DISTRIBUTION OF PICTURE-WINGED FLIES (DIPTERA: ULIDIIDAE) INFESTING CORN IN FLORIDA

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Abstract

The picture-winged fly *Euxesta stigmatias* Loew (Diptera: Ulidiidae) has been a serious pest of sweet corn (*Zea mays* L.) in Florida since 1930. Several other species in the family are known to infest corn grown in the Caribbean, Central America, and South America. Surveys were conducted throughout Florida to evaluate species richness and distribution of corn-infesting Ulidiidae. Adults were sampled with sweep nets and reared from fly larvae-infested corn ears collected from representative corn fields in 16 and 27 counties in 2007 and 2008, respectively. Four Ulidiidae species were found in corn fields using both sampling techniques. *Euxesta eluta* Loew and *Chaetopsis massyla* (Walker) were found throughout the state on field and sweet corn. *Euxesta stigmatias* was only found in Martin, Miami-Dade, Okeechobee, Palm Beach, and St. Lucie Counties on field and sweet corn. *Euxesta annonae* (F.) was found in sweet corn in Miami-Dade, Okeechobee, and Palm Beach Counties, but field corn was not sampled in these counties. *Euxesta eluta*, *E. stigmatias,* and *C. massyla* were collected from corn throughout the corn reproductive stage. Raising adults from fly larvae-infested ears provided the best method for assessing rates of ear infestation and species richness. Sweep netting did not provide reliable information on the presence or species composition of ulidiid species infestation. We report for the first time *E. annonae* and *E. eluta* as pests of corn in Florida and the USA.

Key Words: *Euxesta annonae, Euxesta eluta, Euxesta stigmatias, Chaetopsis massyla,* maíze

Resumen

La mosca de alas pintadas, *Euxesta stigmatias* Loew (Diptera: Ulidiidae), ha sido una plaga seria de maíz dulce (*Zea mays* L.) en la Florida desde 1930. Varias especies de la familia Ulidiidae son conocidas de infestar maíz sembrado en el Caribe y el Centroamérica y Sudamérica. Se realizaron sondeos por todo la Florida para evaluar la diversidad de especies y distribución de moscas de la familia Ulidiidae que infestan maiz. Se muestrearon los adultos con redes de recolección y criandolos de mazorcas infestadas con larvas de moscas de campos representativos de maiz en 16 y 27 condados en 2007 y 2008, respectivamente. Se encontraron *Euxesta eluta* Loew y *Chaetopsis massyla* (Walker) por todo el estado en maíz de campo y maíz dulce. *Euxesta stigmatias* fue encontrada solamente en los condados de Martin, Miami-Dade, Okeechobee, Palm Beach y St. Lucie sobre maíz de campo y maíz dulce. *Euxesta annonae* (F.) fue encontrada en maíz dulce en los condados de Miami-Dade, Okeechobee y Palm Beach, pero no se muestrearon maíz de campo en estos condados. Se recolectaron *Euxesta eluta*, *E. stigmatias* y *C. massyla* durante toda la etapa reproductiva del maíz. *Euxesta annonae* fue criada de mazorcas solamente de 8 a 21 dias de edad, pero los campos con mazorcas de ≤ 8-dias no fueron muestreados en los condados donde esta especie fue encontrada. El criar los adultos de mazorcas infestadas con larvas de moscas fue el mejor metodo para evaluar la taza de infestacion de las mazorcas y la diversidad de especies. Las recolecciones con redes no dieron un estimado confiable para identificar infestaciones de especies de ulidiidos. Reportamos por primera vez *E. annonae y E. eluta* como plagas de maíz en la Florida y EEUU.

There are 671 species of Ulidiidae worldwide, but less than 10 species in 2 genera are known to damage corn (Allen & Foote 1992; Anonymous 2008c; Goyal et al. 2010; Van Zwaluwenburg 1917). Van Zwaluwenburg (1917) first reported the pest nature of *Euxesta stigmatias* Loew (Diptera: Ulidiidae) (Figs. 1 g, 1h) in Puerto Rico where it damaged up to 100% of untreated corn. It was first discovered damaging corn in Miami, Florida in 1938 (Barber 1939) and had moved north into central Florida by 1951 (Hayslip 1951). This species has become a serious pest of Florida sweet corn (*Zea mays* L.) requiring multiple insecticide applications during the ear stage to maintain a marketable crop (Mossler 2008; Nuessly & Hentz 2004; Seal 1996, 2001; Seal & Jansson 1994). Sweet corn is an important crop in Florida with 22.8% of the total USA fresh market sweet corn production (Anonymous 2009). *Euxesta stigmatias* also has been reported infesting sweet corn in Georgia (Daly & Buntin 2005), Texas (Walter & Wene 1951), California (Fisher 1996), Guatemala (Painter 1955) and Brazil (Franca & Vecchia 1986). The insect deposits its eggs primarily on silks (styles) in the tips of ears. The larvae feed on silks, kernels, and cobs. Bailey (1940) observed disruption of pollination due to larval feeding on silks. Larvae enter through the soft pericarp of milk stage kernels to completely consume the developing embryo and endosperm (Seal & Jansson 1989). App (1938) observed larval feeding on cobs followed by mold development resulting in significant reduction in market value.

Several other ulidiid species are known maize pests in the Caribbean and in the Americas south of Texas (Arce de Hamity 1986; Barbosa et al. 1986; Chittenden 1911; Diaz 1982; Evans & Zambrano 1991; Gossard 1919; Painter 1955; Wyckhuys & O'Neil 2007), but only 1 other species is currently recognized as a pest in the USA. *Chaetopsis massyla* (Walker) (Figs. 1 a, b) was recently determined to be a primary pest of sweet corn in Florida (Goyal et al. 2010). Evidence suggesting the possibility of additional picture-winged species attacking corn in Florida include a picture of *Euxesta eluta* Loew (Diptera: Ulidiidae) (Figs. 1 e, f) on the cover of Hayslip's (1951) paper entitled "Corn silk fly control on sweet corn" misidentified as *E. stigmatias*. Examination of the Ulidiidae collection at the Division of Plant Industry in Gainesville, Florida revealed that *E. eluta* and *E. annonae* (F.) (Diptera: Ulidiidae) (Figs. 1 c, d) have been collected in several Florida counties since at least 1948, but these specimens were not labeled as being collected or reared from corn. These later 2 species are recognized pests of corn in South America (Diaz 1982; Frías-L 1978). Therefore, it is possible that additional Ulidiidae species may be feeding on corn in Florida. The objective of this study was to evaluate species richness and distribution of corn-infesting ulidiids throughout Florida.

