

FLORIDA ENTOMOLOGIST

(An International Journal for the Americas)

Volume 72, No. 4

December, 1989

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FLORIDA ENTOMOLOGIST is issued quarterly—March, June, September, and December. Subscription price to non-members is \$30 per year in advance, \$7.50 per copy; institutional rate is \$50 per year. Membership in the Florida Entomological Society, including subscription to *Florida Entomologist*, is \$25 per year for regular membership and \$10 per year for students.

Inquiries regarding membership, subscriptions, and page charges should be addressed to the Business Manager, P. O. Box 7326, Winter Haven, FL 33883-7326.

Florida Entomologist is entered as second class matter at the Post Office in DeLeon Springs and Winter Haven, FL.

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Send to: John R. McLaughlin, 4628 NW 40th Street Gainesville, FL 32606.

This issue mailed December 22, 1989

ANNOUNCEMENT 73RD ANNUAL MEETING FLORIDA ENTOMOLOGICAL SOCIETY

The 73rd annual meeting of the Florida Entomological Society will be held August 5-9, 1990 at the Camino Real Hotel in Cancun, Mexico. Travel and hotel arrangements are being handled through Holbrook Travel, 3540 N.W. 13th Street, Gainesville, FL 32609 (Phone 1-800-345-7111), Attn: Ms. Joyce Rickard. Registration forms and additional information will be mailed to members and will appear in the Newsletter and March issue of *Florida Entomologist*.

SUBMISSION OF PAPERS

The deadline for submission of papers and posters for the 73rd annual meeting of the Florida Entomological Society will be May 15, 1990. The meeting format will contain seven symposia so there will be concurrent sessions. Submitted papers will be eight minutes allocated for the oral presentation with two minutes for discussion. A separate Poster Exhibit Session is planned. There will be student paper and poster sessions with awards as in previous years. Students participating in these judged sessions must be members of the Society and registered at the meeting.

For additional information contact:
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FORUM

A New Type of Article for our Authors and Subscribers

We are proud to announce that, beginning in 1990, scientists may submit articles for publication in a *FORUM* section of *Florida Entomologist*. *FORUM* articles (1-2 per issue) will appear at the beginning of each issue in a section marked *FORUM*. If available, the first *FORUM* articles will appear in the June 1990 issue.

Articles for the *FORUM* section must follow the general style guidelines for all other articles submitted to *Florida Entomologist*. *FORUM* articles must be of high scientific quality, demonstrate acceptable experimental design and analysis, and cite appropriate sources to support findings. *FORUM* articles will include "cutting edge" science, scientifically meritorious but controversial subjects, new methodologies (designed and tested), experimentally-based designs and tests of pedagogical methods, and documented challenges to existing entomological techniques, philosophies or experimental paradigms.

Submitted articles should include "Submitted to *Florida Entomologist*: *FORUM*" on the title page. Three or more peer reviews will be acquired by the Associate Editor for *FORUM* publications.

We feel the addition of a *FORUM* section will expand the scope of *Florida Entomologist* and allow readers and publishing scientists an additional creative outlet that will complement our symposia, research articles, and notes.

EFFECTS OF *DIROFILARIA IMMITIS*
(NEMATODA: FILARIOIDEA)
INFECTION ON LIFE TABLE CHARACTERISTICS OF
SUSCEPTIBLE AND REFRACTORY STRAINS OF
AEDES AEGYPTI (VERO BEACH) (DIPTERA: CULICIDAE)

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ABSTRACT

The effects of *Dirofilaria immitis* (Leidy) infection on the life table characteristics of selected refractory and susceptible *Aedes aegypti* L. (Vero Beach) strains were studied under uninfected and infected conditions. The expectation of life at emergence (e_x) of the infected susceptible females was significantly lower than that of both of the uninfected strains and of the refractory infected strain. The net reproduction rate (R_0) was the highest in uninfected refractory females, while it was lowest in the infected susceptible females. The uninfected refractory strain had the highest values of instantaneous birthrate (b) and instantaneous death rate (d); whereas the lowest values of b and d were in the infected susceptible strain. No interaction was present for the mean generation time (G), age in days at mean cohort reproduction (T_0), instantaneous rate of increase (r_m) or their ratios, r_m/b , and b/d . The refractory mosquitoes lived longer than the susceptible mosquitoes under both uninfected and infected conditions, consequently, the age at maximum reproduction was significantly earlier in the refractory mosquitoes and resulted in their higher r_m values. The uninfected refractory females laid more eggs than the infected refractory, uninfected susceptible, and infected susceptible females throughout their life span. The *D. immitis* infection caused significant mortality in the susceptible strain due to the migration of microfilariae to the Malpighian tubules, at the time of the molt from first stage (L_1) to second stage (L_2), and when infective stage larvae (L_3) left the Malpighian tubules. The major causes of mortality in refractory strain were the migration of the microfilariae to the Malpighian tubules and due to the damage caused by the constant movement of the moribund prelarvae inside the Malpighian tubules.

