Exploration For Natural Enemies Of The Water Hyacinth In Northern South America And Trinidad

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Outstanding examples of the biological control of terrestrial weeds have been known for many years, the most impressive being the control of prickly pear Cactus (*Opuntia* spp.) in Australia. Although the possibilities of the use of the same methods for the control of aquatic weeds have been considered for some years the recent successful introduction of *Agasicles* sp. into the United States for the control of alligatorweed, *Alternathera philoxeroides* has given an added incentive to press on with investigations of the natural enemies of other troublesome aquatic weeds.

The economic importance of *Eichhornia crassipes* is too well known to require detailed discussion. It is sufficient to note that *E. crassipes* is considered to be an actual or potential major aquatic weed in tropical and subtropical areas throughout the world and that on a world basis several million dollars are spent annually on its control by chemical and mechanical methods. In view of this situation, attention to other methods of control is warranted.

The possibilities of biological control, although under consideration for some years have never been fully explored. A search for controlling agents in the northern part of South America, the area where *Eichhornia* appears to have its center of origin although advocated several years ago has not been undertaken previously (4).

In 1967, funds for exploratory work in tropical South and Central America were provided by the Ministry of Overseas Development, London. The object of the survey was to determine whether or not natural enemies, particularly insects, occurring in this area showed sufficient controlling potential to warrant detailed investigations on their biology and, if promising species were encountered to undertake host specificity tests to enable us to select species for introduction into other areas.

PREVIOUS INVESTIGATIONS ON THE NATURAL ENEMIES OF *E. CRASSIPES*

Investigations on the natural enemies of *E. crassipes* have been undertaken in India and Uruguay. In India, where *E. crassipes* is an introduced species it is apparent that organisms feeding on it, unless arriving with the host plant when it was introduced are ones which have moved over from other plants and hence are not host specific. The investigations in India have been summarized briefly by Bennett (4), from reports prepared by Rao (14) and Sankaran (15). In Uruguay, investigations financed by the USDA have been undertaken by Silveire Guido (17). These unpublished reports have been summarized briefly by Bennett (4). During our investigations we have had access to Dr. Silveira-Guido's final (unpublished) report (18) and have used it freely in interpreting our findings and for tentatively identifying some of the species which we have encountered.

AFFINITIES AND DISTRIBUTION OF *E. CRASSIPES*

The genus *Eichhornia* contains five species; *crassipes* (Mart.) Solms., *paniculata* (Spreng) Solms., *paradoxa* (Mart.) Solms., *azurea* (Swartz) Kunth and *diversifolia* (Vahl) Urban. *Eichhornia* together with the genera *Heteranthera, Hydrothrix, Pontederia* and *Reussia* comprise the family Pontederiaceae (9) although according to Willis (21) there are six genera; the additional genus *Monchoria* occurring from East Africa to Australasia. The Pontederiaceae are placed in series Coronarieae, Monocotyledones with the following families—Roxburghiaceae, Liliaceae, Philydraceae, Xyrideae, Mayacaceae, Commelinaceae and Rapateaceae (21) after Engler. Although of South American origin (described from Minas Gerais, Brazil) *E. crassipes* is now widely distributed throughout the Tropics and Subtropics (12). Although there are suitable areas where it still does not occur e.g. much of W. Africa, it has been reported recently from Senegal (2); further it is a pest on the Congo and will probably invade other areas in that region.

E. crassipes is the only species of the Pontederiaceae which is a free floating plant; the other members are rooted either where the water is shallow or near the shore (9). Some of the trailing vinelike species e.g., *E. azurea* and *Reussia rotundifolia* may extend over the water surface several meters from the shore.

CURRENT INVESTIGATIONS

Itinerary

Preliminary investigations were started in late 1967 in Trinidad where collections were made from a number of localities. Regular sampling to assess seasonal fluctuations in populations of two Pyralids was started in January, 1968. These initial investigations provided useful experience in developing sampling techniques and determining the type of equipment needed for the exploratory survey in the northern part of South America.

During the seven weeks in South America, we spent two weeks in Guyana, ten days in Surinam and the remainder of the time in the Amazon region of Brazil.

Methods and materials:

As we travelled by air from country to country the amount of equipment we could transport was limited. In addition to normal field clothing we carried hip waders, rubber boots and rubber gloves (essential for working in areas where Bilharzia was prevalent). Equipment consisted of a series of glass vials of various sizes, plastic containers, small waxed cream containers and plastic bags for collecting and holding living material; a three-pronged drag with 10 meters of light rope designed to obtain floating

plants from the opposite banks of canals, drains etc.; homeopathic vials for preserving specimens in alcohol; specimen boxes, pins etc. for preserving dry specimens; a plant press and a field microscope.

In addition to collections obtained from the shore we travelled and collected from a wide assortment of boats ranging from small rather precarious pirogues, mule drawn barges to large motor boats, made available by cooperating organizations. We attempted to carry out both qualitative and quantitative assessments of insect populations and damage at as many sites as possible. For each quantitative assessment we sampled at least 25 plants i.e. some 125 or more stems recording different types of feeding or other injury to leaves, petioles and roots. Although with the distances involved, the time spent in actual field observations at some localities was relatively short, more intensive observations at other sites compensated for this.

Habitats investigated:

We attempted to examine and to collect on *Eichhornia crassipes* and other species of Pontederiaceae over as wide a range of habitats as possible. Habitats investigated have been classified (somewhat arbitrarily) as follows:

1. Artificial Lakes:

a) Brokopondo Lake, Surinam. A very large lake created recently, the water level is still rising. Large mats of aquatic plants mainly *Eichhornia crassipes* have developed among the partially submerged trees. Because the water level of the lake is low, the amount of water lost from transpiration by *Eichhornia*, which is considerably greater than from evaporation from an open surface (13, 19), may be critical to the efficient operation of the hydroelectric power scheme. Accordingly, a herbicidal control program has been in operation and the *Eichhornia* available for examination was relatively young and in an unsuitable environment for maximum insect development. b) Nanni Lake, Nickerie, Surinam. A large shallow rather swampy lake created to provide water for irrigation. *Eichhornia crassipes* was a minor component of the flora which was mainly rooted and comprised largely of Graminaceous species.

