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BIOLOGICAL CONTROL OF *PISTIA STRATIOTES* L. (WATERLETTUCE) USING *NEOHYDRONOMUS AFFINIS* HUSTACHE (COLEOPTERA: CURCULIONIDAE)

by

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Waterlettuce (*Pistia stratiotes* L.) is a floating plant that often interferes with the proper use of water resources. Consequently, releases of a biological control agent, *Neohydronomus affinis* Hustache (a weevil), were begun in April 1987 at several sites in southern Florida. Self-perpetuating populations had established at four of these sites by September 1988. The plant and weevil populations were monitored on a monthly basis at three sites: Kreamer Island, Torry Island, and Port St. Lucie. By May 1989, Kreamer Island harbored about 45 million weevils, and the plant population had been reduced from 50 acres (202,343 sq m) to less than 5 acres (20,234 sq m). By May 1990, Torry Island harbored nearly 42 million weevils and *P. stratiotes*, which had previously filled the 10-acre (40,468 sq m) site, was virtually absent. The biocontrol agent population at Port St. Lucie never exceeded 100,000 weevils and had little apparent impact on the waterlettuce population at this site.

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Plants under stress from weevil herbivory at Kreamer Island and Torry Island were typically smaller, had fewer leaves, and grew less rapidly than healthy plants. As a result, waterlettuce populations harboring large weevil infestations exhibited reduced vigor, and standing crop and coverage declined until waterlettuce was virtually eliminated from these waterbodies. Why the Port St. Lucie populations failed to increase to damaging levels has not been determined, though several hypotheses present themselves.

Weed control agencies in southern Florida have cooperated to spread this weevil from Torry and Kreamer Islands to other waterways. Additional sites have become infested as the weevils disperse on their own. *Neohydronomus affinis* becoming established throughout Florida and proving invaluable in controlling *P. stratiotes* is expected. Experiences at Port St. Lucie suggest that this weevil will not be universally effective, however, and that additional biological controls should be investigated.

PREFACE

The work reported herein was sponsored by the U.S. Army Engineer District, Jacksonville, and by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Aquatic Plant Control Research Program (APCRP), Work Unit 32406. The APCRP is assigned to the U.S. 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 Mr. James W. Wolcott, HQUSCAE.

The research described in this report was conducted through Specific Cooperative Agreements 58-7B30-3-586 and 58-43YK-8-0005 between the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), South Atlantic Region (SAR), and the University of Florida (UF), Institute of Food and Agriculture Services (IFAS). The report was prepared by Mr. F. Allen Dray, Jr., UF, IFAS, Fort Lauderdale Research and Education Center (FLREC), and Dr. Ted D. Center, USDA, ARS, SAR, Aquatic Weed Research Laboratory (AWRL).

The field research and data analyses were performed by Mr. Dray. Assistance with field collections and laboratory processing was provided by Messrs. Boudanath Maharajh, Mike Bouhadana, and Kevin McKinney, and Ms. Marisa Larouche, FLREC; and Ms. Jane Bergin, Mrs. Donna Niehaus, and Mr. Willey Durden, USDA, ARS, SAR, AWRL.

This research was monitored at WES by Dr. Alfred F. Cofrancesco, Jr., of the EL, Environmental Resources Division (ERD), Aquatic Habitat Group (AHG). The study was conducted under the general supervision of Dr. John Harrison, Director, EL, and Dr. Conrad J. Kirby, Chief, ERD, and under the direct supervision of Dr. Edwin A. Theriot, Chief, AHG.

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

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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	4,046.873	square metres
miles (US statute)	1.609347	kilometres
yards	0.9144	metres

BIOLOGICAL CONTROL OF *PISTIA STRATIOTES* L. (WATERLETTUCE) USING *NEOHYDRONOMUS AFFINIS* HUSTACHE (COLEOPTERA: CURCULIONIDAE)

PART I: INTRODUCTION

Background

1. The use of water bodies for recreation and navigation is often severely restricted by nuisance aquatic plants. These plants also clog agricultural irrigation and drainage canals, impede hydroelectric operations, decrease property values, hinder mosquito control operations, and cause other problems that adversely impact the general populace. Some highly publicized aquatic plants include waterhyacinth (*Eichhornia crassipes* (Mart.) Solms), Eurasian watermilfoil (*Myriophyllum spicatum* L.), hydrilla (*Hydrilla verticillata* L. f.), and alligatorweed (*Alternanthera philoxeroides* (Mart.) Griesb.). Estimates of annual losses and damages to water resources in the United States due to aquatic plants range up to $3 billion.*

2. The floating hydrophyte *Pistia stratiotes* L. (waterlettuce) is a troublesome plant that infests many waterways in the southeastern United States. According to estimates by the Florida Department of Natural Resources (Schardt 1984, 1985, 1986), waterlettuce populations nearly quadrupled during 1982-1985. As a result, efforts to control this plant also increased. Vigorous application of mechanical and chemical control technologies to waterways harboring waterlettuce maintains population levels at about 2,500 acres** statewide (Schardt and Schmitz 1990).

3. Unfortunately, this "maintenance" control is expensive. Florida and the U.S. Army Engineer District, Jacksonville, spend a total of approximately $650,000 annually for waterlettuce control.† These figures are unlikely to decline under current management practices. Many waterways contain inaccessible areas that harbor residual plant populations. These areas provide a constant source for reinfestation by *P. stratiotes*. Managed portions of these

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* Unpublished report, U.S. Department of Agriculture, Agricultural Research Service, Research Planning Conference on Biological Control, 20-22 March 1984, p 157.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

† Personal communication. Nov 1991, J. Schardt and W. Jipsen.

waterways are often reinfested when these residual populations are flushed out of backwater areas into main channels (Schardt and Schmitz 1990). In addition, waterlettuce seeds deposited in hydrosoils readily germinate under the proper environmental conditions (Dray and Center 1989). These are also a potent source of reinfestation in managed areas.

Biological Control

4. The addition of a biological control program to existing control strategies can greatly enhance the effectiveness of plant-management efforts. Biological control agents, unlike chemical and mechanical controls, naturally disperse throughout infested waterways. They also persist for as long as the target plant is available. These attributes permit biological control agents to reduce the potential for reinfestation once a target plant is under control provided, of course, that control is not so complete as to eliminate the biocontrol agent. This is an advantage not shared by other control methods. Also, biological controls are environmentally safe and, being self-perpetuating, they are very cost-effective. Successful biological control projects produce benefit:cost ratios of 30:1 or higher (Andres 1977).

5. Many plant species experience herbivore-induced stresses within their indigenous ranges that prevent them from achieving their full potential for population growth (Huffaker 1964; Strong, Lawton, and Southwood 1984). Biological control programs take advantage of this fact by finding these herbivores and importing them into a target plant's adventive range. Two approaches may be followed in implementing biological control. The first approach is the augmentative-manipulative approach whereby a bioagent is applied at a selected time in varying quantities, very much like a herbicide. Use of the grass carp (*Ctenopharyngodon idella* Val.) against hydrilla is an example of this approach (Pieterse 1981). The second approach, advocated for use against waterlettuce, is an inoculative approach in which host-specific natural enemies of a particular pest are introduced from the pest's native range into its adventive range. The biocontrol agents are then allowed to establish and increase to controlling levels on their own. Insects are the agents used most often in this approach.

6. Frequently, the insects that stress plants are highly specialized, being adapted to feed either on one particular plant species or on a very restricted range of plant species. In their native countries, these insects

are often held in check by diseases, parasites (that are also usually host-specific), and predators. When the insects are released as part of a biological control program, however, these obstacles to population growth are removed. Consequently, the insect populations are free to expand to levels necessary for control of the target plant.

7. An inoculative biological control program proceeds in clearly defined stages. First, natural enemies of the proposed target plant must be located and identified in the native range of the plant. The adventive range of the target plant must also be examined for herbivores attacking the weed. This ensures that time and money are not wasted by importing insects already present in the region where control is desired. Once a list of potential biocontrol agents has been compiled, host testing begins for the most promising of the candidate insect species. Preliminary host range tests involve closely related plants and economically or ecologically important plant species available in the countries where the insect and target plant are native. Potential bioagents that appear host-specific at the conclusion of these tests are then imported into U.S. quarantine for more testing against economically and ecologically important plants in the plant's adventive range.

8. Unfortunately, native herbivores only sporadically exert sufficient feeding pressure to control waterlettuce populations in Florida (Dray et al. 1988). Harley et al. (1984), however, reported successful biological control of waterlettuce in Australia using the South American weevil *Neohydronomus affinis* Hustache (mistakenly identified as *N. pulchellus*, see O'Brien and Wibmer 1989). This encouraged investigation of the use of this biocontrol agent against waterlettuce in Florida. Colonies of this weevil were imported from Australia in 1985, and subsequent studies indicated that it was safe for release in the United States (Thompson and Habeck 1988, 1989). Consequently, the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service and the Florida Department of Agriculture granted permission to release *N. affinis*. This report documents the release and establishment of *N. affinis* and evaluates the performance of this biocontrol agent at three waterlettuce sites in south Florida.

Pistia stratiotes

Description

9. *Pistia stratiotes* L. (Figure 1) is a free-floating aquatic plant having densely hairy, obovate-cuneate leaves arranged as a rosette (Cook et al. 1974). Leaves have parallel veins and are deeply grooved on the underside (Cook et al. 1974). The basal regions of the leaves are often quite swollen with spongy parenchyma (Ito 1899) which provides buoyancy and stability to the plant. A cluster of plumose adventitious roots originates from the base of each leaf (Sculthorpe 1967) and remains attached to the short underwater stem following loss of the leaf. The flowers occur singly in the center of the plant and are composed of a small whitish spathe that is constricted near the middle. Two cavities are thus formed: the upper contains a whorl of three to eight stamens having fused filaments, the lower contains the pistil (Muenscher 1944).

10. Waterlettuce mats consist of numerous genets, each of which may be simply a single plant or a primary ("mother") plant with offsets ("daughters"). Waterlettuce offsets (secondary plants) occasionally produce offsets of their own (tertiary plants), but rarely do these tertiary plants produce offsets (tertiary plants) prior to the secondary plant breaking free from the primary plant. Thus a waterlettuce genet will generally consist of two, occasionally three, and never more than four "generations."

Origin

11. Geographical origins of waterlettuce have been difficult to determine. Fossil records from Louisiana and Georgia place the genus *Pistia* in North America as recently as the Eocene Epoch (36 to 58 million years ago) when much of the continent was subtropical (Stoddard 1989). Within historic times, John and William Bartram reported that waterlettuce often rendered waterways impassable during their explorations of Florida in the mid-1700's (Stuckey and Les 1984). As a result, some workers (Stoddard 1989) considered *P. stratiotes* to be a native North American species, despite the interdiction of climates highly unfavorable to waterlettuce in the interval between the most recent fossil records and historical records (Futuyma 1979).

12. In contrast, Cordo, DeLoach, and Ferrer (1981) suggested a South American origin for this species. They noted that the extensive insect fauna associated with *P. stratiotes* in South America includes several herbivores whose host ranges are restricted to waterlettuce. Such specialists are absent

from the North American waterlettuce fauna (Dray et al. 1988), indicating that this plant and the herbivores attacking it have been associated for a relatively short, in geologic terms, time (Strong, Lawton, and Southwood 1984). Unfortunately, South America's fossil records remain largely unexplored and add little to discussions concerning the geographic origin of *P. stratiotes*.

13. European fossil records (Dorofeev 1955, 1958, 1963; Friis 1985; Mai and Walther 1983) contain the extinct *P. siberica*, seeds of which are present in strata from the Miocene Epoch (12 to 25 million years ago). These are the youngest fossil *Pistia* reported thus far, although some authors (Stoddard 1989) question whether these fossils represent a distinct species from *P. stratiotes*. The cooler, temperate climate prevalent in Europe during historic times has prevented the establishment of permanent waterlettuce populations on that continent (Pieterse, DeLange, and Verhagen 1981).

14. The antiquity of African populations is attested to in the writings of Pliney the Elder (A.D. 77) who reports its use as a medicinal agent in Egypt (Stuckey and Les 1984). Medicinal use of waterlettuce during ancient times was apparently widespread in Africa and Asia (Perry 1978, Pickering 1879, Quisumbing 1951) and argues strongly against introduction into the Old World from the New World during historic times. In fact, Holm et al. (1977) postulated an African origin for waterlettuce based on evidence that reproduction of African plants is predominately sexual.

15. A definitive determination of the geographical region in which *P. stratiotes* originated is probably not yet possible, given the current sparsity of data relating to this question. Nevertheless, the information above suggests that extant waterlettuce populations in Florida are not native, but instead originated from transplanted African or South American stock, or both.

Biology

16. In Florida, vegetative offset (daughter) production is the chief method by which waterlettuce mats expand within a site (DeWald and Lounibos 1990). However, Dray and Center (1989) found that sexual reproduction is also common. In fact, they reported that ramets can constitute a much smaller proportion of the total waterlettuce population than propagules in the seed bank (Dray and Center 1989).

17. Pieterse, DeLange, and Verhagen (1981) reported that *Pistia* seeds germinate at temperatures from 20 to 30°C and pH values from 5 to 8 whether submersed or not. Seeds remain viable for up to 7 months and can withstand

freezing and drought (Pieterse, DeLange, and Verhagen 1981). Dray and Center (1989) reported better than 80 percent germination of mature, field-collected seeds. These data suggest that seed production is the primary means through which waterlettuce populations reestablish in Florida water bodies after natural (Bua-ngam and Mercado 1975; Pieterse, DeLange, and Verhagen 1981) or anthropogenic destruction of mats.

18. *Pistia stratiotes* is a cold-sensitive plant, with populations declining during winter months and increasing again during spring and summer (DeWald and Lounibos 1990, Odum 1957). Odum (1957) reported a maximum standing crop at Silver Springs, FL, of 463 g/m^2, which compares well with the 430 g/m^2 reported by DeWald and Lounibos (1990) for southeastern Florida. Net productivities ranged from -8.4 to 15.3 $g/m^2/day$ at Silver Springs (Odum 1957). Experimental waterlettuce populations in southern Florida never experienced a net loss and achieved a maximum productivity of nearly 30 $g/m^2/day$ (Tucker and DeBusk 1981).

19. Waterlettuce grows by producing new leaves in the center of the rosette, which forces mature leaves toward the perimeter of the plant. Leaf turnover rates have not been reported, but DeWald and Lounibos (1990) found that leaves require about 2 weeks to reach maximum length and decline towards the water surface at a rate of 2.9 deg per day. Root production is apparently not proportional to leaf production because the root:shoot ratio varies seasonally and among sites (DeWald and Lounibos 1990).

20. Dray et al. (1988) investigated the fauna associated with waterlettuce in Florida and reported that 13 of the 109 species of invertebrates found on this plant are herbivores. The most damaging are the polyphagous larvae of the moths *Samea multiplicalis* Guenee and *Synclita obliteralis* Walker (Dray et al. 1988; Habeck, Haag, and Buckingham 1986). Species that may be occasionally abundant, but whose impact is unclear, are *Draeculacephala inscripta* Van Duzee (a leafhopper), *Rhopalosiphum nymphaeae* L. (an aphid), and *Pseudococcus* sp. (a mealybug). Larvae of the moth *Petrophila drumalis* Dyar ingest waterlettuce roots, but the impact to the plant seems minimal (Dray, Center, and Habeck 1989). Dray* and Grodowitz** have observed adults of the duckweed weevil *Tanysphyrus* sp. feeding on waterlettuce, but whether the

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* Personal observation. July 1991, F. A. Dray, Jr., Senior Biologist, Fort Lauderdale Research and Education Center, University of Florida.

** Personal communication. Nov 1991, Dr. Michael J. Grodowitz, Entomologist, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180.

immature stages feed on this host is unclear. Despite the fact that both *S. multiplicalis* and *S. obliteralis* can severely damage waterlettuce mats, the resultant temporarily induced stress has been insufficient to permanently suppress *P. stratiotes*.

