Sugarcane Stemborers and Their Parasites in Southern Texas

R. L. MEAGHER, JR.,[1] J. W. SMITH, JR.,[2] H. W. BROWNING,[3] AND R. R. SALDANA

Texas Agricultural Experiment Station, 2415 East Highway 83, Weslaco, TX 78596

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ABSTRACT Approximately 40,000 stemborer larvae, pupae, and parasite cocoons were collected during 1982–1995 from commercial sugarcane fields and allowed to complete development under laboratory conditions. *Eoreuma loftini* (Dyar) and *Diatraea saccharalis* (F.) comprised 92.4% (36,897/39,945) and 5.2% (2,057/39,945) of the stemborers collected. More than 65% of field-collected stemborer larvae completed development and emerged as adults after being transferred to artificial diet; however, 27.5% died during development. Average seasonal parasitization of *E. loftini* larvae and pupae (including parasites collected during sampling and those that completed development) was 6.2 ± 1.0%. The most numerous parasites collected from *E. loftini* included 2 indigenous braconids, *Chelonus sonorensis* Cameron and *Digonogastra solitaria* Wharton & Quicke, and 2 exotic braconids, *Alabagrus stigma* (Brullé) [=*Agathis stigmatera* (Cresson)] and *Allorhogas pyralophagus* Marsh. Average seasonal parasitization of *D. saccharalis* was 8.9 ± 1.6%, caused mostly by *Cotesia flavipes* (Cameron).

KEY WORDS *Eoreuma, Diatraea,* Mexican rice borer, biological control, sugarcane borer

COMMERCIALLY GROWN SUGARCANE (interspecific hybrids of *Saccharum*) in the lower Rio Grande Valley, TX, is subject to attack from several insect pests. Stemboring pyralids (Lepidoptera: Pyralidae) have been the most serious insect pests of sugarcane since the industry's renewal in 1972. During the 1970s, sugarcane borer, *Diatraea saccharalis* (F.), was the primary pest (Fuchs et al. 1973) until establishment of the braconid parasite *Cotesia flavipes* (Cameron) (Fuchs et al. 1979) reduced stemborer injury (Pfannenstiel and Meagher 1991). Mexican rice borer, *Eoreuma loftini* (Dyar), which originated from Mexico, was first detected in 1980 (Johnson 1981) and is now the key pest of sugarcane in Texas. *E. loftini* has not been reported in other sugarcane-producing states (Florida, Louisiana, and Hawaii); however, it is present in many sugarcane-growing areas in western and eastern Mexico (Riess 1981, Johnson 1984).

When *E. loftini* colonized in Texas, little was known about its biology or effective control measures. During the 1980s an importation biological control program was implemented with surveys for natural enemies concentrated in the presumed area of origin of *E. loftini* in southwestern Mexico (Agnew et al. 1988) and in similar climatic areas harboring ecologically equivalent stemborers on other continents. Fifty species of parasites in 12 dipteran and hymenopteran families were imported into Entomology Quarantine, College Station, TX, for determination of reproductive status; identification; development of laboratory culturing methodology; and numerical increase of potential candidates for field releases. Seventeen of these exotic parasites were field-released from January 1983 to November 1989 (H.W.B. and J.W.S., unpublished data; Browning et al. 1985, Smith et al. 1987, Pfannenstiel et al. 1990). Techniques were developed for mass rearing both *D. saccharalis* and *E. loftini* and selected parasites (Martinez et al. 1988).

Nine of the released parasites were recovered at least once during the 1980s; however, only the recoveries made in 1989 were published (Pfannenstiel et al. 1990). In December 1989 a severe freeze in the subtropical lower Rio Grande Valley killed much of the aboveground sugarcane, and biological control efforts were halted. The freeze occurred during 22–24 December and subfreezing temperatures existed for ≈50 h. Over 7 h were below −6.7°C and ≈22 h between −3.8 and −6.7°C (Sauls and Rouse 1989). Although a few larval parasites became established during the 1980s, overall stemborer damage remained static and above tolerable levels with surveys for 1989 and 1990 detecting an average of 19% bored internodes (Meagher et al. 1992).

