eau Bleu #1	Bayou L'eau Bleu near Lockport, LA	N	Y	N	Y	N
Bayou L'eau Bleu #2	Bayou L'eau Bleu near confluence of Bayou Folse--near Lockport, LA	N	Y	N	Y	N
Lake Long	Amoco Oil Canal near Lake Long--near Lockport, LA	N	Y	N	Y	N
Choctaw	3 miles east of Choctaw, LA, on Hwy. 22	Y	Y	Y	Y	Y

(Continued)

Table 1 (Concluded)

Site	Location	*Neohydronomous affinis*	*Samea multiplicalis*	*Synclita obliteralis*	*Draeculacephala inscripta* (leafhopper)	*Rhopalosiphum nymphaeae* (aphid)
Guedan Canal	Small canal 2 miles from Guedan, LA	N	Y	N	Y	Y
Coulee Baton	Small canal near Coulee Baton, LA	N	Y	N	Y	N
Kaplan Canal	Small canal near Coulee Baton, LA	N	Y	N	N	N
Godchaux Canal	Small canal northeast of Lake Verrette, LA	Y	Y	N	Y	N
Texaco Canal, Lake Verrette	Texaco Oil Canal leading to Lake Verrette, LA	N	Y	N	Y	N
Zero Ranch	Small drainage ditch near Zero Brahma Ranch, 4 miles northeast of Thibodaux, LA	Y	Y	N	Y	N
Houma Mall	Small pond behind Houma Mall	N	Y	Y	Y	N
Winn-Dixie	Bayou behind Thibodaux, LA, Winn-Dixie	N	Y	N	N	N
Mid Bayou Folse	Midway along Bayou Folse	N	Y	N	Y	N

(Sheet 3 of 3)

Table 2

Sites in Texas Examined for Presence of Insect Herbivores Damaging Waterlettuce during 1990 and 1991

Site	Location	*Neohydronomous affinis*	*Samea multiplicalis*	*Synclita obliteralis*	*Draeculacephala inscripta* (leafhopper)	*Rhopalosiphum nymphaeae* (aphid)
Lake McQueeney	Near Marion, TX, on Hwy. 78	N	Y	Y	Y	N
Lake Dunlap	Near Houston, TX	N	Y	Y	Y	Y
Eagle Lake	Near Alleyton, TX, on Hwy. 102	N	Y	Y	Y	N
Brazos Bend	Pilant Lake in Brazos Bend State Park, TX	N	Y	Y	Y	Y

Note: An "N" indicates that no specimens were collected while a "Y" indicates the collection of at least one individual.

Table 3

Density (number of weevils/square meter) of *N. affinis* and Numbers of Weevils Per Plant at Choctaw (CK), Stockyard (SY), Winn-Dixie (WD), and Zero Ranch (ZR) Sites during July, August, and September 1991

	Parameter							
	Density (Numbers/m^2)				Weevils/Plant			
Month	CK	SY	WD	ZR	CK	SY	WD	ZR
July	205.0 x(a)	109.0 y(ab)	0.0 x(b)	129.0 x(ab)	1.4 x(a)	0.8 y(ab)	0.0 x(b)	0.4 x(b)
August	187.3 x(b)	367.5 x(a)	0.0 x(c)	0.0 x(c)	1.6 x(b)	3.1 x(a)	0.0 x(c)	0.0 x(c)
September	153.7 x(a)	0.0 y(b)	0.0 x(b)	0.0 x(b)	1.1 x(a)	0.0 y(b)	0.0 x(b)	0.0 x(b)

Note: Means that are significant at $P < 0.05$ are indicated by different letters using a Least Significant Difference test based on the standard error of the mean based on the overall analysis of variance. X and Y are used for a specific site across months, while A, B, and C are used for a given month across sampling sites. Appropriate statistics for density are $P < 0.0001$ and standard error of the mean = 49.45; for number of weevils/plant, statistics are $P < 0.0001$ and standard error of the mean = 0.32.

Table 4

<u>Plant Density (number of plants/square meter) and Weight (grams)/ Plant for Waterlettuce at Choctaw (CK) and Winn-Dixie (WD) Sites during July, August, and September 1991</u>

Month	Parameter			
	Density		Weight/Plant	
	CK	WD	CK	WD
July	125.0 y	104.0 y	33.6 z*	62.6 x
August	136.0 x*	100.0 y	79.2 x	64.9 x
September	131.0 xy	152.0 x	43.6 y*	68.0 x

Note: Means that are significant at $P < 0.05$ are indicated by different letters or an asterisk using a Least Significant Difference test based on the standard error of the mean from the overall analysis of variance. An asterisk indicates significant differences across sampling sites for a given month, while X and Y are used for a given site across months. Appropriate statistics for plant density are $P = 0.0011$ and standard error of the mean = 7.71, for weight/plant, statistics are $P < 0.0001$ and standard error of the mean = 0.007.

Table 5

<u>Total Wet Weight (kilograms/square meter) of Waterlettuce Partitioned into Above-water, Below-water, and Dead Wet Weight at Choctaw (CK) and Winn-Dixie (WD) Sites During July, August, and September 1991</u>

Month	Partitioned Weight					
	Above-water		Below-Water		Dead	
	CK	WD	CK	WD	CK	WD
July	1.12 c*	4.47 b	0.13 b	0.24 b	0.47 b*	1.59 a
August	7.30 a*	4.57 b	1.70 a	1.70 a	1.73 a*	0.24 b
September	3.40 b*	7.13 a	1.30 a*	1.84 a	1.02 ab	1.18 a

Note: Means that are significant at $P < 0.05$ are indicated by different letters or an asterisk using a Least Significant Difference test based on the standard error of the mean based on the overall analysis of variance. An asterisk indicates significant differences across sampling sites for a given month, while a and b are used to indicate significant differences for a given site across months. Appropriate statistics for above-water biomass are $P < 0.0001$ and standard error of the mean = 0.42; for below-water biomass, $P < 0.0001$ and standard error of the mean = 0.16; and for total dead biomass, $P < 0.0001$ and standard error of the mean = 0.25.