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The Introduction, Establishment, and Spread of *Ormia depleta* in Florida

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***Ormia depleta* (Wiedemann) (Diptera: Tachinidae), native to Brazil, is a parasitoid of some *Scapteriscus* species (Orthoptera: Gryllotalpidae). It was first cultured in a laboratory in Florida in 1987. Releases of *O. depleta* were made against *Scapteriscus* mole crickets in all regions of Florida beginning in 1988. Establishment of populations was achieved at some, but not all, of the release sites. The two earliest-established populations were monitored using traps employing synthetic calling song of male *Scapteriscus* mole crickets, to which gravid female flies are attracted. Additionally, progeny of the released flies were trapped between 1988 and 1993 in 32 peninsular counties, including 15 counties in which no releases had been made. The most parsimonious explanation of the pathways of spread of the current population was inferred from trapping surveys, and this yielded the probable year of colonization for peninsular counties. Reports in successive years by golf course superintendents of damage by mole crickets showed that counties with *O. depleta* populations had significantly less damage than did yet-uncolonized counties.**

KEY WORDS: **mole cricket; *Scapteriscus;* Gryllotalpidae; classical biological control; *Ormia depleta;* Tachinidae.**

INTRODUCTION

In June 1939, a few of several hundred *Scapteriscus* mole crickets collected at Belem, Pará, Brazil, were found to be parasitized by a tachinid (Wolcott, 1940). The hosts were being shipped to Puerto Rico as part of a biological control program against *Scapteriscus didactylus* (Latreille). They were exposed in Brazil to attack by a hymenopteran parasitoid, as a means of transporting larvae of the hymenopteran. Although a few of the tachinids were thus transported to Puerto Rico, there is no mention by Wolcott (1951) of their release, much less their establishment, in Puerto Rico. Those few observations seem to be the first on the existence of a tachinid parasitoid of *Scapteriscus* mole crickets, which was identified as *Euphasiopteryx australis* Townsend (Wolcott, 1940). Specimens collected by Wolcott were reexamined and assigned to *Euphasiopteryx depleta* (Wiedemann) by Sabrosky (1953). Wood (1987) made the generic name *Euphasiopteryx* a synonym of *Ormia,* so the name of Wolcott's fly is *Ormia depleta* (Wiedemann).

In 1978 the University of Florida established a mole cricket research program (MCprogram) because of damage to pasture grasses (Koehler *et al.,* 1979). Vegetables and turf and pasture grasses in Florida and other southern states had for decades been damaged severely by mole crickets, and use of chlordane, a cheap and effective chemical pesticide, was no longer legal. Three southern South American mole cricket species (Walker and Nickle, 1981; Nickle and Castner, 1984), *Scapteriscus abbreviatus* Scudder, *Scapteriscus borellii* Giglio-Tos, and *Scapteriscus vicinus* Scudder, which are immigrants to the United States, caused the damage (Frank, 1990, 1994; Walker, 1985). Studies on phonotaxis to calls of mole cricket males (Forrest, 1980; Ulagaraj and Walker, 1973, 1975) led to an emitter using synthetic calls of mole crickets as the attractant for a trap (Walker, 1982).

In 1983, as part of MCprogram, an emitter that synthesized the call of *S. borellii* attracted gravid adult females of *O. depleta* in Paraguay (Fowler and Kochalka, 1985). More were collected at Rio Claro, São Paulo, Brazil, and found to be larviparous, phonotactic, and nocturnal (Fowler, 1987). In 1986–1990, flies were trapped and mole crickets were collected as hosts for laboratory use at Piracicaba, 32 km south of Rio Claro. In Florida, a diet was developed for adults of *Ormia ochracea* (Bigot), a native parasitoid of *Gryllus rubens* Scudder, and then it was found that *O. depleta* adults, shipped as pupae from Piracicaba, would survive on the same diet and would mate only at twilight (Wineriter and Walker, 1990). The first laboratory colony of *O. depleta* was achieved in 1987. In spring 1988, F_4 progeny of *O. depleta* from Piracicaba were first released in Florida. This paper documents releases, establishment, and initial effect of *O. depleta* (on golf courses) in Florida. Pupae shipped from Piracicaba after 1987 were added to the colony to increase genetic diversity.

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Host Specificity of O. depleta

The host specificity of imported biological control agents released in the United States is of concern. Fowler (1987) showed that gravid *O. depleta* females are attracted to the call of three of five mole crickets tested. Two of the three are *S. borellii* and *S. vicinus,* which are pests in the southeastern United States; the third is an immigrant pest species in Puerto Rico. The call of the only mole cricket native to the coastal, southern United States, *Neocurtilla hexadactyla* (Perty), was not attractive (Fowler, 1987).