Materials and Methods

Corn grown throughout Florida was sampled for ulidiid species. Extension personnel and researchers from all 67 Florida counties provided information on corn types and growing season needed to select representative fields. Corn fields were visited with the assistance of extension agents. One to 2 corn fields were sampled for Ulidiidae in each of 16 counties from Jul through Oct 2007 (Table 2). One to 4 corn fields were sampled for Ulidiidae in each of 27 counties during Feb through Jun 2008 (Table 3), including 10 counties visited in 2007.

Adult ulidiids can be elusive and difficult to reliably observe and collect. They frequently avoid direct sunlight and walk or fly away from the direct line of sight of workers approaching them. They are more easily collected from the tassels and upper leaves of corn plants in the hour just after sunrise and just before sunset, but it was not possible to sample all fields at these times. Adults can also be killed after ovipositing on a plant host before they are sampled, particularly within crops that are frequently treated with insecticides, such as sweet corn. Therefore, fields were sampled for both adults and immatures to determine whether the plants served as developmental hosts for ulidiid species and to determine the feasibility of using adult collection records for determining ear infestation. Preference was given to sampling corn that was between the silking and dough stages because both the adult and immature stages of flies can best be collected during the first 3 weeks of corn reproduction. Neither adults nor immatures in ears were found in fields sampled before silking in Lake County (sweet corn) in 2007 and in Jefferson (field corn) and Walton (sweet corn) Counties in 2008, therefore; data from these 3 fields were not included in the results. Sweet corn fields were preferred over field corn for sampling because the flies cause less damage in field corn than in sweet corn (Scully et al. 2000). Corn type (i.e., field, sweet, Bt-enhanced, and standard corn) and variety, number of days before or after first silk, and locations of the field were recorded. Visual observations were taken for the presence of ulidiid adults.

Flies were collected from corn fields with a sweep net (37.5 cm diameter). The sample size was adjusted depending on the estimated field size. In fields ≤4 ha, 3 pairs of corn rows were selected for sampling: 1 pair from each side of the field and 1 pair in the middle of the field. In fields >4 ha, 9 pairs of rows were selected for sampling: 1 on each side of the field, 1 in the middle of the field, and 6 pairs of rows randomly selected from between the field margins. Sweep net sampling for flies was done while walking the length of the field swinging the net 100 times between 2 rows in each pair of selected rows. Flies were preserved

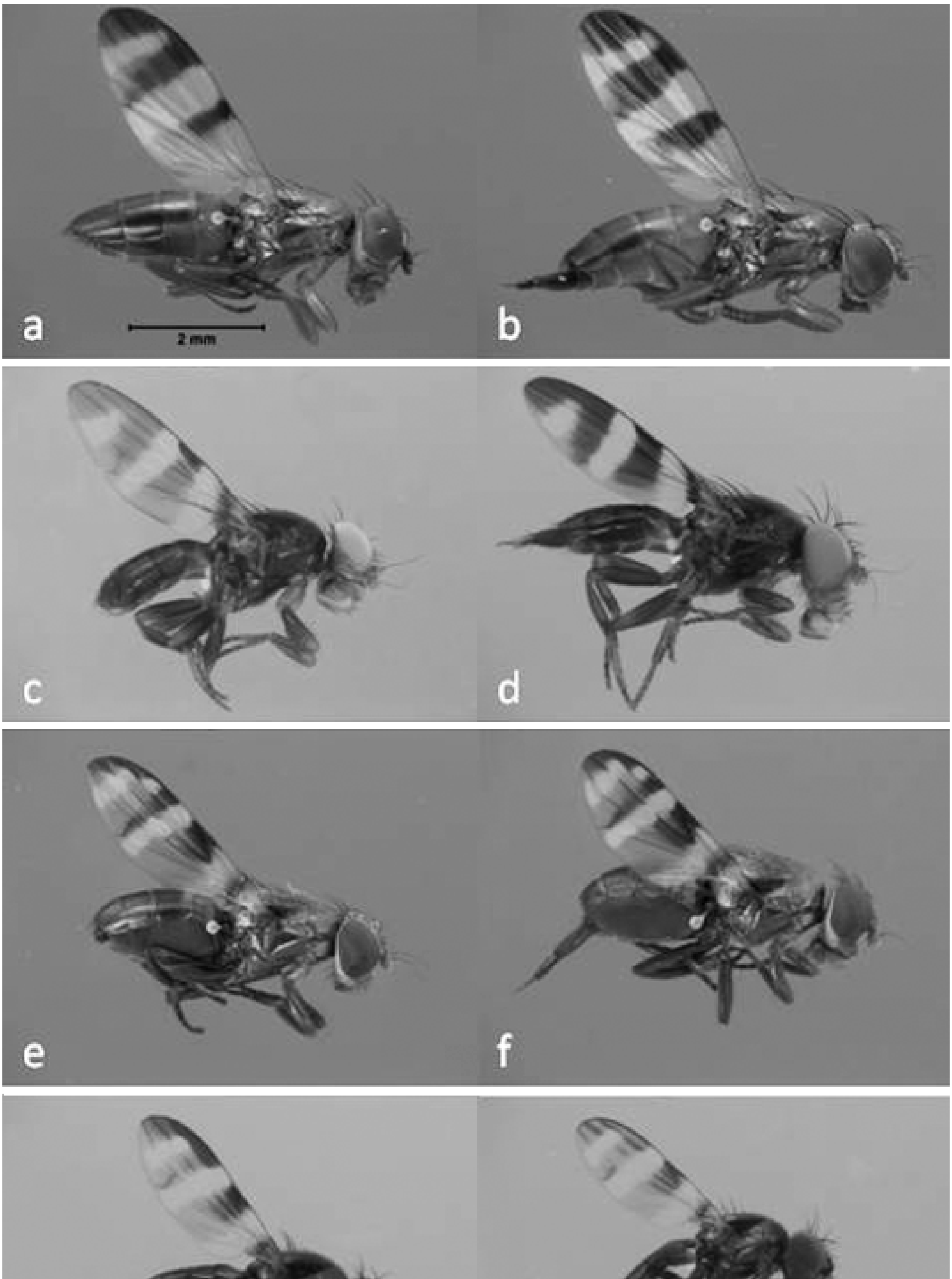

Fig. 1. *Chaetopsis massyla* male (a) and female (b); *Euxesta annonae* male (c) and female (d); *E. eluta* male (e) and female (f); *E. stigmatias* male; and (g) and female (h).

in 70% ethyl alcohol for later identification and counting with a dissecting microscope. Identified Ulidiidae specimens housed at the Division of Plant Industry, Gainesville, FL and keys of *Euxesta* (Ahlmark & Steck unpublished, Curran 1928, 1934, 1935) and *Chaetopsis* (G. Steyskal unpublished) were used to confirm identifications.