2. Artificial Ponds

a) Ornamental pond near IPEAN, Belem, Brazil. Less than one meter deep and 5 to 6 meters in diameter. About 30% of the surface covered by *E. crassipes*, no other plants present. Sections of the pond cleared periodically. b) Ornamental fish pond, Museu, Goeldi, Belem, Brazil. Depth approximately 1 meter, 4 to 5 meters wide and 8 to 19 meters long. *Salvinia auriculata*, the only other plant present. c) Concrete fish tank, Museu Goeldi, Belem, Brazil. Partially shaded approximately 0.5 meter deep, 1 meter wide, less than 2 meters long. *Salvinia* also present. Both *Eichhornia* and *Salvinia* unhealthy, due to low or unbalanced nutrient content of water. d) Pond at Race-course, New Amsterdam, Guyana. Stagnant pond approximately 2 meters deep, 10 meters wide and 150 m. long. Almost 100% surface covered with *E. crassipes*. Some *Salvinia* present. Very vigorous growth, some flowering.

3. Natural lakes and ponds

Moreru Lake, Rupununi, Guyana. *Eichhornia azurea* rooting along borders forming large patches 5 to 15 meters across. *Pleurospera (Montrichardia) arborescens, Sagittaria* and sedges common.

4. Transport canals and drainage ditches

a)New Amsterdam, Guyana; b) Georgetown and vicinity. Canals 1 to 2 meters deep, 5 to 6 meters wide, constructed for drainage and transport of cane by barge. Cleared of aquatic vegetation periodically. Age and density of vegetation usually dependent on time cleared. A complex of floating and rooted plants which in addition to Graminaceae included species of *Marsilea, Pistia, Salvinia, Lemna, Azolla, Mimosa, Cabomba, Commelina* etc. *Eichhornia* flowering in some canals. c) West Bank, Demerara. A roadside drain, small patches of *E. crassipes*, largely over-grown with grasses. d) Paramaribo, Surinam. Roadside ditches and nearby flooded areas 1 to 2 meters deep, 4 to 5 meters wide. Additional plants of the genera *Ipomea, Pistia, Salvinia* and *Wedelia*, as well as sedges and grasses.

5. Swampy pasture lands

a) Paramaribo. Flooded area about 0.5 hectare about 0.5 meter in depth. Vigorous growth of *E. crassipes*, flowers present. Additional vegetation *Pleurospera, Salvinia, Azolla, Ipomea, Sagittaria* etc. b) Belem. Patches of semi-rooted *E. crassipes* in low lying pasture and nearby ditch. Flowering profusely. Wide range of semi-aquatic and terrestrial vegetation in vicinity.

6. Rivers

a) Coesewijne River, Surinam. Small patches of *Eichhornia* among floating grass along borders of river. *Ludwigia* and *Alternanthera* also abundant, no flowers. b) Saranamaca ferry. Small floating mats floating up stream due to influence of rising tide. Origin of mats not known. c) Peixe Boi near Belem, Brazil. Backwaters of small river, the surface largely overgrown by trailing plants from the river banks. Almost dry seasonally but at present with 1-2 meters of water. Both *E. crassipes* and *E. azurea* present and in flower. *Azolla, Salvinia, Pleurospera* etc. present. d) Marajo Island. Floating plants which had drifted ashore at three small ports including Breves. *Eichhornia azurea* was also present. e) Manaus, Paraná do Xiborena. A natural channel connecting the Rio Negro and the Solimoes Rivers. Only isolated plants or small groups of *Eichhornia* present, amongst aquatic grasses, *Paspalum* and *Panicum*. *Reussia rotundifolia* also present.

7. Other types of Habitats

a)Belair dairy, Georgetown, Guyana. Modified drainage canal 4 meters wide, 1 to 2 meters deep, receiving drainage water from cattle pens i.e. high nutrient level. Very vigorous stand of *E. crassipes*. b) Canal do Docko de Souza Franco, Belem. Open city sewerage drain, 10 meters wide, ca 200 mm. long, covered with solid stand of very vigorous *E. crassipes*.

NATURAL ENEMIES OF *EICHHORNIA CRASSIPES* AND RELATED SPECIES

As specialists have not completed the examination of much of the material collected during the survey it is proposed to restrict this report to the species which on the basis of our investigations we consider of sufficient im-