RESUMEN

Se estudiaron los efectos de infección de *Dirofilaria immitis* (Leidy) sobre las características de la tabla de vida de razas seleccionadas refractarias y susceptibles de *Aedes aegypti* L. (Vero Beach) bajo condiciones infectadas y no infectadas. La expectación de vida al emerger (e_x) de hembras susceptibles infectadas fué significativamente más baja que la raza no infectada y la raza refractaria infectada. La raza refractaria no infectada tuvo el valor más alto de tasa de nacimiento instantáneo (b) y de muerte instantánea (d); mientras que los valores más bajos de b y d ocurrieron en la raza susceptible infectada. No ocurrió una interacción entre tiempos de generación (G), entre la edad en días del promedio de reproducción del cohorte (T), en la tasa de aumento instantáneo (r_m) o en su proporción, rm/b , y b/d . Los mosquitos refractarios vivieron más tiempo que los mosquitos susceptibles bajo ambas condiciones de infección y de no infección, consecuentemente, la edad de máxima reproducción fue significativamente más temprano en los mosquitos refractados y resultó en valores más altos de r_m . Las hembras refractadas no infestadas pusieron más huevos que las refractadas infestadas, que las susceptibles no infectadas, y que las hembras susceptibles infectadas durante toda su vida. Infección de *D. immitis* causó una mortalidad significativa en la raza susceptible debido a la migración de microfilarias a los tubos de Malpighios durante el período de muda de la primera etapa (L_1) a la segunda etapa (L_2), y cuando la etapa larval (L_3) salió del

tubo de Malpigio. La mayor causa de la mortalidad de la raza refractoria fué la migración de microfilaria a los tubos de Malpigio y debido al daño causado por el movimiento constante de pre-larvas moribundas dentro de los tubos de Malpigio.

Dirofilaria immitis (Leidy) (Nematoda: Filarioidea) spends part of its life cycle in a mosquito vector. The microfilariae of *D. immitis* migrate after ingestion from the midgut of the mosquito to the primary cells of the Malpighian tubules, where they become intracellular and develop in susceptible mosquitoes through two molts to the infective larval stage (L₃) (Kartman 1953, Taylor 1960). Development of *D. immitis* and other filariids in the mosquito vectors can cause pathological effects, which can subsequently reduce the vector's survival and fecundity (Kershaw et al. 1953, Kershaw & Duke 1954, Javadian & Macdonald 1974, Courtney et al. 1985).

In *Aedes aegypti* L., infection with *D. immitis* and *Brugia pahangi* (Buckley and Edeson) initially increases mortality when microfilariae reach the target organ (Malpighian tubules and thoracic muscles, respectively), where development occurs, and later when the infective larvae exit the target organ (Kartman 1953, Kershaw et al. 1953, Townson 1971). The effect of the filarial infection on the fecundity of vector mosquitoes is, however, not clearly apparent. The number of eggs developed by *Brugia* susceptible *Ae. aegypti* after the first infective blood meal on *B. pahangi* or *D. repens* infected animals was not significantly different from that of mosquitoes having a first uninfected blood meal (Javadian & Macdonald 1974). But when both groups of infected mosquitoes were provided with an uninfected second blood meal, the infected mosquitoes laid significantly smaller egg batches. This difference was attributed to the larger size and greater nutritional requirement of older developing filarial larvae during the second gonotrophic cycle of the mosquitoes (Javadian & Macdonald 1974). Similarly, in *Ae. trivittatus* (Coquillett), egg production decreased as parasite burden increased, but only mosquitoes harboring more than 15 larvae of *D. immitis* showed significant reduction in egg production (Christensen 1981).

We have isolated highly susceptible and highly refractory strains of *Ae. aegypti* (Vero Beach) to *D. immitis* infection by the individual sibling mating method of McGreevy et al. (1974). *Dirofilaria immitis* larvae develop normally from microfilariae to infective third stage larvae in the highly susceptible strain of *Ae. aegypti*, similar to that described by Taylor (1960). On the other hand, in the highly refractory strain of *Ae. aegypti*, the microfilariae do not develop (Sauerman & Nayar 1985). The present study was conducted to determine the effect of *D. immitis* infection on the life table characteristics, especially survival and reproductive potentials, of the highly susceptible and the highly refractory strains of *Ae. aegypti* (Vero Beach).