It is strange that Fowler (1987) found that the call of *Scapteriscus imitatus* Nickle and Castner attracted *O. depleta,* whereas that of *Scapteriscus didactylus* did not; characteristics of the calls suggest that the opposite should have been true and that perhaps Fowler inadvertently transposed the calls (Walker, 1993). Female *O. depleta* in Florida attacked and parasitized *Scapteriscus abbreviatus* in our laboratory, but only when a calling male of *S. borellii* or *S. vicinus* was placed in the same cage; it seems that *O. depleta* females are unable to detect the presence of *S. abbreviatus* males, which do not call, unless calling males of *S. borellii* or *S. vicinus* are placed in very close proximity (Frank and Wineriter, unpublished). We infer that long-range attraction of *O. depleta* females is to a limited range of sound but, once they are very close to that sound, they may detect nearby mole crickets other than the calling male, such as females of the same mole cricket species which likewise are attracted to the call of the male. Alternatively, flies attracted to the call of male *S. borellii* may release larvae—and the larvae may move at most a few centimeters to find the nearby *S. abbreviatus.*

Fowler and Mesa (1987) stated that *O. depleta* had been reared from 4 of 564 *Anurogryllus* sp. crickets collected in São Paulo (state), Brazil. We presume this occurred either because of similarity in call of some Brazilian *Anurogryllus* sp. to *S. borellii* or because the *Anurogryllus* adults in question were in extremely close proximity to *Scapteriscus* adults that were being attacked and were "mistaken" for *Scapteriscus.* Carrier frequencies of the calls of *Anurogryllus* species in Florida are 4.7–7.4 kHz, whereas those of *S. borellii* and *S. vicinus* are 2.7–3.5 kHz, making attraction of *O. depleta* to Florida *Anurogryllus* unlikely (Walker, 1993). The Florida native *Ormia ochracea,* normally attracted to the call of *Gryllus rubens* (4.8 kHz), is rarely attracted to the call of *S. borellii* (Walker, 1993). Tens of thousands of *Scapteriscus* mole crickets had been trapped in Florida and examined by MCprogram personnel prior to release of *O. depleta,* but only once was a tachinid larva (presumably *O. ochracea*) obtained: so *Ormia* females do occasionally attack the "wrong" host.

MATERIALS AND METHODS

Method of Release

A laboratory culture of *O. depleta* was maintained using methods of Wineriter and Walker (1990) but with artificial nectar (sucrose, tartaric acid, sodium benzoate preservative, and red artificial coloring) in place of other nutrients. Fully grown larvae emerge from their mole cricket hosts, below the soil surface, to pupate in surrounding soil (sand) in plastic vials. About 11 days later, at laboratory temperature, the adult flies emerge. For release in the field, cohorts of flies were reared to the pupal stage, sieved from the sand, then concentrated, and buried shallowly in moist sand at a standard number of 200 (when available) per plastic box (32 × 23 cm). A few days before adults were expected to emerge, the boxes were taken to the field and placed in cages of hardware cloth which were designed to permit adults to emerge and escape (Fig. 1). When the boxes were retrieved, the sand in them was sieved, and intact and empty puparia were recorded; each empty pu-

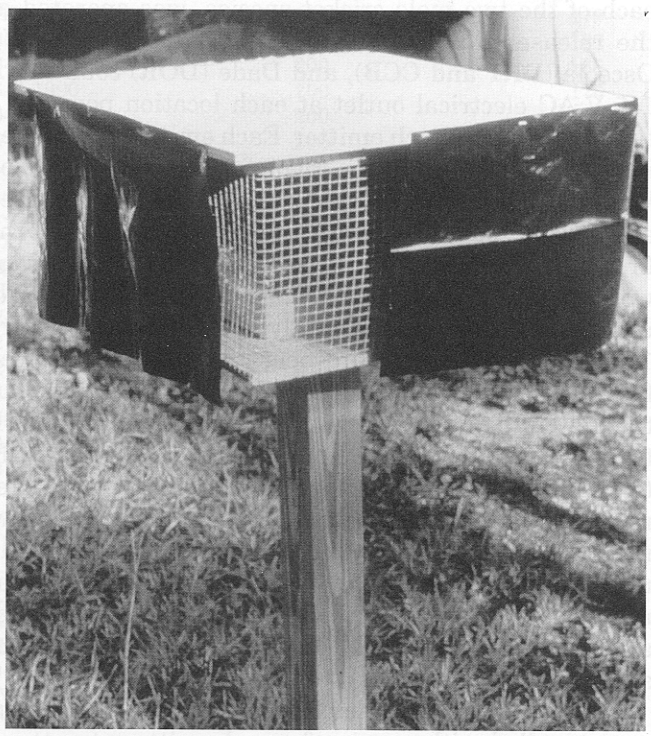

FIG. 1. Cage (width 45 × length 45 × height 18 cm) used to permit emergence and release of *O. depleta* at field sites. Hardware cloth (11 × 11 mm mesh) walls allows flies to escape but prevents predation by birds. The wooden lid (55 × 55 cm) protects from rain and excessive insolation. The wooden post holds the cage about 1 m above ground level and has a band of Tack Trap, preventing access by ants. Fly pupae are spaced evenly 1 cm below the surface of moist sand in a plastic box 24 × 32 cm, and adults emerge and escape at night.

parium recovered allowed the conclusion that an adult fly had emerged (Table 1). Sometimes gravid female flies, surplus to needs for maintenance of the expanded laboratory colony, were released (Table 2). Few flies were released during the summer months, because most mole crickets are in nymphal stages during the summer (Walker, 1985) and nymphs are poor hosts. Few releases were made during the winter months because of cool temperatures and relative shortage of nectar sources and active mole crickets compared with spring or autumn.