Neohydronomus affinis

Description

21. Adult *Neohydronomus affinis* are small (1.7 to 2.3 mm), brown to bluish-gray weevils (DeLoach, DeLoach, and Cordo 1976) (Figure 2). DeLoach, DeLoach, and Cordo (1976) reported they were readily separated from other, similar waterlettuce weevils by the shape of the rostrum which, when viewed laterally, is nearly straight with a strong ventral constriction near the base. Females are generally larger than males (2.1 vs. 1.8 mm long). Eggs are cream-colored and subspherical, measuring 0.35 x 0.400 mm (DeLoach, DeLoach, and Cordo 1976). The larvae are small (2.4 to 3.0 mm as 3rd instars), yellow, and easily identified by the pronounced brown (clear in young 1st instars) anal shield on the dorsum (Thompson and Habeck 1988).

Biology

22. DeLoach, DeLoach, and Cordo (1976) reported that *N. affinis* populations (mistakenly identified as *N. pulchellus*, see O'Brien and Wibmer (1989)) produce three generations per year in Argentina. Thompson and Habeck (1988, 1989), however, suggested that this weevil could produce as many as eight generations per year in Florida. Females produce 1 egg/day (DeLoach, DeLoach, and Cordo 1976) that they deposit into a hole chewed into the distal third of a leaf (Thompson and Habeck 1988, 1989). These oviposition sites are then plugged with a dark secretion (DeLoach, DeLoach, and Cordo 1976), perhaps to protect the egg from desiccation and predation. Larvae emerge in 2 to 4 days (DeLoach, DeLoach, and Cordo 1976; Thompson and Habeck 1988, 1989) and immediately begin mining between the leaf epidermises. This activity produces characteristic brown tunnels (DeLoach, DeLoach, and Cordo 1976) that frequently traverse the leaf in a serpentine pattern* until coming in contact with a leaf rib. The larvae then follow the leaf rib to parenchymous tissue where they complete their development (Thompson and Habeck 1988).

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* Personal observation. F. A. Dray, Jr., University of Florida.

23. Larval development includes three instars and is completed in 11 (DeLoach et al. 1976) to 20 (Thompson and Habect 1988, 1989) days depending upon temperature. Larvae transform into naked pupae within small pockets excavated from the spongy parenchymous tissue of mature leaves. Complete development from oviposition to adult emergence requires 4 to 6 weeks (DeLoach, DeLoach, and Cordo 1976).

24. Adults feed either by scraping the leaf surface, which produces round holes (Thompson and Habeck 1988) about 1.4 mm in diameter (DeLoach, DeLoach, and Cordo 1976), or by burrowing inside the leaf. DeLoach, DeLoach, and Cordo (1976) reported that *N. affinis* populations of eight weevils per plant (the maximum density they observed at field sites) produce an average of 1.6 feeding scars/cm^2. These authors also reported that feeding is affected by temperature. *Neohydronomus affinis* feed most intensely at 30°C, producing 9 feeding scars/weevil/day (DeLoach, DeLoach, and Cordo 1976). They prefer to feed on young leaves (Thompson and Habeck 1988).

Purpose and Objectives

25. This research represents one portion of a multiphased project. The ultimate goal of this project is to effect a reduction in the nuisance level of waterlettuce in Florida. The strategy for accomplishing this goal was to employ the inoculative approach to biological control using bioagents foreign to the United States. The objectives of the first phase of this project were to: (a) ensure that the species being considered for use as biocontrol agents were not already present in Florida, (b) provide baseline data on the distribution of *P. stratiotes* in Florida, and (c) describe the nature and structure of the insect community associated with waterlettuce. Dray et al. (1988) describe results from this phase of the project, the most important of which was that *N. affinis*, the first bioagent proposed for release, was not already present in Florida.

26. The objective of the second phase was to test *N. affinis* on species of plants not tested in South America or Australia to ensure that this insect does not damage beneficial plants. A supplementary task was to ensure that founder colonies used to produce weevils for field releases were disease and parasite free. Thompson and Habeck (1988, 1989) conducted this work and found that *N. affinis* is essentially monophagous and is unable to complete development on hosts other than waterlettuce.

27. The primary objective of the third and fourth phases of the project was to establish field colonies of this weevil. An integral task within this objective was to acquire information about the biology of *N. affinis* that might be critical to its ultimate establishment. A secondary objective was to survey waterlettuce infestations near release sites to gauge the dispersive ability of the weevil. Results are documented in this report.

28. The objective of the fifth phase was to estimate the impact of the weevils on waterlettuce populations at selected field sites and to elucidate the mechanism through which this impact is achieved. Many times biocontrol agents have subtle impacts that are manifested only over long time periods. These can be observed only when host-plant populations are subject to long-term studies composed of periodic, detailed evaluations. Investigations were conducted at three release sites; the data from these are discussed in Part II.

PART II: METHODS

Colony Development

29. Fifty *Neohydronomus affinis* adults were shipped to the USDA-Agricultural Research Service Aquatic Weed Research Laboratory in Fort Lauderdale, FL, from quarantine facilities in Gainesville, FL, on 11 February 1987. Weevils from these shipments were placed in two 6-ℓ beakers containing several waterlettuce plants. Each beaker was inoculated with 25 weevils, then covered with insect netting. The weevils remained in the beakers for 2 days during which they presumedly mated and oviposited. The adults were then removed and transferred to fresh plants. A second shipment of 49 weevils received on 26 February 1987 was handled in a similar manner.

30. Rearing the weevils with this method was both cumbersome and inefficient: cumbersome because the beakers occupied a great deal of space, and manipulating the large water-filled containers was difficult; inefficient because inspecting every leaf on all plants in the beaker for eggs, leaves, and adults was time-consuming. Rather than inoculating whole plants, individual leaves in petri dishes were inoculated. Adults were allowed to oviposit for 2 days and then transferred onto fresh leaves.

31. Inoculated plants from the beakers and leaves from the petri dishes were placed into a large (1.2 m^2), outdoor, concrete aquarium containing additional waterlettuce. Infested plants were carefully placed among the non-infested plants; infested leaves were placed near the centers of uninfested rosettes. As the weevil population increased, infested plants from this aquarium were used to inoculate additional aquaria. Weevil populations were eventually developed in eight aquaria which produced the weevils that were used to establish field colonies.

Release and Establishment

32. Weevils for initial field releases were hand-collected from infested waterlettuce and transferred to fresh plants in 6-ℓ beakers. These adults remained on the plants in the beakers for a minimum of 24 hr. The inoculated plants were then placed into the existing waterlettuce mat at field sites. Marker buoys were attached to nearby plants as an aid in identifying the specific release point during subsequent visits to the site.

33. Waterlettuce at the field sites was examined periodically for the presence of adults, larvae, larval galleries, and adult-feeding scars. Populations were considered to be established only if, after the final release, adults and larvae were recovered during six consecutive months.

Neohydronomus affinis Efficacy

Study sites

34. Three sites in South Florida were selected to study the performance of *Neohydronomus affinis*: a borrow pit on Torry Island in Lake Okeechobee, a marsh on Kreamer Island in Lake Okeechobee, and a canal in Port St. Lucie. Each site was divided into two sections: an experimental area where weevils were released and a control area devoid of weevils. Plant populations in the two sections were compared to evaluate the effects of *N. affinis* on plant population dynamics. Ten samples were collected per month: five in the release (experimental) section and five in the control. Each sample consisted of one insect and three plant collections.

Collection procedures

35. Insects. Leafhoppers were collected by throwing an insect-net-covered, pyramid-shaped, 0.25-m^2 frame onto the plant mat ahead of the boat (or away from shore), then vigorously shaking the plants. Leafhoppers and adult moths that flew onto the net were collected via aspiration and then placed in a small ventilated vial. The vials were placed in an insect-killing jar for about 30 min, then removed and stored for transport to the laboratory.

36. Plant populations. Next, a 1-m^2 frame subdivided into 0.25-m^2 sections was tossed randomly onto the mat. Plant height within the frame was measured, and percent coverage both inside the frame and at the sampling station was estimated. All genets within one 0.25-m^2 section were removed, the number of ramets per genet was recorded, and the plants were stored in a large plastic bag. These were transported to the laboratory where they were processed to remove insects.

37. Offsets were included in the samples only if the apical bud of their attached primary plant was within the frame. If so, then all offsets, whether in the frame or not, were included. If the apical bud of the attached primary plant was not within the frame, then none of the offsets were included.

38. The remaining genets were removed from the 1-m^2 frame, and the number of offsets per genet was recorded. The rosette diameter was recorded for each of the first ten ramets removed from the frame. Each ramet's status as a primary, secondary, or tertiary plant was also recorded. These ramets were then placed individually into bags and transported to the laboratory for further analysis. Each ramet not included in the 10-plant subsample was discarded after the number of offsets attached to the plant was recorded.

39. Plant growth. Finally, a 0.25-m^2 frame subdivided by ten wires numbered 0 to 9 on each side was tossed randomly onto the mat. A two-digit number (e.g., 49) was selected from a random numbers table. The number corresponded to the intersection of two wires (e.g., 4 on one side and 9 on the other), and the genet whose apical bud was closest to this point was selected. The rosette diameter, apical bud width, and number of live (50 percent green tissue) leaves was recorded for each attached rosette. Then the apical bud and 2nd position leaf of each ramet were marked by attaching a colored tag (labeled as "bud" or "2nd") to each stem. A marker buoy (e.g., plastic milk jugs) was tied to the stems of all the ramets, and the genet was then carefully placed back into the mat to be retrieved the following month. Retrieved plants were placed in plastic bags for transport to the laboratory where they were processed.

Sample Processing

Insects

40. The ramets from each 0.25-m^2 section of the frame were removed from the bags and counted (a ramet was defined as an offset with a minimum stolon length of 2.5 cm). The roots and stem below the leaves were removed and discarded. The bottom of the leafy portion of the stem was split in an "X" shape, and the plants were placed split-end up in Berlese funnels. The funnel lids were fitted with 100-w incandescent light bulbs and were elevated slightly above the funnel cylinders to allow escape of moisture. Collecting jars (filled with 70 percent isopropanol) were suspended below the funnels by a strip of fine-meshed insect netting. Plant material remained in the funnels for a minimum of 3 days, which was usually sufficient to dry it and force all insects into the collecting jars. After 3 days the plants were removed from the Berlese funnels, placed in paper bags, and dried to a constant weight, which was then recorded.

41. The insects from the Berlese funnels were sorted to species (i.e., mites, mealybugs, aphids, leafhoppers, moths, and *Neohydronomus*). These were counted and the latter three identified as either adult or immature (counts for adult and penultimate-instar leafhoppers were from the field-collected samples, not the Berlese funnels). Moth larvae and all *Neohydronomus* were stored in vials (one vial for each species); the remaining insects were discarded.

Plant populations

42. We recorded the number of live leaves, length and width of a "typical" mature (4th to 6th position) leaf, number of floral structures, number of fruits, and number of seeds for each ramet of the 10-ramet samples. Again, a leaf was considered live only if greater than 50 percent of its surface tissues were green. The floral structures and fruits, roots and rhizome, and leaves and stem from each ramet were placed in separate bags and dried to a constant weight, which was then recorded.

Plant growth

43. Roots, rhizomes, and leaves below the level of the bud tags on genets left in the field for a month were discarded, and the number of old leaves, the number of new leaves, and the number of new ramets were recorded. If the bud tag was missing, the 2nd tag was used and the two oldest leaves inside the tag were discarded as well. The portion of each ramet represented by new growth was bagged separately and dried to constant weight, which was then recorded.

PART III: RESULTS AND DISCUSSION

Colony Development

44. The *N. affinis* cultures at Fort Lauderdale yielded nearly 11,000 weevils from February 1987 through April 1989. Most were produced during February 1987 - March 1988 under the intensive culturing associated with efforts to establish field populations. Confirmation of establishments at several of the release sites permitted redirection of resources from culturing to efficacy studies.

45. The intensive efforts associated with culturing *N. affinis* afforded an opportunity to examine the biology of this weevil. Many of these observations confirmed the findings of DeLoach, DeLoach, and Cordo (1976) and Thompson and Habeck (1988, 1989). However, contrary to observations by DeLoach, DeLoach, and Cordo (1976), *N. affinis* adults and larvae often damaged the meristematic tissues concentrated in the crown of the plant. This was particularly apparent on younger plants, both independent ramets and offsets (Figure 3), and is likely an important factor in the demise of waterlettuce infestations.

46. DeLoach, DeLoach, and Cordo (1976) reported that weevil densities were highest during the summer in Argentina. Surprisingly, weevil abundances in the outdoor aquaria plummeted during the summers of 1987 and 1988. However, factors affecting new colonies developing in concrete aquaria can be substantially different from those affecting well-established populations in natural water bodies. The importance of these observations is, therefore, suspect, although such intriguing data certainly invite further investigation.

47. Because adults often burrow within leaves, the presence of larval galleries (Figure 4) was frequently found to be the only clear indication that a plant was infested. This was especially true during periods of low weevil population density when feeding scars were seldom readily visible. This knowledge became extremely important during efforts to confirm establishment and investigate dispersal.

Release and Establishment

48. Kreamer Island (Palm Beach Co.) in Lake Okeechobee was the first field release site for *N. affinis* in the United States. A waterlettuce mat

that occupies abandoned (and flooded) agricultural fields on this island was inoculated with 727 weevils on 29 April 1987 (Center and Dray 1990, Dray et al. 1990). Two additional sites in southeastern Florida (Torry Island and Port St. Lucie) were selected for inoculation, where laboratory-bred weevils were released during July 1987 (Appendix A; see also Dray et al. 1990).

49. Initial releases were small, partially because stock cultures produced limited numbers of weevils; however, researchers also wanted to determine the effectiveness of the release strategy and confirm establishment at a few sites prior to initiating large-scale releases. Eventually, as field colonies became established and weevil abundances increased, weevils from the first sites were removed to inoculate additional waterlettuce infestations.

50. Initial postrelease examinations at Kreamer Island, Torry Island, and Port St. Lucie failed to provide evidence of persistent weevil populations. Consequently, a series of monthly releases (Appendix A, see also Dray et al. 1990) was begun in September at these three sites as well as a fourth site at the Plantation Golf Club (Appendix A). These releases continued through January 1988 at Kreamer Island, February 1988 at the Plantation Golf Club, and March 1988 at Torry Island and Port St. Lucie (Appendix A, see also Dray et al. 1990).

51. The first evidence that a weevil population had become established came from the Port St. Lucie site where larval galleries and adult feeding scars were consistently found after September 1987 (Dray et al. 1990). This continued through winter. After April 1988, adults and larvae were consistently recovered during each monthly examination of the site (Dray et al. 1990). Beginning in May 1988, adults and larvae were regularly recovered from all three original sites (Table 1) as well as from the fourth site (Appendix A). Persistence of these populations through September 1988, 6 months after releases were terminated (March 1988), indicated that *N. affinis* was established in southeastern Florida (Dray et al. 1990).

52. Weevil abundances increased slowly until spring 1989 when the Kreamer Island population increased dramatically (Figure 5). By May 1989 an estimated 45 million weevils were present at the site (Table 1). The Torry Island population reached similar proportions a year later when the site harbored an estimated 42 million weevils (Table 1, Figure 5). Although the Port St. Lucie site was the first at which *N. affinis* population establishment was confirmed, weevils never became very abundant at this site (Table 1, Figure 5).

Weevil Dispersal

53. Several cooperating agencies assisted with dispersing *N. affinis* by removing weevils and infested plants from Kreamer Island and moving them to sites throughout Florida during spring 1989 (Center and Dray 1990). Additional sites were infested with weevils and plants removed from Torry Island during spring 1990. More than 87,000 *N. affinis* are estimated to have now been released at 88 sites on 34 water bodies in Florida (Figure 6, Appendix A). Further, recently initiated surveys have shown that the weevils are dispersing throughout Lake Okeechobee and to nearby water bodies.

Neohydronomus affinis Efficacy

54. Evaluating the performance of *N. affinis* as a biological control of waterlettuce requires a clear understanding of the phenology of *P. stratiotes* in southern Florida. Unfortunately, the biology of waterlettuce in Florida had not been investigated prior to the initiation of this project. This required that baseline data be established (Appendix B) against which to compare the performance of waterlettuce populations after being impacted by the weevils.