MATERIALS AND METHODS

STRAINS

Highly susceptible and highly refractory strains of *Ae. aegypti* (Vero Beach) were used throughout the study. All experiments were conducted at 25°C, 80% relative humidity and 12:12 LL:DD photoperiod.

LARVAL REARING

Eggs collected from gravid females of both the susceptible and the refractory strains were hatched in an egg hatching medium, prepared by adding a small amount of Brew-

ers yeast to boiled water. Groups of 100 first instar larvae of each strain were counted into 12 enamel pans (34 x 21.5 cm) with glass lids containing 500 ml of water. The larvae were provided daily a measured amount of a 1:1 mixture of Brewers yeast and liver powder. A total of 1000 mg of food was added to each pan during the entire rearing period. Pupae were picked daily from each pan and were placed in separate emergence cups. Newly emerged adults were lightly anesthetized with chloroform and were sexed and recorded by pan number and date of emergence.

ADULT MAINTENANCE

Twelve groups of 25 newly emerged males and 25 females were allowed to cohabit in 3.8 liter ice cream carton cages. A 10% sugar solution was provided for ad lib. feeding and was changed every three days. Six of these groups were used as uninfected controls and were fed daily for 30-45 minutes on tethered chicken from one day after emergence until the day the last mosquito died. The mosquitoes from the remaining six groups of each strain were fed daily for 30-45 minutes on the hind legs of a dog, naturally infected with *D. immitis*, for 4 days starting from one day after emergence. At the time of these experiments the microfilaremia was between 40-60 microfilariae per microliter of cutaneous blood. During these 4 days all the females fed to repletion, thereafter, these infected females were allowed to feed daily for 30-45 minutes on tethered chicken until the day the last mosquito died.

Dead mosquitoes were removed and recorded daily and the remaining mosquitoes were provided a blood meal on a restrained chicken. A petri dish (15 x 4 cm), lined with wet filter paper, was provided daily for oviposition. The oviposition petri dishes containing the eggs were kept separate by the date of oviposition and the cage number. The eggs were allowed to incubate for 15 days and were then hatched in the egg hatching medium for two days. The medium was filtered and the eggs dried again at 25°C for an additional two days and then again immersed in the hatching medium for 2 days. The eggs were classified into three categories: hatched, unhatched embryonated and unembryonated eggs.

Additionally, a group of 300 mosquitoes of each strain was fed on the infected dog and ten mosquitoes were dissected daily from each strain to follow their developmental patterns.

STATISTICAL METHODS

The statistical methods, formulae, rationale and terminology described previously (Reisen et al. 1979, Reisen & Mahmood 1980) were used to calculate life table parameters including life expectancy at emergence (e_x in days), net reproductive rate (R_0 in females per female per generation), the mean age of reproduction (T_0 in days), the intrinsic rate of increase (r_m in females per female), the instantaneous birth rate (b in females per female) and generation time (G in days). In addition, various immature developmental characteristics of both the strain were compared using Student's *t*-test, which was adjusted to take into account any significant differences in the variances. The percent survivorship data were transformed to arcsine before subjecting to Student's *t*-test. The different life table attributes were also compared by using two-way analysis of variance.

RESULTS

The immature survivorship from first instar larvae to pupae and from first instar larvae to adults were significantly greater for the refractory strain as compared to the

susceptible strain, but there was no significant difference in survivorship from pupae to adults for either strain (Table 1). Similarly, the survivorship of males and females from first instar to adult, the median pupation and median emergence times of females were not significantly different when tested by χ^2 and Student's *t*-test, respectively (Table 1). The median emergence time of refractory males was significantly earlier than the males of the susceptible strain (Table 1). There was no significant difference between the sex ratio of the two strains.

Normal development of *D. immitis* larvae observed in the Malpighian tubules of the susceptible females was similar to that described by Taylor (1960). Microfilariae, which were very mobile and $300 \pm 15\mu$ in length, entered the Malpighian tubules within 24 h of the infective blood meal, became intracellular and changed to immobile L₁ stage, which first decreased in length to $150 \pm 10\mu$ and then increased in length to $217 \pm 4\mu$ during the next 4 days. On the 9th day, these larvae increased to $460 \pm 5\mu$ in length and molted to the second stage (L₂) larvae. These larvae further increased in length to $1100 \pm 10\mu$ by the end of the 13th day. During the next 2 days, these larvae molted to the third stage (L₃) larvae, and were $1300 \pm 18\mu$ in length. The larvae were now very active and moved out of the Malpighian tubules into the hemocoel and then to the head capsule, where they stayed until they were transmitted during the next blood meal. There was substantial cellular damage to the Malpighian tubule cells during the development of the larvae.