Corn ears were examined for the presence of fly larvae in the same fields sampled with sweep nets. Ears found to contain larvae were collected and held for adult emergence to confirm species infestation. The number of ears sampled per field was adjusted depending on the number of planted rows in each field. Fifty-six ears were examined in fields with ≤90 rows and 88 ears were examined in fields with >90 rows. In a field with <90 rows, 10 groups of 4 plants each were randomly selected for ear inspection. In a field with 90 rows, ears were examined in every tenth row starting from the first row and continuing to the other side of the field (total of 10 rows). In a field with >90 rows, 6 rows were sampled from each side of the field (each sampled row separated by 10 rows), and 6 additional rows were randomly selected and sampled in the middle of the field. One ear on each of 4 plants in the middle of each selected row was examined for fly larvae (40 and 72 ears per field for ≤90 and >90 rows, respectively). An additional 4 plants in each corner of the field were examined for larvae-infested ears (16 ears per field). The top third of each infested ear was removed with a knife and placed individually in a Ziploc® bag (1.83 L, S.C. Johnson & Son, Inc., Racine, WI). Two paper towels were added to each bag to reduce moisture accumulation. Bags were stored in portable coolers in the field and during transportation back to the laboratory.

Infested ears kept in the Ziploc bags were held in an air conditioned room maintained at 26.0 ± 1°C and L14:D10 h photoperiod to collect pupae for adult identification. To reduce the accumulation of moisture and associated fungus growth, bags with corn were left partially open, paper towels were changed frequently, and the air was constantly circulated by box fans. Corn ears collected on Mar 6, 2007 were placed collectively in 3.78 L Ziploc bags and then transferred to plastic containers with mesh tops. Pupae were removed from the bags and plastic containers, and placed on moistened filter paper (Whatman® 3, Whatman International Ltd., Maidstone, England) in covered Petri dishes for adult emergence. The dishes were sealed with Parafilm® (Pechiney Plastic Packaging, Chicago, IL) to reduce moisture loss. Adults that emerged were preserved in 70% ethyl alcohol for later identification and counting as above.

Statistical Analysis

The results were tested by analysis of variance to examine the effects of sample technique, corn type (field and sweet), corn ear age day and month of sampling (1-7, 8-14, 15-21 d) and sample year on the mean numbers of each species collected (Proc GLM, Version 9.0; SAS Institute 2008). Year was used as a random variable in the model. The mean number of flies sweep netted per pair of rows used in the data analysis was calculated for each field by dividing the total number of flies caught in sweep nets by the number of pairs of rows sampled in that field. The mean number of flies per infested ear was calculated for each field by dividing the total number of flies reared from infested corn ears by the number of infested ears in each field. Different numbers of ears and plant rows were sampled in each field and more fields were sampled in 2008 than in 2007; therefore the results were presented as least square means rather than arithmetic means of flies caught per row and reared per corn ear.

RESULTS

The mean number of ulidiid adults caught in sweep nets was significantly affected by fly species, corn type, survey year, and the species × year interaction (Table 1). Significantly more *E. eluta*

TABLE 1. ANALYSIS OF VARIANCE FOR FLIES CAPTURED BY SWEEP OR REARED FROM CORN EAR ON SPECIES, CORN TYPE, AGE OF CORN AND YEAR

		Sweep net		Corn ears	
Source	*df*	*F*	*P*	*F*	*P*
Species of Ulidiidae	3	8.12	<0.0001	3.73	0.0120
Corn type	1	6.77	0.0099	6.53	0.0113
Age of corn	2	1.82	0.1638	1.09	0.3368
Year	1	33.17	<0.0001	13.82	0.0003
Species × corn type	3	0.68	0.5642	1.52	0.2091
Species × age of corn	6	0.31	0.9304	0.67	0.6739
Species × year	3	5.50	0.0011	2.00	0.1145

ANOVA (Proc GLM, SAS Institute 2008); denominator *df* = 236.

(least squares mean ± SEM; 3.80 ± 0.63) and *C. massyla* (3.62 ± 0.63) were caught in sweep nets per row than *E. stigmatias* (1.33 ± 0.63) and *E. annonae* (0.14 ± 0.63). More adults were caught per row with sweep nets in sweet corn (2.95 ± 0.34) than in field corn (1.49 ± 0.49). Sweep net counts per row were greater in 2007 (3.89 ± 0.51) than in 2008 (0.55 ± 0.32).

The mean number of adults emerged per ear were significantly affected by fly species, corn type, and survey year (Table 1). Significantly more *E. eluta* (1.41 ± 0.30) were reared from each corn ear than *E. stigmatias* (0.40 ± 0.30) and *E. annonae* (0.05 ± 0.30). The mean number of *C. massyla* per ear (0.82 ± 0.30) was not significantly different than the other species. More adults were reared from each corn ear in 2007 (1.19 ± 0.25) than in 2008 (0.15 ± 0.15). Significantly more adults per ear were reared from sweet corn (1.02 ± 0.16) than from field corn (0.33 ± 0.24). Results for species by county and reared from fields were presented separately for 2007 (Table 2) and 2008 (Table 3) due to significant differences in mean counts between years.

The correlation between adults caught in sweep nets and those reared from ears varied by species. Correlation coefficients were as follows: 0.79 ($P < 0.0001$) for *E. stigmatias*, 0.62 ($P < 0.0001$) for *C. massyla*, 0.58 for ($P < 0.0001$) *E. annonae*, and 0.51 ($P < 0.51$) for *E. eluta*.

2007 Field Survey

Four Ulidiidae species were caught in sweep nets and reared from fly larvae-infested ears in Florida corn during the first survey year (Table 2). *Chaetopsis massyla* was collected in more counties throughout the state than other species and was netted in 100% of the sampled fields. This was followed by *E. eluta,* which was netted in 88% of sampled fields in all counties except Lake and Lee Counties (Table 2). *Euxesta annonae* and *E. stigmatias* were netted from only 3 counties in central and southern Florida, i.e., Miami-Dade, Okeechobee, and Palm Beach Counties. As a result of the more limited distribution, both *E. annonae* and *E. stigmatias* were netted in only 18% of fields sampled. The species netted and reared varied by corn type. Adults of *E. annonae* and *E. stigmatias* were netted only from sweet corn fields in Miami-Dade, Okeechobee, and Palm Beach Counties, but field corn was not sampled in these counties (Table 2). Adults of *E. eluta* and *C. massyla* were netted from both field and sweet corn fields throughout the state. *Euxesta eluta* and *C. massyla* were netted from 50 and 100% of field corn fields, respectively, while both species were netted from 100% of sweet corn fields.