After the 1989 freeze, and in concert with sugarcane grower's reluctance to invest in insecticidal control (Meagher et al. 1994), releases of selected exotic parasites were continued from October 1993 to February 1995. A total of 102,232 *C. flavipes* and 1,532 *Alabagrus stigma* (Brullé) [=*Agathis stigmatera* (Cresson)] was released in 12 and 10 commercial sugarcane fields, respectively. This report documents 13 yr (1982–1995) of parasite releases to establish exotic parasites for biological control of *E. loftini*. Although sugarcane damage surveys have suggested clear numerical dom-

[1] Current address: USDA-ARS CMAVE, 1700 S.W. 23rd Drive, Gainesville, FL 32608.

[2] Department of Entomology, Texas A&M University, College Station, TX 77843.

[3] Citrus Research and Education Center, University of Florida, 700 Experiment Station Road, Lake Alfred, FL 33850.

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inance of *E. loftini*-damaged internodes soon after its introduction in 1980 (Pfannenstiel and Meagher 1991), a related objective of this research was to estimate the relative abundance of the 2 stemborers in Texas sugarcane over the 13-yr period and to gain insight into the probable reason(s) for the decline in *D. saccharalis* damage.

Materials and Methods

Study Sites and Sampling Procedures, 1982–1989. Evaluation of parasites in commercial sugarcane fields (0.2–43 ha) was conducted in Cameron, Hidalgo, and Willacy counties during 7 seasons. In Texas, a sugarcane season includes fields vegetatively planted in late summer, and regrowth fields (ratoons) that are harvested 12–19 mo later. Harvesting begins in late September and may last until April. Therefore, our samples were organized into seasons rather than calendar years. Samples were taken from 8 December 1982 to 15 December 1983 (14 fields), 3 January 1984 to 12 March 1985 (11 fields), 13 April 1985 to 27 January 1986 (10 fields), 26 February 1986 to 31 March 1987 (11 fields), 23 April 1987 to 7 March 1988 (13 fields), 15 April 1988 to 3 January 1989 (14 fields), and 10 February 1989 to 27 November 1989 (7 fields). Sugarcane cultivars sampled included 'CP 61-37', 'CP 65-357', 'CP 68-350', 'CP 70-321', 'CP 71-1038', and 'NCo 310'.

Fields were sampled monthly from ratoon initiation until harvest by randomly selecting 50–100 stalks, or by sampling within fields for 1–4 h. Recovered stemborer larvae were placed in rearing cups containing synthetic diet (Shaver and Raulston 1971) so that development of hosts or parasites could be completed (Browning et al. 1985). Stemborer pupae and parasite immatures were placed in cups without diet.

Study Sites and Sampling Procedures, 1991–1995. Samples collected after the December 1989 freeze were designed to gather information from as many different fields as possible to determine which parasites were still active in the Texas sugarcane agroecosystem. Samples were taken from 5 December 1991 to 17 March 1992 (26 fields), 3 August 1992 to 18 February 1993 (52 fields), 26 July 1993 to 17 March 1994 (61 fields), and 25 April 1994 to 6 March 1995 (62 fields). Samples were collected from NCo 310 (105 fields), CP 70-321 (68 fields), 'CP 70-324' (6 fields), 'TCP 81-3058' (6 fields), 'CP 72-1210' (3 fields), CP 65-357 (2 fields), CP 68-350 (1 field), and CP 71-1038 (1 field), and the noncommercial clones TCP 87-3388 (4 fields), TCP 83-3196 (3 fields), and TCP 83-3215 (2 fields).

Fields were sampled by randomly selecting sufficient numbers of stalks to collect 100 stemborer larvae or parasite immatures (larvae or pupae) residing in the stalk. No effort was made to collect stemborer eggs. Stemborer larvae were placed singly into diet cups containing meridic diet (Martinez et al. 1988); stemborer pupae and parasite immatures were placed in cups without diet. All specimens were transported to the laboratory and placed in environmentally controlled chambers (Percival, Boone, IA) (28°C, photoperiod of 14:10 [L:D] h) and allowed to complete development.

Classification and Analysis. Each stemborer immature was identified and assigned to an age class as either small (1st and 2nd instars), medium (3rd and 4th instars), or large (5th and 6th instars) larvae, or pupae. Stemborer larvae parasitized by ectoparasites and parasite pupae (cocoons) with no visible host remains also were collected. Stemborer larvae that were dead within the stalk were tallied.

