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Effects of Pesticides on the Arthropod Community in the Agricultural Areas near the Everglades National Park

Divina M. Amalin[1*], Jorge E. Peña[2], Rita Duncan[2], John Leavengood[3], and Suzanne Koptur[4]

[1]*University of Florida c/o USDA, ARS, SHRS, 13601 Old Cutler Road, Building #22, Miami, FL 33158*

[2]*TREC–IFAS, University of Florida, 18905 SW 280 Street, Homestead, FL 33031*

[3]*Division of Plant Industry, FDACS, 1911 SW 34 Street, Gainesville, FL 32608*

[4]*Florida International University, University Park Campus, Department of Biology, 11200 SW 8 Street, Miami, FL 33199*

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We investigated the effects of pesticides on the arthropod community in the agricultural areas near the Everglades National Park (ENP). Sampling of arthropods was done using visual observation, destructive sampling, pitfall trap and sweeping methods in two successive years, 2000 and 2001, in a field planted with native ornamental plants, which are also commercially used for landscaping. The field was divided into two areas: sprayed and non-sprayed. Overall results showed that more arthropod taxa were present in the non-sprayed area than in the sprayed area. Likewise, greater arthropod diversity was calculated in the non-sprayed area than in the sprayed area. These findings suggest that chemical application in the agricultural areas near the park should be used sparingly and wisely (if chemicals cannot be avoided) to maintain the natural balance in the arthropod community existing near the Everglades National Park.

The Everglades National Park encompasses more than 600,000 ha (1.5 million acres) and is considered the only subtropical wilderness in the continental United States. The Park supports a wide range of diverse and functionally important arthropod communities (Pascarella et al., 2001; Perez, 2004). Many of these arthropod species have not yet been described and their role in the natural habitats near the agricultural areas in south Florida is also not known. Arthropods could be a useful tool in characterization of protected natural areas due to their diversity and ecological role in natural ecosystems. Thus, the steady maintenance of the diversity of the arthropod communities is vital to the sustainability of the ecosystem surrounding the Everglades National Park.

The Everglades National Park is surrounded by areas dedicated to agricultural enterprises as well as urban dwellings. The development of agriculture in the Everglades is one of the human-induced factors that contribute to the alteration of natural functions of the Everglades National Park (West and Allen, 1999). To maintain a balance between the economically important agricultural sector and environmentally sensitive areas that are found in the Park, agricultural technologies should be adopted that will benefit natural ecosystems, the general public, and producers. Biodiversity is a measurement of ecological complexity, and is expected to be higher in less disturbed ecosystems; overall, biodiversity is highly threatened by agriculture (Amman, 2005). Agricultural intensification (i.e., use of pesticides) is significantly correlated to reduction in biodiversity at various taxonomic levels. For instance, a review of studies on arthropod diversity in agricultural landscapes found species biodiversity to be higher in less intensely cultivated habitats (Amman, 2005; Deuelli et al., 1999; Koptur and Peña, unpublished data). There is an urgent need to transform agricultural pest control practices, so that agriculture can assist, rather than inhibit, the recovery of ecosystems in the Everglades National Park. The development and implementation of cost-competitive and sustainable farming system, using non-chemical pest control measures, could serve as a model for ecosystem restoration. Furthermore, the implementation of such a system, would demonstrate that agriculture and natural ecosystems could coexist without mutual detriment.

The objective of this study was to evaluate arthropod communities in a biological and in a chemical plant pest system. Our goal is to promote the conservation of existing natural biological control agents through major reduction in pesticide use by comparing the diversity of arthropods in the two pest management strategies presented in this paper.

Materials and Methods

Study site and test plants. Our study site was established in the Frog Pond, an area adjacent to the eastern boundaries of the Everglades National Park (approximate GPS coordinates: lat. 25.362991 and long. –80.578545). An uncultivated area (approximately 2 ha of marl-rockdale soil located in the northwestern flood-prone area of the Frog Pond) was disked and 0.5-m-wide raised beds were produced at 4-m intervals in between. The field was divided into two areas designated as sprayed and non-sprayed

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*Corresponding author; email: dmam@ufl.edu; phone: (305) 969-8701

areas. Plant species included in the study were laurel oak, *Quercus laurifolia* Michx. (Fagaceae); gumbo limbo, *Bursera simaruba* (Linnaeus) Sarg. (Burseraceae); green buttonwood, *Conocarpus erectus* Linnaeus (Combretaceae); silver buttonwood, *C. erectus* var. *sericeae* (Combretaceae); and the state tree of Florida, sabal palm, *Sabal palmetto* (Walter) Lodd. Ex Schult. & Schult. f. (Arecaceae). The plant species were selected because of their popularity in the nursery trade and potential marketability. Forty-five seedlings per plant species (grown in 3-gal containers) were removed from the individual pots and planted singly in the beds every 3 m by plant species in the following order: gumbo limbo, laurel oak, silver buttonwood, green buttonwood, and sabal palm for both sprayed and non-sprayed areas.