In refractory females, the microfilariae migrated from the midgut to the Malpighian tubules, where their development was arrested. These microfilariae, called prelarvae, became moribund and caused some cellular damage at the distal and proximal ends of the Malpighian tubules due to their constant spasmodic movement.

The expectation of life at emergence (e_x) of females was not significantly different in the uninfected refractory (40.5 days) and susceptible strains (33.5 days); but it was significantly longer than the infected females (11.0 and 8.9 days, respectively) (Table 2). A large number of females of both the strains died during the first four days after ingestion of an infective blood meal as depicted by the l_x curves (age specific survivorship curves) (Fig. 1a and 1b). This initial sharp decline in survival of the infected females

TABLE 1. IMMATURE DEVELOPMENTAL ATTRIBUTES OF TWO STRAINS OF *Aedes aegypti* (VERO BEACH), SUSCEPTIBLE AND REFRACTORY TO *Dirofilaria immitis* INFECTION.

Attributes	Strain	
	Susceptible	Refractory
Total Survivorship:		
First instar larva-Adult	0.81 ± 0.08	0.91 ± 0.04 ¹
First instar larva-Pupa	0.85 ± 0.07	0.93 ± 0.05 ¹
Pupa-Adult	0.96 ± 0.03	0.095 ± 0.03
First instar larva-Adult (♂)	0.71	0.89 ³
First instar larva-Adult (♀)	0.91	0.94 ³
Median pupation time (days):	7.11 ± 0.32	6.64 ± 1.01 ²
Median emergence time (days):		
Female	9.49 ± 0.79	9.04 ± 0.48 ²
Male	9.39 ± 9.50	8.42 ± 1.01 ²
Sex ratio:		
Males/Total adults	0.56 ± 0.05	0.52 ± 0.08

¹Means indicated in each row were significantly greater when compared by Student's *t*-test $P < 0.05$.

²Means in each row were not significantly different when compared by Student's *t*-test.

³Means in each row were not significantly different when compared by χ^2 test.

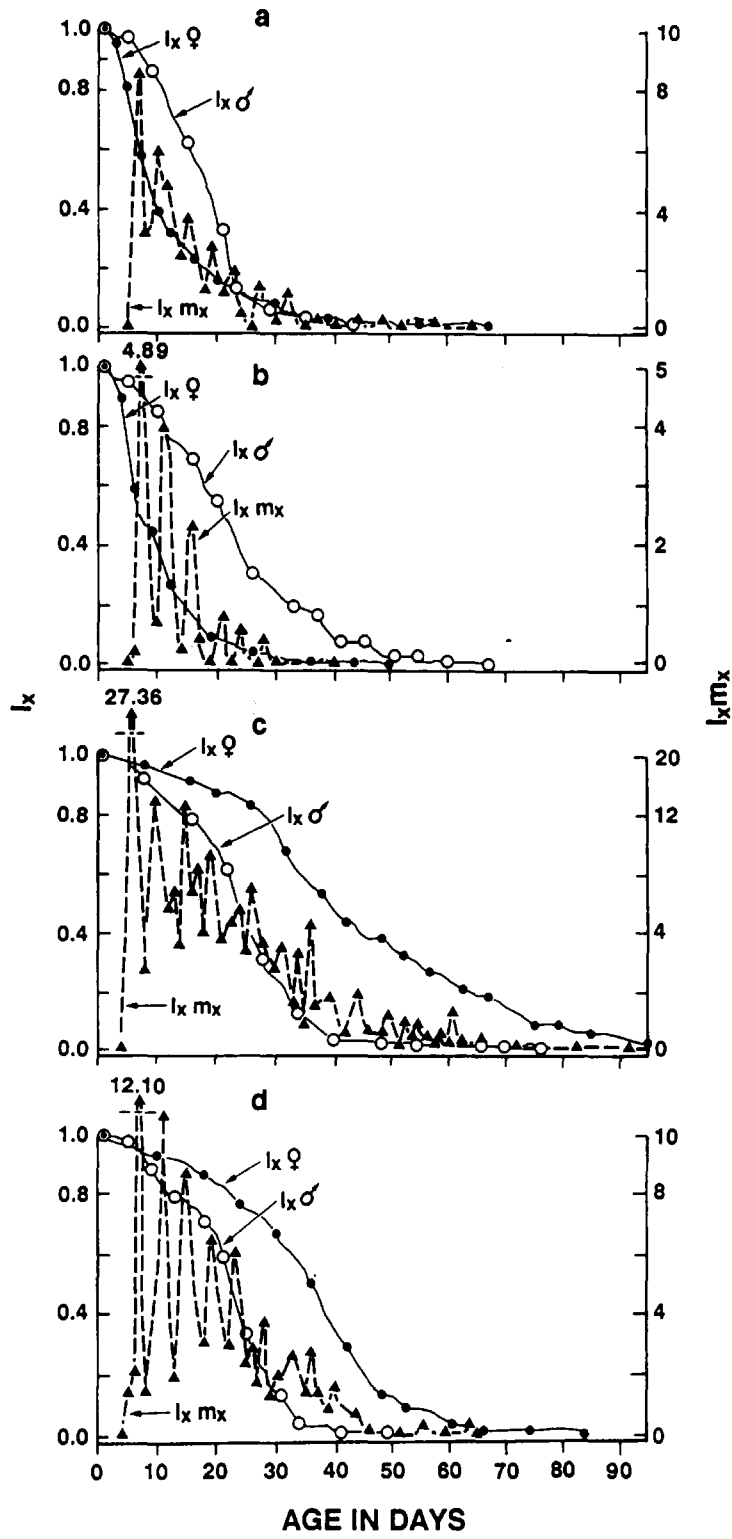
was due to trauma and injury caused during the migration of the microfilariae from the midgut into the Malpighian tubules in both strains. At 6 days after emergence, i.e., 2-3 days after an infective blood meal, 67% of 150 infected refractory females were alive as compared to 59% of the 150 infected susceptible females (Figs. 1b and 1d). But the rate of mortality continued to increase for the infected refractory females and they died faster as compared to the infected susceptible females, with the result that at 6-8 days after an infective blood meal 50% of the infected females were dead in both strains (Fig. 1a and 1b). The increase in the number of dead females during the time period for the refractory strain might be due to the cellular damage caused by the continued spasmodic movement of the moribund prelarvae, whereas, in the Malpighian tubules of the susceptible females the first stage larvae were inactive. The next decline for e_x among infected susceptible females was observed at the time of molting of first (L_1) to second (L_2) stage larvae of *D. immitis*, i.e., at 12-14 days after emergence of females. An increased mortality was also observed at the time of exit of third stage infective (L_3) larvae from the Malpighian tubules, i.e., 16 days after emergence of females, at this time infective larvae were present in the hemocoel, thorax and head of the susceptible females. After 16 days the l_x curves were similar in both the infected refractory and susceptible strains (Fig. 1a and 1b). No interaction was present in e_x of females between the two strains and their state of infection.