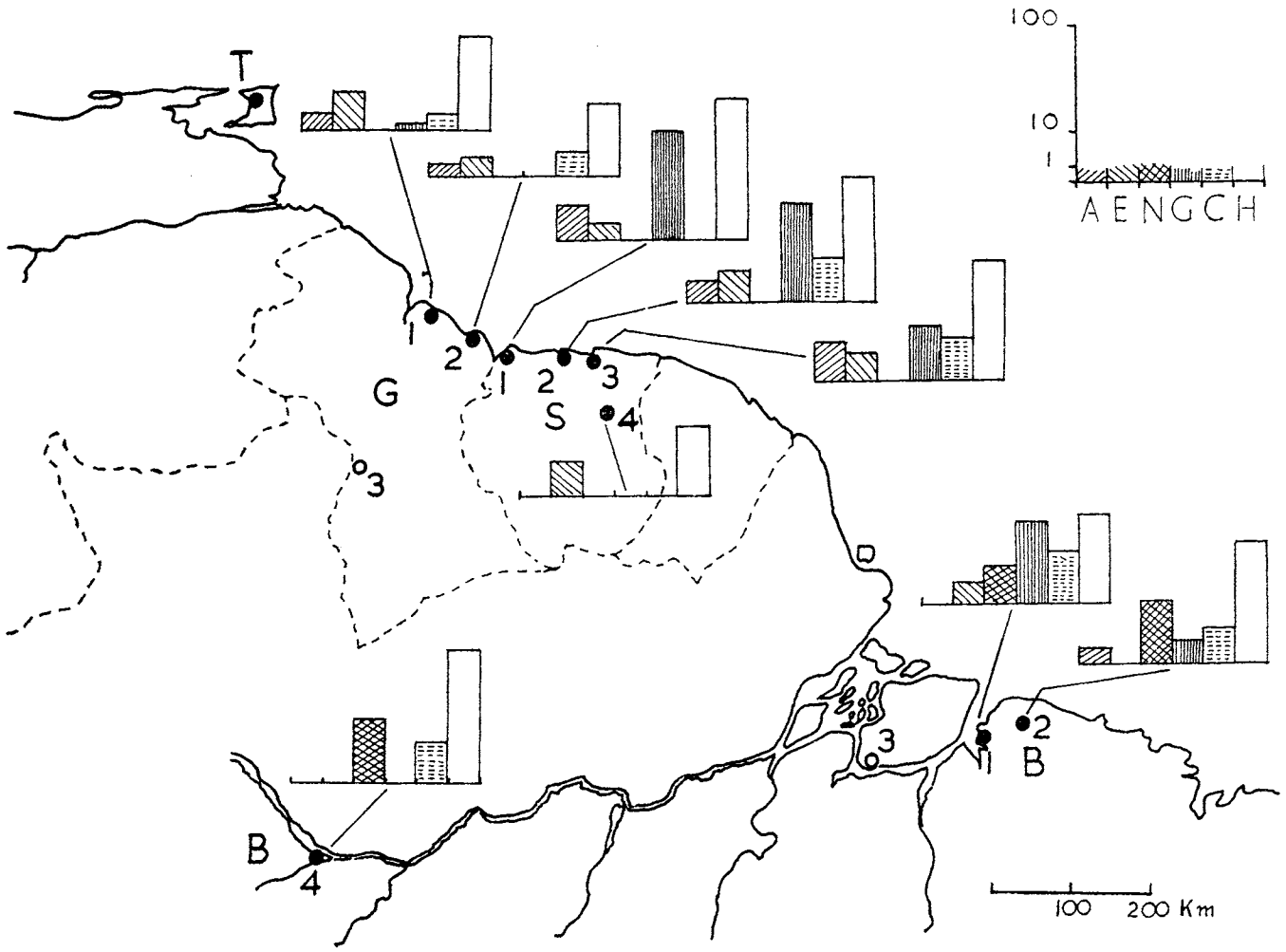

Figure 1. Map showing the region where the survey was conducted.
Black circles: areas of quantitative and qualitative sampling.
Open circles: areas of qualitative sampling only.

T: Trinidad

G: Guyana 1, Vicinity of Georgetown, Demarara; 2, Vicinity of New Amsterdam, Berbice; 3, Moreru Lake, near Good Hope air strip, Rupununi district.

S: Surinam 1, Nanni Lake near Nickerie; 2, Coesewijne River; 3, Vicinity of Paramaribo; 4, Brokopondo Lake.

B: Brazil 1, Vicinity of Belem, Pará; 2, Peixe Boi, Pará; 3, Breves; 4, Parana do Xiborena, near Manaus.

Histograms showing in logarithmic scale the average attack of 100 stems of *Eichhornia crassipes* by:

Acigona (Chilo) ignitalis Hmps. (A)
Epipagis albiguttalis Warr. (E)
Neochetina sp. (*bruchi*) (N)
Leptogalumnus (G)
Cornops longicorne (C)
Thrypticus, sp. (H)

portance to warrant detailed studies and to a few of the other relatively abundant species. The species to be discussed in detail in this report are: *Neochetina bruchi* Hulst., Curculionidae, *Acigona (Chilo) ignitalis* Hmps., Crambinae, *Epipagis albiguttalis* Hmps., Pyralidae, *Cornops longicorne* (Bruner), Tettigoniidae and *Leptogalumna* sp.,[1] Galumnidae (Acarina). The relative abundance of these species as well as of an undetermined Dolichopodid at the various localities is shown in Figure 1. Collection sites where these were found are given in Table 1.

Neochetina bruchi **Hulst Curculionidae Bagoini**

During our survey we found *Neochetina* attacking *E. crassipes* at Belem, Marajao and Manaus; *E. azurea* at Moreru Ranch, Rupununi, Guyana, and *Reussia rotundifolia* at Manaus. Although determinations of the material are still pending and hence the possibility exists that a complex of species may be involved, adults from the Rupununi fed and oviposited readily in *E. crassipes* and those from Belem fed and oviposited readily on *Reussia*. *N. bruchi* has been collected in Uruguay from *E. crassipes* by Prof. Silveira-Guido who did not find it on any other plant; it is listed by Blackwelder (5) from Brazil and Argentina.

Eggs are imbedded singly in the stem petioles near the base and the larvae complete their development in the base of plant, feeding in sections of the plant both below and above water level. In the laboratory, eggs may also be placed in feeding punctures on the leaves but this may be atypical (Figure 2A). Although development is probably normally completed in one plant, larvae are capable of leaving one stem and entering an adjacent one of either the same or of another plant. Larvae usually leave the

[1]This species has since been determined as *Orthogalumna terebrantis* Wallwork.

TABLE 1. SUMMARY: RELATIVE ABUNDANCE OF INSECTS AND MITES ON *Eichhornia crassipes* IN IN THE INDIVIDUAL SURVEY AREAS (FIGURES GIVE THE PERCENTAGE OF INSECTS FOUND PER 100 STEMS, BASED ON THE QUANTITATIVE ASSESSMENT).