55. Waterlettuce exhibited clear seasonal growth patterns during the investigation. Ramet density (Figure 7) and offset production (Figure 8) were typically highest during winter and spring, and lowest during late summer. In contrast, ramet size (rosette diameter, Figure 9, and plant height above water surface, Figure 10), number of leaves/ramet (Figure 11), average leaf weight (Figure 12), new growth (Figure 13), and leaf area/ramet (Figure 14) were typically highest during late summer and lowest from winter through early spring. These findings are supported by DeWald and Lounibos (1990) who recently described the seasonal growth of waterlettuce. Their data show that biomass, leaf area, and ramet density increase during spring and early summer, remain constant during late summer and autumn, then decline during winter.

56. Floral production patterns differed between this investigation and the study by DeWald and Lounibos (1990). The latter reported that peak flowering occurred during December. However, this investigation revealed that the maximum number of inflorescences/ramet occurred during late summer or fall (Figure 15). The standing crop data also differed from that reported by DeWald and Lounibos (1990). They reported maximum standing crops of 430 g/m^2,

which compared favorably with Odum's (1957) report of 463 g/m^2. However, standing crops well in excess of these reports were recorded and a maximum standing crop was observed of nearly 2,000 g/m^2 (Figure 16).

57. The impact of *N. affinis* populations was evaluated by comparing seasonal performance of the waterlettuce populations at each site prior to and following the release of the weevils. Comparing release and control areas within each site was also planned. Unfortunately, weevils spread rapidly into control areas (Figure 5) preventing many of these analyses. However, plant population responses in control areas typically lagged behind responses in release areas by 2 to 3 months, and this allowed some comparisons to be made. In addition, the absence of a weevil-population increase at Port St. Lucie allowed the use of that site as a control for some analyses.

58. Seasonal patterns were similar at all sites for many of the parameters studied (Table 2, Figures 7-16). Thus, differences in population dynamics between years within a single site could be measured against the performance of the waterlettuce populations at the other sites. This reduced the risk that the weevils would be credited with changes in the dynamics of the affected waterlettuce populations that might properly be attributable to climatic differences between years.

59. Concurrent weevil population increases and waterlettuce population declines were observed at Kreamer Island in spring 1989 and at Torry Island in spring 1990. The most obvious change in the waterlettuce populations at these two sites was a precipitous drop in the proportion of the water surface area covered by *P. stratiotes* as weevil populations increased. Figure 17 shows the extent of waterlettuce coverage at the Kreamer Island study site at the time weevils were released in April 1987, and the same area in May 1989 when weevil abundance was at its maximum. This figure graphically illustrates the drastic reduction in waterlettuce coverage associated with an estimated population of 45 million weevils. Waterlettuce coverage at Torry Island followed a similar pattern (Figure 18). Waterlettuce covered at least 85 percent of the water surface at Torry Island during May in 1987, 1988, and 1989. By May 1990, 1 month after the weevil population peaked at 42 million, waterlettuce covered less than 5 percent of the site.

60. High *N. affinis* densities during spring apparently interfere with its host's ability to grow and to replace damaged and senescing tissue. The large weevil population at Kreamer Island during spring 1989 (Figure 5) severely stressed the waterlettuce plants. As a consequence, plants were

smaller than during spring 1988 (Table 2). Torry Island and Port St. Lucie plants in spring 1989, however, were unchanged in size from 1988 (Table 2, Figures 9 and 10).

61. The waterlettuce mat at Torry Island harbored a heavy herbivore load during spring 1990 (Figure 5), and plant size was greatly reduced relative to spring in 1988 and 1989 (Table 2, see also Figures 9 and 10). Mild reductions in ramet diameter and canopy height at Port St. Lucie in spring 1990 (Table 2) suggest that cold damage contributed to the observed waterlettuce decline at Torry Island. However, the severity of reductions at Torry Island in 1990 relative to Port St. Lucie in 1990 or Kreamer Island in 1989 (Table 2) clearly indicates that changes at Torry Island were caused by herbivory.

62. Waterlettuce ramets under severe stress by weevil herbivory were not only smaller, but also had fewer live leaves. Table 2 shows that plants at Kreamer Island in spring 1989 were composed of fewer live leaves than in spring 1988. In contrast, Torry Island plants supported a similar number of live leaves for each of these years as did Port St. Lucie plants (Table 2). In spring 1990, however. waterlettuce at Torry Island were composed of 30 percent fewer live leaves than during the previous 2 years (Table 2).

63. This reduction of live tissue is directly attributable to limited growth by severely stressed plants Waterlettuce ramets at Kreamer Island produced an average of only 1.3 g/ramet/month of new leaf tissue each month during spring 1989 as compared with 3.7 g/ramet/month during the previous spring. The decline was even more striking at Torry Island during spring 1990 when ramets averaged only 0.1 g/month, a tenfold reduction from the previous two springs (Table 2). The waterlettuce population at Port St. Lucie produced similar amounts of leaf tissue during each of these three springs, although growth was much lower than at Kreamer Island and Torry Island prior to influence by the weevil (Table 2).

64. During periods of high weevil density (Figure 5), *P. stratiotes* populations were composed of smaller plants producing less new tissue and having fewer leaves per ramet. This resulted in standing crop and coverage reductions at Kreamer Island in 1989 and Torry Island in 1990 (Table 2). In contrast, ramets had more leaves, were bigger, and produced more new tissue at Torry Island and Port St. Lucie (Table 2) during springs when weevil densities were low (Figure 5). As a result, standing crops were approximately the same during spring 1988 and spring 1989 at Torry Island and Port St. Lucie.

Further, despite reductions in number of live leaves per ramet and ramet size during spring (probably a response to the Christmas freeze of 1989) at Port St. Lucie between 1989 and 1990, standing crop increased substantially (Table 2). This increased standing crop reflects greatly increased ramet (320.8 vs. 150.8; $t = 13.08$, $p < 0.001$ and genet (46.5 vs. 20.1; $t = 9.48$, $p < 0.001$) densities at Port St. Lucie during February in 1990 as opposed to 1989. These densities, in turn, reflect substantially greater growth at Port St. Lucie during November (2.38 vs. 0.80 g/ramet; $t = 2.16$, $p = 0.0447$) and December (1.97 vs. 0.93 g/ramet; $t = 2.37$, $p = 0.0294$) in 1989 as compared with 1988.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

65. The waterlettuce weevil *Neohydronomus affinis* has previously been proven effective at reducing infestations of this plant to acceptable levels in Australia (Harley et al. 1984), South Africa (Cilliers 1987), and Zimbabwe (Chickwenhere and Forno 1991). Research shows that *N. affinis* was also quite effective at controlling waterlettuce at some, but not all, of the Florida study sites. Plants under stress from weevil herbivory (at Kreamer Island and Torry Island) were typically smaller, had fewer leaves, and grew less rapidly than healthy plants. As a result, waterlettuce populations harboring large weevil infestations exhibited reduced vigor, and standing crop and coverage declined until waterlettuce was virtually eliminated from these water bodies.

66. Although waterlettuce is clearly intolerant of periods of prolonged cold temperatures or hard freezes, the population declines at Kreamer Island and Torry Island cannot be attributed to climatic conditions. Instead, data demonstrate that the waterlettuce populations at Kreamer Island and Torry Island would still be extant, as is the population at Port St. Lucie, without the development of large weevil populations at these sites.

67. Unfortunately, data from Port St. Lucie suggest that this weevil may be more effective at some sites than others. Explanations for the apparent inability of the Port St. Lucie weevil population to build to densities harmful to the plant remain elusive. Perhaps local mosquito-control operations are harmful to the weevils. Perhaps there are important differences in waterlettuce leaf chemistry between this site and those where the weevil has been effective. Comparison of the profuse seed production at Port St. Lucie with the meager seed production at Kreamer and Torry Islands suggests the possibility that these sites are infested with two distinct genetic strains of waterlettuce. Whatever the explanation for the weevil's failure to control waterlettuce at Port St. Lucie, its success at Kreamer and Torry Islands is impressive.

68. Recent surveys have shown that small weevil populations are present at some water bodies inoculated with infested plants during spring 1989. Additionally, weevils are beginning to appear at waterlettuce infestations where they have not been released, an encouraging sign that they can spread without human intervention. Therefore, the thought that *Neohydronomus affinis* will become established throughout Florida and will prove to be invaluable in controlling the troublesome aquatic plant *Pistia stratiotes* is regarded with

optimism. Further effort to release *N. affinis* at other sites should be undertaken to minimize the time required for *N. affinis* populations to become established throughout Florida.

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Table 1

Estimated *Neohydronomus affinis* Abundances*
at Torry Island, Kreamer Island, and Port St. Lucie

Date	Torry Island	Kreamer Island	Port St. Lucie
Sep 87	0	0	0
Jan 88	0	0	0
May 88	68,705	1,629	6,576
Sep 88	331,854	67,505	1,956
Jan 89	7,512,851	1,344	0
May 89	44,764,373	6,622,295	83,664
Sep 89	--	13,442,464	10,440
Jan 90	--	7,650,735	1,440
Mar 90	--	41,838,938	16,800
May 90	--	236,147	14,400

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* Abundance = *N. affinis* density x site coverage x site size x proportion of site infested by weevils. Kreamer Island is approximately 125 acres, Torry Island 10 acres, and Port St. Lucie 3 acres in size.

Table 2

Comparison of Waterlettuce Population Parameters Measured During Spring (March - May)*

Parameter	Site	1988	1989	1990	F(p)
Ramet diameter, cm	Kreamer Island	22.0^{a}	15.2^{b}	--	18.96 (0.0001)
	Torry Island	19.9^{a}	19.0^{b}	8.7^{b}	43.19 (0.0001)
	Port St. Lucie	13.2^{a}	12.3^{a}	10.4^{b}	12.33 (0.0001)
Canopy height, cm	Kreamer Island	12.4^{a}	10.4^{b}	--	6.44 (0.0140)
	Torry Island	11.7^{a}	11.6^{a}	4.8^{b}	70.68 (0.0001)
	Port St. Lucie	6.6^{a}	6.4^{a}	5.0^{b}	8.94 (0.0003)
Live leaves/ramet	Kreamer Island	10.0^{a}	8.0^{b}	--	17.33 (0.0001)
	Torry Island	8.7^{a}	9.1^{a}	6.0^{b}	22.77 (0.0001)
	Port St. Lucie	9.1^{a}	8.9^{ab}	8.1^{b}	2.99 (0.0554)
Standing crop, g/m^2	Kreamer Island	621.2^{a}	475.2^{b}	--	5.06 (0.0283)
	Torry Island	628.3^{a}	697.5^{a}	151.7^{b}	39.34 (0.0001)
	Port St. Lucie	558.5^{b}	509.4^{b}	679.5^{a}	6.62 (0.0021)
Growth, g/ramet	Kreamer Island	3.7^{a}	1.3^{b}	--	9.51 (0.0031)
	Torry Island	2.0^{a}	1.9^{a}	0.1^{b}	22.17 (0.0001)
	Port St. Lucie	0.7^{a}	0.7^{a}	0.4^{a}	2.19 (0.1183)

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* Parameters were measured at Kreamer Island, Torry Island, and Port St. Lucie. Numbers followed by the same letter indicate no significant difference ($p = 0.05$) among years.

Figure 1. A *Pistia statiotes* genet

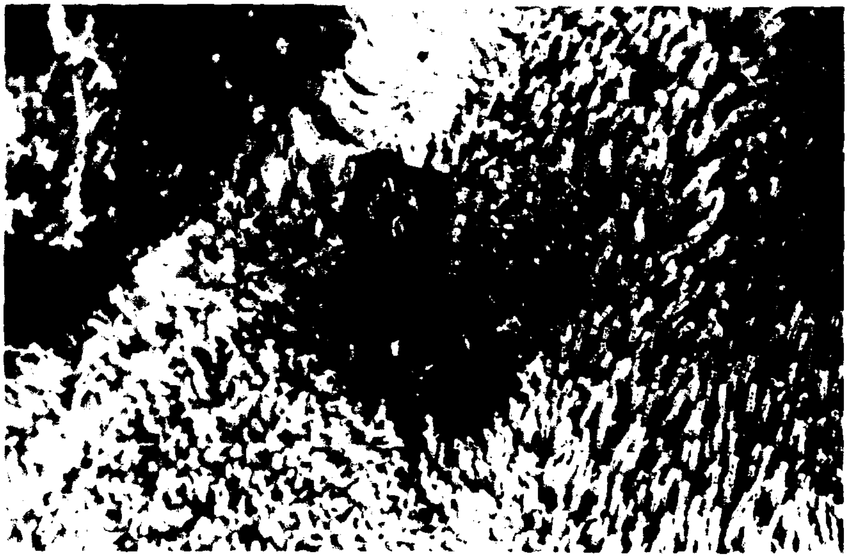

Figure 2. A *Neohydronomus affinis* adult

Figure 3. *Pistia stratiotes* rosette with meristem damaged by *Neohydronomus affinis* attack

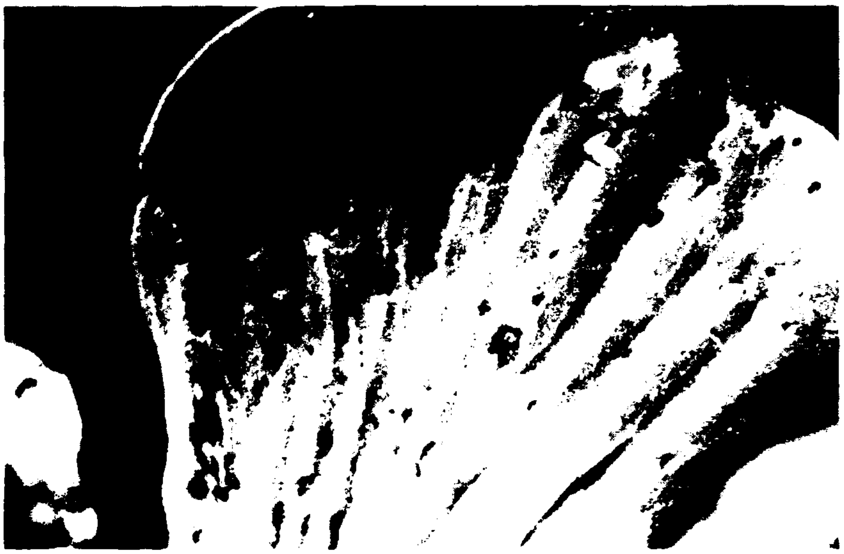

Figure 4. *Neohydronomus affinis* larval galleries and adult feeding scars on a waterlettuce leaf