The percentage of ulidiid-infested ears ranged from 5% in Escambia to 38% in Santa Rosa County (Table 2). *Euxesta eluta* and *C. massyla* were reared from ears collected from all but Lee, Lake and St. Johns Counties. These 2 species were reared from infested ears in 82% of corn fields statewide. *Euxesta annonae* and *E. stigmatias* were reared only from corn ears collected from Miami-Dade, Okeechobee, and Palm Beach Counties, amounting to only 18% of fields sampled. Adults of *E. eluta* and *C. massyla* were reared from both field and sweet corn ears. *Euxesta annonae* and *E. stigmatias* emerged from sweet corn ears in fields from Miami-Dade, Okeechobee, and Palm Beach Counties, but field corn fields were not sampled in these counties. *Euxesta eluta* and *C. massyla* were each reared from 50% of field corn and 92% of sweet corn fields. *Euxesta annonae* and *E. stigmatias* were reared from 100% of the sweet corn fields in above mentioned Counties.

The age of sampled corn in 2007 ranged from 4 to 21 d after first silk (Table 2). *Chaetopsis massyla* was sweep netted in fields of all ages sampled. *Euxesta eluta* was sweep netted in fields 7-21 d after first silk. *Euxesta annonae* and *E. stigmatias* were sweep netted from fields 8 to 21 d after first silk, but no fields <8 d after first silk were sampled in counties infested with these 2 species. *Euxesta eluta* and *C. massyla* emerged from corn ears collected from fields 4 to 21 d after first silk, while *E. annonae* and *E. stigmatias* from ears collected 8 to 21 d after first silk (Table 4). Corn ears were not collected from fields <8 d after first silk in counties with *E. annonae* and *E. stigmatias*.

2008 Field Survey

The same 4 species were again collected in sweep nets and reared from fly-larvae infested ears in Florida corn during the second study year (Table 3). Ulidiid adults were netted in 23 of 27 counties sampled in 2008. No adult picture-winged flies were captured in corn in Dixie, Jackson, Sumter, Taylor or Volusia Counties. *Chaetopsis massyla* was collected from more counties than other species throughout the state and was netted in 66% of the fields sampled. *Euxesta eluta* was netted in 49% of the fields sampled. *Chaetopsis massyla* was the only species collected from corn in Alachua, Jefferson and Marion Counties, while *E. eluta* was the lone species collected from corn in Okaloosa County. *Euxesta stigmatias* was netted only in Martin, Okeechobee, Palm Beach, and St. Lucie Counties amounting to only 11% of the fields sampled. *Euxesta annonae* was not collected in sweep samples in 2008. *Euxesta eluta, E. stigmatias* and *C. massyla* were netted from field and sweet corn fields (Table 3). *Euxesta eluta* were netted from 27 and 59%, and *C. massyla* from 40 and 78% of the field and sweet corn fields throughout the state, respectively. *Euxesta stigmatias* was caught from 100 and 67% of the field and sweet corn fields, respectively, in Martin,

TABLE 2. ULIDIIDAE SPECIES COLLECTED IN FIELDS OR REARED FROM INFESTED EARS IN FLORIDA, 2007.

County-field no.	Corn type[1]	Sample date	Ear age (d)[2]	No. rows sampled with sweep net	Mean no. adults captured per 100 sweeps[3]				No. ears sampled (no. infested)	Mean no. adults emerged per ear (per infested ear)			
					E. annonae	*E. eluta*	*E. stigmatias*	*C. massyla*		*E. annonae*	*E. eluta*	*E. stigmatias*	*C. massyla*
Alachua	Swt	16 Aug	15-21	3	0.0	1.8	0.0	4.2	56 (6)	0.0 (0.0)	0.9 (8.3)	0.0 (0.0)	1.4 (13.5)
Bradford	Swt	17 Oct	15-21	9	0.0	0.9	0.0	2.9	88 (14)	0.0 (0.0)	0.7 (4.4)	0.0 (0.0)	1.6 (9.9)
Miami-Dade	Swt	6 Mar	15-21	3	2.8	26.0	11.2	11.7	56 (16)	0.4 (1.3)	17.5 (61.3)	5.6 (19.4)	5.9 (20.7)
Escambia - 1	Fld	2 Aug	8-14	3	0.0	11.5	0.0	3.8	56 (5)	0.0 (0.0)	0.2 (2.2)	0.0 (0.0)	0.3 (3.2)
Escambia - 2	Bt swt	2 Aug	7	9	0.0	5.8	0.0	6.9	56 (3)	0.0 (0.0)	0.3 (6.3)	0.0 (0.0)	0.6 (10.3)
Gadsden	Swt	17 Sep	7	3	0.0	6.3	0.0	4.8	56 (6)	0.0 (0.0)	1.1 (10.3)	0.0 (0.0)	1.0 (9.3)
Holmes	Swt	16 Oct	15-21	3	0.0	3.7	0.0	2.3	56 (11)	0.0 (0.0)	0.6 (3.2)	0.0 (0.0)	0.6 (2.8)
Lake	Fld	14 Sep	4-5	9	0.0	0.0	0.0	3.2	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Lee	Fld	17 Oct	15-21	3	0.0	0.0	0.0	1.5	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Liberty	Fld	13 Sep	15-21	3	0.0	2.3	0.0	1.8	56 (4)	0.0 (0.0)	0.3 (4.3)	0.0 (0.0)	0.5 (7.3)
Marion	Swt	4 Sep	8-14	3	0.0	16.5	0.9	26.0	56 (11)	0.0 (0.0)	4.2 (21.2)	0.0 (0.0)	7.1 (36.3)
Okeechobee	Swt	18 Sep	8-14	3	1.1	0.9	1.0	2.9	88 (6)	0.1 (1.3)	0.6 (8.3)	0.3 (4.3)	0.8 (12.3)
Palm Beach	Swt	14 Nov	8-14	3	1.7	21.3	33.5	18.3	56 (17)	1.7 (5.5)	5.8 (19.1)	8.8 (29.1)	1.8 (5.9)
Santa Rosa	Swt	3 Aug	8-14	3	0.0	3.7	0.0	8.3	56 (21)	0.0 (0.0)	4.5 (12.1)	0.0 (0.0)	1.1 (3.0)
St. Johns	Swt	13 Sep	15-21	3	0.0	10.7	0.0	11.3	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Suwannee	Swt	13 Sep	15-21	3	0.0	11.5	0.0	2.7	56 (12)	0.0 (0.0)	2.8 (13.2)	0.0 (0.0)	4.6 (21.3)
Washington	Swt	2 Aug	15-21	3	0.0	4.3	0.0	3.3	88 (16)	0.0 (0.0)	11.3 (62.3)	0.0 (0.0)	3 (16.3)

[1]Corn type: Fld = field corn; Swt = sweet corn; Bt swt = *Bacillus thuringiensis*-enhanced sweet corn.
[2]Estimated days after first silk at time of sampling.
[3]0 = no flies were detected in sweep nets.