Area	Map Code[1]	Average number of stems with *Acigona* La/Pu[2]	*Epipagis* La/Pu[2]	Dolichopodid	*Leptogalumna*	*Neochetina* larva	*Cornops* ootheca	No. of Stems Dissected
Guyana, Georgetown	G-1	1.2	5.4	36.4	0.1	....	0.8	1876
Guyan, New Amsterdam	G-2	1.4	1.8	23.1	....	....	2.9	654
Surinam, Nickérie	S-1	4.7	1.2	79.6	48.2	....	....	172
Surinam, Coesewijne River	S-2	2.1	4.1	63.3	39.5	....	8.2	146
Surinam, Paramaribo	S-3	5.6	3.3	61.5	12.7	....	7.4	425
Surinam, Brokopondo	S-4	....	4.3	17.1	....	....	....	610
Brazil, Belem	B-1	....	1.8	34.1	27.7	5.6	11.6	1146
Brazil, Peixe Boi	B-2	1.1	....	61.7	2.2	16.9	5.2	178
Brazil, Manaus	B-1	....	[3]	68.4	[4]	16.7	6.4	156

[1]Map code refers to localities shown in Figure 1.
[2]La/Pu = larvae and pupae.
[3]*Epipagis present in low numbers, percentage of attacks of stems* below 0.6%
[4]No galumnid found in *Eichhornia*. However, near the observation locality a galumnid sp. (possibly different from the galmnid attacking *Eichhornia*) was observed on leaves of *Reussia*.

stem and form pupation cells among the root hairs below the surface of the water. Adults and larvae appear to be unaffected by long periods of emersion.

Both adults and larvae cause damage to *Eichhornia*. The adults feed mainly at night both on the leaves and on the stems. On the leaves squarish feeding punctures approximately 2 mm. across are made in the upper epidermis. Many of these are made while the leaf is still partly rolled around an older leaf petiole. Punctures similar in shape are made in the leaf petiole and if sufficiently abundant they may cause the death of the leaf and subsequent dieback of stems. Larval damage is even more severe as the larvae bore into the base of the plant. Although relatively small in size, the larvae tunnel extensively and the surrounding tissue darkens and collapses following the attack of secondary organisms (Fig. 2 b,c,d.). Silveira-Guido (17) noted that in Uruguay adults live four months or longer. There is apparently a preoviposition period of about 19 to 20 days; while the length of the larval stages is not known, it is probably 2 months or longer.

We did not observe any specific natural enemies of *Neochetina*. However, the larvae, after they leave the base of the plant to pupate would appear to be very vulnerable to attack by predaceous insects, fish etc. Nevertheless *Neochetina bruchi* is considered one of the most promising species and merits further investigations.

Acigona ignitalis Hmps. (Pyralidae Crambinae)

We found *A. ignitalis* consistently in Trinidad and (apart from the Brokopondo Lake, Surinam) in all areas where we examined *E. crassipes* in South America. We did not note it on *Eichhornia azurea, E. paniculata* nor on *Reussia rotundifolia. E. paniculata* held in tanks in Trinidad were killed by *Acigona*. Silveira-Guido (18) reported that *E. azurea, Pontederia lanceolata* Nuttal, *Pontederia unisesma* in addition to *E. crassipes* are attacked in Uruguay. Bleszynski lists its distribution (under *infuscella*) as Guatemala, Guyana, Surinam, Brazil and Colombia (7).

Eggs are laid in masses usually of 10 or more on the leaves or petioles in crevices or other irregularities in the plant tissue. Newly hatched larvae mine in the leaf tissue and later enter the stem either by tunnelling directly from the leaf or emerging from the leaf, crawling and entering the stem at a lower level. Frequently the small larva girdles the stem, causing the death of the leaf and upper sector of the petiole and then tunnels downward into the base of the plant where it may tunnel upwards into another leaf letiole. Occasionally the larva transfers from one plant to another by boring through the interconnecting stem. Prior to pupation, which occurs in the tunnel, the larva cuts a circular "window" in the stem leaving only the epidermis. The tissue within the circle dies and turns brown. As the adult emerges, the pupal case is left projecting through the emergence hole.

Silveira-Guido reared *Apanteles abditus* Mues., *Iphiaulax* sp. and *Basseus* sp. from *A. ignitalis* in Uruguay. During our survey we found little or no evidence of parasitism but some indication that predation may occur. Subsequently *Spilochalcis* sp. and *Apanteles* sp. have been reared from *Acigona* in Trinidad.

As *A. ignitalis* has not been recorded from hosts outside the Pontederiaceae and has not been observed either by Silveira-Guido or ourselves attacking other groups of plants in the field, it appears sufficiently host specific to warrant detailed tests. Silveira-Guido (18) carried out some preliminary tests. In these tests large larvae fed on certain economic plants e.g. onion. In general results were somewhat inconclusive and to date there is no evidence that larval development can be completed on plants other than members of the Pontederiaceae.

This species is capable of severely weakening or killing plants outright and patches of unthrifty or dying plants several meters in diameter have been observed. Therefore *Acigona* appears to have good potential as a controlling agent.

Epipagis albiguttalis Hmps. (Pyralidae: Pyraustinae)

During our survey we encountered *Epipagis* regularly in Trinidad, Guyana, Surinam and Brazil on *Eichhornia crassipes,* but did not find it on other Pontederiaceae nor on other plants. Silveira-Guido also found it only on *E. crassipes* (18).