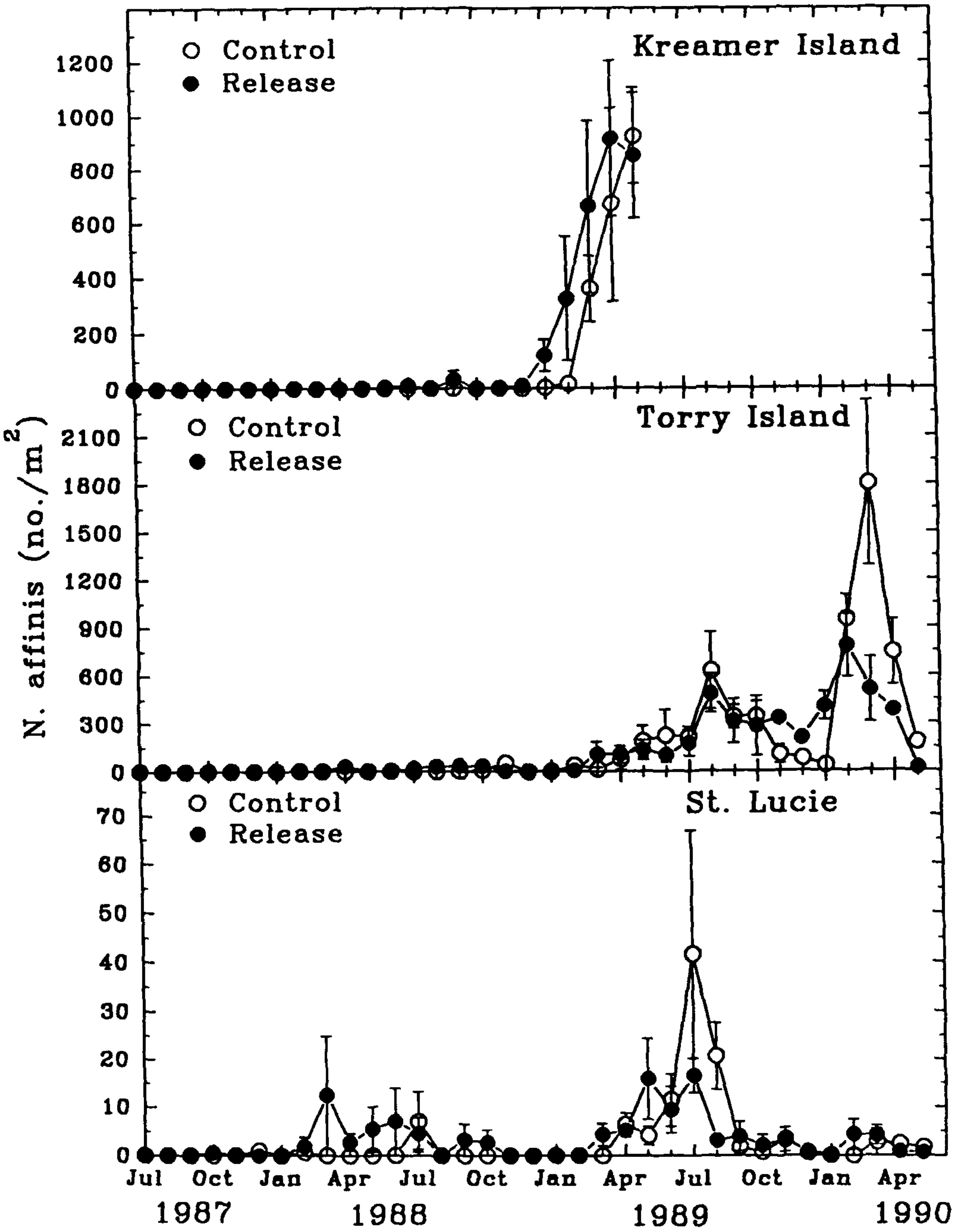

Figure 5. *Neohydronomus affinis* densities at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

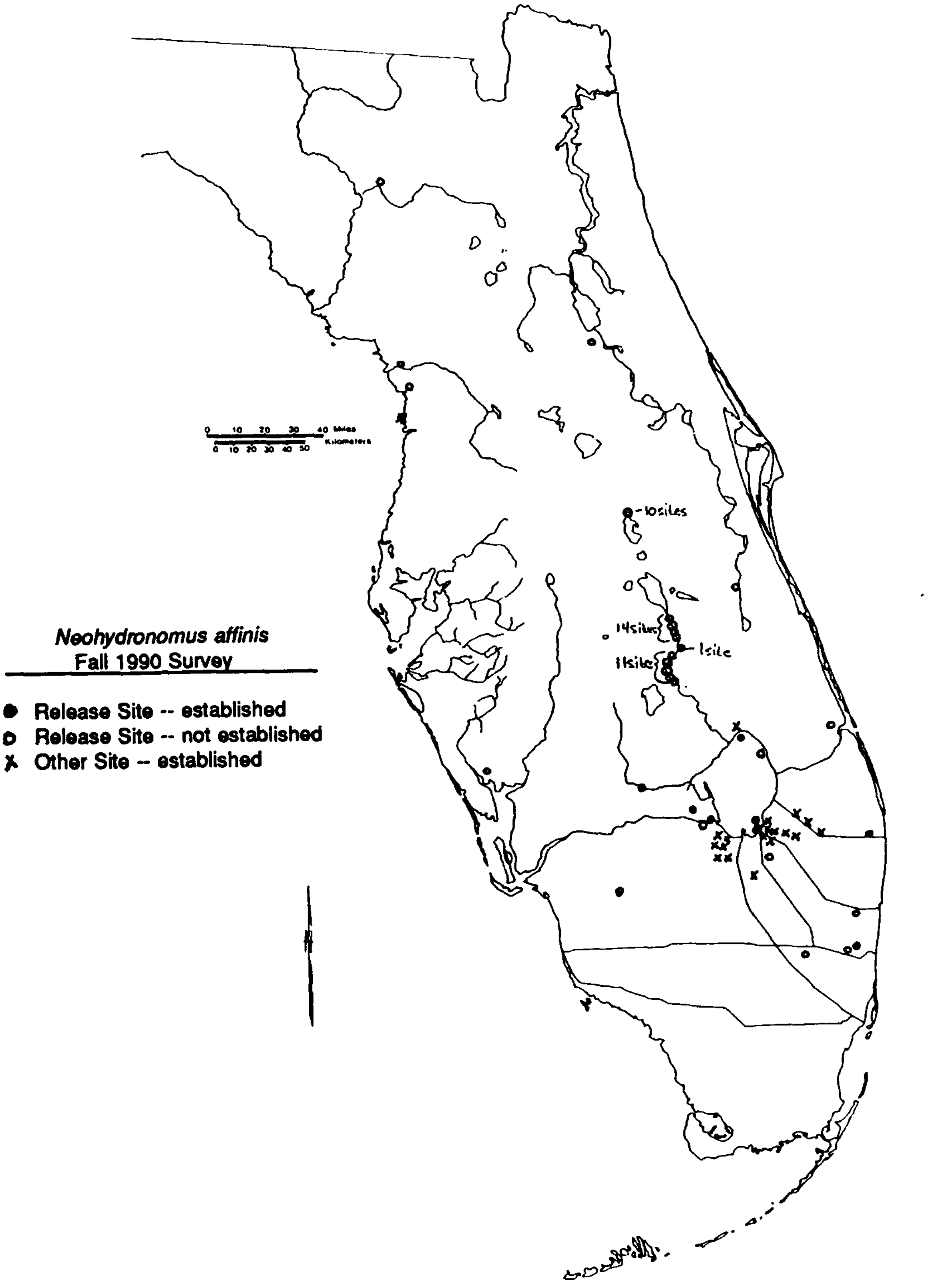

Figure 6. Water bodies where *Neohydronomus affinis* was released and where populations have become established

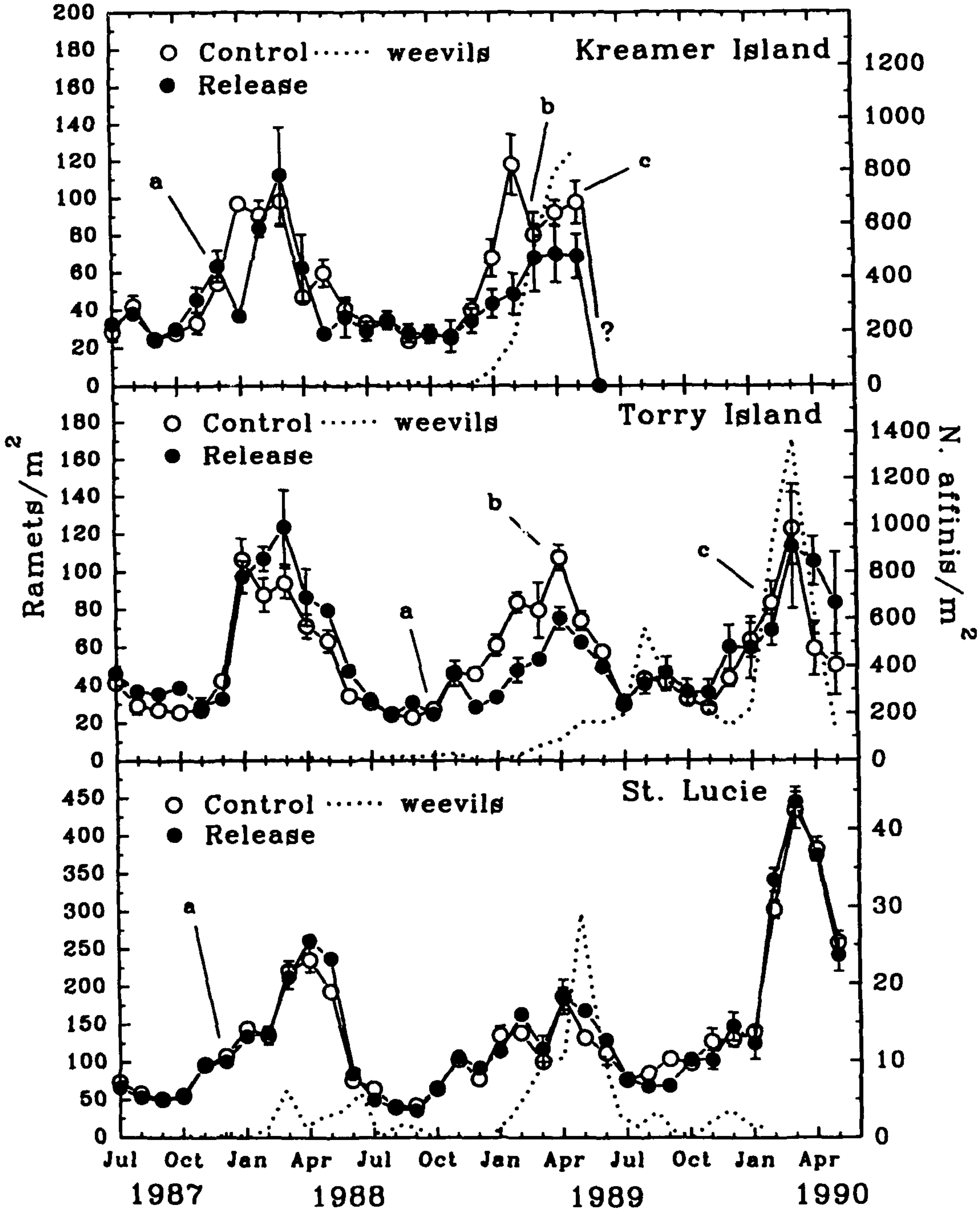

Figure 7. *Pistia stratiotes* ramet densities at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

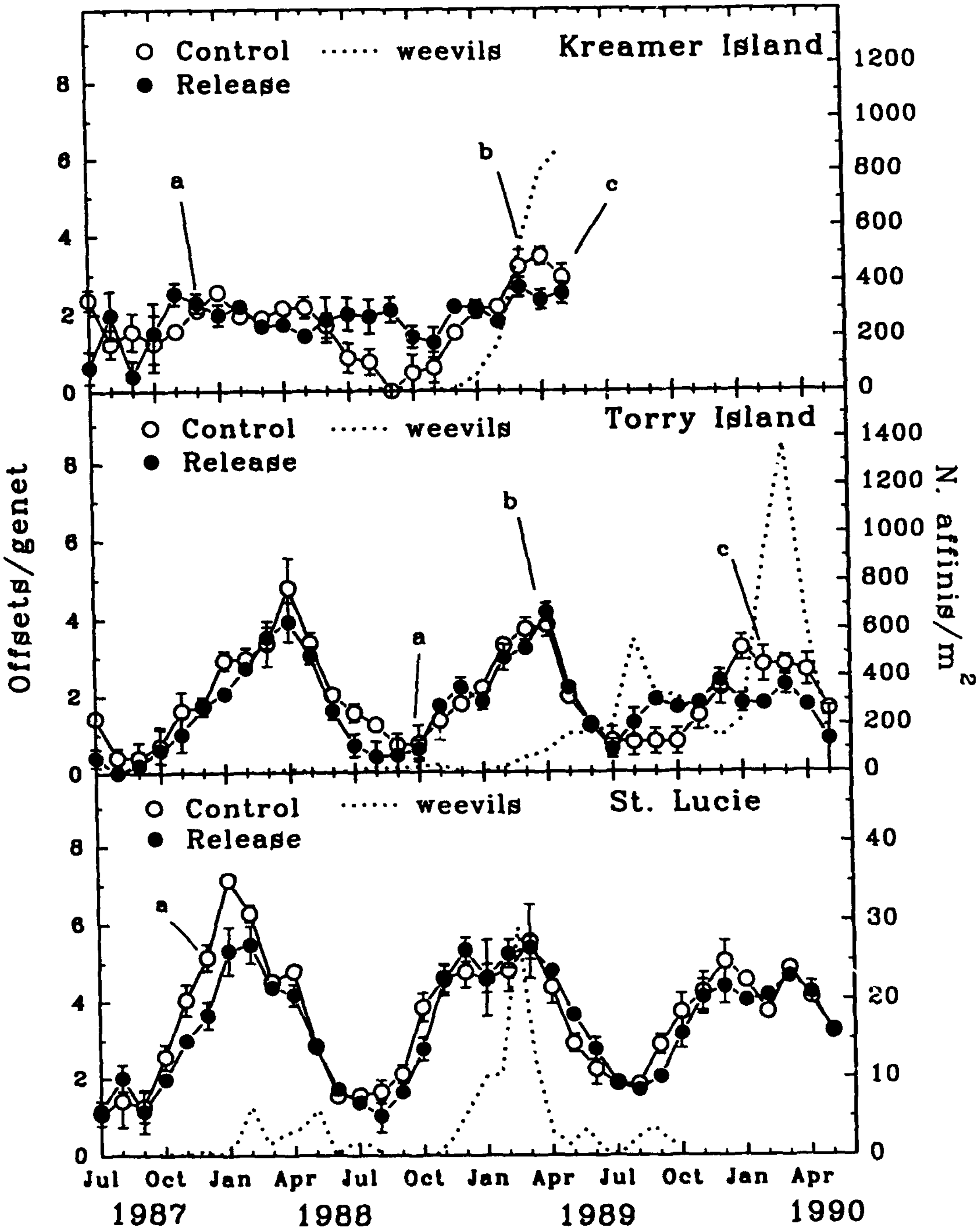

Figure 8. Number of *Pistia stratiotes* offsets per parent plant at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

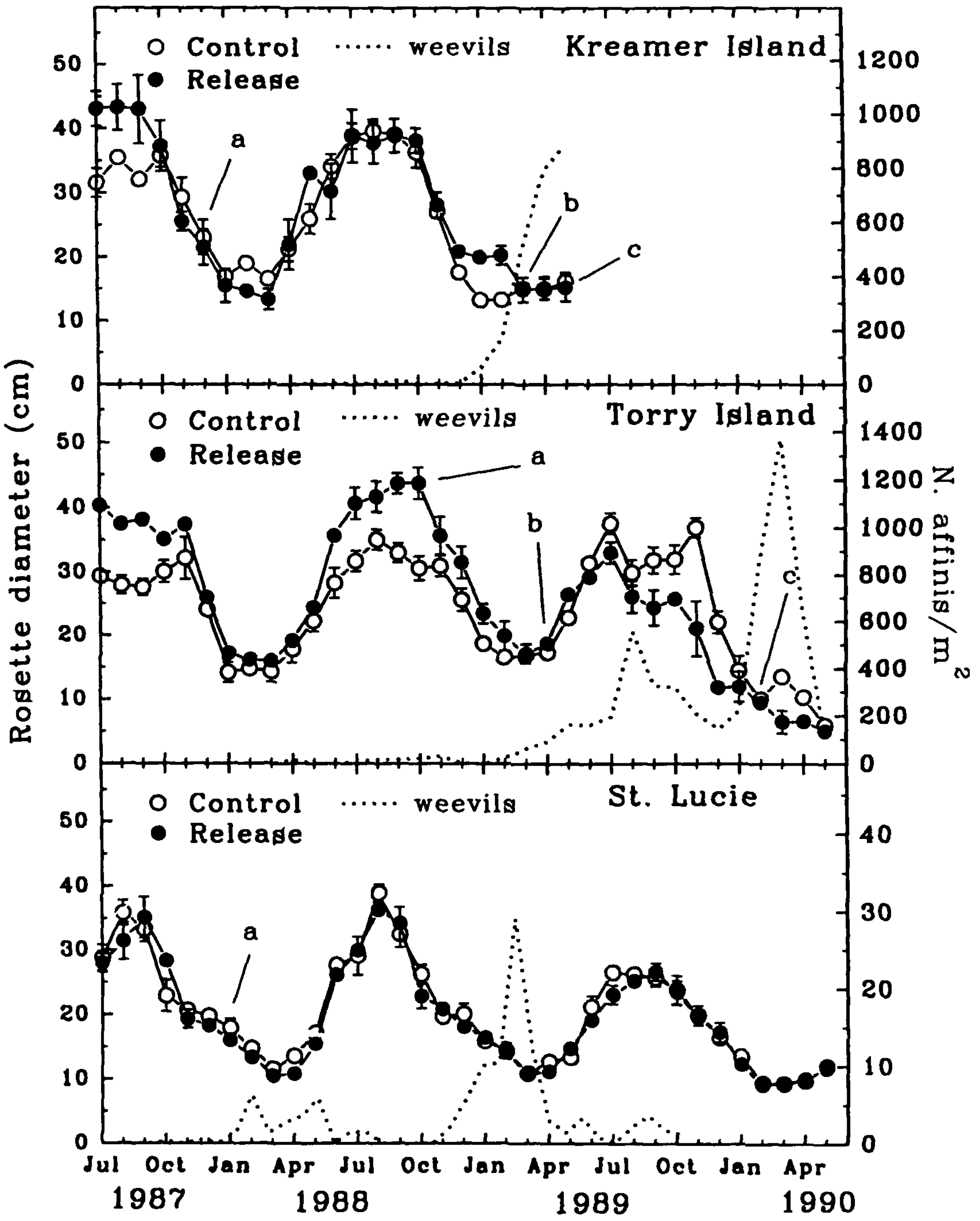

Figure 9. *Pistia stratiotes* rosette diameters at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