Live stemborer larvae either developed into adults, produced adult parasites, died during development, or died as a result of handling (e.g., dried meridic diet, larval escape from cups, infestation by mites). Larvae with visible ectoparasites or parasite cocoons were held for adult parasite emergence and subsequent identification. Emerged adult parasites were curated, and voucher specimens were placed in the Texas A&M University Insect Collection, College Station, and in the Weslaco Research and Extension Center Insect Collection. Levels of parasitization were compared among sugarcane cultivars, between eastern (Cameron and Willacy counties) and western (Hidalgo County) areas of the lower Rio Grande Valley, and across seasons sampled using analysis of variance (ANOVA) (PROC GLM; SAS Institute 1995). Parasitization included parasites that emerged during host development or were collected as parasite immatures with host remains.

Results

1982–1989. Table 1 provides a list of parasites, their origin, number released and dates liberated during the 1982–1989 interval of intensive parasite releases. A total of 22,678 stemborer larvae, pupae, or parasite immatures (hosts that produced parasite immatures) was collected and processed from 80 sugarcane fields during this period. *E. loftini* was the most common stemborer collected, ranging from 87.2–96.8% of total individuals collected each season (Fig. 1), whereas *D. saccharalis* represented only 1.9–11.3% of the stemborer larvae collected each season. Parasite cocoons with no visible host remains were found in relatively low numbers. Small-, medium-, and large-sized larvae were collected in high numbers, but surprisingly few stemborer pupae were collected.

Greater than 50% of the *E. loftini* larvae collected each season completed development and emerged as adults in the laboratory (55.1–64.5%) (Fig. 2). Developmental mortality (0–33.2%) and mortality due to handling (2.6–40.8%) were variable and depended upon season collected and efficiency in rearing procedures. Parasitization of *E. loftini* ranged from a low of 2.7% (103/3,755) in the 1982–1983 season to a high of 7.1% (120/1684) in the 1989 season (Fig. 2). Parasitization of *D. saccharalis* ranged from a low of 2.9% (1/34) in 1989 to a high of 18% (40/222) in 1987–1988. The exotic parasites *Allorhogas pyralophagus* Marsh, *Macrocentrus prolificus* Wharton, *C. flavipes*, *Lydella jalisco* Woodley, *A. stigma*, and *Goniozus indicus* Ashmead were recovered from *E. loftini* larvae infesting

Table 1. Country of origin, host insects, and mode of reproduction for exotic parasites released during the 1980s for biological control of *E. loftini* in sugarcane. Modified from Browning and Smith (unpublished report [1987]), except where noted.

Order/Family/Parasite	Country of origin[a]	Host insect	Progeny allocation/ feeding site/ life stage attacked[b]	Attack method[c]
Diptera				
Tachinidae				
Lydella jalisco Woodley[d]	Jalisco, Mexico	*E. loftini*	sol, endo; larvae	planidial ingress
Palpozenillia sp.	Bolivia	*Diatraea* sp.	greg, endo; larvae	bait & wait
Hymenoptera				
Bethylidae				
Goniozus indicus Ashmead = *G. natalensis* (Gordh)[e]	South Africa	*Eldana saccharina* Walker	greg, ecto; larvae	ingress & sting
Braconidae				
Alabagrus stigma (Brullé) = *Agathis stigmateris* (Cresson)	Bolivia, Mexico	*Diatraea* sp.	sol, endo; larvae	probe & sting
Allorhogas pyralophagus Marsh[f]	Sinaloa & Nuevo Leon, Mexico	*E. loftini, Diatraea* sp.	greg, ecto; larvae	drill & sting
Apanteles minator Muesebeck	Bolivia	*Diatraea* spp.	greg, endo; larvae	ingress & sting
Digonogastra kimballi Kirkland	Sinaloa, Mexico	*Diatraea* sp.	greg, ecto; larvae	wait & sting
Macrocentrus prolificus Wharton	Sinaloa, Mexico	*E. loftini, Diatraea* spp.	poly, endo; larvae	probe & sting
Rhaconotus roslinensis Lal[g,h]	southern India (Pakistan)	*Chilo* spp.; *Scirpophaga* spp.	greg, ecto; larvae	drill & sting
Eulophidae				
Pediobius furvus Gahan[i]	Kenya	*Chilo partellus* (Swinhoe)	greg, endo; pupae	ingress & sting
Trichospilus diatraeae Cherian & Margobandhu	India (Florida)	[*Trichoplusia ni* (Hübner)]	greg, endo; pupae	ingress & sting
Ichneumonidae				
Dentichasmias busseolae Heinrich	Kenya	*C. partellus*	sol, endo; pupae	ingress & sting
Mallochia pyralidis Wharton[j]	Sinaloa, Mexico	*E. loftini*	sol, ecto; larvae	probe & sting
Xanthopimpla stemmator Thunberg	SE Asia (Mauritius)	*Chilo* sp.	sol, endo; pupae	drill & sting
Trichogrammatidae				
Trichogramma atopovirilia[k] Oatman & Platner	Sinaloa, Mexico	*Diatraea* spp.	greg, endo; egg	direct attack
T. chilonis Ishii[k]	Pakistan	*C. infuscatellus* (Snelling)	greg, endo; egg	direct attack
Trichogrammatoidea eldanae[k] Viggiani	Ivory Coast	*E. saccharina*	greg, endo; egg	direct attack