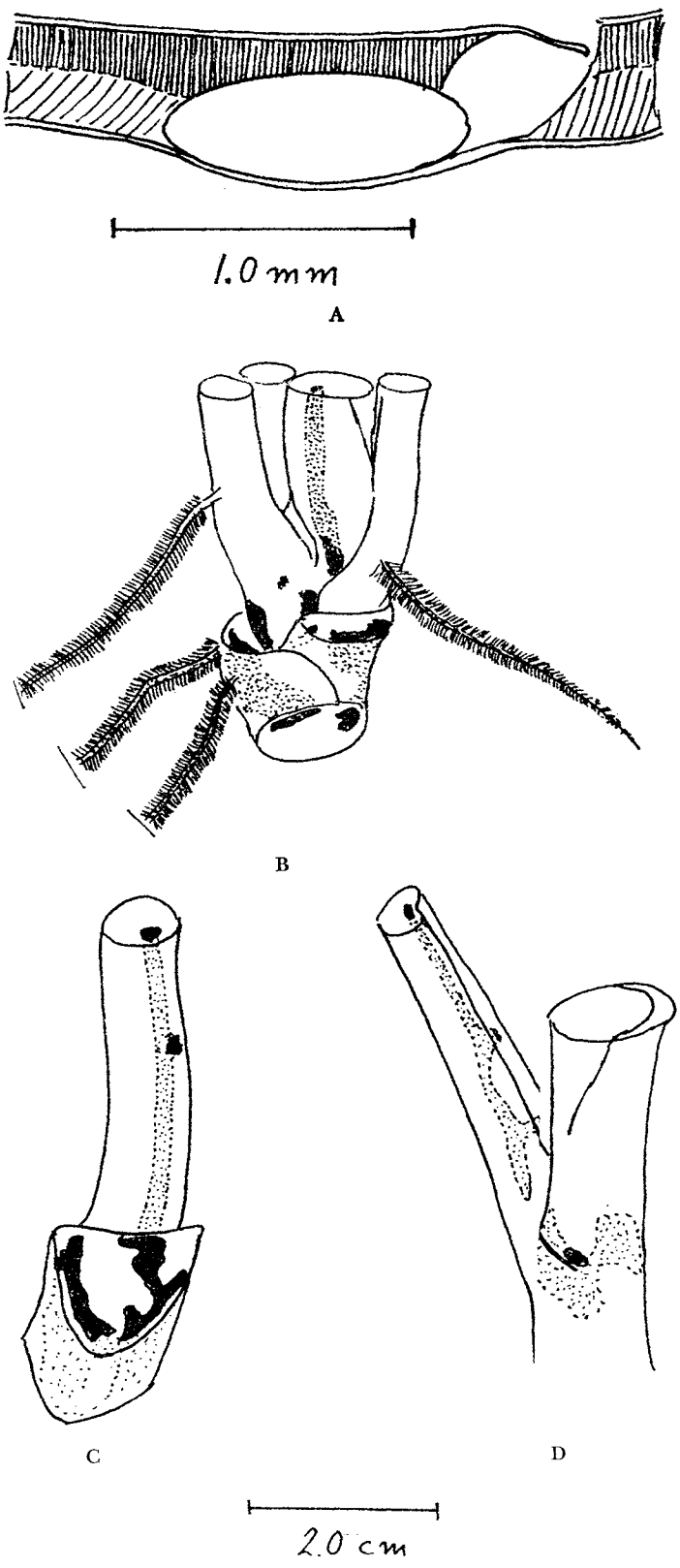

Figure 2.

A. Cross-section through leaf of *Eichhornia crassipes* showing an egg of *Neochetina* sp., imbedded within the sponge parenchyma. Oviposition hole in the upper surface of the leaf. (Oviposition obtained under laboratory conditions, possibly atypical).

B, C, D. Tunnels and blotch mines in the basal region of the stems of *Eichhornia crassipes*, made by larvae of *Neochetina* sp.

The eggs are usually laid singly or in small groups in crevices or feeding punctures on the leaves. The small larvae may enter the leaves or more frequently bore directly into the petioles. They may emerge and re-enter the same or adjacent petioles from time to time. Whereas a single larva per petiole is usual for *Acigona,* two or more *Epipagis* are frequently present in the same stem. Further *Epipagis* is usually more abundant in small plants with greatly inflated petioles whereas *Acigona* is usually more abundant in large plants with petioles only slightly inflated. The larvae tunnel extensively and extrude frass from the tunnel entrances. When fully developed they frequently leave the petiole where they have been feeding and enter another constructing pupation chambers and spinning cocoons priod to pupation.

Two species of parasites, *Bracon* sp., a gregarious ectoparasite of the larvae and *Spilochalcis* sp. attacking the pupae were reared, the former being quite abundant. For example from one collection at Belem, Brazil, 11 of 30 individuals contained either parasite larvae or cocoons and 3 others were paralysed but eggs had not been laid; from another collection at Paramaribo, Surinam, 20 out of 30 were either parasitised or paralysed.

Cornops longicorne (Bruner) (Acrididae Cyrtacanthacridinae:)

We collected specimens of *Cornops* on *Eichhornia crassipes* in Trinidad, Guyana, Surinam and Brazil; on *E. azurea* in Guyana and Brazil and on *Reussia* in Brazil. Specimens from Surinam and Belem, Brazil, were determined as *Cornops longicorne* by Mr. A. B. Gurney, USDA, Washington, who noted that our specimens seem to differ from *Cornops aquaticum* Bruner in some minor characters, but pointed to the need of a revisionary work in the genus. Silveira-Guido (18) collected *Cornops aquaticum* on *Eichhornia crassipes* and details of the biology of this species have been given by Zolessi (22). Silveira-Guido noted that it fed readily on the epidermis of the leaf and petiole of *E. azurea* and *E. crassipes* attacking these species indiscriminately but was rarely found on *Pontederia* spp.

Eggs are laid within the leaf petiole in a chamber made by the ovipositor of the female. The opening of the chamber is above water level. The elongate yellowish eggs surrounded by a creamy sticky froth are usually laid in two overlapping rows. The remaining upper part of the chamber is filled with the creamy froth which darkens later. The young nymphs feed on the epidermis of the leaf whereas large nymphs and adults eat the other leaf tissue as well and will also feed on the petioles. Detailed feeding tests are necessary to determine the feeding and oviposition preferences and limitations of this species.

Nymphs and possibly adults as well are subject to attack by predaceous spiders and the former by the predatory grasshopper,*Phlugis teres* (DeGeer). Eggs are attacked by the curious weevil, *Ludovix fasciata* Gyll. and also by Hymenopterous egg parasites.

Leptogalumna sp.[2] (Acarina: Oribatidae: Galumnidae)

Specimens collected several years ago at Belem, submitted to the Commonwealth Institute of Entomology, were tentatively identified as a new species of *Leptogalumna* new species. During our survey we found evidence of a very light attack at Georgetown, questionably at New Am-

[2]Now identified as *Orthogalumna terebrantis* Wallwork.

sterdam, Guyana, and heavy attack at Paramaribo, Surinam, and at Belem and Marajo, Brazil. We did not find it on *E. azurea* nor on plants of *Reussia* growing in close proximity to heavily attacked *E. crassipes* at the Museu Goeldi at Belem. The same or a similar species was noted on *Reussia* near Manaus. Silveira-Guido (18) reported that this species also attacked *E. azurea* and *Pontederia cordata.*

This mite makes narrow elongate mines on the leaves; although each tunnel is only a few mm's in length there may be fifty or more tunnels per leaf and hence a high percentage of the leaf tissue may be destroyed. Damage is quite characteristic and not readily confused with that caused by other organisms feeding on *Eichhornia.* We have never observed damage of this type on other species of plants. Similarly, Silveira-Guido noted it only on members of the Pontederiaceae.