Pupae were released in 30 counties in 1988–1994 (Table 1). Some releases were sponsored (see Acknowledgments), which dictated sites of release, especially on golf courses.

Routine Monitoring

Emitters that synthesized calls of *S. borellii* or *S. vicinus,* operating at 106 dB, attract gravid female *O. depleta* and were the exclusive means used for routine monitoring. A pair of these emitters, one with the call of each of the two mole cricket species, was operated at the release sites in Alachua (GVA), Manatee (BDN), Osceola (DRT and CCB), and Dade (DOR) counties. A 115-V AC electrical outlet at each location powered a timer controlling each emitter. Each emitter was placed inside the base of a live trap (for flies) designed by Walker (1989). An identical pair of traps was operated at a second Alachua County site (GVC), 3 km from the first, but at which flies had not been released. Traps were operated nightly at GVA and GVC from the time of release of the flies, and nightly at BDN from January 1990. At DRT, traps were operated four nights/week from the time of release of flies for several months, but then fell into disuse when no flies were caught. At CCB the traps were operated only occasionally. At DOR, traps were not operated for the first 8 weeks after release of flies, but then were operated for one or a few nights near the beginning of each month; after about 18 months these, too, fell into disuse, though here it was not because flies were not being trapped. Only the traps at GVA, GVC, and BDN provided data routinely for several years.

Each golf course participating in the FTGA program was supplied with a pair of sound emitters to attract mole crickets. Cardboard templates coated with Tack Trap (Animal Repellents, Griffin, GA) were supplied, each to be placed on the upper surface of an emitter, used until flies were captured, and then replaced by an unused one. However, few golf courses used these, and no templates with flies adhering were returned to program personnel.

Trapline Surveys

Emitters were placed in plastic bags to exclude rain and operated from 12-V rechargeable batteries. An area of 12.5 × 15 cm of each bag (equal to the area of the upper surface of each emitter) was coated with Tack Trap. Flies attracted to emitters became embedded in the Tack Trap and were picked out for identification. Traps thus constructed and emitting calls were placed on occasion in a ring (of several kilometers in diameter) around a release site to detect dispersal of flies from the site. On other occasions, traps were placed at intervals of 8 km (5 miles) along rural or suburban roads to detect continuity and limits of populations of the flies. Concealment of the traps, emission of sound only after dark, and placement in any given location for at most a few hours combined to avoid interference by humans.

Damage on Golf Courses

To document changes in mole cricket damage throughout Florida, survey forms were mailed to Florida Turfgrass Association (FTGA) members (see Acknowledgments) in November 1991 and November 1992. Surveys asked whether mole cricket damage during the past year (1991 and 1992) was (1) much worse, (2) slightly worse, (3) the same, (4) slightly less, or (5) much less than the previous year (1990 and 1991, respectively). Responses from counties where *O. depleta* was believed to be well established [i.e., estimated to occur in approximately 50% or more of the county (see below)] by midpoint of the survey year were compared to those from counties where the fly was believed to be absent or not well established by midpoint of the survey year. For 1991, responses of slightly less and much less were combined as were responses of slightly more and much more. Thus, a 2×2 χ^2 comparison could be made for the counties with and without the fly and for responses of more and less damage. In 1992, responses of less damage and the same damage were combined for the counties where the fly was well established by mid 1991. They were compared to the same combined results from counties where the fly was believed not to be established or well established with a 2×2 χ^2 comparison. For the counties where the fly was believed to be well established by mid 1992, responses were combined as for the 1991 survey and compared to the same combined results from those counties without the fly.

RESULTS AND DISCUSSION

Adult flies were trapped at sound in 32 counties at some time between 1988 and late 1993 (Fig. 2). However, the northern counties did not maintain *O. depleta* populations constantly after initial establishment. Fur-