The e_x at emergence of males showed a significant interaction ($P < 0.05$) ($F = 6.2$), since the susceptible males in groups with the infected females had significantly longer e_x at emergence than the males in groups with uninfected females (Table 2).

The net reproductive rate (R_0) in females progeny per female per generation had a significant interaction ($P < 0.05$) ($F = 35.5$). The uninfected refractory females showed the highest R_0 (314.0 ± 64.1 , $\bar{x} \pm sd$) and this is very well depicted by their $l_x m_x$ curve (Fig. 1c). The maximum reproductive effort ($l_x m_x$) value, i.e., 27.4, was observed for the uninfected refractory females as compared to the infected refractory (8.8), uninfected susceptible (12.1) and infected susceptible females (4.9) (Figs. 1a-1d). The lowest value of R_0 was observed for the infected susceptible females (Table 2). Both uninfected refractory and susceptible females had higher R_0 values than their infected counterparts (Table 2).

The females of the refractory strain lived longer than the females of the susceptible strains in both the uninfected and infected groups, consequently, the mean generation time (G) and the mean age of reproduction (T_0) were later for them than of the susceptible females (Table 2). No significant interaction was present in the value of G of both strains whether infected or not ($P < 0.05$), but the uninfected refractory females had significantly longer G than the infected refractory females. Similarly uninfected susceptible females had longer G than the susceptible infected females ($P < 0.05$) ($F = 28.6$ and $F = 10.7$, respectively) (Table 2). The mean age of reproduction (T_0) was significantly greater for the refractory females than the susceptible females ($P < 0.05$) ($F = 8.9$) (Table 2). Similarly, infected refractory females and infected susceptible females had significantly smaller values of T_0 than the uninfected females ($P < 0.05$) ($F = 33.5$) (Table 2). There was no interaction between either strain and its state of infection ($P < 0.05$).

Although the age at first reproduction was not different in the two strains, the age at maximum reproduction, was significantly earlier ($P < 0.05$) for the refractory females (Fig. 1a to 1d) and resulted in their higher values of instantaneous rate of increase (r_m) (Table 2). The r_m value was significantly greater for the refractory females than the susceptible females ($P < 0.05$) ($F = 4.6$). The uninfected refractory females and uninfected susceptible females had greater r_m values than their respective infected counterparts ($P < 0.05$) ($F = 52.4$) (Table 2).