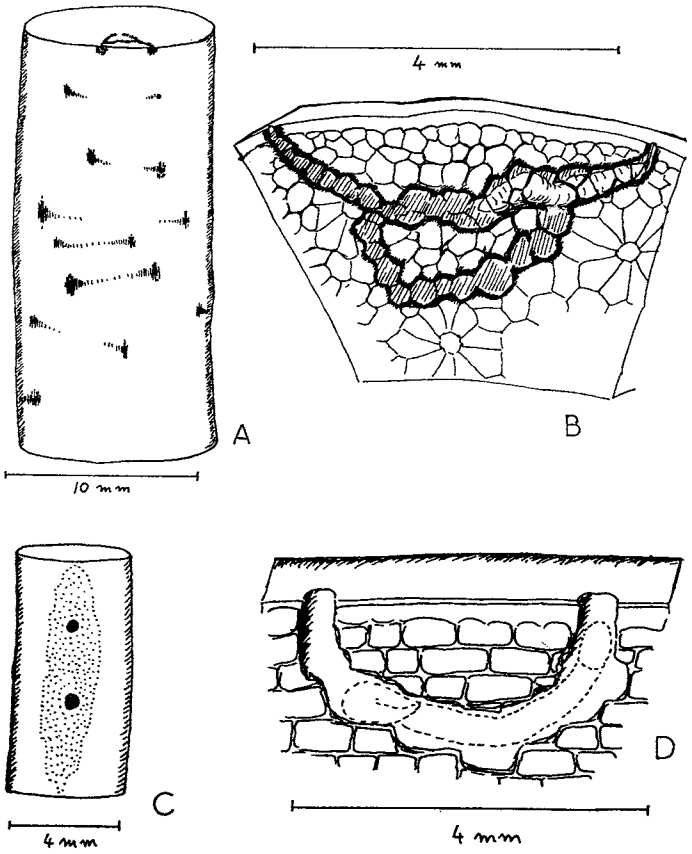

Figure 3.

A. Section of stem of *Eichhornia crassipes* showing the holes leading to the tunnels made by larvae of *Thrypticus* sp. All mines are oriented more or less horizontally.

B. Section of a stem of *Eichhornia crassipes* showing the larva of *Thrypticus* in its tunnel. The tunnel is situated within the aerenchyma tissues; it always has two openings which are from 4 to 10 mm. distant from each other. The larva moves in both directions within the tunnel. Each tunnel is occupied by a single larva. The tissues adjacent to the walls of the tunnel are of a dark, blackish colour, possibly due to initial decay.

C. Section of stem of *Reussia rotundifolia* showing holes made by the larva of a Chironomid. Position of the tunnel vertical. Also found on *Eichhornia crassipes.*

D. Stem cut to show the tunnel made by the Chironomid larva.

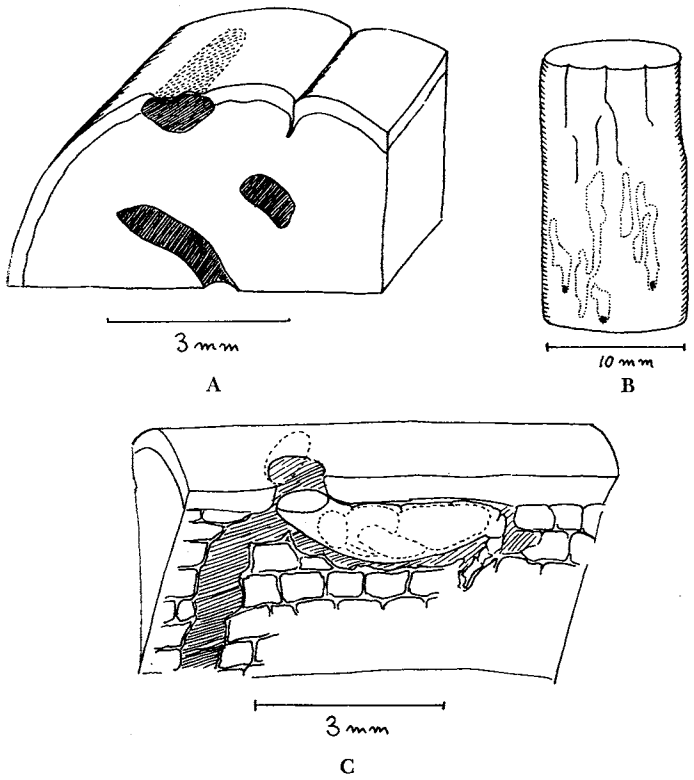

Figure 4.

A. Section of a stem of *Eichhornia azurea* (B-9) showing mines made by *Hydrellia* n. sp. Older mines under the epidermis of the plants are transferred into characteristic scars.

B. Section of stem showing position of mines and scars. Species as in A.

C. Section of stem showing position of the puparium. Species as in A.

Thrypticus sp. (Diptera: Dolichopodidae)

The larvae of *Thrypticus* sp. bore small tunnels in the bases of the petioles below water level. These tunnels are open at either end (Fig. 3a, b). Attacked plants are recognized by the small blackened tunnel orifices; frequently thirty or more occur on one stem. The two openings of each tunnel are usually on the same horizontal plane and the older tunnels are readily traced by the darkening of the tissue of the neighboring cells. We have no information on the host specificity nor on the effect of the attack of this species on the growth rate of *Eichhornia.* At present at least until the identity of the species has been established, priority should be given to the investigation of other species. Stems of *E. crassipes* are also attacked by a Chironomid; typical damage is shown in Fig. 3c and d. Another dipterous leaf-miner *Hydrellia* n. sp. (Ephydridae) was noted on *Eichhornia azurea* at Peixe Boi, Brazil, and Moreru Lake, Guyana. Damage caused by this species is illustrated in Figure 4.