Treatments. There were no agrichemicals used in the non-sprayed area except a single application of N–P–K at time of planting to facilitate plant establishment on the nutrient deprived marl-rockdale soil. In the sprayed area, traditional agricultural practices were followed such as application of agrichemicals. The two areas were separated by 8 m and each had a refuge section of 4 m around the planting area. The refuge sections were not treated with any pesticides. Weed control in the non-sprayed area was done by a single application of mulch at the start of the project and portable weeding machine four times throughout the study period; in the sprayed area it consisted of a total of five applications of 2.5 gal per acre of the systemic, broad spectrum herbicide, Roundup®. To facilitate plant establishment on the nutrient deprived Rockdale soil, a single application of 10N–52P–8K (1 gal per tree) was applied to both areas at the time of planting (16 June 1999). Additionally, the non-sprayed area received organic compost (Milorganite, 6N–2P–0K) three times throughout the study period (7 July 1999, 25 Jan. 2000, and 4 Apr. 2001); trees in the sprayed area received two additional fertilizer treatments with 8N–3P–9K ratio (25 Aug. 2000 and 9 Feb. 2001). Pesticides were applied in the sprayed area as needed for pests found following the local growers practices. There were a total of eleven pesticide applications in the sprayed area throughout the study period as follows: Admire 2 flowable insecticide applied one time (0.33 lb a.i. per acre) on 25 May 2000; Dipel® DF applied one time (1 lb a.i. per acre) on 30 Aug. 1999; Ethion 4EC applied three times (2.5 lbs a.i. per acre) on 8 Mar. 2000, 11 Jan. 2001, and 6 Apr. 2001; Sevin ATS applied five times (5 lbs a.i. per acre) on 30 Aug. 1999, 9 Feb. 2000, 19 Apr. 2000, 15 Feb. 2001 and 1 June 2001; and Provado 1.6F applied one time (0.04 lb a.i. per acre) on 21 Mar. 2001.

Data collection. Four sampling methods were used to quantify arthropod communities in the sprayed and non-sprayed areas and in refuge sections adjacent to both areas. These methods were visual observations, destructive sampling, pitfall traps, and sweep netting.

1. Visual observation: five trees chosen at random were inspected for arthropod settlers on the tree. Observations were done by walking around the tree for one minute and recording all arthropods that were settlers on the tree. Transient arthropods were not included in the count. Hand lenses (10X) were used to look for tiny settlers (e.g., mites and early instars).

2. Destructive sampling: five shoots or palm fronds were collected from each of the same trees as above and brought to the laboratory, where they were checked under a dissecting microscope for arthropods.

3. Pitfall traps: five traps per area and five in the adjacent refuge section to each of these areas (total of 20 traps) were randomly set to determine the presence of soil dwelling arthropods. Samples were processed in the laboratory and specimens were identified to family level using taxonomic keys.

4. Sweeping method: sweep nets were used to sample between the rows of trees in both sprayed and non-sprayed areas (and their respective refuge sections). We used pendulum sweeping, repeated 10 times across the entire length of each row where pitfall traps were located. All specimens in the net were collected at the end of each row and brought back to the laboratory for identification.

For all collecting methods, arthropods observed or collected were counted and recorded for data analysis.

Arthropod identification. Once arthropod specimens were recorded, samples were processed in the laboratory and specimens were identified at least to family level using taxonomic keys. Spider identification was done using the keys and description of Kaston (1978). Insects and other arthropods were identified by John Leavengood (DPI, Gainesville). Representative specimens of all identified species are deposited in the arthropod collection of TREC–IFAS, University of Florida, Homestead.

Data analyses. Mean abundance was computed using total number of individuals collected per family rather than species abundance since few specimens were identified to the species level. Family diversity was calculated using these abundance data following Simpson's diversity index (D) (Krebs, 1989):

$$D = 1/\sum (pi)^2$$

where D = Simpson's diversity index; and *pi* = proportion of individuals in the family.

Results

Visual observation. A higher number of predators in the families Phytoseiidae and Coccinellidae were collected from the non-sprayed area than from the sprayed area (Fig. 1). Likewise, higher numbers of predatory spiders belonging to the orb weaving, hunting, and space web guilds were collected from all plants in the non-sprayed area than in the sprayed area (Fig. 1).

Destructive sampling. Hervibores collected from the foliage were represented by the families Aphididae, Coccidae, Diaspididae, Tetranichydae, Tenuipalpidae, Tydeidae, Eriophyidae, and other Lepidoptera. No differences were observed in the two areas for the families Aphididae, Coccidae and Tenuipalpidae; but more Diaspididae, Eriophyidae and Lepidoptera larvae were observed in the non-sprayed area than in the sprayed area (Fig. 2). Families Tetranychidae and Tydeidae were in higher number in the sprayed area than in the non-sprayed area (Fig. 2).

Some biological control activities were observed in both areas (Table 1). Numbers of parasitized Aphididae and Coccidae were similar between the two areas but numbers of Phytoseiidae were higher in the non-sprayed area than in the sprayed area. The plant species with the highest number of phytoseiid predators was *C. erectus* var. *sericeus,* representing 80% of the sample. The numbers of Tetranychidae were higher in *C. erectus* than in the other plant species.

Comparison of abundance and diversity between sprayed and non-sprayed areas using sweeping and pitfall methods. More arthropods were collected in the year 2000 than 2001 by both sweeping and pitfall methods. Using the sweeping method, a total of 48 families belonging to 11 orders were collected in 2000 (Table 2); whereas in 2001, only 30 families in 9 orders were collected (Table 3). On the other hand, a total of 94 families belonging to 18 orders and 61 families belonging to 14 orders were identified using the pitfall trap collection in 2000 (Table 4)

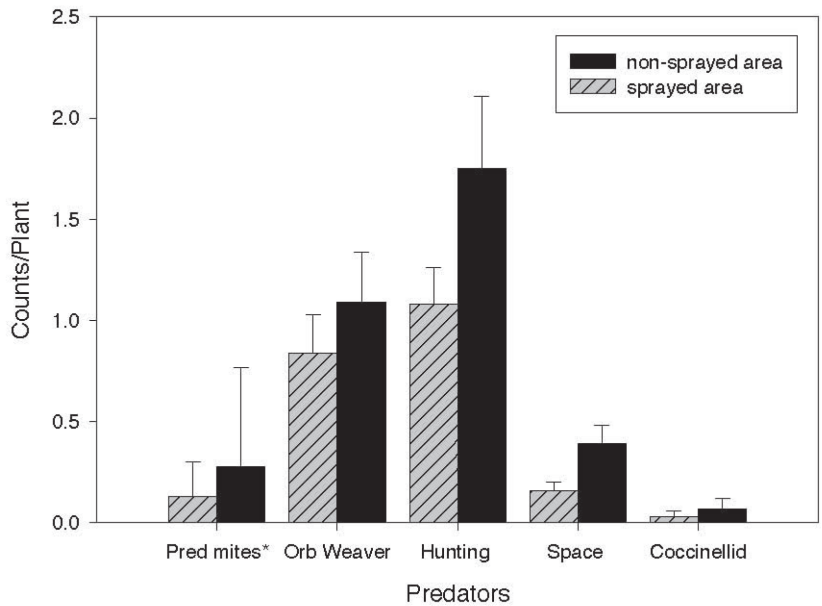

Fig. 1. Mean numbers of predators alive per plant in the non-sprayed and sprayed areas. (Note: Pred mites = predatory mites alive per shoot).