TABLE 1

Releases of *Ormia depleta* Pupae in Florida

County	Location	Date pupae delivered	No. pupae	Adults emerged
Alachua	Gainesville (GVA)	22-IV-1988	231	204
Alachua	Gainesville (GVA)	1,8-VI-1988	315	301
Manatee	Bradenton (BDN)	28-X-1988	100	95
Manatee	Bradenton (BDN)	10-XI-1988	112	110
Manatee	Bradenton (BDN)	23-II-1989	106	102
Osceola	Deseret Ranch (DRT)	5-IV-1989	200	196
Osceola	Deseret Ranch (DRT)	22-V-1989	200	197
Collier	Golden Gate GC	24-VI-1989	400	381
Osceola	Deseret Ranch (DRT)	5-X-1989	227	218
Dade	Doral R&CC (DOR)	22-III-1990	220	203
Palm Beach	Banyan CC[a]	25-V-1990	200	193
Palm Beach	Delaire CC[a]	25-V-1990	200	188
Palm Beach	Woodfield CC[a]	25-V-1990	200	187
Collier	Riviera GC[a]	25-V-1990	202	185
Collier	Royal Poinciana GC[a]	25-V-1990	201	183
Lee	Fiddlesticks CC[a]	3-VI-1990	200	190
Sarasota	Foxfire GC[a]	3-VI-1990	200	171
Sarasota	Waterford GC[a]	3-VI-1990	200	181
Hillsborough	Sun City South GC[a]	3-VI-1990	200	177
Baker	Pineview G&CC[a]	7-VI-1990	194	180
Volusia	Riviera CC[a]	14-VI-1990	176	160
St. John's	TPC at Sawgrass[a]	14-VI-1990	200	184
Marion	Golden Hills CC[a]	28-IX-1990	200	179
Citrus	Citrus Hills GC[a]	3-X-1990	200	182
Pasco	Quail Ridge GC[a]	3-X-1990	200	166
Orange	Bay Hill CC[a]	26-X-1990	200	176
Orange	Cypress Creek CC[a]	26-X-1990	200	175
Orange	Interlachen CC[a]	26-X-1990	200	196
Hillsborough	Northdale CC[a]	31-X-1990	200	192
Pinellas	Cypress Run GC[a]	31-X-1990	200	195
Pinellas	Countryside CC[a]	31-X-1990	200	193
Osceola	CC Ranch (CCB)	9-XI-1990	160	90
Osceola	CC Ranch (CCB)	31-I-1991	200	180
Osceola	CC Ranch (CCB)	18-III-1991	110	23
Orange	Grand Cypress GC[a]	2-V-1991	200	192
Volusia	Ocean's West GC[a]	2-V-1991	200	197
Broward	Pompano Bch GC[a]	2-V-1991	200	187
Sarasota	Bobby Jones GC[a]	3-V-1991	200	180
Sarasota	Englewood CC[a]	3-V-1991	200	189
Highlands	Golf Hammock GC[a]	3-V-1991	200	190
Okaloosa	Ft. Walton Bch GC[a]	10-V-1991	200	178
Osceola	CC Ranch (CCB)	17-V-1991	200	94
Hillsborough	Duda Sod[a]	25-IX-1991	200	197
Polk	Providence	8-IV-1992	400	386
Liberty	CES: Bristol	15-X-1992	215	209
Duval	Jacksonville	24-XI-1992	210[b]	50
Wakulla	CES: Crawfordville	2-XII-1992	123*	24
Nassau	CES: Callahan	29-III-1993	200	190
Calhoun	CES: Blountstown	9-V-1993	200	[c]
Clay	CES: Green Cove Spg	16-VI-1993	200	[c]
Leon	CES: Tallahassee	22-VI-1993	200	169
Wakulla	CES: Crawfordville	10-X-1993	200	104
Jackson	CES: Marianna	27-V-1994	200	178
Calhoun	CES: Blountstown	16-VII-1994	200	[c]
Lafayette	CES: Mayo	24-IX-1994	200	183

Note. GC, golf course; CC, country club; G&CC, golf and country club; R&CC, resort and country club; TPC, tournament players' club (each including at least one golf course); CES, the release site was chosen by Cooperative Extension Service personnel based in the city mentioned.

[a] See acknowledgments.

[b] The box was returned partially emptied of sand, only 123 puparia were found in it, and 99 of these were intact.

[c] The box was returned empty of sand, so no estimate of number of flies emerging could be made.

TABLE 2

Releases of *O. depleta* Adults in Florida

County	Location	Date and number released	
Manatee	Bradenton (BDN)	28-X-1988	1♀ gravid
Manatee	Bradenton (BDN)	10-XI-1988	3♀ gravid
Collier	Golden Gate GC	2-II-1989	37♀ gravid
Osceola	Deseret Ranch (DRT)	5-IV-1989	2♀ gravid
Osceola	Deseret Ranch (DRT)	22-V-1989	3♀ gravid
Duval	Nutriturf	27-XI-1989	31♀ gravid
Osceola	CC Ranch (CCB)	9-XI-1990	9♀ gravid
Osceola	CC Ranch (CCB)	9-I-1991	10♀ gravid
Osceola	CC Ranch (CCB)	31-I-1991	2♀ gravid
Osceola	CC Ranch (CCB)	9-V-1991	21♀ gravid
Osceola	CC Ranch (CCB)	31-V-1991	24♀ gravid
Osceola	CC Ranch (CCB)	2-VII-1991	71♀ 87♂
Duval	Jacksonville	24-XI-1992	15♀ gravid

ther, 1 county was populated as early as 1988, and others not until 1993, and the date of population is not related simply to dates of release. No releases were made in 15 of the colonized counties. Data from trap catches are detailed below, so that they may be interpreted under Discussion. The date of colonization of each county provided the basis for contrasting effects of flies on mole cricket populations during the period of expanding fly populations.