TABLE 3. ULIDIIDAE SPECIES COLLECTED IN FIELDS OR REARED FROM INFESTED EARS IN FLORIDA, 2008.

County-field no.	Corn type[1]	Sample date	Ear age (d)[2]	No. rows sampled with sweep net	Mean no. adults captured per 100 sweeps[3] *E. annonae*	*E. eluta*	*E. stigmatias*	*C. massyla*	No. ears sampled (no. infested)	Mean no. adults emerged per ear (per infested ear) *E. annonae*	*E. eluta*	*E. stigmatias*	*C. massyla*
Alachua	Swt	4 Jun	7	3	0.0	0.0	0.0	1.3	56 (8)	0.0 (0.0)	0.2 (1.4)	0.0 (0.0)	0.0 (0.0)
Bradford - 1	Swt	23 Jun	18-21	3	0.0	2.3	0.0	8.7	56 (15)	0.0 (0.0)	3.3 (12.3)	0.0 (0.0)	1.1 (4.3)
Bradford - 2	Swt	23 Jun	10-14	3	0.0	3.3	0.0	5.7	56 (17)	0.0 (0.0)	10.2 (33.5)	0.0 (0.0)	0.4 (1.5)
Columbia	Swt	24 Jun	8-14	9	0.0	1.1	0.0	2.2	88 (2)	0.0 (0.0)	0.1 (2.5)	0.0 (0.0)	0.05 (2.0)
Dixie	Fld	4 Jun	2-3	9	0.0	0.0	0.0	0.0	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Gilchrest - 1	Swt	23 Jun	15-21	9	0.0	0.7	0.0	1.3	88 (6)	0.0 (0.0)	0.6 (9.3)	0.0 (0.0)	0.8 (11.3)
Gilchrest - 2	Bt fld	23 Jun	7	9	0.0	0.0	0.0	2.1	88 (4)	0.0 (0.0)	0.1 (2.3)	0.0 (0.0)	0.2 (5.3)
Gilchrest - 3	Bt fld	23 Jun	7	9	0.0	1.8	0.0	0.8	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hamilton - 1	Swt	24 Jun	7	3	0.0	1.3	0.0	1.3	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hamilton - 1	Fld	24 Jun	14	3	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hendry	Swt	26 Feb	15-21	9	0.0	4.6	0.0	1.4	88 (18)	0.0 (0.0)	2.7 (13.3)	0.0 (0.0)	4.4 (21.4)
Holmes - 1	Swt	26 Jun	21	3	0.0	8.3	0.0	0.7	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Holmes - 2	Fld	26 Jun	21	9	0.0	2.1	0.0	2.9	88 (9)	0.0 (0.0)	0.4 (3.4)	0.0 (0.0)	0.1 (1.4)
Jackson - 1	Bt fld	5 Jun	2-3	9	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jackson - 2	Bt fld	5 Jun	2-3	9	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jefferson -1	Fld	25 Jun	8-14	9	0.0	0.0	0.0	0.0	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Jefferson - 1	Swt	25 Jun	14	3	0.0	0.0	0.0	0.7	56 (10)	0.0 (0.0)	0.4 (2.4)	0.0 (0.0)	0.0 (0.0)
Lafayette - 1	Swt	24 Jun	14	3	0.0	1.0	0.0	1.3	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Lafayette - 2	Swt	24 Jun	14	3	0.0	0.0	0.0	1.7	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Lafayette - 3	Fld	24 Jun	14	9	0.0	0.0	0.0	0.0	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Lake - 1	Swt	6 Jun	21	9	0.0	0.0	0.0	5.2	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Lake - 2	Swt	6 Jun	21	9	0.0	2.0	0.0	1.8	56 (22)	0.0 (0.0)	1.7 (4.4)	0.0 (0.0)	4.1 (10.4)
Marion	Bt fld	3 Jun	14	3	0.0	0.0	0.0	*	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Martin - 1	Swt	11Mar	7	3	0.0	3.0	1.0	1.3	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Martin - 2	Swt	11 Mar	1-2	3	0.0	0.0	0.0	0.0	56 (9)	0.0 (0.0)	0.4 (2.3)	3.1 (19.0)	0.5 (3.3)
Martin - 3	Swt	11 Mar	1-2	9	0.0	0.0	0.0	0.9	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Martin - 4	Swt	11 Mar	14	3	0.0	0.0	14.3	4.7	56 (8)	0.0 (0.0)	0.0 (0.0)	0.5 (3.4)	0.0 (0.0)
Nassau - 1	Swt	23 Jun	15-21	3	0.0	*	0.0	*	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Nassau - 2	Fld	23 Jun	15-21	9	0.0	0.0	0.0	0.0	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Okaloosa - 1	Swt	5 Jun	5	3	0.0	2.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Okaloosa - 2	Swt	5 Jun	10	3	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

[1]Corn type: Fld = field corn; Swt = sweet corn; Bt swt = *Bacillus thuringiensis*-enhanced sweet corn.
[2]Estimated days after first silk at time of sampling.
[3]0 = no flies were detected in sweep nets; * = fly species was observed only, not collected.

TABLE 3. (CONTINUED) ULIDIIDAE SPECIES COLLECTED IN FIELDS OR REARED FROM INFESTED EARS IN FLORIDA, 2008.