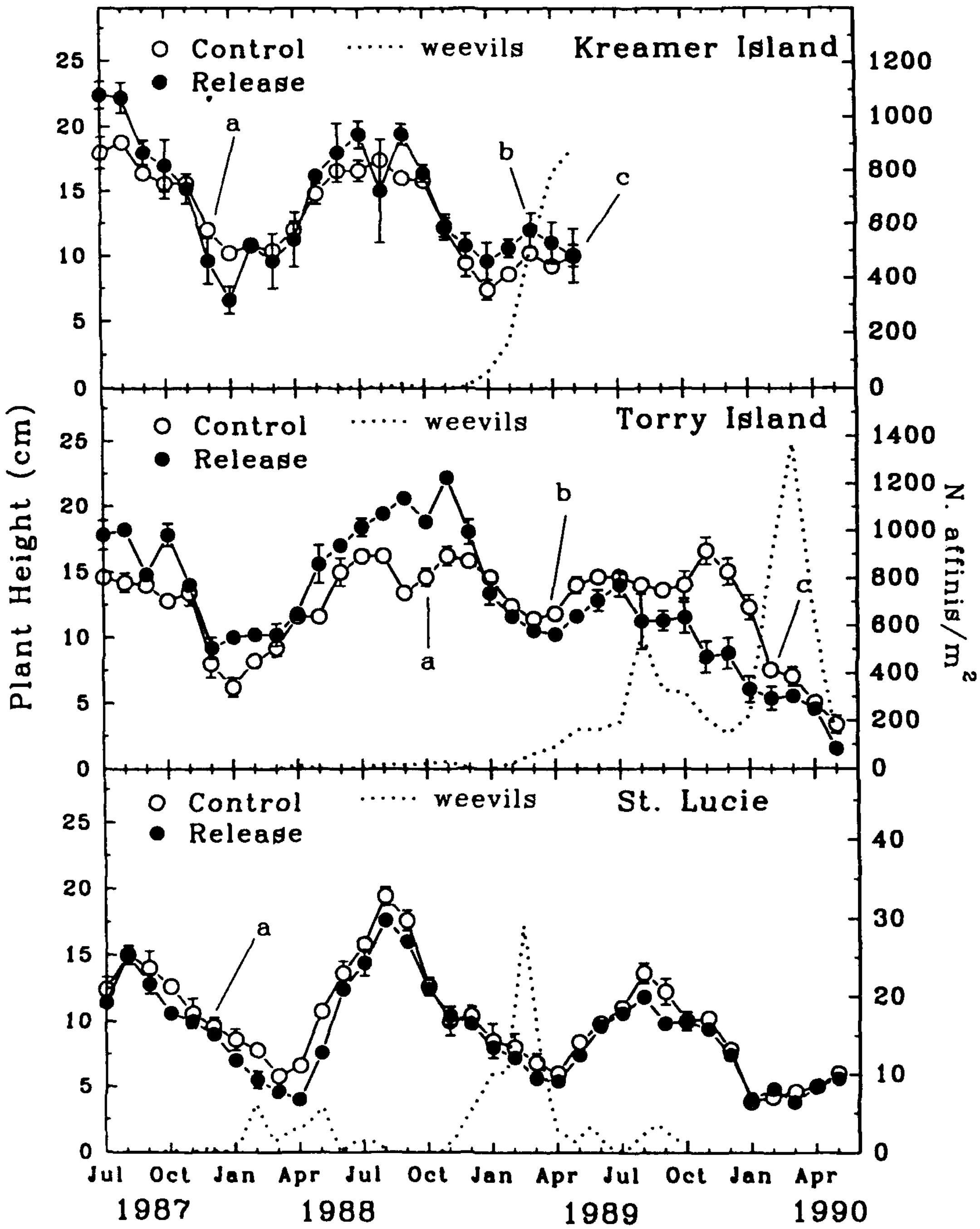

Figure 10. Height above the water surface of *Pistia stratiotes* leaves at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

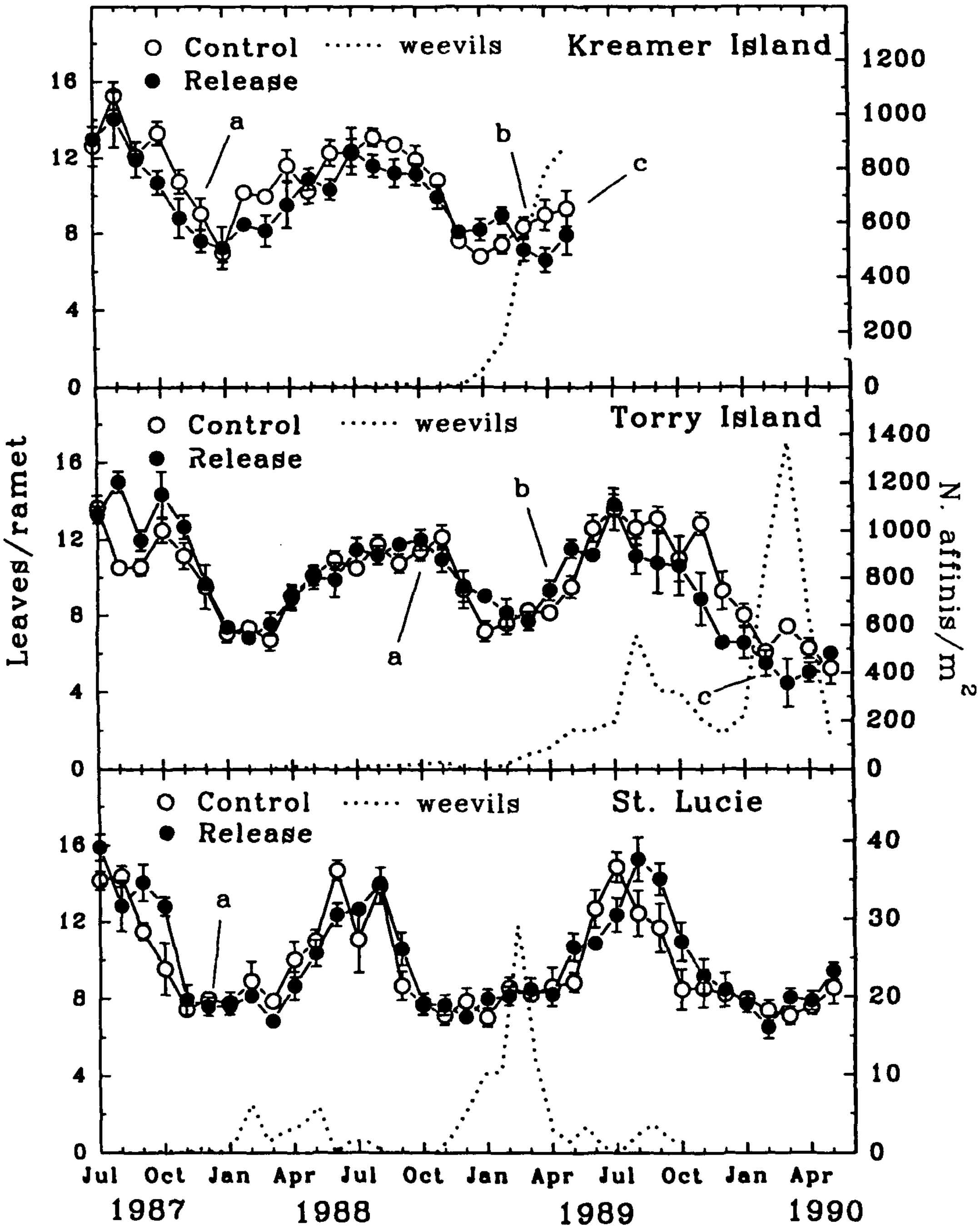

Figure 11. Number of *Pistia stratiotes* leaves/ramet at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

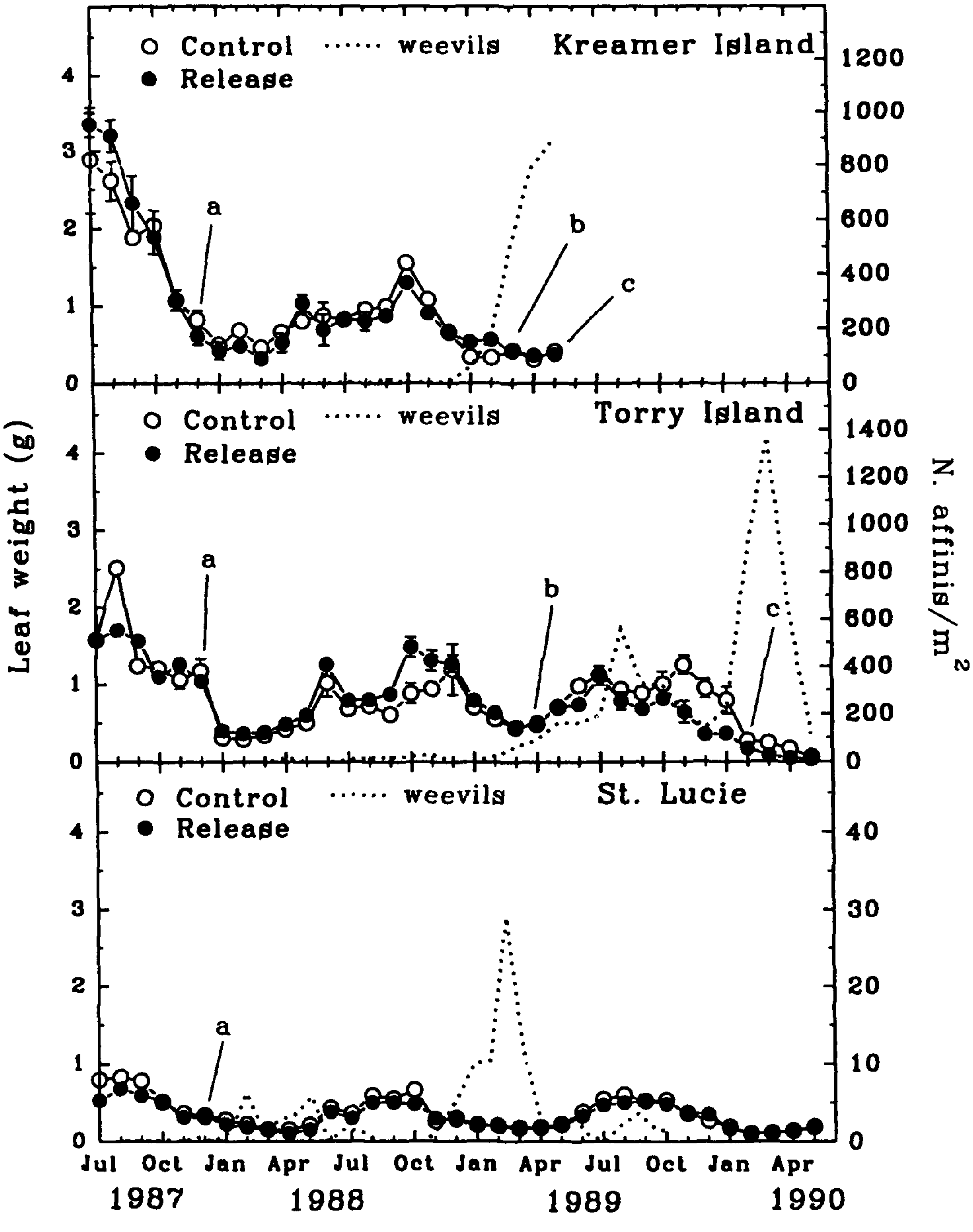

Figure 12. Average weights of *Pistia stratiotes* leaves at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

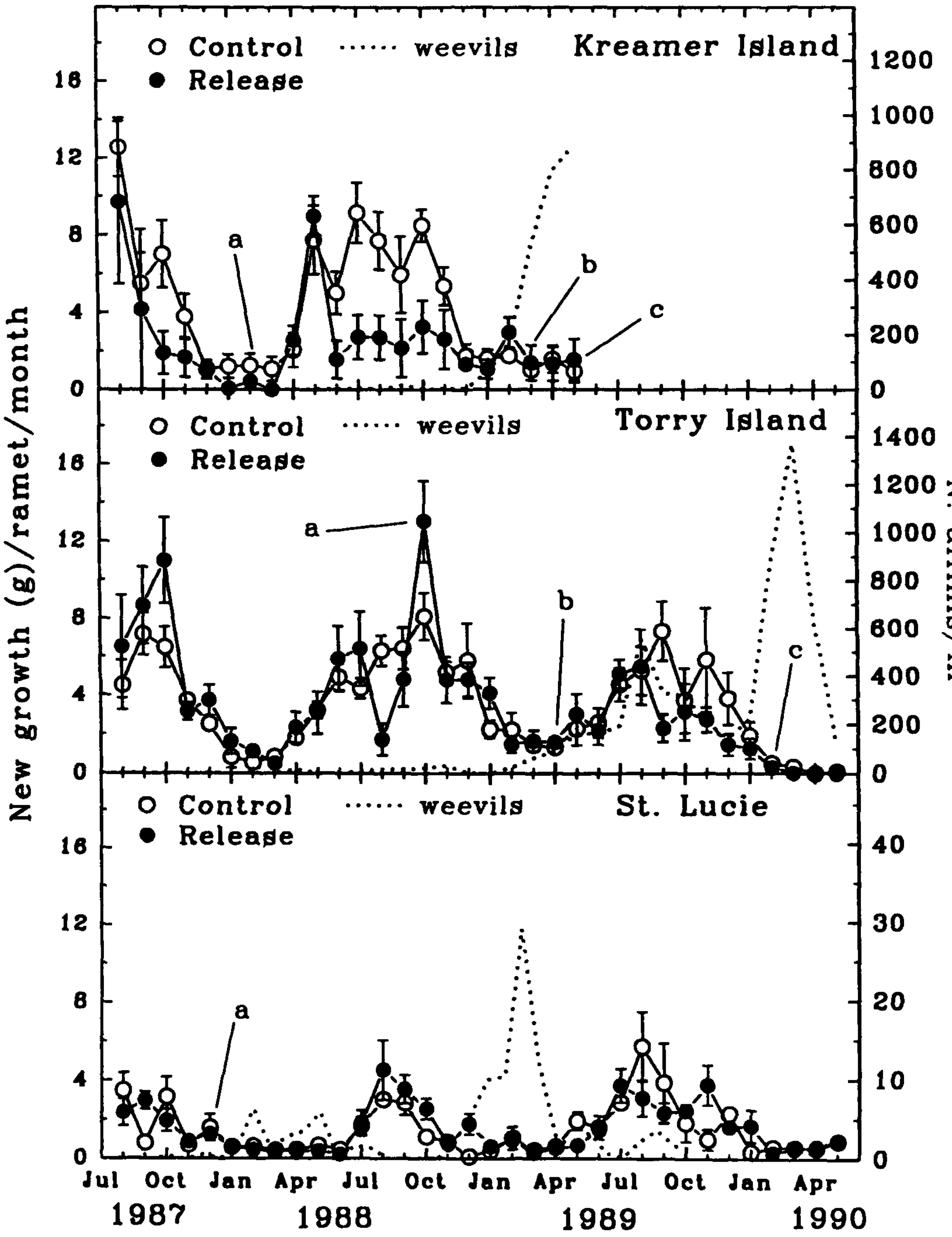

Figure 13. Monthly growth of *Pistia stratiotes* ramets at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