[a] Locations in parenthesis are where parasite populations were cultured.
[b] Sol, solitary; greg, gregarious; poly, polyembryonic, endo; endoparasitic; ecto, ectoparasitic.
[c] Derived from Smith et al. (1993).
[d] Pfannenstiel et al. (1990) and Woodley (1994).
[e] Species synonymized by Polaszek et al. (1994).
[f] Marsh (1984).
[g] Hawkins and Smith (1986).
[h] Browning et al. (1985).
[i] Pfannenstiel et al. (1992).
[j] Smith et al. (1990).
[k] Browning and Melton (1987).

sugarcane (Table 2). Collections of other exotic parasites were rare. Two larvae parasitized by *M. pyralidis* in 1985–1986, 1 larva parasitized by *R. roslinensis* in 1984, and a single pupa parasitized by *P. furvus* in 1984 were recovered from *E. loftini*. The indigenous parasites *Chelonus sonorensis* Cameron and *Digonogastra* (=*Iphiaulax*) *solitaria* Wharton & Quicke were commonly reared from *E. loftini* larvae, whereas *Bracon rhyssaliformis* Quicke & Wharton was collected only once. *A. pyralophagus* was found in relatively high numbers during the 4-yr period immediately following initial release, but by 1985, *C. sonorensis* became the most commonly collected parasite of *E. loftini* (Table 2). *C. flavipes* was the most commonly collected parasite of *D. saccharalis* with *A. pyralophagus, M. prolificus, D. solitaria,* and *Apanteles minator* Muesebeck rarely collected.

1991–1995. A total of 17,267 stemborer larvae, pupae, or parasite immatures was collected and processed from 201 commercial sugarcane fields during 4 seasons following the December 1989 freeze. Again, *E. loftini* was the most common stemborer, representing 88.2–96.2% of the collection (Fig. 1). *D. saccharalis* represented only 1.9–7.4% of the stemborer larvae collected. Average *E. loftini* larvae per stalk was 1.45 for 1991–1992, 1.63 for 1992–1993, 2.38 for 1993–1994, and 1.54 for 1994–1995, whereas *D. saccharalis* averaged only 0.02, 0.05, 0.08, and 0.08 larvae per stalk, respectively. A higher percentage of *E. loftini* subsequently completed development and emerged as adults in the laboratory (71.3–78.0%) compared with individuals obtained in collections prior to the freeze. Both developmental mortality (6.6–14.1%) and mortality due to handling (0.7–8.9%) were lower during the latter sampling period. Lower mortality was attributed to improved rearing procedures.

Parasitization of *E. loftini* was recorded in all fields sampled, averaging 12.1 ± 0.6% (mean ± SE), but it