OTHER SPECIES OF INSECTS AND MITES FROM *EICHHORNIA*

Until identification of our specimens have been made and the literature pertaining to these has been reviewed

we are unable to discuss other species in much detail. However, we have prepared the following list with tentative determinations and also included other records of insects, mainly from Silveira-Guido's report, and from the American Continent.

Lepidoptera

Arctitdae—*Palustra silveiraguido* Orfila, *Palustra tenuis* Berg., *Palustra azollae* Berg. Silveira Guido (18) found these species of arctiids on *Eichhornia* in Uruguay. *P. silveiraguido* is apparently restricted to the Pontederiaceae, but prefers *E. azurea* to *E. crassipes*. Both *P. tenuis* and *P. azollas* have been reported from other aquatic weeds but they may be more restricted in feeding habits than earlier reports indicate. We did not encounter arctiid larvae on *Eichhornia* during our survey. Larvae hatching from eggs of an unidentified species from Peixe Boi died without feeding on *Eichhornia*.

Ecpantheria icasia Cram. This species has been collected on *E. crassipes* in Trinidad, but it is known to attack a wide range of other plants as well and hence cannot be considered for release elsewhere.

Noctuidae. We noted damage to *E. crassipes* caused by an undetermined noctuid near Fort Lauderdale, Florida, USA. It may be the following species: *Arzama densa* (Walker). This species has been recorded from *Eichhornia crassipes* and *Pontederia cordata* L. in Louisiana. If restricted to the Pontederaceae it might be considered for introduction to other areas.

Pyraustidae—*Samea multiplicalis* Guenee. At the Museu Goeldi, Belem, *Eichhornia crassipes* growing in a concrete tank was heavily attacked by this species. Unattacked as well as attacked plants had a very unthrifty appearance probably due to the lack of nutrients in the water. We did not encounter this species elsewhere on *Eichhornia* although it is widespread on *Salvinia* and *Pistia* (3). It is probable that the unsuitable conditions rendered them susceptible to attack.

Tortricidae. Silveira-Guido (18) found an aquatic tortricid damaging the roots of *Eichhornia crassipes* in Uruguay. As many as five larvae per plant were found in some instances.

Coleoptera

Silveira-Guido (18) refers to the following species of Coleoptera collected or reared from *Eichhornia* spp. in Uruguay: Scarabeidae—*Dyscinetus sp., Dyscinetus rugifrons, Dyscinetus* sp. nr. *luridus;* Curculionidae—*Hyperodes ater* Boh., Bagoini, and *Ludovix fasciatus* Gyll (now known to attack *Cornops* eggs); Carabidae, attacking flowers of *E. crassipes* and other Pontederiaceae in Uurguay. During our survey we noted damage to flowers by a carabid at Manaus. Occasionally we collected dynastid adults within the stems of *E. crassipes* both in Trinidad and Brazil.

Orthoptera

Gryllidae—*Argizala hebardi* (Rehn). Silveira-Guido (18) reported damage by this species to the roots of *E. crassipes* in Uruguay. Damage to the stem caused by oviposition punctures was also noted. During our survey we collected crickets on *E. crassipes* and noted eggs laid in the lower section of the leaf petioles.

Tettigoniidae: Listroscelinae—*Phlugis teres* (DeGeer). Although predatory on other insects, this species causes slight damage to the plant while inserting its eggs into the stem.

Tettigoniidae: Cyrtacanthacridinae—*Tetrantaenia phila* Rehn. In Surinam and Brazil this grasshopper feeds on *E. crassipes* and also oviposits in the leaf petioles. The egg mass is larger, less elongate than that if *Cornops* and the eggs lie with the longitudinal axis almost horizontal whereas those of *Cornops* are more vertical. Eggs of this species are also attacked by *Ludovix*.

Tettigoniidae: Cantantopinae — *Opshomala marshalli* (Brunner). This species is common on *E. crassipes* in Trinidad, but probably feeds as readily on grasses or other vegetation.

Tettigoniidae. Adults of this large species, as yet the genera and species is not identified, are not uncommon on *E. crassipes* in South America and eggs are either inserted into plant tissue or between two tightly oppressed stems.

Blattaria

Blattidae. Adults of a blattid were observed as they attacked flowers of *E. crassipes* at Belem, Brazil.

Hemiptera

Pentatomidae—*Macocephala acuminata* Dallas. In *Uruguay* (18), this species attacks the roots, but as it has been recorded as a pest of rice it is not suitable for biological control.

Miridae. At Belem, we noted heavy attacks of a mirid on *E. crassipes* at the Museu Goeldi. Heaviest attack was noted to plants growing under unfavourable conditions.

Cicadellidae. Reported from Uruguay (18). *Poecilloscarta victina* Fr. In Uruguay, this species feeds on *Eichhornia* spp. (*azurea* and *crassipes*) and eggs are imbedded in the petioles. Specimens of another cicadellid were present in Guyana, Surinam and Brazil on *E. crassipes* and *E. azurea*.

Dictyopharidae—*Taosa inexacta* Walk. This large green "leaf hopper" is common on *E. crassipes* in Trinidad. Eggs are inserted in the leaf petioles and both the nymphs, bluish-grey in color and the adults feed on the stem. The same or a closely related species was found on *E. crassipes* in Surinam and Brazil. A related species in which the nymphs are covered with a white-waxy exudate was reared from *Reussia* at Belem.

Coccidae. Colonies of pseudococcids within *Acigona* tunnels and occasionally on the stems of *E. crassipes* were collected at Paramaribo, Surinam. Occasionally individuals of *Saissetia* and of *Diaspine* scales occur on the leaves of *E. crassipes*.