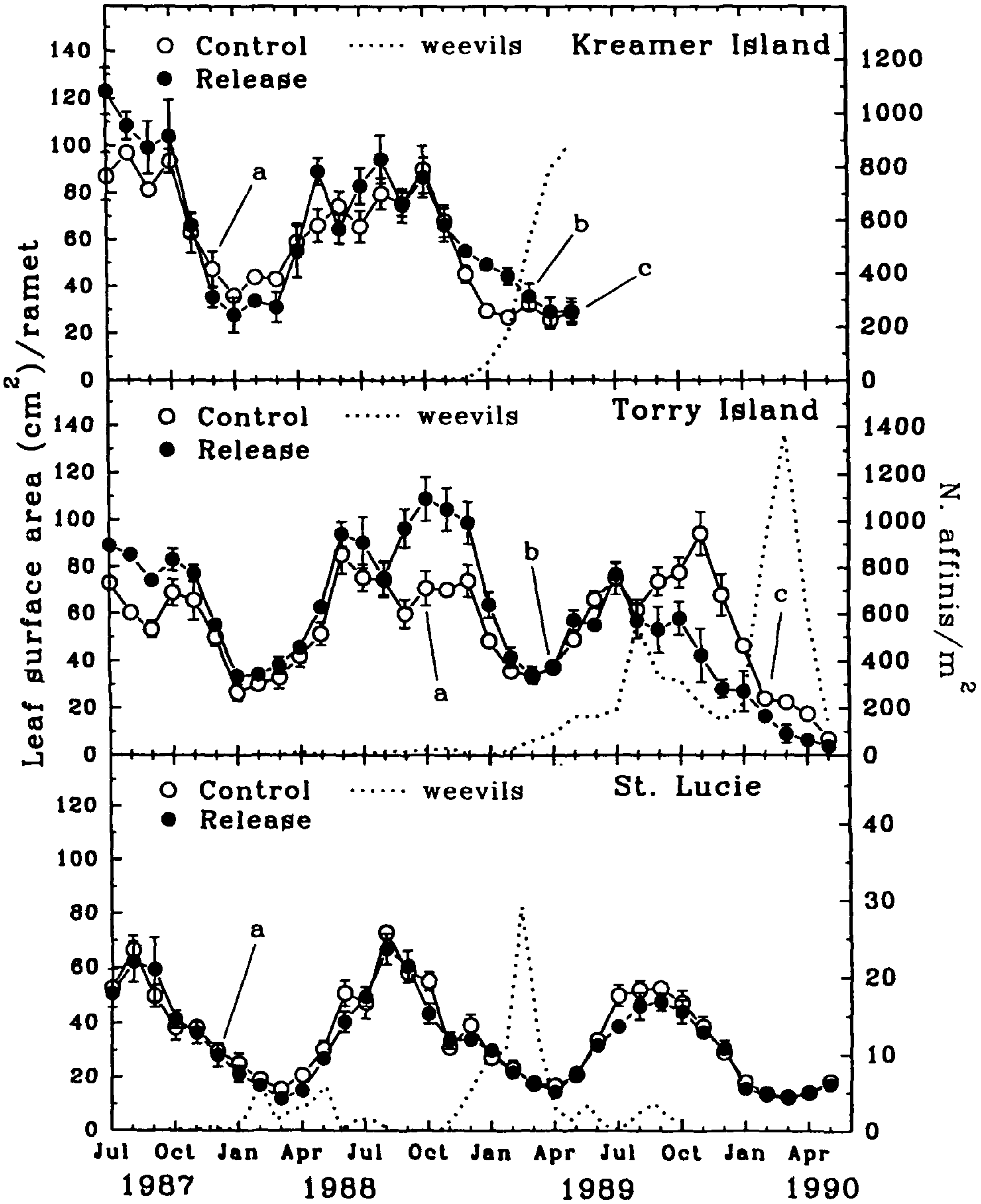

Figure 14. *Pistia stratiotes* leaf area per ramet at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

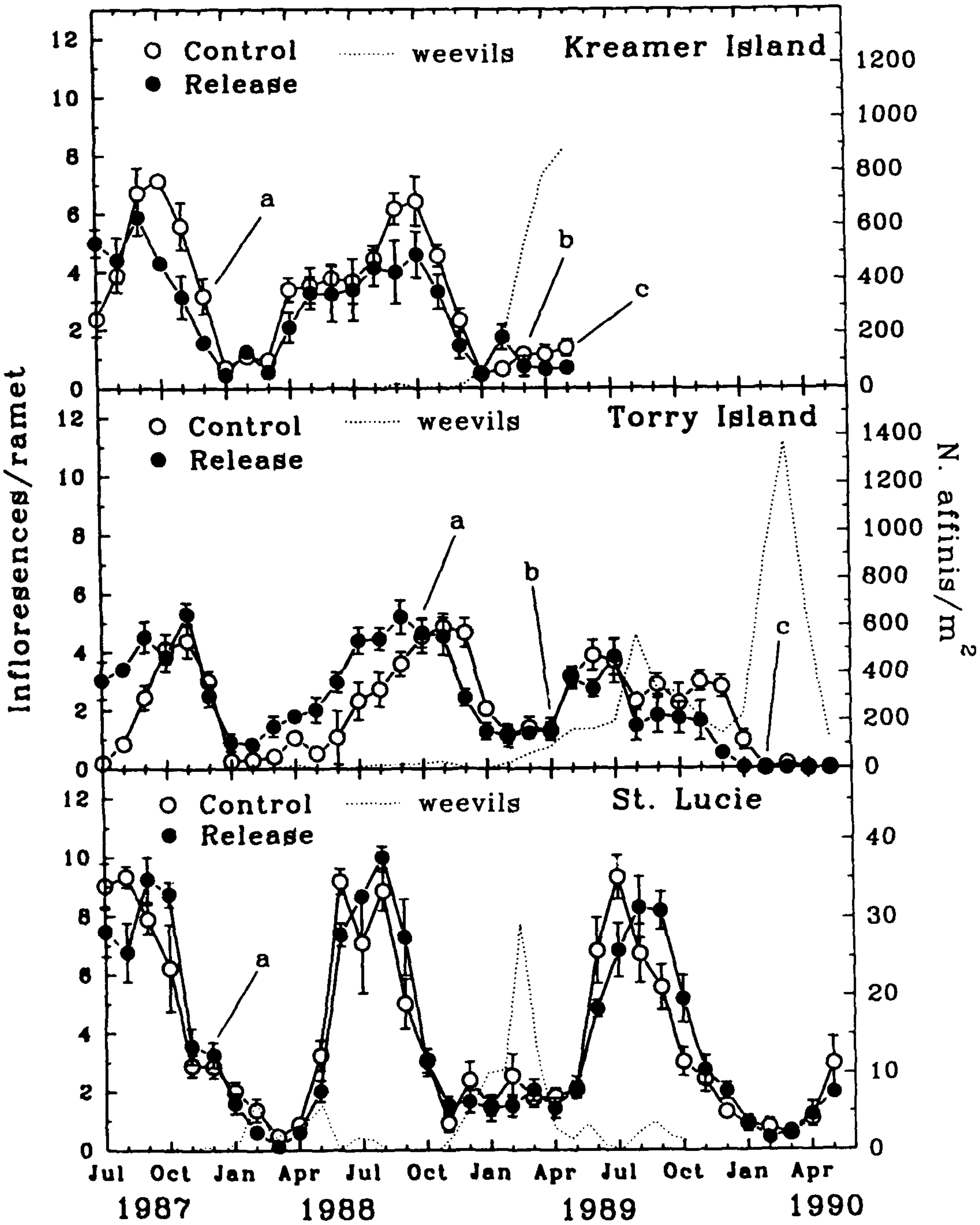

Figure 15. Number of *Pistia stratiotes* inflorescences per ramet at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

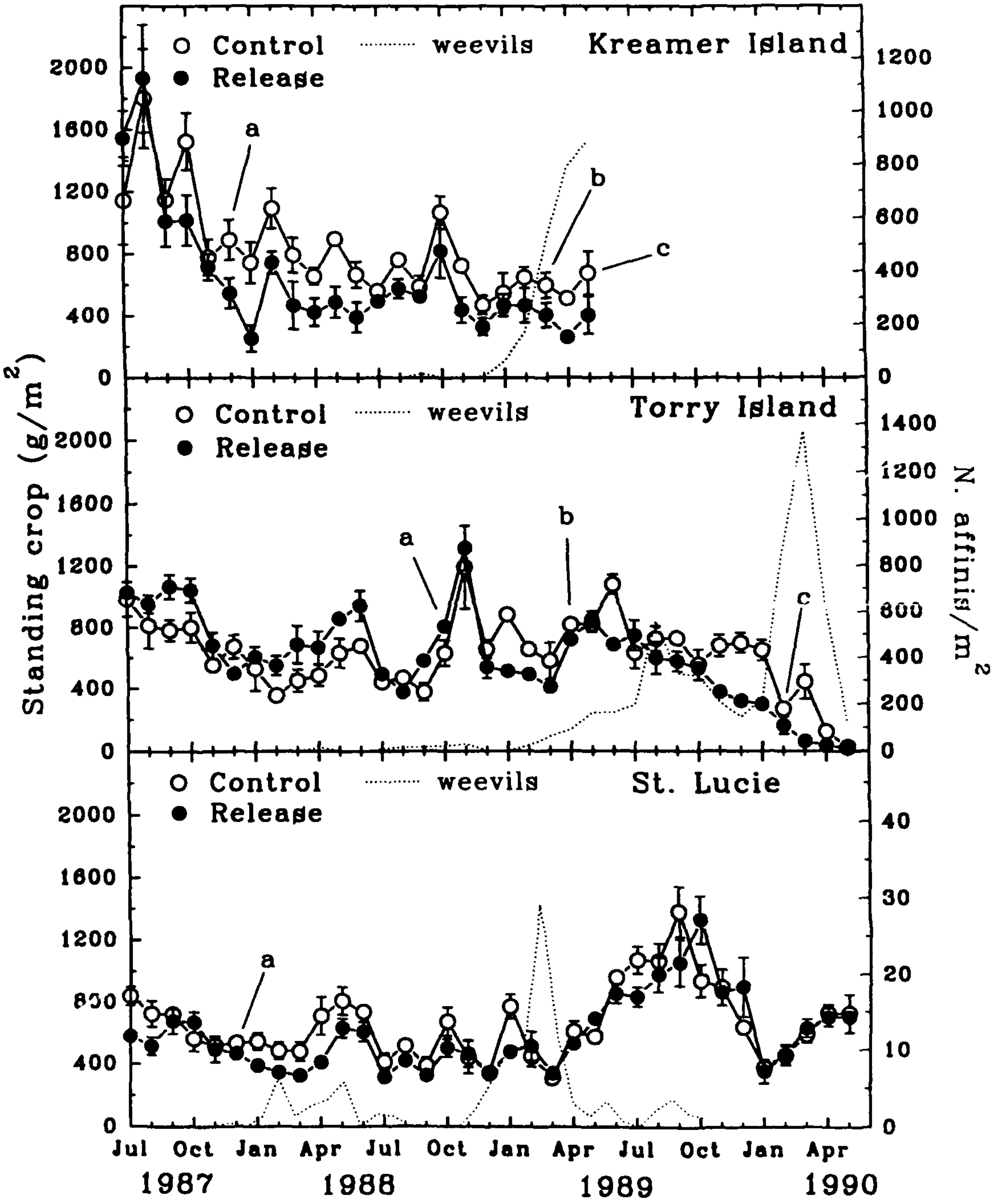

Figure 16. *Pistia stratiotes* standing crops at Kreamer Island, Torry Island, and Port St. Lucie, July 1987-May 1990

a. April 1987

b. May 1989

Figure 17. Waterlettuce infestation at Kreamer Island in Lake Okeechobee, FL, soon after the *Neohydronomus affinis* release in April 1987(a), and in May 1989(b) following the weevil population increases

a. July 1987

b. June 1990

Figure 18. Waterlettuce infestation at Torry Island in Lake Okeechobee, FL, soon after the *Neohydronomus affinis* release in July 1987(a), and in June 1990(b) following the weevil population increase

APPENDIX A: LIST OF RELEASE SITES

Table A1

Releases of the Waterlettuce Weevil (*Neohydronomus affinis*) in Florida During the Period April 1987 to April 1990

Site	Date	Material Released		
		Adults	Larvae	Plants
Lake Okeechobee	4/29/87	727	--	--
Kreamer Island	9/16/87	67	--	--
Palm Beach County	10/14/87	96	--	11
	10/27/87	144	--	--
	11/18/87	307	--	5
	12/16/87	357	--	--
	1/20/88	659	--	--
Lake Okeechobee	7/17/87	115	--	--
Torry Island	9/30/87	136	--	28
Palm Beach County	11/4/87	209	--	--
	12/2/87	499	--	--
	1/7/88	61	--	--
	2/3/88	87	--	--
	3/2/88	345	--	--
Port St. Lucie	7/17/87	115	--	--
St. Lucie Canal	8/11/87	112	--	--
St. Lucie County	9/9/87	88	--	--
	10/7/87	129	--	51
	12/9/87	105	--	--
	1/13/88	150	--	--
	3/9/88	345	--	--
	1/6/89	267	--	--
Plantation Golf	10/16/87	587	--	--
Club	10/27/87	154	--	--
Broward County	11/25/87	306	--	--
	1/11/88	527	--	--
	2/2/88	496	--	--
	5/1/88	126	1060	489
Conservation Area 3A Broward County	2/26/88	736	--	--
Bolles Canal East of US 27 Palm Beach County	7/2/88	500	--	--
M-Canal Palm Beach County	7/19/88	69	--	--
M-Canal, 1 mile W	5/16/89	202	312	229
Florida turnpike	4/26/90	--	--	--
Palm Beach County				

(Continued)

(Sheet 1 of 4)

Table A1 (Continued)

		Material Released		
Site	Date	Adults	Larvae	Plants
Ichetucknee Springs State Park Suwannee County	3/23/89 5/16/89	257 202	-- 312	-- 229
Fisheating Creek 26°55.63' N 81°18.85' W Glades County	4/28/89	126	--	--
Lake Hicpochee 26°47.45' N 81°7.80' W Glades County	4/8/89	202	312	229
Lake Rousseau 100 yd N of channel marker 139 Levy County	5/17/89	202	312	229
Kings Bay/Crystal River 400 yd S of Pete's Pier Citrus County	5/17/89	202	312	229
Alexander Spring Creek 100 yd S of SR 445 Lake County	5/19/89	404	624	458
Snover Waterway 27°04.35' N; 82°0.4.41' W Sarasota County	5/19/89	202	312	229
Moorehaven Canal 26°49.09' N; 81°06.37' W Glades County	5/19/89	202	312	229
Lake Trafford 26°24.85' N; 81°28.96' W Collier County	5/19/89	202	312	229
Canal at US 27 and SR 78 26°49.76' N; 81°11.18' W Glades County	5/19/89	202	312	229
West Palm Beach Near fairgrounds Palm Beach County	8/28/89 9/4/90 9/26/90	30 404 375	8 2028 205	68 296 315
St. Johns Marsh Canal 27°56.51' N; 80°45.85' W 27°56.76' N; 80°45.85' W Orange County	10/31/89	400 300	2144 1608	272 204