North

Although a fly was trapped at GVA (Alachua County) on May 20, 1988, this probably was one of the individuals released as a pupa. Three were caught in August 1988, here taken to be the month of establishment in Alachua County, and numbers trapped increased monthly through December. Flies were first trapped at GVC in February 1989, and the catch there was subsequently greater than at GVA. In November 1991,

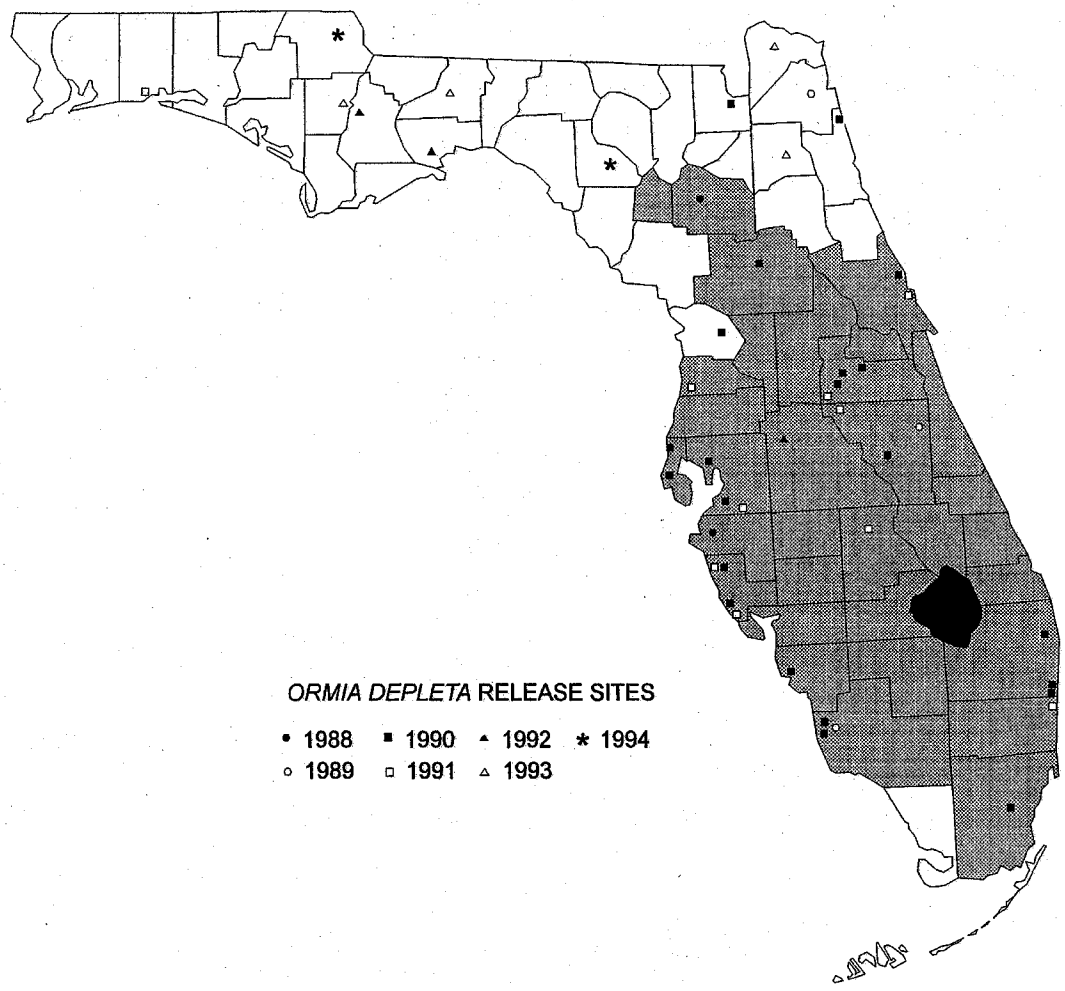

FIG. 2. Counties (shaded) in which gravid female *O. depleta* were trapped at sound at some time in 1988–1993. Trapping was not attempted in most of the counties north and west of the shaded area. Sites of release (from Tables 1 and 2) are shown as dots.

traplines were run north to 11, 19, and 27 km from GVC, catching flies at each location; east to 8, 16, and 24 km, catching flies only at the nearest location; south to 6 and 14 km, catching flies at both locations; and west to 11 km, catching flies here too. The trapline westward continued into Gilchrist County and caught flies at 0, 8, and 16 km (but not 24 km) into that county. These traplines extended north from Alachua County into Union County and Columbia County, east into Putnam County, and southwest into Levy County, but no flies were caught there. Flies released in Alachua County in 1988 had colonized the western part of that county and the eastern part of Gilchrist County by late 1991.

No flies were trapped in springs of 1992, 1993, or 1994 at GVA or GVC, but were trapped later in those years. All three winters (1991/1992, 1992/1993, and 1993/1994) were mild. Populations declined sharply in Alachua County from 1991, as judged by declining catches at GVA and GVC.

Some gravid female flies were released in Duval County late in 1989 (Table 2), but no sound traps were operated at that site. In March 1990, T. Pitman, an employee at the site, observed flies around a white vehicle, trapped one in a jar, and brought it to us for examination: it was *O. depleta*. He reported more flies in May–June 1990. This provides evidence that a population of the fly occurred in Duval County, at least for some months of 1990.