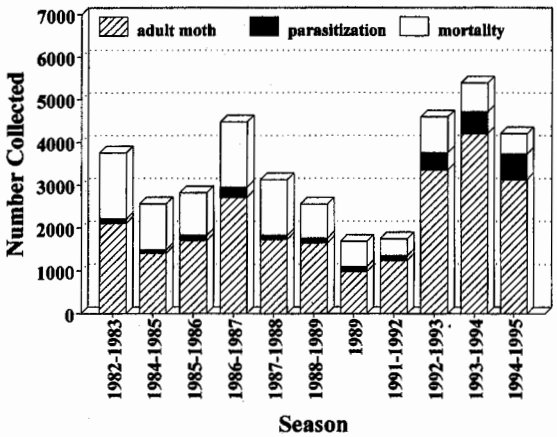

Fig. 2. Fate after laboratory rearing of *E. loftini* immatures and parasites collected in the lower Rio Grande Valley, Texas, 1982–1995. Mortality includes individuals that died during development or died as a result of handling (e.g., dried meridic diet, larval escape from cups, infestation by mites); parasitization includes parasites that emerged during host development or that were collected as parasite immatures with host remains.

steadily increased from 1991–1992 (5.7 ± 1.0%) through 1994–1995 (16.8 ± 1.3%; df = 3, 171; $F = 3.6$; $P = 0.0156$). Parasitization was similar across the lower Rio Grande Valley (east 12.7 ± 1.0% versus west 11.7 ± 0.8%; df = 1, 171; $F = 0.4$; $P = 0.5105$) and was similar across cultivars (df = 10, 171; $F = 1.6$; $P = 0.1089$). Parasitization of *D. saccharalis* was recorded in 85 fields, averaging 12.2 ± 2.8%, and was similar across seasons, valley locations, and cultivars ($P > 0.100$).

The indigenous parasites *C. sonorensis* and *D. solitaria* and the exotic *A. stigma* were the most commonly collected parasites from *E. loftini* (Table 2). *A. pyralophagus*, although established, was collected in low numbers. As in the earlier evaluations, *C. flavipes* was commonly collected from *D. saccharalis*, although *A. stigma* became common during 1994–1995. Numerous *D. solitaria* and *C. sonorensis* cocoons were collected without host remains, presumably most emerged from *E. loftini* larvae in stalks (Table 2).

During this sampling period the number of moribund larvae found within stalks was recorded. High relative numbers of dead *E. loftini* were found in 1991–1992 compared with the other years (1991–1992, 715; 1992–1993, 315; 1993–1994, 249; 1994–1995, 252). The causal factors for this mortality were not investigated.

Discussion

***Diatraea saccharalis* Populations and *Cotesia flavipes*.** *E. loftini* became the numerically dominant stemborer attacking sugarcane in the lower Rio Grande Valley soon after its discovery in 1980. Our results show that *E. loftini* have generally represented > 90% of the stemborer larvae in stalks throughout the sugarcane production area since 1982,

Table 2. Parasites collected from *E. loftini* and *D. saccharalis* larvae and pupae and parasite immatures in south Texas sugarcane before and after the 1989 freeze

	Seasons	
	1982–1989	1991–1995
Stemborer/Parasite		
E. loftini	20,972	15,922
C. sonorensis	564	1,415
A. pyralophagus	153	16
D. solitaria	79	47
M. prolificus	25	0
C. flavipes	13	5
L. jalisco	13	0
A. stigma	4	112
G. indicus	3	0
M. pyralidis	2	0
R. roslinensis	1	0
P. furvus	1	0
B. rhyssaliformis	1	2
Macrocentrus n. sp.	0	5
unidentified	34	12
D. saccharalis	1,302	800
C. flavipes	127	45
A. pyralophagus	3	1
M. prolificus	3	0
D. solitaria	1	0
A. minator	1	0
A. stigma	0	12
Macrocentrus n. sp.	0	1
unidentified	1	4
Parasites[a]		
A. pyralophagus	164	39
D. solitaria	83	255
C. sonorensis	59	149
C. flavipes	13	6
M. pyralidis	3	0
G. indicus	5	0
M. prolificus	2	0
A. stigma	1	6
B. rhyssaliformis	0	2
unidentified	100	88

[a] Host species not identified.

although in each season some individual fields contained a predominance of *D. saccharalis*. A recent unrelated study in the same region corroborated our conclusion, in which 94% of 835 stemborer larvae

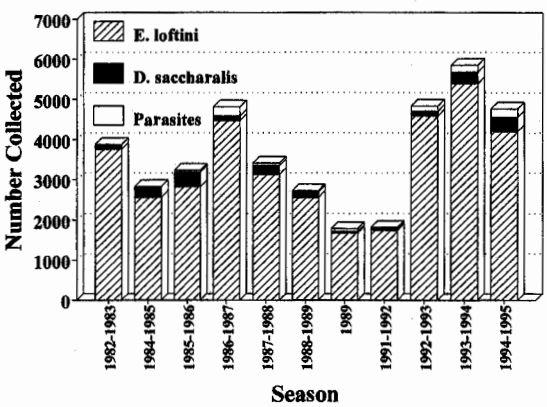

Fig. 1. Number of stemborer or parasite immatures collected during biological control evaluations, 1982–1995, lower Rio Grande Valley, TX.

collected from sugarcane were *E. loftini* (Spurgeon et al. 1997).