(Continued)

(Sheet 2 of 4)

Table A1 (Continued)

Site	Date	Material Released		
		Adults	Larvae	Plants
Lake Griffin	10/24/89	150	275	--
S-22, T-18s, R-25E		150	275	--
S-22, T-18S, R-25E				
Lake County				
Bug Springs	10/24/89	150	275	--
S-15, T-20S, R-24E				
Lake County				
Plant City	10/24/89	150	275	--
Hillsborough County				
Loxahatchee National Wildlife Refuge	5/23/89	217	672	83
0.5 mile from boat ramp on levee no. 39				
Palm Beach County				
Conservation Area 2A				
Near S-10A	5/23/89	651	2016	249
Near S-10C		217	672	83
Palm Beach County				
Hiatus Rd. canal	5/24/89	1085	3360	415
0.6 mile N of Broward Blvd. *in Plantation*				
Broward County				
Lake Tohopekaliga	5/26/89	2170	6720	830
Lakeshore N of Paradise Island				
Osceola County				
Lake Okeechobee	6/2/89	2170	6720	830
Eagle Bay Island				
Okeechobee County				
Lake Okeechobee	6/8/89	2170	6720	830
Shore between Chancy Bay and Henry Creek				
Martin County				
Kissimmee River	5/31/89	1302	4032	498
Pool "A"	6/2/89	217	672	83
Osceola County				
Kissimmee River	5/31/89	1736	5376	664
Pool "A"				
Polk County				
Kissimmee River	6/2/89	434	1344	166
Pool "B"				
Osceola County				

(Continued)

(Sheet 3 of 4)

Table A1 (Concluded)

Site	Date	Material Released Adults	Material Released Larvae	Material Released Plants
Kissimmee River Pool "B" Okeechobee County	6/2/89 6/6/89	217 651	672 2016	83 249
Kissimmee River Pool "B" Highlands County	6/2/89 6/6/89	217 868	672 2688	83 332
Private Canal 12535 US441 SE Okeechobee County	6/8/89	868	2688	332
Tenoroc State Reserve Polk County	8/16/90	274	?	--

(Sheet 4 of 4)

APPENDIX B: MONTHLY PLANT AND INSECT DATA

Table B1

Plant Population Data and Herbivore Counts for Pistia stratiotes Infestations Examined From February 1986 Through May 1990. Except Where Noted Data are Reported as Monthly Averages

											Leaves							Insects*				
											Produced/ramet											
											gross		net									
Site	Date	Cover %	Genets #/m²	Ramets #/m²	Moms %	Offsets/ramet	Hgt cm	Diam cm	Standing Crop g	Root:shoot Ratio	#	g	#	No./ramet	Area cm²	Wgt g	Inflorescences/ramet	Na #/m²	Sm #/m²	So #/m²	Di #/m²	Rn #/m²
Kreamer	Jul 87	90.5	24.6	30.5	7.1	1.5	20.2	37.3	1343.8	0.00	.	.	.	12.8	104.9	3.12	3.7	0.0	92.2	0.4	0.8	10.7
Island	Aug 87	99.0	30.0	40.0	11.8	1.6	20.5	39.5	1865.3	0.00	6.1	11.2	3.3	14.6	102.8	2.91	4.1	0.0	37.8	0.3	7.1	32.6
	Sep 87	99.0	20.4	24.4	9.5	1.0	17.2	37.5	1080.2	0.62	3.5	4.8	1.4	12.0	90.3	2.10	6.3	0.0	178.9	0.0	4.6	462.7
	Oct 87	99.5	24.9	28.8	6.5	1.4	16.3	36.5	1271.4	0.76	4.6	4.7	-1.0	12.0	98.8	1.97	5.7	0.0	305.9	0.0	10.7	720.6
	Nov 87	97.5	25.3	39.2	14.9	2.0	15.4	27.4	748.0	0.61	2.9	2.7	1.5	9.8	64.5	1.07	4.4	0.0	586.2	1.3	2.7	1275.7
	Dec 87	83.0	34.1	58.6	18.4	2.2	10.8	22.3	718.4	0.54	2.2	1.0	1.8	8.3	41.4	0.71	2.4	0.4	724.3	13.1	0.3	242.3
	Jan 88	82.0	38.2	66.6	16.9	2.3	8.4	16.2	498.6	0.42	2.1	0.6	0.4	7.1	31.8	0.46	0.6	0.0	164.8	42.5	0.8	230.0
	Feb 88	92.5	48.4	87.2	21.9	2.1	10.8	16.8	918.4	0.39	2.7	0.8	2.2	9.3	38.7	0.58	1.2	0.0	126.2	73.0	0.7	29.6
	Mar 88	92.0	70.6	104.9	18.9	1.8	10.0	15.0	630.9	0.38	1.8	0.5	-0.5	9.1	37.0	0.39	0.7	0.3	168.1	22.4	0.0	46.2
	Apr 88	74.5	36.6	54.5	16.9	1.9	11.7	21.6	540.2	0.49	3.6	2.3	0.7	10.5	57.1	0.59	2.7	1.0	78.3	4.4	3.9	4.5
	May 88	96.5	29.0	43.5	14.8	1.8	15.5	29.5	692.6	0.46	8.1	8.4	2.1	10.6	77.6	0.91	3.4	1.2	131.4	3.1	2.2	0.3
	Jun 88	98.5	28.3	38.3	13.8	1.8	17.3	32.2	529.9	0.50	5.3	3.3	4.8	11.3	69.4	0.78	3.5	2.5	123.2	3.6	4.2	3.5
	Jul 88	100.0	22.5	30.7	10.7	1.4	18.0	38.9	529.0	0.59	6.6	5.9	6.6	12.3	74.3	0.83	3.5	6.4	98.8	1.9	4.5	10.3
	Aug 88	100.0	27.2	34.2	10.7	1.3	16.7	38.7	669.2	0.67	5.8	5.2	2.0	12.3	87.1	0.88	4.3	0.5	88.2	0.5	0.0	17.6
	Sep 88	99.0	18.7	25.6	10.7	1.1	17.7	39.0	557.9	0.79	3.8	4.1	1.6	11.9	75.1	0.93	5.1	16.4	140.9	2.8	0.0	93.7
	Oct 88	99.0	23.2	27.0	6.3	0.9	16.1	37.2	942.3	0.99	5.3	5.9	0.7	11.5	88.4	1.42	5.5	1.7	373.7	8.2	0.0	505.9
	Nov 88	83.5	21.0	25.7	9.3	0.9	12.2	27.6	581.3	1.05	5.0	4.0	2.3	10.4	67.2	0.99	3.9	3.3	300.4	6.6	0.0	166.1
	Dec 88	67.8	29.7	36.9	12.1	1.8	10.0	19.2	399.8	0.74	3.4	1.5	1.1	7.8	50.2	0.65	1.9	5.7	74.6	13.8	0.0	74.8
	Jan 89	72.0	34.0	55.4	17.3	2.1	8.5	16.6	508.8	0.87	4.4	1.3	1.1	7.5	39.3	0.43	0.5	61.9	221.9	37.6	0.0	212.5
	Feb 89	58.0	42.6	83.0	23.1	2.0	9.6	16.8	557.0	0.66	5.7	2.4	2.1	8.2	35.4	0.45	1.2	172.3	200.1	13.2	0.3	127.5
	Mar 89	69.5	28.2	73.8	21.5	2.9	11.1	15.0	500.3	0.58	3.4	1.2	-0.4	7.7	33.7	0.42	0.9	513.0	72.6	24.1	0.0	36.0
	Apr 89	78.5	32.8	80.8	21.2	2.9	10.0	15.0	386.0	0.43	3.3	1.4	2.4	7.8	27.4	0.33	0.9	793.6	100.8	10.5	10.8	26.8
	May 89	72.0	35.2	83.0	21.2	2.7	10.0	15.7	539.2	0.47	3.2	1.3	3.5	8.6	29.0	0.39	1.0	889.3	220.6	3.0	2.4	41.9

(Continued)

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* Na = Neohydronomus affinis, SM = Samea multiplicalis, So = Synclita obliteralis, Di = Draeculacephala inscripta, Rn = Rhopalosiphum nymphaeae.

(Sheet 1 of 5)

Table B1 (Continued)

Site	Date	Cover %	Genets #/m^2	Ramets #/m^2	Moms %	Offsets/ ramet	Hgt cm	Diam cm	Standing Crop g	Root: shoot Ratio	Leaves Produced/ramet gross #	Leaves Produced/ramet gross g	Leaves Produced/ramet net #	Leaves No./ ramet	Leaves Area cm^2	Leaves Wgt g	Inflorescences/ ramet	Insects[a] Na #/m^2	Insects[a] Sm #/m^2	Insects[a] So #/m^2	Insects[a] Di #/m^2	Insects[a] Rn #/m^2
Torry Island	May 86	98.0	48.2	127.9	53.9	3.1	8.3	22.0	754.1	0.40	.	.	.	.	.	.	.	.	77.7	0.0	0.0	14.1
	Jun 86	100.0	47.8	61.5	21.1	1.4	16.2	29.6	730.7	0.44	.	7.8	.	.	.	.	.	.	28.3	0.0	0.0	15.7
	Jul 86	100.0	54.9	58.8	5.8	1.2	14.7	33.9	958.6	0.35	8.4	6.8	.	.	.	.	.	.	16.5	0.0	0.0	23.1
	Aug 86	100.0	40.5	43.3	5.1	1.3	15.7	35.7	897.3	0.48	.	7.3	.	.	.	.	.	.	8.2	0.0	0.0	0.4
	Sep 86	100.0	53.2	54.2	1.0	1.8	16.2	36.6	1462.3	0.50	.	7.6	.	.	.	.	.	.	7.3	0.0	0.0	18.5
	Oct 86	100.0	44.6	45.8	1.5	2.3	14.8	32.8	1072.9	0.66	.	8.3	.	.	.	.	.	.	29.8	0.0	0.0	7.8
	Nov 86	100.0	37.4	40.2	3.2	1.9	14.1	36.0	860.6	0.61	.	.	.	.	.	.	.	.	52.2	0.0	0.0	464.9
	Dec 86	.	.	.	.	.	.	30.8	.	0.49	.	.	.	.	.	.	.	.	.	.	.	.
	Jan 87	95.5	58.7	99.7	38.1	1.9	8.3	30.6	621.5	0.47	7.1	3.8	.	.	.	.	.	.	79.9	0.0	0.5	372.5
	Feb 87	75.6	29.8	56.6	32.0	2.7	8.4	22.2	314.7	0.61	10.0	3.2	.	.	.	.	.	.	29.8	0.0	0.0	148.8
	Mar 87	94.5	40.9	113.1	54.0	3.7	9.3	16.2	488.1	0.59	7.2	3.0	.	.	.	.	.	.	214.2	0.0	1.9	7.8
	Apr 87	91.0	28.9	121.0	69.6	4.7	11.5	26.9	467.6	0.31	7.2	2.6	.	.	.	.	.	.	62.6	0.3	0.0	31.9
	Jul 87	100.0	41.1	43.9	4.7	0.9	16.2	34.8	1007.8	0.00	.	.	.	13.5	80.9	1.59	1.6	0.0	26.5	0.0	5.0	3.2
	Aug 87	100.0	32.6	33.0	1.2	0.2	16.2	32.8	883.6	0.00	6.6	5.5	1.5	12.8	72.6	2.10	2.1	0.0	67.4	0.0	0.0	1.4
	Sep 87	96.1	30.7	31.2	0.8	0.3	14.4	32.9	924.8	0.79	9.0	7.9	.	11.3	63.7	1.40	3.5	0.0	190.5	0.0	7.1	20.2
	Oct 87	96.5	30.4	32.1	1.8	0.7	15.3	32.6	922.4	0.84	8.7	8.7	4.8	13.4	76.0	1.15	4.0	0.0	274.2	0.3	4.4	239.2
	Nov 87	91.5	25.2	28.1	6.3	1.3	13.7	34.8	616.1	0.41	5.1	2.4	2.5	11.9	71.4	1.16	4.9	0.0	216.4	0.4	0.8	220.1
	Dec 87	97.0	31.6	37.4	8.4	1.7	8.6	25.0	583.7	0.43	5.9	3.1	2.0	9.6	52.6	1.10	2.8	0.0	217.2	2.0	0.0	414.7
	Jan 88	84.5	62.4	101.7	16.5	2.5	8.1	15.6	565.6	0.57	3.1	1.2	2.5	7.2	30.0	0.35	0.6	0.0	441.4	12.8	4.1	494.8
	Feb 88	92.0	50.6	97.2	16.9	2.8	9.2	15.5	450.7	0.41	3.3	0.8	1.7	7.1	32.1	0.33	0.6	0.0	180.4	18.7	0.0	824.0
	Mar 88	83.5	43.0	108.6	17.4	3.4	9.7	15.2	567.7	0.31	3.1	0.7	-0.7	7.2	35.5	0.36	0.9	0.0	238.8	24.3	0.6	213.7
	Apr 88	81.5	26.5	78.7	16.4	4.4	11.7	18.5	574.7	0.34	4.5	2.1	2.3	9.0	43.7	0.45	1.4	16.6	295.2	9.7	0.0	89.5
	May 88	90.5	31.2	71.3	17.8	3.2	13.6	23.3	742.5	0.40	6.4	3.2	2.0	10.0	57.0	0.55	1.3	0.4	256.4	4.0	0.0	79.5
	Jun 88	97.5	27.1	41.0	18.8	1.8	16.0	32.0	809.6	0.53	7.7	5.4	1.0	10.4	89.6	1.14	2.0	0.0	59.9	0.0	3.9	98.4
	Jul 88	100.0	26.6	31.4	9.6	1.1	17.3	36.2	466.2	0.76	7.6	5.4	2.5	11.0	82.7	0.74	3.4	9.0	97.5	0.5	21.1	145.1
	Aug 88	100.0	22.2	24.1	6.3	0.8	17.8	38.4	422.0	0.99	6.4	4.0	4.2	11.5	74.9	0.76	3.6	16.7	23.1	0.4	0.0	29.6
	Sep 88	95.5	24.8	26.7	4.9	0.6	17.0	38.4	477.7	1.11	7.5	5.6	1.0	11.2	78.1	0.74	4.4	16.6	107.5	0.4	0.0	115.5
	Oct 88	100.0	24.2	25.9	4.5	0.7	16.7	37.2	718.3	0.95	8.5	10.6	0.6	11.7	89.7	1.18	4.6	21.4	209.7	0.0	0.0	265.8

(Continued)

Table B1 (Continued)