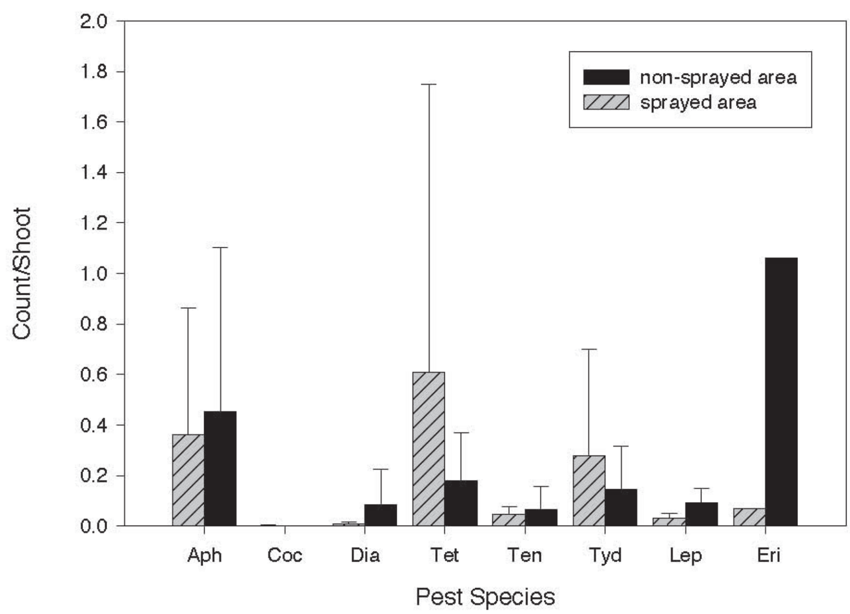

Fig. 2. Mean number of herbivores alive per shoot in the non-sprayed and sprayed areas.
(Note: Lepidoptera larvae/plant; Aph = Aphididae, Coc = Coccidae, Dia = Diaspididae, Tet = Tetranychidae, Ten = Tenuipalpidae, Tyd = Tydeidae, Lep = Lepidoptera larvae, Eri = Eriophyidae).

and 2001 (Table 5), respectively. The overall abundance of taxa varied between the two areas and sampling years and was higher in the non-sprayed area than in the sprayed area. Both years, total arthropod count was higher in the non-sprayed area than in the sprayed area during most of the monthly sampling periods either by sweeping or pitfall methods (Fig. 3). Similar trends were observed in the refuge sections, where the total arthropod count was higher in the refuge section adjacent to non-sprayed than in the refuge section adjacent to the sprayed area using either sweeping or pitfall methods (Fig. 3).

During 2000, the families Formicidae and Chloropidae numerically dominated the class Insecta collected from the pitfall traps, while the family Lycosidae dominated the order Aranea collected from the pitfall traps in both sprayed and non-sprayed areas. A

Table 1. Biological control activities recorded from non-sprayed and sprayed areas.

Arthropod species	Status	Mean abundance Non-sprayed	Sprayed
Aphids	Alive	0.452	0.362
	Parasitized	0.005	0.007
Philapedra	Alive	0.001	0.002
	Parasitized	0.000	0.000
Phytoseiid	Predator	0.276	0.130
Tetranychid	Plant mite	0.449	2.636

*Data from *C. erectus* var. *sericeus*

similar trend was observed in 2001. Both years, when the sweeping method was used, the families Coccinellidae and Lygaeidae were more frequent in the class Insecta, while the family Araneidae was more frequent in the order Aranea. Among the beneficial arthropods, the family Formicidae was mainly represented by *Solenopsis invicta* Buren (= *S. geminata)*. The Coccinellidae included *Diomus* sp., *Cycloneda sanguinea* Linnaeus, *Scymnus* sp., and *Hippodamia convergens* Guerin-Meneville. Among the insect herbivores, the family Lygaeidae was represented by *Blisspus* sp., *Pseudopachybrachius* sp., *Neopamera albocincta* (Barber); species for family Chloropidae and those in the family Araneidae were not determined.

A higher number of spider in the families Araneidae and Thomisidae were collected using the sweeping method in the non-sprayed area than in the sprayed area during most of the monthly sampling periods. An exception to this trend occurred from May to July 2000, when more individuals were collected in the sprayed area. At the end of the sampling periods during the year 2000, the number of spiders within the family Thomisidae was greater in the non-sprayed area than in the sprayed area. The families Chrysomelidae and Coccinellidae were more abundant in the non-sprayed area than in the sprayed area throughout the sampling periods. In the order Heteroptera, the family Lygaeidae was more abundant in the sprayed area during the first month of sampling, and then more were recorded in the non-sprayed area than in sprayed area in the succeeding sampling periods. No individuals were collected for the families Miridae and Aphididae in the first 2 months of collection. Succeeding samplings showed greater abundance in the non-sprayed area compared to the sprayed area. The family Formicidae dominated the order Hymenoptera, and was more numerous in the non-sprayed area than in the sprayed area.