Although *E. loftini* has become the predominant stemborer in sugarcane, stalk injury from infestations of both stemborers, expressed as percentage of bored internodes, has remained static since 1977 when *D. saccharalis* was the sole stemborer attacking sugarcane. Percentage of bored internodes caused by *D. saccharalis* in 1977 ranged from 12–51% (Reeves 1978), whereas percentage of bored internodes from concurrent attack by both stemborers in 1988–1989 ranged from 11–53% (Pfannenstiel and Meagher 1991) and 10–19% in 1991–1992. Stalk injury from *D. saccharalis* larval tunneling has declined drastically since the 1970s from an average 18.7% (Fuchs et al. 1973) and 31% (Reeves 1978) bored internodes in 1972 and 1977–1978, respectively, to < 1% bored internodes in 1988–1990 (Pfannenstiel and Meagher 1991).

The precipitous decrease in injury to sugarcane stalks from *D. saccharalis* larval tunneling occurred over several years and in reasonable temporal concert with the introduction and establishment of 2 exotic insects that could have impacted *D. saccharalis* populations. One, the gregarious larval endoparasitic braconid *C. flavipes*, was purposefully introduced for biological control of sugarcane borer in 1977. The other, *E. loftini*, was an accidental immigrant from Mexico that arrived in 1980. Both exotic insect introductions may have negatively impacted the *D. saccharalis* population; the parasite by inflicting indispensable larval mortality and *E. loftini* through competition for resources. An attempt to estimate the impact of *C. flavipes* on *D. saccharalis* in 1981 was thwarted by the invasion of *E. loftini*. A historical accounting of sugarcane management practices coupled with the resource use behavior of *E. loftini* larvae coexisting with *D. saccharalis* larvae in sugarcane in Mexico follow to provide insight into the possible cause(s) of the recent decline in *D. saccharalis* populations in sugarcane.

From the renewal of the sugar industry in 1972 until introduction of *C. flavipes*, management of *D. saccharalis* was dependent upon broad-spectrum insecticides (Fuchs et al. 1979). The indigenous parasite fauna that had accepted the exotic *D. saccharalis* as a host was impoverished and not impacting the stemborer in sugarcane (Fuchs and Harding 1979). In 1977 ≈16,700 *C. flavipes* were released at 3 different sites in sugarcane to provide a natural enemy component that could enhance natural mortality of *D. saccharalis* (Fuchs et al. 1979). *C. flavipes* increased numerically, rapidly dispersed downwind of colonization sites, and subsequently became established in many sugarcane fields. As *C. flavipes* was spreading over much of the sugarcane growing area, educational programs were developed to increase grower and consulting entomologist awareness of biological control and the newly colonized parasite.

The reduction in *D. saccharalis* injury was most apparent in the western and northern areas of the lower Rio Grande Valley, and conspicuously absent in the eastern area where the prevailing southeasterly winds restrained natural dispersal of *C. flavipes* from the initial areas of colonization. To increase the range of the parasite, USDA–APHIS, in cooperation with Rio Grande Valley Sugar Growers, mass reared *C. flavipes* on *D. saccharalis* and successfully inoculated the eastern growing area in 1980. Before a planned evaluation of the impact of *C. flavipes* on *D. saccharalis* management over the entire production area was initiated, *E. loftini* invaded and began to devastate sugarcane fields in the western areas. The full attention of the sugarcane industry was captured when studies revealed that *E. loftini* was not a suitable host for *C. flavipes* (Johnson 1981) and that suppression of the new pest would require a different management strategy.