Diptera

Ephydridae—*Hydrellia* sp. Reported to be common in *E. crasipes* in Uruguay (18). We reared *Hydrellia* n. sp. from *E. azurea* at Piexe Boi, Brazil and noted similar damage to this species at Moreru Lake, Guyana.

Chloropidae—*Eugaurax* n. sp. We reared this species from stems of *E. crassipes* at Georgetown, Guyana, and Brokopondo Lake, Surinam and from *E. paniculata* from Georgetown.

Chironomidae. We found species of this family in stems of *E. crassipes* in Surinam and Brazil. From material collected at Belem, *Chironomus falvipilus* Rempel was reared. Silveira-Guido also mentions an undetermined species of this family.

Acarina

Tetranychidae—*Tetranychus telarius.* Silveira-Guido (18) reported the occurrence of a tetranychid on *E. crassipes* in Uruguay. *Tetranychus* sp. We encountered tetranchids frequently in Guyana, Surinam and Brazil, and occasionally high concentrations caused severe discoloration and drying of the leaves. A colony collected on *E. crassipes* in Guyana was offered a choice of *Ixora, Hibiscus,* banana, breadfruit and rose leaves. Adults and nymphs transferred readily to *Hibiscus* and to rose. Eggs were laid on *Hibiscus* and the emerging nymphs fed readily, indicating that the species in not obligatorily restricted to *E. crassipes.*

We collected two species of coccinellids, one of them *Coleomegilla maculata,* attacking this tetranychid.

Eriophyidae. Silveira-Guido reported an undetermined Eriophid from *E. crassipes* in Uruguay (18).

DISCUSSION AND RECOMMENDATIONS

Although our survey was of relatively short duration, we encountered several species of insects and mites which cause significant damage and warrant further studies. It cannot be claimed with any certainty that the complex of insects and mites occurring in northern South America does effectively limit the rate of growth, reproduction and spread of *E. crassipes.* However, there is no doubt that heavy attack by one or more of these species can and does destroy individual plants and localized groups of plants of *E. crassipes.*

There is some indication that natural enemies may at times play a significant role in reducing the level of attack of at least some of the phytophages.

Investigations have not proceeded adequately to enable us to recommend the introduction and release of any of the species into areas outside the geographic boundaries where they now occur. Certain of the species will be viewed by some workers with considerable suspicion because of their affinities to pests of economic importance. For example, in addition to *Acigona* the Crambini contains the genera *Chilo, Diatraea* and *Xubida* of which one or more species are pests of graminaceous crops, such as sugarcane and rice. It is significant to note, however, that in Guyana, *Acigona ignitalis* occurs on *E. crassipes* in transport canals lined on either side by sugarcane. Although stalk borers of sugarcane have been collected intensively from time to time over the past forty years, *A. ignitalis* has never been recorded from cane. Similarily, it has never been reported from rice grown in close proximity in Guyana nor Surinam. Similarily species of other genera of the Bagoini related to *Neochetina* have been reported as serious pests of rice: e.g. *Lissorhoptrus* in both South and North America (1, 11), *Neobagous* and *Hydrotimetes* sp. in Brazil (1) and *Hydronomus* in Soviet Central Asia (16). Despite fairly intensive research on rice weevils *Neochetina* has never been reported from rice. It is also encouraging to note that *Cyrtobagous singularis* Hust., another bagoine weevil has been studied in detail and feeding tests indicate that it is highly host-specific to *Salvinia* spp. (3). Since host specificity tests are a prerequisite to the introduction of *Eichhornia* insects, it is encouraging that the species considered to be of most importance have not been recorded from economic plants frequently growing in close proximity.

Several oribatids are known to be vectors of tapeworms. Some of these belong to the genus *Galumna* and hence the possibility that *Leptogalumna* might also be a potential vector should be investigated.

Our attempts to determine whether *Eichhornia* growing in certain types of habitats was less prone to attack than in others were rather inconclusive. Although it is clear that isolated plants growing in small ponds and tanks frequently have a smaller complex of natural enemies, this is the result of isolation rather than immunity to attack. The exploitation by *E. crassipes* of new areas is frequently either by seeds or by small healthy plants, and a lengthy internal may occur before insects arrive by either active or passive means.

Control measures in the area may also influence the abundance of insects attacking *Eichhornia.* In Guyana, where the drainage and transport canals are cleared mechanically once or twice a year, a rich complex of natural enemies remains. On the Brokopondo Lake, where an intensive chemical program had been undertaken for the control of *Eichhornia* the associated fauna was very meager. *Acigona ignitalis* and *Leptogalumna* for example, although present in the coastal areas near Paramaribo, were not found on the Brokopondo Lake; whether it has never been present or whether it has been eliminated by the spray program could not be determined. We do not hold that control with herbicides and biological control are incompatible. It is possible that the introduction of insects into a new area may never achieve outright control. However, should sufficient damage be caused to reduce the rate of growth and spread to the point where herbicides need be applied only half as frequently, a tremendous saving would still be accomplished. If this were achieved it might then be necessary to alter a herbicidal program to leave strips or plots of unsprayed plants to provide a reservoir of insects to cope with regrowth. This is perhaps anticipating the future prematurely.

SUMMARY

The species which we consider to be most promising are (1) the weevil, *Neochetina bruchi*; (2) the lepidopterous stem borers, *Acigona ignitalis* and *Epipagis albiguttalis,* the aquatic grasshopper,*Cornops longicorne* and the mite *Leptogalumna* sp. We can perhaps add to this list, others reported by Silveira-Guido e.g. *Palustra* spp. and possibly the noctuid, *Arzama densa* reported from Louisiana, U.S.A.

For the immediate future, life history studies and host specificity tests of *Acigona, Epipagis* and *Cornops,* the three species present in Trinidad will be undertaken. Studies on *Neochetina* and *Leptogalumna* conducted by Dr. D. Perkins, USDA, are underway in Argentina and results of his studies will be applicable to our work. It is also proposed to continue with exploratory surveys on the American mainland and in certain of the West Indies to obtain additional information on the complex of natural enemies of *Eichhornia* and factors influencing their abundance.

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