A significant interaction was present for the instantaneous birth rate (b) between the two strains and their state of infection ($P < 0.05$) ($F = 15.9$) (Table 2). The highest value of b was for uninfected refractory females and lowest value of b was for infected susceptible females (Table 2). Similarly, a significant interaction existed between the type of strains and their state of infection for the instantaneous death rate (d) ($P < 0.05$) ($F = 6.9$) (Table 2). The highest value of d was for the uninfected refractory females and lowest value of d was observed in infected susceptible females (Table 2). The r_m/b and b/d ratios were not significantly different and there was no interaction present between either strain and its state of infection ($P < 0.05$) (Table 2).

A higher percentage of the infected refractory (85.7%) and infected susceptible (92.9%) females were present in the younger classes of the stable age distribution or the proportion of the population falling into each age class (1-6 days) as compared to the uninfected refractory (82.2%) and uninfected susceptible (71.5%) females (Figs. 2a-2d). The presence of a higher proportion of the infected females in the lower age distribution classes suggested that a larger proportion of the infected females died earlier in life.

Total number of eggs laid by and the mean percentage of hatched eggs from one female each week during their life span for all the four different groups is presented in Table 3. No differences were observed for the number of eggs laid by uninfected and infected susceptible females during the first four weeks of their life ($P < 0.05$). The percent hatch was significantly lower for the infected susceptible females ($P < 0.05$). The proportion of females laying higher number of unembryonated eggs increased in older females for the uninfected refractory females. There was no significant difference for the number of eggs laid per female per week during the first 7 weeks by refractory females, whether uninfected or infected ($P < 0.05$) (Table 3). There was a significant difference in the total number of eggs laid per female during their life span among all the four groups ($P < 0.05$, $F = 1.6$).

DISCUSSION

The present study suggested that the genotype of the mosquitoes does not affect their survival during immature development and that the eggs laid by susceptible females had an equal chance of reaching adulthood as those laid by refractory females. The immature survivorship of both susceptible and refractory strains was similar to that observed in field collected *Ae. aegypti* (Gainesville) by Wijeyaratne et al. (1974). The larval development time was similar to their laboratory observed value of 8-9 days but was less than their field values which could be due to differences in temperature and/or food. The male larvae developed faster than the female larvae which agreed with the observations of Putnam & Shannon (1934). The rate of female larval development was faster in the present study.

Life table characteristics of *Ae. aegypti*, which were fed fruit juices and blood were determined by Putnam & Shannon (1934). The life expectancy of their mosquitoes was greater than that observed here for the uninfected refractory females in the present



Fig. 1. The age specific survivorship in individuals per individual per day (L_x) and reproductive effort in the number of female off-springs produced per living female per day ($l_x m_x$), plotted as a function of age in days of a) infected refractory females, b) infected susceptible females, c) uninfected refractory females, and d) uninfected susceptible females of *Aedes aegypti*. l_x females $\bullet-\bullet-\bullet-\bullet-$, l_x males $-o-o-o-o-$, and $l_x m_x$ females \blacktriangle ----- \blacktriangle . The area under $l_x m_x$ curve represents the mean net reproductive rate per cohort (R_0). Each point represents the mean of 6 replicated groups.

TABLE 2. COMPARISON OF THE LIFE TABLE ATTRIBUTES OF SUSCEPTIBLE AND REFRACTORY STRAINS OF *Aedes aegypti*, WITH AND WITHOUT INFECTION WITH *Dirofilaria immitis*.