Apparently the *D. saccharalis* population density was already abating when *E. loftini* invaded the sugarcane agroecosystem. Although the impact of *E. loftini* competition on *D. saccharalis* abundance has not been investigated, numerous stemborer surveys in the aboriginal and newly invaded areas of Mexico inhabited by *E. loftini* provide insight into this species' relative abundance when it occurs in concert with other stemborers inhabiting sugarcane. In eastern Mexico, where *E. loftini* has had a recent association with *D. saccharalis*, and in southwestern Mexico where it has an old association with several *D. saccharalis* congeners in sugarcane, *E. loftini* is not the dominant stemborer (Melton et al. 1986, Rodriguez-del-Bosque and Smith 1989, Rodriguez-del-Bosque et al. 1989). Therefore, we provisionally conclude that *E. loftini* is not typically the dominant stemborer in sugarcane when it occurs sympatrically with other stemborers.

In summary, we conclude that the general decline in *D. saccharalis* injury to sugarcane that began in the late 1970s and remained low through 1995 was predominately caused by parasitization by *C. flavipes* and less influenced by exploitive competition for resources by *E. loftini*. *C. flavipes* remains the most commonly collected parasite from *D. saccharalis*. The gradual reduction in *D. saccharalis* injury to sugarcane in Texas after introduction of *C. flavipes* and the continued maintenance of a subeconomic population is in concordance with the biological control successes in the Caribbean (Alam et al. 1971, Baker et al. 1992). The characteristic linear functional response of *C. flavipes* to *D. saccharalis* larval densities helps explain this gradual temporal pattern of *D. saccharalis* suppression with continued maintenance of the pest below economically damaging levels (Wiedenmann and Smith 1993).

Parasites of *E. loftini*. Although *C. flavipes* has been reared from *E. loftini* larvae (Table 2), *E. loftini* is not a suitable host for *C. flavipes* (Johnson 1981). *C. flavipes* attacked exposed *E. loftini* larvae in the laboratory, but the parasite progeny were commonly encapsulated. The rare cocoon masses from *E. loftini* were typically much smaller (usually <10 individuals per brood, unpublished data) than cocoon masses from *D. saccharalis* (≈44 individuals per brood [Wiedenmann and Smith 1995]), suggesting that cocoon masses from *E. loftini* represented survivors of a partially successful host immune reaction (Wiedenmann and Smith

1995). Successful parasitization of *E. loftini* larvae by *C. flavipes* in the field is further diminished by the characteristic larval habit of tightly packing the traversed portion of the feeding tunnel with frass and detritus (Smith et al. 1993). Therefore, the ingress and sting attack strategy employed by *C. flavipes* is precluded because the parasite is denied physical access to the host.

The most commonly collected parasite of *E. loftini* was the indigenous, solitary, egg–larval endoparasitic *C. sonorensis*. The distribution of *C. sonorensis* is consistent with the past and most recent distribution of its only recorded host, *E. loftini* (Shenefelt 1973). *C. sonorensis* parasitizes *E. loftini* within its original distribution in Mexico (Sinaloa: van Zwaluwenburg [1926], Melton et al. [1986]; Jalisco: Rodriguez-del-Bosque and Smith 1989; Nayarit: unpublished data) and the more recent expanded distribution in Mexico and Texas (Tamaulipas: Rodriguez-del-Bosque et al. 1989, 1990; Nuevo Leon: unpublished data). Apparently *C. sonorensis* has expanded its range coincident with the range expansion of its obligate host and remains a common parasite throughout its host range, especially on corn (Rodriguez-del-Bosque et al. 1990).

Other indigenous larval parasites have used the immigrant *E. loftini* as a host. *D. solitaria*, a solitary endoparasite endemic to southern Texas and northeastern Mexico, has been reared from *E. loftini*, *Diatraea lineolata* (Walker), and *D. saccharalis* in sugarcane, maize, *Zea maize* L., and Johnson grass, *Sorghum halepense* (L.) (Pers.), unpublished data (Wharton et al. 1989, Rodriguez-del-Bosque et al. 1990). *D. solitaria* is a sibling species to the gregarious *D. kimballi* Kirkland, indigenous to central Mexico (Wharton et al. 1989), that was released in 1985 against *E. loftini* but was never recovered. Other indigenous parasites infrequently recovered from *E. loftini* included *B. rhyssaliformis* and *Macrocentrus* n. sp. *B. rhyssaliformis* is a gregarious larval ectoparasite that typically parasitizes lepidopteran larvae tunneling in grasses in the genera *Setaria*, *Cynodon*, and *Sorghum* (Wharton and Quicke 1988).