											Leaves							Insects[a]				
											Produced/ramet											
											gross		net									
Site	Date	Cover %	Genets #/m²	Ramets #/m²	Moms %	Offsets/ramet	Hgt cm	Diam cm	Standing Crop g	Root: shoot Ratio	#	g	#	No./ramet	Area cm²	Wgt g	Inflorescences/ramet	Na #/m²	Sm #/m²	So #/m²	Di #/m²	Rn #/m²
Torry	Nov 88	100.0	32.9	46.2	14.9	1.5	19.2	33.3	1254.0	0.64	5.0	5.0	2.0	11.5	87.2	1.13	4.7	29.8	797.2	4.9	0.0	1971.6
Island	Dec 88	97.0	23.4	37.2	19.5	2.0	16.9	28.6	596.7	0.33	5.1	5.3	-0.1	9.4	86.4	1.23	3.5	1.9	986.3	12.7	0.0	1002.3
(Cont)	Jan 89	100.0	21.4	47.3	26.1	2.0	14.0	21.1	697.2	0.40	5.0	3.2	2.2	8.1	56.0	0.74	1.7	0.3	641.3	7.4	0.0	301.2
	Feb 89	96.0	21.3	65.8	21.2	3.2	12.0	18.2	572.0	0.35	2.9	1.8	-1.3	7.9	38.4	0.59	1.1	24.5	674.4	7.2	0.0	296.9
	Mar 89	98.0	18.9	66.5	20.5	3.5	11.0	17.0	493.3	0.36	3.7	1.5	2.4	8.0	33.8	0.43	1.3	62.3	277.7	17.2	0.0	296.1
	Apr 89	96.0	24.6	91.3	18.4	4.0	11.0	18.0	765.3	0.42	4.1	1.4	-2.1	8.8	36.9	0.49	1.3	91.9	154.8	8.7	0.0	113.2
	May 89	99.0	35.2	68.1	23.5	2.1	12.8	24.6	833.8	0.47	4.7	2.6	0.6	10.5	52.9	0.70	3.1	162.6	252.9	12.2	0.0	55.8
	Jun 89	100.0	45.8	53.5	11.4	1.2	13.7	30.3	881.1	0.47	3.7	2.4	-0.4	11.9	60.3	0.86	3.3	163.0	203.9	2.6	0.4	23.7
	Jul 89	93.3	29.1	30.6	3.9	0.7	14.3	35.3	688.3	0.47	6.5	4.8	2.1	13.7	75.8	1.11	3.7	195.5	49.4	2.6	0.0	175.3
	Aug 89	91.5	37.8	41.7	5.2	1.0	12.6	28.0	659.4	0.36	6.4	5.4	0.5	11.9	59.1	0.85	1.9	559.2	28.4	2.8	0.0	139.0
	Sep 89	85.0	34.6	43.6	11.8	1.3	12.6	28.5	657.7	0.48	5.9	4.8	1.9	12.0	64.4	0.79	2.4	329.3	34.5	2.6	1.2	172.3
	Oct 89	67.2	27.0	34.0	12.9	1.2	12.9	29.2	542.8	0.45	4.2	3.4	-0.9	10.8	68.7	0.91	2.0	318.1	365.3	2.7	0.0	172.5
	Nov 89	65.0	24.0	31.2	12.2	1.6	13.0	29.9	542.8	0.46	4.9	4.4	0.8	11.1	71.1	0.98	2.4	207.4	179.9	4.7	0.6	1071.0
	Dec 89	63.8	24.5	51.6	23.7	2.3	11.9	16.9	506.9	0.32	3.8	2.6	-0.5	7.9	47.9	0.64	1.6	144.4	254.6	5.3	1.1	752.2
	Jan 90	57.5	30.0	61.5	20.3	2.5	9.1	13.2	473.0	0.64	4.6	1.6	4.3	7.3	36.5	0.57	0.5	221.6	69.9	7.2	0.0	156.0
	Feb 90	47.1	35.7	76.9	22.2	2.3	6.6	9.8	222.5	0.45	2.2	0.4	1.1	5.8	20.7	0.23	0.0	878.2	88.1	8.4	2.0	128.8
	Mar 90	49.2	52.5	119.3	21.3	2.6	6.5	11.2	314.8	0.32	1.0	0.2	-1.9	6.4	17.8	0.19	0.1	1370.0	101.6	4.6	3.6	101.6
	Apr 90	11.7	48.8	74.2	15.6	2.3	4.8	9.0	95.4	0.40	0.0	0.0	.	5.8	13.7	0.13	0.0	622.0	72.1	2.2	3.0	20.3
	May 90	3.2	52.6	63.4	10.1	1.3	2.6	5.5	23.6	0.36	0.8	0.1	-1.6	5.5	5.5	0.04	0.0	116.0	28.7	0.5	0.0	0.0
Port	Jul 87	100.0	61.0	69.8	9.6	1.1	11.9	28.4	709.5	.	.	.	.	15.0	51.5	0.66	8.3	0.0	8.5	0.0	5.0	0.4
St. Lucie	Aug 87	100.0	52.9	55.5	2.4	1.7	15.0	33.6	619.0	.	6.8	2.9	0.3	13.6	64.2	0.76	8.1	0.0	77.9	0.0	2.3	0.0
	Sep 87	100.0	47.5	50.1	2.5	1.2	13.4	34.2	697.5	0.61	5.8	1.9	-1.0	12.8	54.5	0.69	8.6	0.0	224.2	0.0	7.6	0.0
	Oct 87	100.0	38.2	54.5	12.3	2.3	11.6	25.6	615.2	0.59	6.4	2.5	3.9	11.2	40.0	0.51	7.5	0.3	227.2	0.0	2.7	2.0
	Nov 87	100.0	30.1	96.3	19.6	3.5	10.3	20.0	503.5	0.21	3.4	0.8	0.6	7.7	37.4	0.33	3.3	0.0	335.8	0.0	5.2	13.6
	Dec 87	100.0	27.3	104.0	17.2	4.4	9.3	19.0	498.6	0.22	4.9	1.4	2.5	7.8	29.0	0.32	3.1	0.5	537.0	0.0	0.8	3.4
	Jan 88	100.0	23.4	139.3	13.9	6.2	7.8	16.9	464.2	0.16	4.1	0.6	0.7	7.7	23.2	0.25	1.8	0.0	320.6	0.0	0.0	8.9
	Feb 88	100.0	21.8	136.9	14.6	5.9	6.8	14.0	412.3	0.15	4.6	0.5	1.4	8.5	18.0	0.20	1.0	1.3	351.1	0.0	0.0	11.4
	Mar 88	97.0	26.8	216.4	19.9	4.4	5.2	11.0	400.7	0.17	4.8	0.4	2.6	7.4	13.7	0.14	0.3	6.2	196.9	0.0	0.0	8.6

(Continued)

Table B1 (Continued)

Site	Date	Cover %	Genets #/m²	Ramets #/m²	Moms %	Offsets/ ramet	Hgt cm	Diam cm	Standing Crop g	Root: shoot Ratio	Leaves Produced/ramet gross #	Leaves Produced/ramet gross g	Leaves Produced/ramet net #	Leaves No./ ramet	Leaves Area cm²	Leaves Wgt g	Inflo-resences/ ramet	Insects[a] Na #/m²	Insects[a] Sm #/m²	Insects[a] So #/m²	Insects[a] Di #/m²	Insects[a] Rn #/m²
Port	Apr 88	100.0	37.7	248.1	19.2	4.5	5.3	12.2	557.9	0.28	3.1	0.4	1.9	9.4	17.9	0.13	0.7	1.4	167.7	0.0	0.9	7.9
St. Lucie	May 88	100.0	68.3	215.4	24.3	2.8	9.0	16.3	716.8	0.27	2.8	0.5	0.4	10.7	28.7	0.18	2.7	2.7	264.4	0.0	1.9	28.7
(Cont)	Jun 88	100.0	52.0	80.9	21.9	1.6	13.0	26.9	670.3	0.35	1.2	0.3	-1.6	13.5	45.7	0.41	8.3	3.5	208.2	0.0	4.0	81.5
	Jul 88	100.0	45.7	57.5	12.5	1.4	15.1	29.6	361.3	0.38	6.7	1.8	2.3	11.9	48.6	0.33	7.9	5.8	63.0	0.0	50.6	101.2
	Aug 88	100.0	33.0	39.5	7.9	1.3	18.5	37.7	466.9	0.42	8.2	3.8	-0.5	14.0	70.1	0.55	9.4	0.0	43.6	0.0	0.0	15.9
	Sep 88	100.0	23.2	38.9	19.7	1.9	16.8	33.4	354.5	0.31	6.5	3.2	-1.5	9.6	59.6	0.53	6.2	1.6	398.6	0.0	2.0	9.6
	Oct 88	100.0	19.2	64.4	21.9	3.3	12.5	24.6	586.0	0.23	5.2	1.8	0.4	7.7	49.3	0.57	3.1	1.3	63.0	0.0	0.0	5.0
	Nov 88	91.0	21.3	104.9	17.8	4.6	10.2	20.3	452.1	0.24	3.6	0.8	-2.0	7.4	32.4	0.28	1.2	0.0	174.6	0.0	1.3	250.1
	Dec 88	97.5	15.4	85.1	16.4	5.0	10.1	19.1	341.4	0.26	3.8	0.9	1.7	7.5	36.7	0.28	2.0	0.0	126.3	1.4	0.0	116.8
	Jan 89	100.0	20.7	180.1	18.3	5.0	8.2	16.2	900.8	0.38	3.1	0.5	0.9	7.5	28.7	0.20	1.5	0.0	333.8	0.0	0.0	205.2
	Feb 89	98.0	20.1	150.8	18.0	5.0	7.6	14.3	479.2	0.29	4.4	1.0	2.5	8.4	22.5	0.20	2.0	0.0	534.9	3.6	0.0	121.8
	Mar 89	80.5	16.1	109.0	16.3	5.4	6.2	10.8	322.2	0.33	1.6	0.3	1.9	8.4	17.8	0.18	1.9	2.2	156.2	3.1	0.0	14.0
	Apr 89	100.0	31.2	185.2	18.7	4.6	5.7	12.0	567.7	0.58	4.3	0.6	2.0	8.4	15.7	0.17	1.6	5.8	156.7	2.2	34.5	20.7
	May 89	100.0	46.6	150.0	20.9	3.3	7.9	14.1	632.3	0.61	6.6	1.3	2.3	9.8	21.1	0.21	2.1	10.0	74.1	0.0	128.4	87.9
	Jun 89	100.0	50.8	120.6	21.9	2.5	9.7	20.2	904.9	0.56	5.0	1.5	2.4	11.8	32.8	0.35	5.8	10.4	61.2	0.4	66.1	32.8
	Jul 89	100.0	49.1	77.3	19.1	1.8	10.8	24.9	951.9	0.51	7.1	3.3	2.8	13.6	44.4	0.51	8.1	29.1	49.0	0.0	76.4	43.5
	Aug 89	100.0	57.7	76.5	13.1	1.8	12.7	25.8	1019.0	0.58	8.4	4.4	-2.0	13.9	49.2	0.55	7.5	11.9	63.6	0.4	68.7	113.7
	Sep 89	100.0	48.8	86.3	15.5	2.4	11.0	26.3	1213.9	0.60	5.2	3.1	0.2	13.0	50.2	0.52	6.9	2.9	106.3	0.0	70.7	73.8
	Oct 89	100.0	36.7	101.1	18.4	3.4	10.0	23.7	1132.8	0.43	4.9	2.1	-1.8	9.7	45.9	0.51	4.1	1.4	316.0	0.0	138.4	749.5
	Nov 89	100.0	29.5	115.0	17.6	4.2	9.8	19.8	878.4	0.39	5.7	2.4	-3.0	8.9	37.8	0.37	2.6	3.3	312.2	0.0	158.7	440.3
	Dec 89	100.0	27.9	139.2	17.6	4.7	7.6	16.9	767.0	0.39	6.0	2.0	3.4	8.4	30.0	0.31	1.7	0.7	215.3	0.0	128.8	376.5
	Jan 90	100.0	25.6	133.0	19.1	4.3	3.9	13.0	364.1	0.36	3.8	1.0	1.6	7.9	16.9	0.17	0.9	0.1	158.0	0.0	1.0	40.4
	Feb 90	100.0	46.5	320.8	21.9	3.9	4.5	9.3	455.9	0.34	3.6	0.5	2.3	7.0	13.6	0.11	0.6	2.2	362.7	0.0	3.0	2.1
	Mar 90	100.0	60.1	437.3	18.3	4.7	4.2	9.4	609.7	0.29	5.1	0.5	3.0	7.6	12.4	0.11	0.6	3.5	385.8	0.5	4.6	0.0
	Apr 90	100.0	71.6	376.3	19.6	4.2	5.0	10.0	715.5	0.28	4.0	0.6	0.6	7.8	14.3	0.14	1.2	1.7	238.5	0.0	0.8	1.5
	May 90	100.0	65.4	249.7	23.1	3.2	5.8	11.9	713.4	0.35	4.9	0.9	1.3	9.0	17.9	0.18	2.5	1.2	37.7	0.0	4.9	0.0
Moore	Feb 86	85.0	19.3	52.4	50.1	3.5	10.3	23.6	466.7	0.27	.	.	.	.	.	.	.	.	113.4	0.0	2.2	194.6
Haven	Mar 86	81.5	23.6	83.9	75.7	3.8	8.1	19.8	577.7	0.40	.	.	.	.	.	.	.	45.0	0.0	0.0	3.0	

(Continued)

(Sheet 4 of 5)

Table B1 (Concluded)

											Leaves						Inflo-resen-ces/ramet	Insects[a]				
											Produced/ramet											
											gross		net									
Site	Date	Cover %	Gen-ets $\#/m^2$	Ram-ets $\#/m^2$	Moms %	Off-sets/ramet	Hgt cm	Diam cm	Stand-ing Crop g	Root: shoot Ratio	#	g	#	No./ramet	Area cm^2	Wgt g		Na $\#/m^2$	Sm $\#/m^2$	So $\#/m^2$	Di $\#/m^2$	Rn $\#/m^2$
Moore	Apr 86	85.0	28.3	135.2	76.7	4.5	9.1	24.4	560.5	0.24	.	.	.	.	.	.	.	.	91.5	0.0	1.6	94.4
Haven	May 86	65.5	32.7	89.6	56.8	2.9	11.0	27.7	711.2	0.30	.	.	.	.	.	.	.	.	65.1	0.0	6.1	193.3
(Cont)	Jun 86	77.0	29.0	38.1	20.6	1.6	21.0	36.3	559.1	0.27	.	15.7	.	.	.	.	.	.	13.7	0.0	29.7	41.1
	Jul 86	53.0	22.3	69.4	50.6	2.6	25.6	47.3	1053.3	0.37	12.9	14.3	.	.	.	.	.	.	71.6	0.0	232.3	149.1
	Aug 86	74.0	17.4	50.1	61.6	3.1	20.0	47.5	519.5	0.25	.	20.6	.	.	.	.	.	.	32.4	0.0	94.5	802.7
	Sep 86	54.0	26.5	53.3	37.0	2.8	23.2	43.1	697.4	0.16	.	17.3	.	.	.	.	.	.	30.0	0.0	13.3	25.6
	Oct 86	70.0	24.1	54.6	45.2	3.0	23.1	46.1	781.8	0.12	.	19.7	.	.	.	.	.	.	115.7	0.0	3.7	162.7
	Nov 86	88.5	18.9	53.3	62.2	3.0	19.9	49.0	680.7	0.15	.	.	.	.	.	.	.	.	68.9	0.0	0.0	851.3
	Dec 86	.	.	.	.	.	.	50.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Jan 87	88.5	14.5	48.2	52.7	4.9	15.4	37.2	454.7	0.23	11.4	7.8	.	.	.	.	.	.	81.3	0.0	4.4	196.1
	Feb 87	90.5	22.7	87.4	57.3	5.1	14.0	19.8	536.4	0.19	11.5	5.6	.	.	.	.	.	.	110.3	3.0	1.0	297.5
	Mar 87	87.5	26.6	133.6	74.8	5.5	12.7	27.6	555.6	0.33	10.6	4.9	.	.	.	.	.	.	25.1	1.0	0.8	69.4
	Apr 87	89.5	31.0	92.0	65.0	3.1	7.7	20.8	372.1	0.49	8.7	3.9	.	.	.	.	.	.	190.6	4.2	2.8	26.8
Loxahatchee	Sep 86	92.5	86.5	90.5	2.6	2.1	12.7	25.0	1141.0	0.35	.	.	.	.	.	.	.	.	17.6	0.0	6.9	5.5
Wildlife	Oct 86	92.5	82.6	83.3	0.8	2.0	11.5	23.9	993.5	0.34	.	3.5	.	.	.	.	.	.	98.6	0.0	1.9	9.0
Refuge	Nov 86	89.5	58.7	90.5	24.0	2.3	10.5	26.6	1107.5	0.39	.	.	.	.	.	.	.	.	145.2	0.0	14.6	43.3
	Dec 86	.	.	.	.	.	.	28.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Jan 87	95.5	51.0	65.6	14.7	2.1	11.0	21.0	701.3	0.62	4.9	1.4	.	.	.	.	.	.	49.8	0.0	25.0	53.8
	Feb 87	93.5	37.0	109.8	66.1	3.0	6.5	30.4	522.0	0.51	8.3	1.2	.	.	.	.	.	.	42.2	0.0	31.0	11.3
	Mar 87	95.5	33.9	176.9	82.2	5.2	4.6	20.4	422.2	0.53	10.5	1.7	.	.	.	.	.	.	20.9	0.0	29.9	3.6

(Sheet 5 of 5)