Attributes	Strains ¹			
	Susceptible		Refractory	
	Uninfected ($\bar{x} \pm sd$)	Infected ($\bar{x} \pm sd$)	Uninfected ($\bar{x} \pm sd$)	Infected ($\bar{x} \pm sd$)
Mean life expectancy (days) (e_x ♀)	33.5 ± 2.3 ^{be}	8.9 ± 1.2 ^d	40.5 ± 11.0 ^{ace}	11.0 ± 2.4
Mean life expectancy (days) (e_x ♂)	19.9 ± 1.7	21.7 ± 3.3 ^{de}	21.5 ± 2.7 ^a	16.7 ± 3.8 ^e
Reproduction rate (R_0)	98.2 ± 20.0 ^b	24.4 ± 11.5	314.0 ± 64.1 ^{ac}	64.2 ± 24.2 ^d
Mean age of reproduction (T_0)	18.1 ± 2.4 ^b	9.6 ± 2.6	21.2 ± 3.9 ^{ac}	14.4 ± 3.8 ^d
Instantaneous rate of increase/♀ (r_m)	0.28 ± 0.02	0.23 ± 0.03	0.3 ± 0.01 ^{ac}	0.24 ± 0.2
Mean generation time (G)	16.1 ± 1.8 ^b	13.4 ± 1.6	18.2 ± 0.5 ^{ac}	17.3 ± 1.1 ^d
Instantaneous birth rate (b)	1.1 ± 0.2 ^b	0.9 ± 0.1	1.9 ± 0.1 ^c	1.3 ± 0.2 ^d
Instantaneous death rate (d)	0.8 ± 0.1 ^b	0.7 ± 0.1	1.6 ± 0.1 ^{ac}	1.1 ± 0.2 ^d
Ratio r_m/b	0.23 ± 0.02	0.25 ± 0.01	0.2 ± 0.01 ^{ac}	0.2 ± 0.01
Ratio b/d	1.4 ± 0.04	1.33 ± 0.02 ^d	1.2 ± 0.01 ^c	0.2 ± 0.1

¹Means significantly greater ($P < 0.05$) when compared by unpaired Student's t-test; a = comparison uninfected refractory strain and infected refractory strain; b = comparison between uninfected susceptible strain and infected susceptible strain; c = uninfected refractory strain compared to uninfected susceptible strain; d = infected refractory strain compared to infected susceptible strain; e_x mean life expectancy from emergence in days of females compared to the mean life expectancy in days from emergence of males. Each value represents the mean of 6 replicated groups.