County-field no.	Corn type[1]	Sample date	Ear age (d)[2]	No. rows sampled with sweep net	Mean no. adults captured per 100 sweeps[3]				No. ears sampled (no. infested)	Mean no. adults emerged per ear (per infested ear)			
					E. annonae	*E. eluta*	*E. stigmatias*	*C. massyla*		*E. annonae*	*E. eluta*	*E. stigmatias*	*C. massyla*
Okeechobee	Swt	19 Apr	14	9	0.0	3.6	7.2	1.9	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Palm Beach	Swt	10 Apr	15-21	3	0.0	11.3	20.7	12.7	56 (15)	0.9 (3.2)	3.3 (12.3)	1.1 (4.3)	2.5 (9.2)
Santa Rosa - 1	Bt swt	5 Jun	10	3	0.0	0.0	0.0	1.7	56 (16)	0.0 (0.0)	16.1 (56.4)	0.0 (0.0)	0.4 (1.4)
Santa Rosa - 2	Swt	5 Jun	14	3	0.0	*	0.0	*	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Santa Rosa - 3	Bt swt	5 Jun	15-21	3	0.0	2.3	0.0	*	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
St. Johns - 1	Bt swt	6 Jun	8-14	3	0.0	6.3	0.0	*	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
St. Johns - 2	Bt swt	6 Jun	14	3	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
St. Lucie	Bt fld	29 May	14	9	0.0	0.0	4.1	5.7	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Sumter	Swt	6 Jun	15-21	3	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Suwannee	Fld	4 Jun	15-21	3	0.0	1.0	0.0	1.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Taylor	Fld	25 Jun	15-21	3	0.0	0.0	0.0	0.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Volusia	Swt	6 Jun	21	3	0.0	0.0	0.0	0.0	56 (1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.02 (1.0)
Walkulla	Swt	25 Jun	14	3	0.0	2.0	0.0	*	56 (6)	0.0 (0.0)	0.3 (3.2)	0.0 (0.0)	0.3 (2.3)
Walton	Fld	26 Jun	14	9	0.0	1.8	0.0	0.0	88 (4)	0.0 (0.0)	0.1 (2.3)	0.0 (0.0)	0.0 (0.0)
Walton	Swt	26 Jun	15-21	3	0.0	*	0.0	2.0	56 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Walton	Swt	26 Jun	15-21	9	0.0	0.0	0.0	0.0	88 (0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

[1]Corn type: Fld = field corn; Swt = sweet corn; Bt swt = *Bacillus thuringiensis*-enhanced sweet corn.
[2]Estimated days after first silk at time of sampling.
[3]0 = no flies were detected in sweep nets; * = fly species was observed only, not collected.

TABLE 4. PERCENTAGE OF FIELDS WITH ULIDIIDAE SPECIES SWEEP NETTED OR REARED FROM CORN EARS BY EAR AGE

	Sweep netted Ear age (d)			Reared from corn ears Ear age (d)		
Species	0 to 7 d	8 to 14 d	15 to 21 d	0 to 7 d	8 to 14 d	15 to 21 d
2007						
E. annonae	0	100	100	0	100	100
E. eluta	67	100	89	67	100	78
E. stigmatias	0	100	100	0	100	100
C. massyla	100	100	100	67	100	78
2008						
E. annonae	0	0	0	0	0	100
E. eluta	36	42	64	27	32	35
E. stigmatias	33	100	100	33	33	100
C. massyla	54	68	71	18	21	41

Okeechobee, Palm Beach, and St. Lucie Counties. No *E. annonae* adults were netted in field or sweet corn fields.

Ulidiid-infested ears were found in 13 of 27 counties sampled (Table 3). The percentage of ulidiid infested ears ranged from 2% in Volusia to 39% in Lake County. Only *E. eluta* were reared from corn ears collected from Alachua, Jefferson, and Walton Counties. *Chaetopsis massyla* was the only species reared from corn ears collected from Volusia County. *Euxesta eluta* and *C. massyla* were reared from 32% and 28% of the corn fields sampled throughout the state. *Euxesta eluta* were reared from 20 and 38% and *C. massyla* from 13 and 34% of the field and sweet corn fields, respectively throughout the state. *Euxesta stigmatias* was only reared from infested sweet corn ears in Martin and Palm Beach Counties amounting to 6% of the total fields sampled. Adults of *E. annonae* were only reared from infested sweet corn ears collected from Palm Beach County amounting to approximately 2% of the total fields sampled. Field corn fields were not sampled in the counties where *E. stigmatias* and *E. annonae* were reared from ears.

The age of corn ears in surveyed fields ranged from 1 to 21 d after first silk (Table 3). More *E. eluta* and *C. massyla* were caught in sweep nets and reared from corn ears 15 to 21 d post-silking compared to 0 to 14 d post-silking. More *E. stigmatias* were caught in sweep nets and reared from corn ears in fields with 15 to 21 d post-silking ears than in younger fields. In counties where *E. annonae* was found, it was only reared from fields sampled 15 to 21 d after first silk.

DISCUSSION

The results of this 2-year study confirmed that several species of Ulidiidae flies were infesting corn in Florida. Ulidiidae flies were found infesting both sweet and field corn fields across the Florida panhandle from Escambia to Nassau Counties and south through the peninsula to Miami-Dade County. Flies were collected in sweep nets or reared from corn ears from 29 out of 33 sampled counties during the 2 survey years (Fig. 2). Flies were more common in the 2007 compared to 2008 surveys probably due to differences in sampling times. Corn fields in 2007 were largely sampled from Aug to Oct, except for Miami-Dade County that was sampled in Mar. In contrast, surveys were conducted from Feb to Jun in 2008. The flies may be more common in midsummer through fall months in northern Florida. While more research has been conducted on *E stigmatias* than the other species, it was found to be much less common than *C. massyla* and *E. eluta* in this survey. *Euxesta eluta* and *C. massyla* were distributed in most fields sampled throughout the state in both years, while *E. stigmatias* and *E. annonae* were found in only several counties of southern Florida (Martin, Miami-Dade, Okeechobee, Palm Beach, and St. Lucie).

The distribution of alternate host plants and differences in acceptable temperature ranges for each species may explain some of the variation present in the distribution of ulidiids infesting corn in Florida. *Euxesta eluta*, *E. stigmatias*, and *C. massyla* were collected from both field and sweet corn, while *E. annonae* was collected only from sweet corn fields. Sweet corn is mostly grown in southern Florida in comparison to northern Florida where field corn predominates (Anonymous 2008a). However, *E. stigmatias* was not collected or reared from sweet corn fields in northern Florida. Frías-L (1978) in Chile found that higher temperature and lower relative humidity led to greater numbers of *E. annonae* while the reverse led to greater numbers of *E. eluta*.