In the initial pitfall trap samples, there were more spiders in the family Lycosidae in the sprayed area than in the non-sprayed area; however, the reverse was observed in the succeeding sampling periods. Several families in the order Coleoptera were collected throughout the sampling periods with relatively high abundance. In the first sampling period (Jan. 2000), the families Carabidae, Coccinellidae, Staphylinidae, and Tenebrionidae occurred in higher numbers in the sprayed area than in the non-sprayed area, and vice versa in the succeeding sampling periods.

Several families in the order Hymenoptera were collected in the pitfall traps throughout the sampling periods. In general, more individuals in the families Pompilidae, Scelionidae, Halictidae, Mutilidae, Apidae, and Eulophidae, were sampled in the non-sprayed area than in the sprayed area; however, no difference was observed for the family Formicidae.

In the order Orthoptera, more individuals were collected in the non-sprayed area than the sprayed area, especially from the second sampling period (Feb. 2000) and onward for families Acrididae and Gryllidae.

Several families in the order Diptera occurred throughout the sampling period. In the first sampling period (Jan. 2000), there were no differences between non-sprayed and sprayed areas in

Table 2. Abundance of arthropods collected in 2000 by sweeping in non-sprayed and sprayed areas.

Order	Family	Non-sprayed area Abundance (mean ± SE)	Sprayed area Abundance (mean ± SE)
Coleoptera	Bruchidae	0.00±0.00	1.08±0.16
	Buprestidae	1.08±0.18	1.08±0.18
	Carabidae	0.00±0.00	1.08±0.18
	Chrysomelidae	2.16±0.37	1.08±0.18
	Coccinellidae	10.22±2.33	4.52±0.88
	Curculionidae	3.41±0.64	0.00±0.00
	Languriidae	1.31±0.31	0.00±0.00
	Latridiidae	4.64±0.97	0.00±0.00
	Mordeliidae	2.29±0.65	0.00±0.00
	Phalacridae	0.00±0.00	1.08±0.16
Collembola	Entomobryidae	1.29±0.40	0.00±0.00
Diptera	Ceratopogonidae	1.08±0.18	1.08±0.18
	Chloropidae	3.45±1.02	1.08±0.18
	Dolichopodida	3.25±0.56	1.20±0.45
	Drosophilidae	1.15±0.33	0.00±0.00
	Muscidae	2.45±0.60	1.08±0.18
	Sarcophagidae	0.00±0.00	1.08±0.18
	Sciaridae	1.08±0.18	1.08±0.18
	Syrphidae	1.08±0.18	0.00±0.00
	Tipulidae	2.16±0.37	0.00±0.00
Heteroptera	Coreidae	1.08±0.18	0.00±0.00
	Lygaeidae	8.83±2.50	2.25±0.53
	Miridae	5.42±1.48	3.05±0.87
	Nysidae	0.00±0.00	1.46±0.27
	Pentatomidae	3.33±0.60	3.27±0.56
	Reduviidae	2.16±0.37	1.08±0.18
	Scutelleridae	1.08±0.18	0.00±0.00
	Thyreocoridae	2.23±0.51	0.00±0.00
Homoptera	Aphididae	6.90±1.68	1.08±0.18
	Cicadellidae	1.08±0.18	0.00±0.00
	Issidae	1.23±0.33	0.00±0.00
	Psyllidae	1.08±0.18	0.00±0.00
Hymenoptera	Eulophidae	1.08±0.18	1.10±0.21
	Formicidae	5.48±1.07	6.19±2.02
	Sphecidae	0.00±0.00	1.08±0.18
Lepidoptera	Gelechiidae	1.08±0.18	0.00±0.00
	Noctuidae	3.31±0.69	0.00±0.00
	Pyralidae	1.16±0.23	1.08±0.18
Mantodea	Mantidae	0.00±0.00	1.08±0.18
Orthoptera	Acrididae	2.16±0.37	2.23±0.51
	Tetrigidae	0.00±0.00	1.10±0.21
	Tettigonidae	2.16±0.37	0.00±0.00
	Tridactylidae	1.08±0.18	0.00±0.00
Araneae	Araneidae	10.38±3.75	9.93±2.79
	Lycosidae	1.20±0.44	2.76±1.24
	Salticidae	4.88±1.38	6.84±1.67
	Thomisidae	5.58±1.52	4.87±0.97
Miscellaneous	(1 order)	0.00±0.00	1.25±0.23

Notes: Pendulum sweeping, repeated 10 times across the entire length of each row.

Table 3. Abundance of arthropods collected by sweeping in 2001 in the non-sprayed and sprayed areas.

Order	Family	Non-sprayed area Abundance (mean ± SE)	Sprayed area Abundance (mean ± SE)
Coleoptera	Chrysomelidae	5.75±1.42	2.24±0.45
	Coccinellidae	7.75±1.62	2.32±0.60
	Languriidae	1.08±0.18	0.00±0.00
	Mordeliidae	2.16±0.37	0.00±0.00
	Staphylinidae	1.10±0.21	0.00±0.00
Diptera	Ceratopogonidae	1.08±0.18	0.00±0.00
	Chironomidae	1.13±0.24	0.00±0.00
	Choloropidae	1.08±0.18	0.00±0.00
	Muscidae	1.08±0.18	0.00±0.00
	Sciaridae	0.00±0.00	1.14±0.24
	Sepsidae	1.16±0.23	0.00±0.00
Heteroptera	Lygaeidae	1.10±0.21	1.27±0.24
	Miridae	7.16±1.27	0.00±0.00
	Pentatomidae	2.31±0.52	0.00±0.00
	Scutelleridae	1.08±0.18	0.00±0.00
	Thyreocoridae	1.08±0.18	0.00±0.00
Homoptera	Aphididae	2.41±0.52	1.43±0.51
	Cicadellidae	0.00±0.00	1.14±0.24
	Delphacidae	1.08±0.18	0.00±0.00
	Membracidae	1.08±0.18	0.00±0.00
Hymenoptera	Formicidae	2.37±0.54	2.82±1.0
Lepidoptera	Gelechiidae	1.10±0.21	0.00±0.00
Orthoptera	Acrididae	2.19±0.39	0.00±0.00
Thysanoptera	Unidentified	2.26±0.55	0.00±0.00
Araneae	Araneidae	9.92±2.27	6.23±1.63
	Salticidae	5.52±0.80	3.66±0.84
	Thomisidae	6.38±1.44	3.93±1.11
	Unidentified	1.08±0.18	1.00±0.00
Miscellaneous	(2 orders)	1.28±0.43	4.70±2.56

Notes: Pendulum sweeping, repeated 10 times across the entire length of each row.