Southwest

Releases of flies in October–November 1988 at BDN (Table 1) were the reason for the population in Manatee County which had become established by February 1989. By June 1990, the population had spread west to the Gulf of Mexico, north to the Hillsborough County boundary, and some 8 km east and south. By May 1991, it had spread much farther east to occupy much of Hardee County (Fig. 3). In June 1990, however, fly pupae had been released in Hillsborough County and Sarasota County, with more in both those counties in 1991, so that it was becoming difficult to attribute the origin of flies trapped in those counties. Routine trapping at BDN showed the continued presence of a population there from 1989 through 1994, with peak numbers trapped in May–June and again in November–December, in contrast to the declining populations at GVA and GVC in Alachua County with their peak numbers in November–December only (Walker *et al.*, 1996).

Far Southeast

The 220 pupae released in March 1990 at DOR (Dade County) established a population: traps operated on

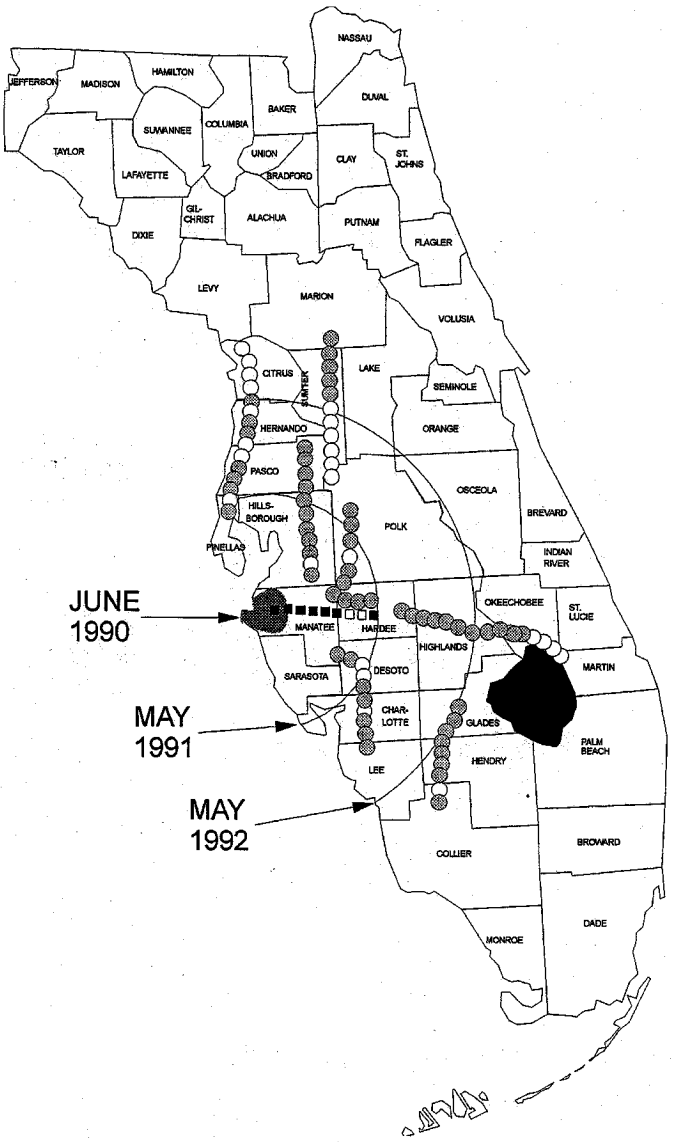

FIG. 3. Traplines operated in southwestern Florida in May 1991 and June 1992, showing those traps which caught (solid square: May 1991; solid circle: June 1992) or did not catch (hollow square: May 1991; hollow circle: June 1992) flies. A few of the sound emitters were not operating when picked up and may not have been capable of catching flies. The arcs suggest a population spreading from the BDN site at 64 km/year over 2 years.

May 25–29, 1990 captured 5 flies. The traps were operated for 1–4 nights at roughly monthly intervals until the beginning of August 1991, on only two occasions (March 4–7, 1991 and July 31–August 2, 1991) failing to catch flies. The rule was that if flies were trapped on the first night of operation, the traps would not be operated again for a month. Single-night captures built up to a peak on December 3, 1990 (22) and January 3, 1991 (23), declined, rose again on April 3, 1991 (18), and declined again. Traps were not operated

after August 1991 until, inadvertently, they were operated for approximately a week in February 1992. During that week, they were reported to be filled with "enormous numbers" of flies (G. Mahannah, personal communication).

Center

Pupae released in 1989 (Table 1) do not seem to have established a population: no flies were trapped at the DRT release site (Osceola County) in 1989–1990. A new release site (CCB) was selected where pupae and adults were released on several occasions in 1990–1991 (Tables 1 and 2), but no flies were trapped at CCB in 1990–1991. More flies were released at these two sites in Osceola County than in any other county, deflating any concept of ready establishment of a population after release. This surprised researchers (and disillusioned sponsors) because there seemed to be no shortage of mole crickets at the Osceola County sites, nor of vegetation in which adult flies might conceivably find shelter and nutrition. Finally, a fly was trapped at CCB on June 3, 1992, with more thereafter.