Sampling with both sweep nets and collecting infested corn ears gave a more complete picture of

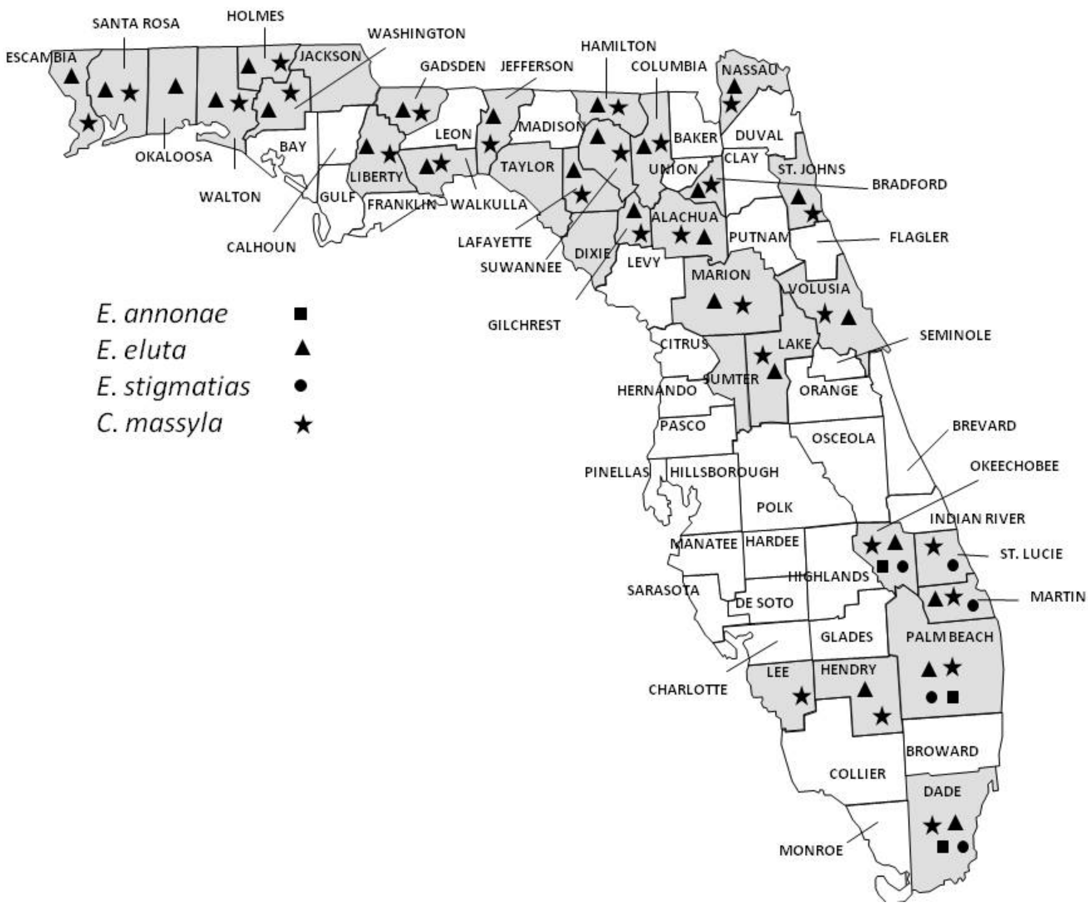

Fig. 2. Distribution of Ulidiidae species infesting corn in Florida by county during the 2007-2008 surveys. Symbols in figure represent species collected using sweep nets and reared from corn ears in each of the sampled (shaded) counties.

fly distribution in Florida corn fields than either sampling technique alone. Low correlation values indicate that sweep netting is not an efficient method to estimate ulidiid species infesting corn ears. The relationship between sweep nets and fly species that emerged from infested ears accounted for >60% of the variation for *E. stigmatias* and *C. massyla*, but <60% for *E. eluta* and *E. annonae*. There were also a few locations where flies were observed but not collected with sweep nets. These were the places where flies were uncommon (1 or 2 per site) and netting was not the best sampling technique for insects at low densities. Seal et al. (1996) found that *E. stigmatias* congregated on the top of plants late in the evening. Fly species in our study may have been more active or more accessible with nets at times of the day other than when sampling was conducted. Therefore, sweep netting can be used to indicate the potential for ear infestation, but the identification of adults reared from infested ears is currently the only method available for differentiating the species developing within ears. The external physical characteristics of the immature stages of Ulidiidae infesting Florida corn are currently being examined by the authors to determine the possibility of using eggs, larvae or pupae for the identification of species of flies infesting corn.

Euxesta eluta, *E. stigmatias* and *C. massyla* were collected from corn throughout the reproductive stage of corn. Adult *E. annonae* may be present in fields during the first week of silking, but only fields ≥8 d after first silk were sampled in counties where this species was found. In general, there was a tendency for greater infestation by all 4 species as sweet corn ears neared harvest and as field corn ears approached the dough stage. The authors also have frequently reared *E. eluta*, *E. stigmatias,* and *C. massyla* from tassels and stems of corn plants. Therefore, the potential host period on this crop is longer than just the reproductive stage.

This is the first report of *E. annonae* infesting corn in Florida and the USA. This species was not common in any location but was always netted from fields and reared from ears along with other Ulidiidae species. *Euxesta annonae* was the least collected species in sweep nets and it was reared from corn ears collected only from the southern end of the Florida peninsula (Fig. 2). *Euxesta annonae* is also reported as a pest of corn in Chile (Frías-L 1978). The authors have frequently observed *E. annonae* on *Annona* spp. (Magnoliales: Annonaceae) and Chinese long bean, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc. (Fabales: Fabaceae) in southern Florida and reared *E. annonae* adults from field collected *Annona* spp. fruit (Magnoliales: Annonaceae). Plants of *Annona* spp. are recorded in several southern and central Florida counties (Brevard, Broward, Collier, De Soto, Glades, Hendry, Highlands, Indian River, Lee, Manatee, Martin, Miami-Dade, Monroe, Palm Beach, and St. Lucie) (Wunderlin & Hansen 2008) where they may provide alternative food resources for this species. The authors have reared this species from decaying corn stalks and from spiny amaranth, *Amaranthus spinosus* L. (Caryophyllales: Amaranthaceae) roots collected from the field at Belle Glade, Florida.