Table 4. Abundance of arthropods collected by pitfall in 2000 in the non-sprayed and sprayed areas.

Order	Family	Non-sprayed area Abundance (mean ± SE)	Sprayed area Abundance (mean ± SE)
Coleoptera	Alleculidae	1.08±0.18	0.00±0.00
	Anthicidae	2.16±0.37	1.08±0.18
	Brenthidae	0.00±0.00	1.08±0.18
	Carabidae	7.64±1.44	6.56±1.25
	Chrysomelidae	13.31±2.27	2.16±0.37
	Coccinellidae	4.33±0.74	4.48±0.92
	Curculionidae	0.00±0.00	3.33±0.60
	Elateridae	2.16±0.37	1.16±0.23
	Languriidae	1.08±0.18	0.00±0.00
	Latridiidae	1.20±0.44	1.15±0.33
	Mordeliidae	1.08±0.18	1.08±0.18
	Nitidulidae	1.0±0.188	1.08±0.18
	Scarabaeidae	9.93±3.61	8.92±3.33
	Scydmaenidae	0.00±0.00	1.08±0.18
	Silvanidae	1.08±0.18	0.00±0.00
	Staphylinidae	7.79±1.60	8.40±3.05
	Tenebrionidae	6.56±1.25	4.56±0.87
	Trogidae	0.00±0.00	1.08±0.18
Collembola	Entomobryidae	4.50±2.02	2.55±1.22
	Isotomidae	1.15±0.33	0.00±0.00
	Poduridae	1.33±0.74	1.20±0.45
Dermaptera	Labiduridae	2.25±0.41	6.99±0.72
	Unidentified	2.16±0.37	0.00±0.00
Diptera	Agromyzidae	2.23±0.51	0.00±0.00
	Anthomyiidae	7.43±1.94	4.19±1.23
	Chironomidae	2.28±0.63	0.00±0.00
	Chloropidae	24.33±10.25	26.35±19.02
	Dolichopodida	14.86±4.68	10.32±3.43
	Drosophilidae	5.72±1.61	3.39±0.70
	Ephydridae	1.08±0.18	0.00±0.00
	Micropezidae	2.46±0.67	2.16±0.37
	Muscidae	9.48±3.27	6.19±1.95
	Mycetophilidae	12.66±8.13	9.99±5.09
	Otitidae	1.33±0.73	3.46±1.02
	Phoridae	2.35±0.77	5.92±1.59
	Sarcophagidae	1.15±0.33	2.16±0.37
	Sciaridae	0.00±0.00	1.08±0.18
	Sciomyzidae	0.00±0.00	1.08±0.18
	Sphaeroceridae	2.37±0.83	0.00±0.00
	Stratiomyidae	1.08±0.18	0.00±0.00
	Tachinidae	0.00±0.00	1.08±0.18
	Tephritidae	3.36±0.82	7.07±1.68
	Tipulidae	0.00±0.00	1.08±0.18
Heteroptera	Anthocoridae	1.08±0.18	0.00±0.00
	Cydnidae	2.25±0.41	1.08±0.18
	Lygaeidae	8.75±2.41	5.74±2.18
	Miridae	1.15±0.33	0.00±0.00
	Pentatomidae	3.33±0.60	1.08±0.18
	Reduviidae	3.33±0.60	2.15±0.37

Table 4 continued on next page.

Note: Five traps randomly set per plant system (non-sprayed and sprayed areas).

the number of individuals collected for most of the families. However, in the succeeding sampling periods, more individuals were sampled from the non-sprayed area than in the sprayed area for the families Chloropidae, Dolichopodidae, Muscidae, Mycethopilidae, Drosophilidae, and Anthomyiidae. The Chloropidae showed no specific abundance pattern. For other families Entomobryidae (order Collembola), Aphididae (order Homoptera), and Lygaeidae (order Heteroptera), more individuals occurred in the non-sprayed than in the sprayed area starting Mar. 2000 sampling and onwards.

The calculated diversity indices from data collected by sweeping and pitfall methods revealed greater diversity of the arthropod community in the non-sprayed area than in the sprayed area. This was the case both in the main experimental plots and also in their respective refuge sections for both years (Table 6).

Tree growth. Plant height did not differ among trees in the non-sprayed and sprayed areas. However, there was a considerable difference in trunk diameter between plants grown in the sprayed area than those grown non-sprayed area (Fig. 4).

Discussion

The results of our study showed that both visual observation and destructive sampling methods reveal higher numbers of

Table 4. Continued from previous page.