In April 1992, 400 pupae were released at a ranch in Polk County (immediately west of Osceola County), at two sites within 1 km of each other (Table 1). Trapping of flies on June 9, 1992 at both sites, which appeared vegetationally much like the Osceola County sites, raised the suspicion that a population of flies already was established, perhaps having spread from Hardee County to the southwest and perhaps having just invaded Osceola County. This prompted operation of traplines through most counties of southern Florida.

Trapline Surveys in Several Counties

Lines of traps were operated across several counties in the latter part of June 1992, and in December 1992, and showed that some of the populations had spread (Figs. 3 and 4). Flies were trapped at sites throughout Osceola County in November–December 1992 at one trap which was moved from place to place. Not shown are traplines in November 1993 in Citrus County, Levy County, Alachua County, and Putnam County, none of which caught flies, whereas six of eight traps in Seminole County caught flies.

Chronology of Colonization of the Counties

Available data were used to summarize establishment and spread of populations of *O. depleta* in Florida. Data were subjected to the most parsimonious interpretation. Results denied that a population became established in Osceola County until June 1992, even though more flies were released in that county than in any other. Therefore, even though releases were made in 30 counties, no assumption was made that any release led to establishment of a local population; only data showing presence of flies at the location, inexplicable by spread from another location, are accepted as evidence of success of a release there.

Reviewers of the manuscript thought that the three pages detailing the argument for the chronology given below were superfluous, so that information has been deleted. Authors will provide the information upon request.

Counties are grouped below by year in which we believe that at least 50% of the county in question was occupied by a population of *O. depleta* by June of the year in question. We made no attempt to discover whether a population is established in Monroe County, because most of it [swamps (the Everglades) and rocky islands (the Keys)] is unsuitable for *Scapteriscus* mole crickets. Some northern counties seem to have declining populations, so they are classified separately. Finally, there is a large group of northern counties, in some of which the attempts to trap flies were unsuccessful and in most of which there has been no attempt to trap flies.

1990. Manatee.

1991. Hardee, Hillsborough, Sarasota.

1992. Broward, Charlotte, Dade, DeSoto, Glades, Hernando, Highlands, Lake, Lee, Martin, Palm Beach, Pasco, Pinellas, Polk, Sumter.

1993. Brevard, Collier, Hendry, Indian River, Okeechobee, Orange, Osceola, St. Lucie, Seminole, Volusia.

Declining populations. Alachua, Gilchrist, Marion, and perhaps Duval.

Northern counties without evidence of flies by December 1993. Baker, Bradford, Citrus, Clay, Columbia, Flagler, Levy, Nassau, Putnam, St. John's, Union, and all the counties to their west.

In retrospect, it could be argued that the population established in Manatee County might by itself have been capable of achieving the current distribution by summer 1994, so that all subsequent releases were unnecessary. However, the success of the Manatee County population could scarcely have been predicted before June 1992, by which time most other releases had been made. Further, the other releases may have contributed locally to reduction in mole cricket populations before the Manatee County population could have reached those areas. Releases after June 1992 were all north of the 32 occupied counties.

Survey of Damage on Golf Courses

One hundred and seventy-four superintendents, from 34 counties, responded to the survey in 1991; 115 superintendents from 30 counties responded in 1992 (Table 3). In the counties where *O. depleta* was believed