Euxesta eluta was widely collected in this study from fields sampled throughout Florida (Fig. 2). These flies were commonly observed in fields and as many as 62 were reared from an individual ear. While this is the first known record of *E. eluta* being a pest of corn in Florida and the USA, its image in Hayslip (1951) suggests that it was present in Florida corn fields >50 yr ago, but incorrectly identified as *E. stigmatias*. The wide distribution of *E. eluta* in Florida and its discovery on both sweet and field corn indicates this fly is a much greater threat to corn than *E. stigmatias*, which is found in a much smaller portion of Florida. *Euxesta eluta* was recognized as infesting corn in Puerto Rico >60 yr ago (Wolcott 1948) and has been recorded as an ear pest in Ecuador (Evans & Zambrano 1991), Chile (Frías-L 1978; Olalquiaga 1980), Peru (Diaz 1982), Argentina (Arce de Hamity 1986), and Brazil (Franca & Vecchia 1986). *Euxesta eluta* is a pest of loquat, *Eriobotrya japonica* (Thumb.) Lindl. (Rosales: Rosaceae) in Alachua County, Florida (Anonymous 2008b). Loquat is grown as a dooryard plant and is distributed in several counties throughout the state (Wunderlin & Hansen 2008).

Euxesta stigmatias was found in sweep net collections and reared from corn ears from southern and central Florida counties only (Fig. 2). Weather differences in southern and northern Florida may explain part of the variation in distribution of the species. Adult *E. stigmatias* have been reared from damaged or decayed inflorescences of sorghum, *Sorghum bicolor* (L.) Moench (Cyperales: Poaceae), tomato fruit, *Lycopersicon esculentum* L. (Solanales: Solanaceae) (Seal & Jansson 1989), and decaying carrot roots, *Daucus carota* L. (Apiales: Apiaceae) (Franca & Vecchia 1986).

Chaetopsis massyla was caught in sweep nets and reared from corn ears in the majority of surveyed counties (Fig. 2). This fly was common in field and sweet corn fields throughout the year in southern Florida counties. The relative abundance and development range across corn types indicates this species is a much greater threat to Florida corn than previously recognized. Its habit of feeding on a range of monocots may help explain its widespread distribution throughout Florida. Allen & Foote (1992) reported it to be a secondary invader of wetland monocots. *Chaetopsis massyla* has been reared from cattail, *Typha* spp. (Typhales: Typhaceae) in California (Keiper et al. 2000). *Typha* spp. are found in most Florida counties except Flagler, Gadsden, Glades, Hernando, and Suwannee (Wunderlin & Hansen 2008). The authors made several personal observations of *C. massyla* plant associations during the course of this statewide survey. *Chaetopsis massyla* was frequently observed by the authors on cattail plants on ditch banks and feeding on sugary exudates from sugarcane plants (a complex hybrid of *Saccharum* spp.) in Belle Glade (Palm Beach County). *Chaetopsis massyla* adults were reared from sugarcane stems that were actively infested with the sugarcane borer, *Diatraea saccharalis* (F). (Lepidoptera: Crambidae) collected by the authors in November 2009 from sugarcane fields at Clewiston (Hendry County) and Sebring (Highlands County), Florida. *Chaetopsis massyla* was also successfully reared by the authors from otherwise healthy sugarcane stems exposed to colonies in the laboratory in which 0.5 cm diam holes were drilled in billets to simulate emergence and frass evacuation holes produced by *D. saccharalis*. Other plants from which *C. massyla* has been reared include hairy sedge, *Carex lacustris* Willd. (Cyperales: Cyperaceae) (Allen & Foote 1992), *Narcissus* spp. (Liliales: Liliaceae) (Blanton 1938) and onions, *Allium cepa* L. (Asparagales: Alliaceae) (Merrill 1951). *Carex* spp. are found throughout the state while the distribution of *Narcissus* spp. is considered to be limited to Alachua, Calhoun, Escambia and Leon Counties (Wunderlin & Hansen 2008).

Two additional *Chaetopsis* spp. have been reported feeding on corn, but neither was found in this 2-year survey of Florida corn fields. Large populations of fly larvae that were discovered in corn stalks within tunnels likely produced by European corn borer, *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae) in Ohio were reared to adults and identified as *Chaetopsis aenea* (Wiedemann) by Gossard (1919). Larvae of *C. fulvifrons* (Macquart) were reared from within the tunnels of southwestern corn borer, *Diatraea grandiosella* Dyar (Lepidoptera: Crambidae), in the Texas high plains (Knutson 1987). Langille (1975) reported that *Chaetopsis* spp. larvae were commonly associated with diapausing *D. grandiosella* within corn stalks in Missouri and hypothesized that ulidiid larvae feed on the decaying stalks or microbial growth within the bored stalks.

In conclusion, 4 species of picture-winged flies were found infesting corn in Florida. Evidence presented herein is the first known documentation for *E. annonae* and *E. eluta* as pests of corn in Florida and the USA. The 4 species were not uniformly distributed throughout Florida corn growing regions. *Euxesta eluta* and *C. massyla* were found infesting field and sweet corn throughout Florida. *Euxesta stigmatias* was only found infesting corn in Martin, Miami-Dade, Okeechobee, Palm Beach, and St. Lucie Counties. *Euxesta annonae* (F.) was found in sweet corn in Miami-Dade, Okeechobee, Palm Beach Counties, but field corn was not sampled in these counties. *Euxesta eluta*, *E. stigmatias* and *C. massyla* were collected from corn throughout the corn reproductive stage. *Euxesta annonae* was reared from 8-21 d old ears only, but fields with ears <8 d old were not sampled in the counties where this species was found. The relative abundance of *E. eluta* and *C. massyla* in Florida field and sweet corn indicates the need for more research into their biology and ecology. The discovery of *E. eluta* and *C. massyla* attacking corn ears in many of the northernmost Florida counties suggests that further surveys of corn growing areas across the borders into neighboring states is warranted to determine the extent of corn infesting picture-winged fly infestations in the southern U.S. The statewide distribution of *E. eluta* and *C. massyla* in reproducing corn also suggests that studies should be conducted to evaluate additional food sources that support these species in the absence of corn.

ACKNOWLEDGEMENTS

We thank Harsimran K. Gill and Bijayita Thapa for assistance in rearing Ulidiidae from collected ears, and Nicholas A. Larsen for help contacting extension agents and field navigation. We acknowledge Jaya Das for help with the Florida county maps. The photographic assistance of Lyle Buss was instrumental in producing the fly images used in this report. We are also thankful to University of Florida Cooperative Extension Agents and researchers for their help in selecting corn fields and arranging the visits, and corn growers of Florida for allowing us to survey their fields. This research was made possible by a Hand Fellowship awarded by the Dolly and Homer Hand Group.

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