Order	Family	Non-sprayed area Abundance (mean ± SE)	Sprayed area Abundance (mean ± SE)
Homoptera	Aphidiidae	7.72±3.27	4.86±1.75
	Cercopidae	0.00±0.00	1.08±0.18
	Cicadellidae	1.15±0.33	0.00±0.00
	Cixiidae	1.08±0.18	0.00±0.00
	Delphacidae	1.08±0.18	1.08±0.18
	Psyllidae	1.08±0.18	1.08±0.18
Hymenoptera	Anthoporidae	1.08±0.18	0.00±0.00
	Apidae	7.78±2.10	11.46±2.84
	Braconidae	2.23±0.51	0.00±0.00
	Ceraphronidae	2.16±0.37	2.16±0.37
	Diapriidae	0.00±0.00	1.28±0.44
	Eulopidae	6.15±1.76	5.12±1.35
	Eupelmidae	0.00±0.00	2.31±0.52
	Formicidae	32.40±13.95	29.76±16.30
	Halictidae	5.41±0.93	1.08±0.18
	Ichneumonidae	2.16±0.37	3.39±0.74
	Mutilidae	4.33±0.74	1.08±0.18
	Myrmaridae	1.08±0.18	0.00±0.00
	Platygastridae	1.08±0.18	1.19±0.27
	Pompilidae	5.50±0.97	1.08±0.18
	Pteromalidae	1.08±0.18	1.08±0.18
	Scelionidae	8.32±2.43	9.88±2.58
	Sphecidae	2.31±0.52	2.16±0.37
	Vespidae	0.00±0.00	1.08±0.18
Lepidoptera	Danaeidae	0.00±0.00	1.08±0.18
	Hesperiidae	2.16±0.37	0.00±0.00
	Noctuidae	1.08±0.18	0.00±0.00
	Pyralidae	4.79±1.42	3.48±0.74
Neuroptera	Hemerobiidae	0.00±0.00	1.08±0.18
Orthoptera	Acrididae	7.93±1.64	4.41±0.74
	Gryllidae	13.35±2.70	5.41±0.93
	Tetrigidae	2.16±0.37	1.08±0.18
	Tridactylidae	2.16±0.37	1.15±0.33
Thysanoptera	Thripidae	2.16±0.37	0.00±0.00
	Unidentified	1.08±0.18	2.16±0.37
Araneae	Araneidae	13.74±0.18	1.45±0.62
	Lycosidae	14.86±10.31	22.29±5.72
	Salticidae	1.15±0.33	1.08±0.18
	Unidentified	0.00±0.89	2.39±0.88
Miscellaneous	(6 Orders)	6.56±1.25	4.62±1.23

Note: Five traps randomly set per plant system (non-sprayed and sprayed area).

Table 5. Abundance of arthropods collected by pitfall in 2001 in the non-sprayed and sprayed areas

Order	Family	Non-sprayed area Abundance (mean ± SE)	Sprayed area Abundance (mean ± SE)
Blattaria	Blatellidae	1.08±0.18	0.00±0.00
Coleoptera	Anthicidae	1.10±0.21	0.00±0.00
	Brenthidae	1.08±0.18	0.00±0.00
	Carabidae	1.08±0.18	0.00±0.00
	Chrysomelidae	1.10±0.21	0.00±0.00
	Coccinellidae	1.08±0.18	1.16±0.47
	Curculionidae	1.08±0.18	0.00±0.00
	Languriidae	1.08±0.18	0.00±0.00
	Latridiidae	3.25±0.55	1.08±0.18
	Mordeliidae	0.00±0.00	1.08±0.18
	Phalacridae	0.00±0.00	1.08±0.18
	Scarabaeidae	4.14±1.26	2.45±0.87
	Scydmaenidae	1.10±0.21	0.00±0.00
	Silvanidae	1.08±0.18	0.00±0.00
	Staphylinidae	2.16±0.37	1.08±0.18
	Tenebrionidae	3.48±1.04	1.14±0.24
	Trogidae	2.21±0.41	0.00±0.00
Collembola	Entomobryidae	5.06±1.02	7.92±4.15
Diptera	Agromyzidae	1.08±0.18	0.00±0.00
	Ceratopogonidae	1.08±0.18	1.15±0.33
	Chironomidae	1.60±0.89	1.39±0.57
	Chloropidae	5.88±1.90	4.05±1.78
	Dolichopodida	1.16±0.23	0.00±0.00
	Drosophilidae	1.08±0.18	0.00±0.00
	Muscidae	1.15±0.33	1.08±0.18
	Mycetophilidae	3.82±1.35	4.03±0.85
	Phoridae	1.25±0.55	0.00±0.00
	Sarcophagidae	0.00±0.00	1.08±0.18
	Sepsidae	2.16±0.37	1.43±0.44
	Simuliidae	1.08±0.18	1.15±0.33
Heteroptera	Anthocoridae	0.00±0.00	1.08±0.18
	Cydnidae	4.47±1.22	5.32±1.30
	Lygaeidae	5.52±0.99	5.43±1.03
	Miridae	0.00±0.00	1.08±0.18
	Pentatomidae	2.64±0.87	3.50±0.64
	Reduviidae	4.35±0.76	0.00±0.00
	Thyreocoridae	1.10±0.21	0.00±0.00
Homoptera	Aphididae	8.60±3.50	7.20±2.81
	Delphacidae	1.08±0.18	0.00±0.00

Table 5 continued on next page.

Note: Five traps randomly set per plant system (non-sprayed and sprayed areas)

carnivorous arthropods (such as predaceous spiders, predatory mites, and lady bird beetles) on plants in the non-sprayed area compared to the sprayed area. Results for herbivorous arthropods were split, with a higher number of spider mites and chalk mites in the sprayed area and a higher number of armored scales, eriophyid mites, and butterfly and moth larvae in the non-sprayed area. Moreover, the sampling results from both pitfall and sweeping methods showed a higher diversity and more abundant arthropod community in the non-sprayed area than in the sprayed area. Our findings seem to indicate that the arthropod community was negatively affected by the pesticide treatments. This finding coincided with other previous studies in different ecological systems showing the impact of chemical sprays on specific arthropod species, group or community (Amalin et al., 2001; Amman, 2005; Goh and Lange, 1989; Hesler et al., 1993; Mansfield et al., 2006; Marquini et al., 2003; Santos et al., 2007; Settle et al., 1996; Woin, 1998). It was evident from the results of our study that for most of the arthropod families there was no considerable difference in their abundance in the non-sprayed area and sprayed area during the first sampling period in 2000; subsequently, a reduction in abundance was observed in the sprayed area during the succeeding sampling periods of 2000 and 2001. This finding seems to indicate that the chemicals applied might not instantly show their negative impact on the arthropod community, but may produce detrimental effects afterwards.