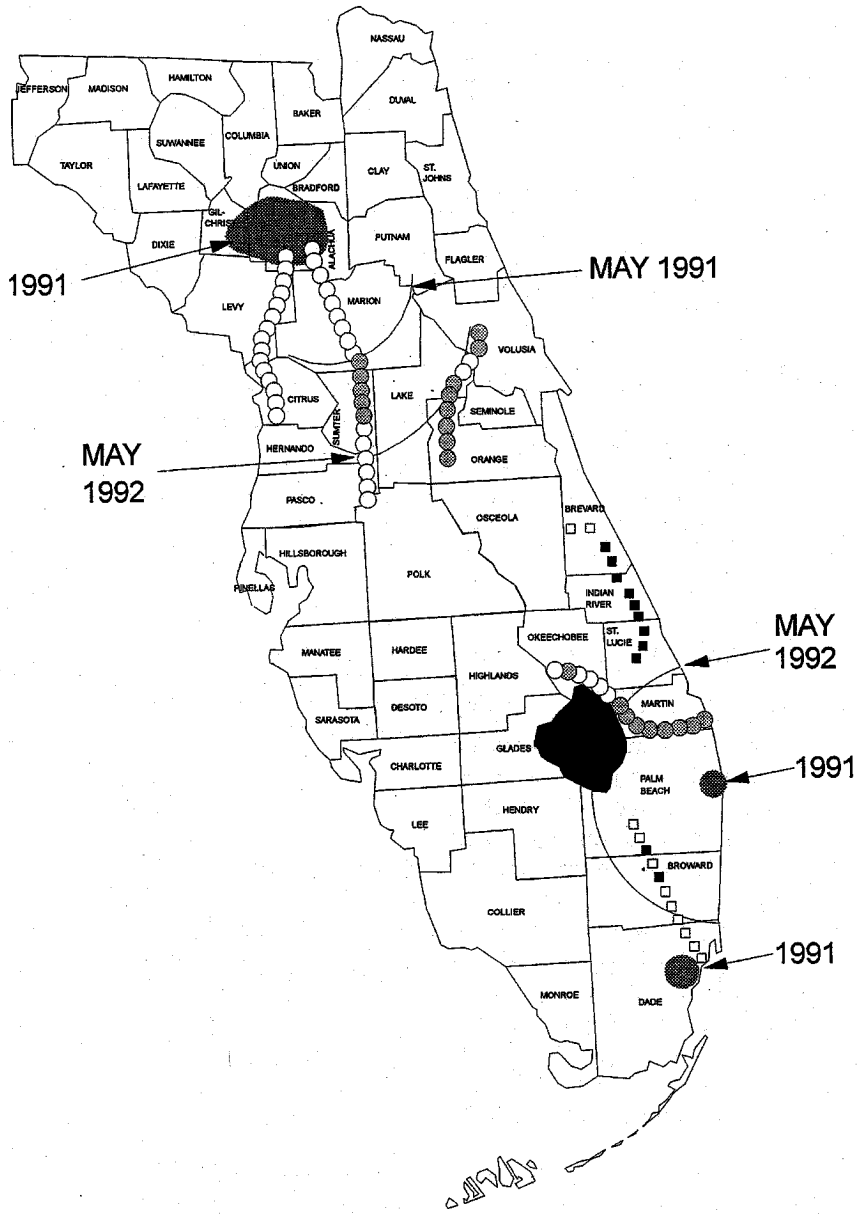

FIG. 4. Traplines operated in eastern and northern Florida in June 1992 and December 1992, showing those traps which caught (solid circle: June 1992; solid square: December 1992) or did not catch (hollow circle: June 1992; hollow square: December 1992) flies. A few of the sound emitters were not operating when picked up and may not have been capable of catching flies. The arcs suggest populations spreading (a) from a release site in Palm Beach County and (b) southeast from the GVA and GVC sites, at 64 km/year over 2 years.

to be well established by mid 1991, 85% had less damage in 1991 when compared to 1990. In the counties without the fly, 46% had less damage (Table 3). Responses from counties with *O. depleta* differed significantly from the responses from counties without the parasitoid ($\chi^2_1 = 32.582$, $P < 0.001$). The differences in damage in 1992 were also significantly different; 63% of the respondents in the counties where *O. depleta* was believed to be well established by 1991 said they had less or the same damage in 1992 than in 1991, whereas 48% of respondents in the counties without the fly said they had less or the same damage in 1992 (Table 3) ($\chi^2_1 = 4.863$, $P < 0.05$). Fifty percent of the respondents in counties where the fly was established by 1992 had less damage in 1992, while only 30% in counties without the fly had less damage (Table 3), another significant difference ($\chi^2_1 = 8.075$, $P < 0.01$).

In four counties from which responses were received and where *O. depleta* was believed to be well established (Hillsborough, Manatee, Marion, and Sarasota),

TABLE 3

Responses of Golf Course Superintendents Asked to Compare Damage by Mole Crickets in 1991 with That in 1990 and Damage in 1992 with That in 1991

Years compared	*O. depleta* established?	No. of counties	Numbers responding[a] (% of total)		
			Less damage	Less/same damage	More damage
1991/1990[b]	Yes	4	11 (85)	—	2 (15)
	No	30	54 (46)	—	63 (54)
1992/1991[c]	Yes	3	—	12 (63)	7 (37)
	No	15	—	21 (48)	23 (52)
1992/1991[b]	Yes	11	17 (50)	—	17 (50)
	No	15	10 (30)	—	23 (70)

Note. Respondents are grouped based upon establishment of *O. depleta* in ≥50% of the county containing the golf course. Survey forms were mailed and collected by the Florida Turfgrass Association.

[a] All comparisons of responses significantly different by 2×2 χ^2 analysis.

[b] Responses from counties where *O. depleta* was established by midpoint of the survey year (1991 and 1992, respectively) were compared to those from counties where *O. depleta* was not established by midpoint of the survey year.

[c] Responses from counties where *O. depleta* was established by mid 1991 were compared to those from counties where *O. depleta* was not established by mid 1992.

1991 was a year of substantially reduced damage. If classical biological control was the cause of reduced damage in these areas in 1991, then reductions must be attributed to *O. depleta.* In the other counties surveyed in 1991, the fly was believed either absent or more recently established (see chronology above). The method depends on ability to detect a decline in damage as each county was colonized substantially for the first time by the fly; the limitations are obvious.

It seems that *O. depleta* reduced damage levels on golf courses significantly as populations spread. At present we lack (but are trying to obtain) data on percent reduction of current mole cricket populations on golf courses, in pastures, and in vegetable fields attributable to the fly. In a companion paper (Walker *et al.,* 1996) we discuss ways of enhancing the effects of *O. depleta.*

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