The exotic parasites *A. pyralophagus* and *A. stigma* were recovered from *E. loftini* larvae before and after the December 1989 freeze. *A. pyralophagus* was originally collected from *E. loftini* infesting Johnson grass near Marin, Nuevo Leon, Mexico, in 1981, and later from *E. loftini* infesting sugarcane and maize near Los Mochis and Culiacan, Sinaloa, Mexico, in 1983 (Smith et al. 1987). By 1985, 2.15 million individuals had been released and subsequently became established in commercial sugarcane fields (Browning et al. 1985). However, life history observations and field cage studies concluded that only the few *E. loftini* larvae tunneling near the periphery of the sugarcane stalk were physically accessible to attack by *A. pyralophagus* (Hawkins et al. 1987). Because ovipositor length limits *A. pyralophagus* access to the majority of hosts tunneling in large diameter stalks, this parasite would be more successful when hosts are tunneling in small-diameter stems and should complement mortality induced by other parasites employing different host attack strategies (Melton and Browning 1986; Smith et al. 1987, 1993).

Alabagrus stigma successfully parasitized both *E. loftini* and *D. saccharalis*. It was reared from *E. loftini* infesting sugarcane and Johnson grass in Sinaloa, Mexico, during collections made in September 1984 (Melton et al. 1986) and was recorded parasitizing *D. saccharalis* in Cuba as early as the 1920s (=*Bassus stigmaterus* Cresson, [Box 1928]). The population of *A. stigma*, now considered established in Texas, consists of descendants of founders imported from Bolivia by the authors in 1984. Increased recoveries from *E. loftini* and the ability of *A. stigma* to attack both stemborers provided the incentive for making additional releases of this parasite during 1993–1995.

Only isolated recoveries were made of the exotic larval parasites *M. prolificus*, *L. jalisco*, *G. indicus*, *M. pyralidis*, and *R. roslinensis*, and the exotic pupal parasite *P. furvus*. *M. prolificus* was more successful parasitizing *Diatraea* species than *E. loftini* when initially collected (Melton et al. 1986). Parasitism by *L. jalisco* reached 48% in 1 field of sugarcane when initially collected in Mexico (Rodriguez-del-Bosque and Smith 1996), but recoveries were low in Texas because of small numbers of adults released. *G. indicus* uses an ingress and sting host attack strategy that limits its effectiveness against *E. loftini* (Smith et al. 1993). *M. pyralidis* is a native parasite of *E. loftini* in western Mexico (Wharton 1985); however, the short temporal duration of the acceptable host stage (prepupa) and limited host availability probably impeded successful colonization (Smith et al. 1990). *E. loftini* is an acceptable and suitable host for *R. roslinensis* (Hawkins and Smith 1986); however, this parasite uses the same drill and sting host attack strategy as *A. pyralophagus* (Smith et al. 1993) and thus had limited access to hosts in the large stemmed sugarcane because of ovipositor length (Hawkins and Smith 1986). *E. loftini* pupae are acceptable and suitable hosts for *P. furvus* (Pfannenstiel et al. 1996), but the ingress and sting attack strategy employed (Smith et al. 1993) was impeded by the intact moth emergence window constructed by *E. loftini* (Pfannenstiel et al. 1992).

Although *D. saccharalis* is considered under good biological control by *C. flavipes*, no effective parasites have been established for *E. loftini*. Parasites collected from *E. loftini* within its indigenous distribution have resulted in only *A. pyralophagus* and *A. stigma* becoming established. Importation of parasites attacking ecologically equivalent stemborers on other continents to form new host–parasite associations (Wiedenmann and Smith 1997) has been equally unsuccessful for establishing and suppressing *E. loftini*. Thus, we conclude that none of the new association parasites established and 2 of 4 old association parasites became established. Poor establishment by the introduced parasites is attributed to either the sugarcane plant providing the stemborer safe refuges from parasite attack or *E. loftini* being not suitable for parasite development. Physical and chemical modifications of modern crop plants, such as sugarcane, often provide stemborers structural, chemical, and behavioral ref-

uges from parasite attack (Smith and Wiedenmann 1997).

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