Table 5. Continued from previous page.

Order	Family	Non-sprayed area Abundance (mean ± SE)	Sprayed area Abundance (mean ± SE)
Hymenoptera	Braconidae	1.08±0.00	1.08±0.00
	Ceraphronidae	1.10±0.21	0.00±0.00
	Eulophidae	2.19±0.39	3.25±0.56
	Eupelmidae	0.00±0.00	1.08±0.00
	Formicidae	53.99±22.25	43.08±16.15
	Ichneumonidae	1.08±0.18	0.00±0.00
	Mutilidae	1.08±0.18	0.00±0.00
	Platygastridae	0.00±0.00	2.25±0.41
	Scelionidae	8.20±2.09	5.99±1.51
Orthoptera	Acrididae	0.00±0.00	1.14±0.24
	Gryllidae	1.08±0.18	2.22±0.42
	Tetrigidae	1.08±0.18	0.00±0.00
Thysanoptera	Thripidae	1.08±0.18	0.00±0.00
	Unidentified	3.39±0.70	0.00±0.00
Araneae	Araneidae	9.20±2.58	7.32±2.44
	Lycosidae	12.55±3.83	15.95±5.69
	Salticidae	1.08±0.18	2.36±0.42
	Thomisidae	3.50±1.48	0.00±0.00
Miscellaneous	(4 Orders)	9.21±2.26	8.31±4.15

Note: Five traps randomly set per plant system (non-sprayed and sprayed areas)

The sensitivity of most of the taxa to the chemicals was apparent in both pitfall trap and sweeping catches. The effect of the chemical sprays was even more pronounced in 2001 as evidenced in the abundance and diversity data. The most sensitive among the predators were the coccinellids. A number of studies have shown the sensitivity of coccinellids to chemical sprays, particularly broad spectrum insecticides (Ba M'hamed and Chemseddine, 2002; Iperti, 1999; Santos et al., 2006). Among the pest species, the most sensitive was the family Chrysomelidae followed by Aphididae. It is interesting to note that species within the families Formicidae, and Lycosidae showed little or no sensitivity to the chemicals applied during this study. Several authors have reported that species within the Formicidae could serve as bioindicators of environmental stress by insecticides (Morris et al., 1999; Pereira et al., 2004; Santos et al., 2006). However, we cannot be certain that formicids will serve as bioindicators of environmental stress of insecticides in the Everglades National Park since the information concerning the effect of pesticides over this group in the Park is scarce. Other studies have suggested that formicids can be considered good bioindicators (Kaspari and Majer, 2000). For instance, Santos et al. (2006) could not agree if reduction of ant numbers in an olive grove was caused by chemical sprays or by prey depletion in the tree canopy. Collembola is also documented as a bioindicator of pesticide usage (Frampton, 1994, 1997). Our study also showed the relatively high sensitivity of Collembola to chemical sprays, which could mean that Collembola could

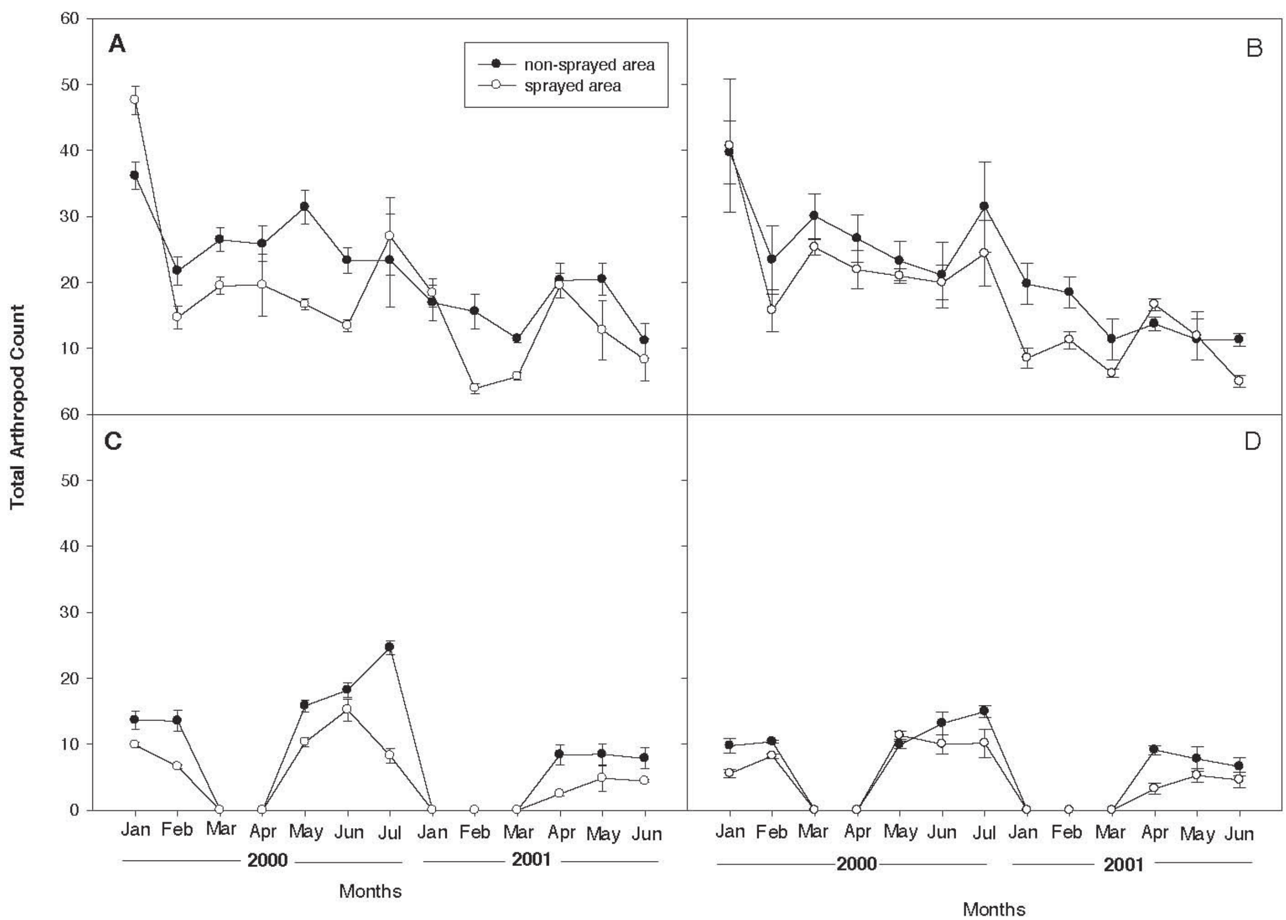

Fig. 3. Comparison of total arthropod counts in 2000 and 2001 between non-sprayed and sprayed areas using different collecting methods in different experimental areas (**A**) pitfall from main plot and (**B**) pitfall from refuge area, (**C**) sweeping from main plot, and (**D**) sweeping from refuge area.

Table 6. Simpson diversity indices of arthropods collected in the non-sprayed and sprayed areas and their respective refuge areas

Year	Collecting method	Experimental area	Simpson diversity index[z] Non-sprayed area	Sprayed area
2000	Pitfall	Main plot	32.34	25.87
		Refuge	33.56	32.81
	Sweeping	Main plot	22.80	16.99
		Refuge	15.18	5.70
2001	Pitfall	Main plot	10.04	9.37
		Refuge	13.90	2.94
	Sweeping	Main plot	14.58	9.35
		Refuge	9.21	8.78

[z]Diversity index was calculated based on the total samples collected.

serve as bioindicators in the Everglades area. However, other studies claimed that there should be caution in using Collembola as bioindicators of insecticidal impacts because they may not properly represent the arthropod community due to their extreme susceptibility to some insecticides (Marquini et al., 2003; Sphar, 1981). The spider Lycosid was also not showing sensitivity to the chemical spray in our study. It was reported by Mansfield et al. (2005) that since lycosids are nocturnal and ground-burrowing they may have been less exposed to diurnal foliage sprays. This may also explain why the Lycosidae in our study showed less sensitivity to the chemical spray than other spiders. Nevertheless, other studies proved that lycosids were still susceptible to insecticides such as the pyrethroid alphamethrin but less so than to other insecticides such as endosulfan (van den Berg et al., 1990). The foliage-dwelling spiders such as Araneidae, Salticidae, and Thomisidae showed sensitivity to the chemical application in our study, which indicates that their being diurnal exposure on the foliage makes them more sensitive to chemical sprays compared to lycosids. It has been documented that there are differences between the susceptibility to pesticide exposure of different spider families (Mansfield et al., 2005). The abundance of Dermapterans, Lepidopterans, Neuropterans, Thysanopterans Blattarians, and Mantodeans was very low on both systems and the impact of the chemical application may be misleading.

Our study demonstrated that the chemicals applied in the sprayed area had a negative effect on the arthropod community as a whole. Therefore, the use of non-selective agrichemicals in the agricultural areas near the Everglades National Park should be minimized if not avoided. Our findings on the sensitivity of certain taxa to chemical sprays can contribute in the identification of bioindicators for environmental stress due to pesticide usage in the Everglades National Park. We further showed in our study that a purely biological system can sustain a very good plant stand since there were no major differences in the quality of plants grown under both non-sprayed and sprayed areas. Therefore, the use of best management practices should be taken into serious consideration in controlling the pests in the agricultural areas near the Everglades National Park to reduce the negative impacts on biodiversity and continuously provide ecological services such as biological control.

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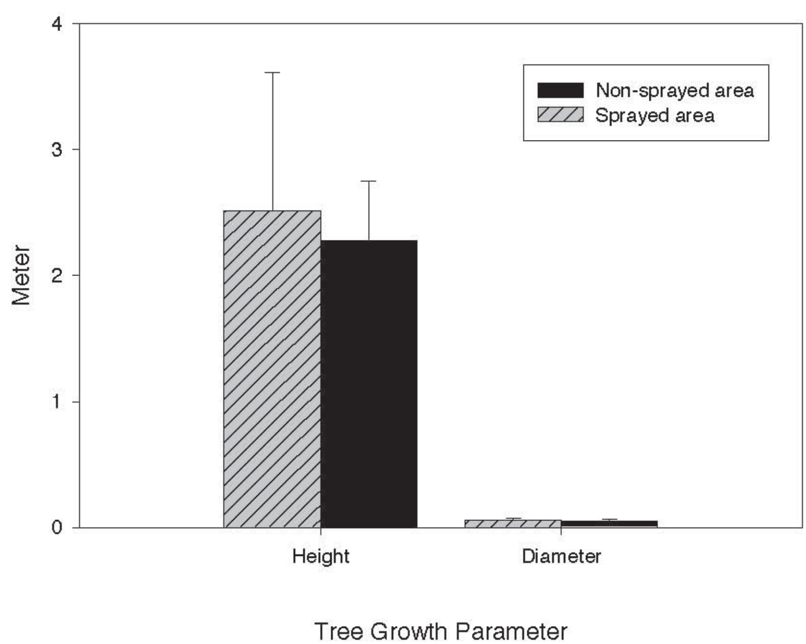

Fig. 4. Comparison in the growth of trees grown under the non-sprayed and sprayed areas.

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