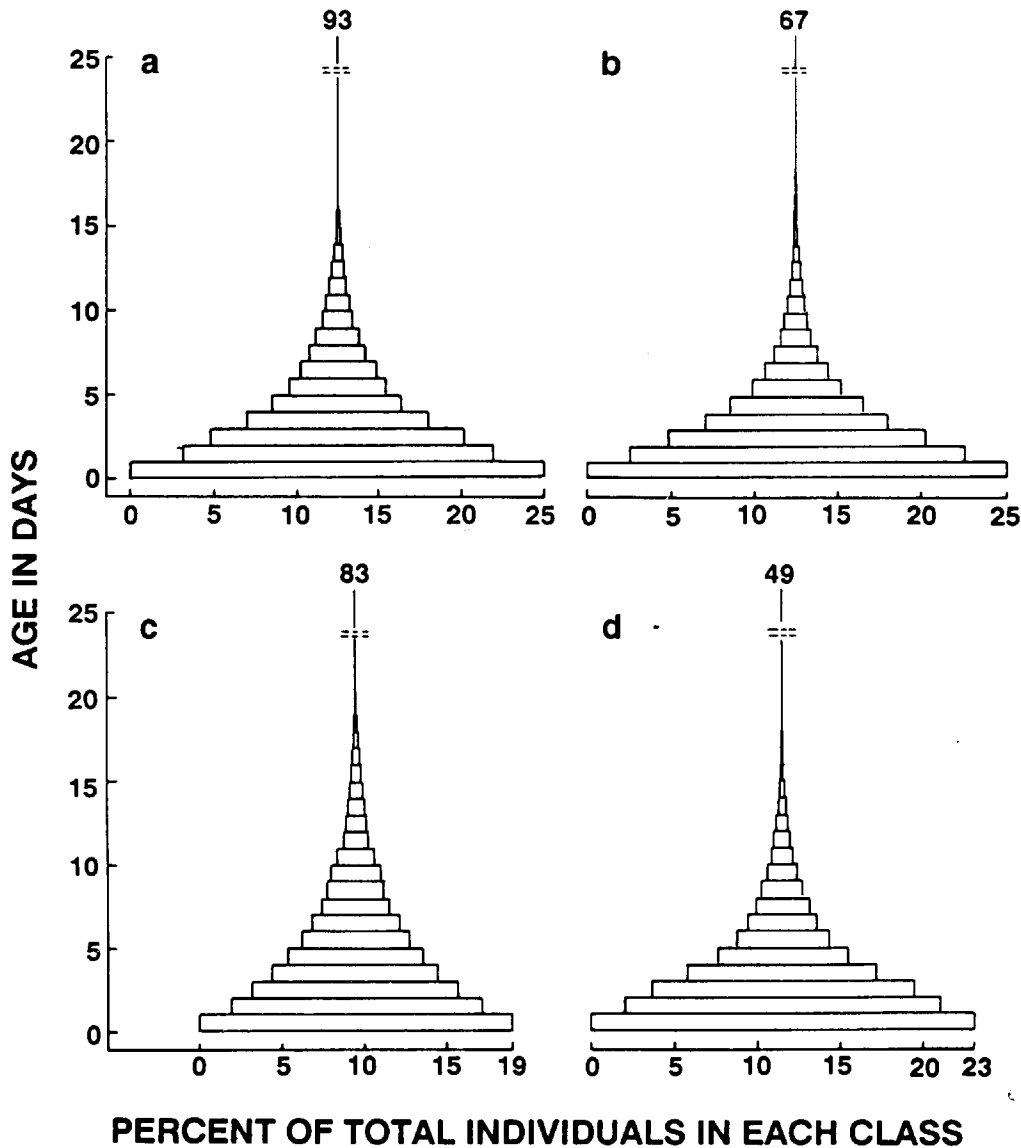


Fig. 2. The stable age distribution of the refractory and susceptible *Aedes aegypti* (Vero Beach) strains to *Dirofilaria immitis* infection, plotted as a function of age. a) uninfected refractory females, b) infected refractory females, c) uninfected susceptible females, d) infected susceptible females. Each figure represents the mean of 6 replicated groups.

study. In multivoltine species, the best comparison between the capabilities of two species which occupy the same habitat is their r_m value (Hacker 1972). In the present study the uninfected refractory strain of *Ae. aegypti* had a significantly higher value of r_m (0.32) than the susceptible strain (0.28). The value of r_m can also be affected by the age of maximum reproduction (MacArthur & Wilson 1967). The time of maximum reproduction was one day earlier in the refractory strain than in the susceptible strain.

A comparison of the infected refractory and infected susceptible females showed that the initial mortality was similar for both the strains, but from the 4th day to the 7th day it was significantly greater for the susceptible strain which agreed with the

TABLE 3. NUMBER OF EGGS LAID PER FEMALE PER WEEK AND THE MEAN PERCENTAGE HATCH OF EGGS WITHIN EACH WEEK IN UNINFECTED AND *DIROFILARIA IMMITIS* INFECTED SUSCEPTIBLE AND REFRACTORY STRAINS OF *Aedes aegypti* (VERO BEACH).

Time (week)	Susceptible ¹				Refractory ¹			
	Uninfected		Infected		Uninfected		Infected	
	No. eggs per ♀/week	% eggs hatched	No. eggs per ♀/week	% eggs hatched	No. eggs per ♀/week	% eggs hatched	No. eggs per ♀/week	% eggs hatched
1	66.8	58.4 ± 21.9	37.2	51.9 ± 26.6	114.9	92.7 ± 3.0	61.6	85.9 ± 4.5
2	129.3	80.8 ± 3.4	158.8	70.5 ± 12.0	197.6	91.7 ± 2.0	200.9	92.2 ± 3.3
3	157.5	76.5 ± 4.4	176.6	68.6 ± 9.0	218.2	93.7 ± 1.2	211.9	88.7 ± 6.3
4	129.3	74.1 ± 8.2	129.4	36.4 ± 23.7	186.6	89.9 ± 8.0	158.8	93.4 ± 4.2
5	157.5	59.2 ± 7.2	60.1	50.2 ± 3.0	159.8	84.5 ± 3.4	128.4	81.5 ± 32.6
6	126.6	46.8 ± 20.8	30.0	0.0	166.1	83.2 ± 7.3	169.5	91.7 ± 6.7
7	108.1	25.0 ± 16.9			102.1	72.1 ± 11.8	119.3	80.9 ± 10.9
8	118.5	41.7 ± 41.7			109.8	59.2 ± 18.1	129.0	75.2 ± 3.9
9	157.4	30.8 ± 41.6			119.8	48.3 ± 18.7	67.5	89.7 ± 2.6
10	94.4	1.9 ²			77.0	26.6 ± 14.9	40.0	95.0 ²
11					56.6	13.9 ± 22.1		
12					113.6	1.7 ± 2.2		
13					79.3	7.5 ± 15.1		
14					29.5	0.7 ± 1.0		
Total eggs	84,378		15,567		143,874		27,771	
Total percent hatch		69.96		58.78		84.89		90.37

¹Each value represents the mean of 6 replicated groups.

²Eggs were laid on one day only during the week.

earlier observations by Townson (1971), who observed higher mortalities for the susceptible females of *Ae. aegypti* infected with *Brugia pahangi*. The r_m values can as well depend upon the number of microfilariae initially ingested by the females while feeding on an infected dog; because females with more prelarvae died earlier. In the present study more microfilariae moved into the Malpighian tubules of the susceptible females than in the refractory females as was observed by Sulaiman & Townson (1980). Initial mortalities were observed within 48 h after an infective blood meal in both strains which agreed with the observation of Ramachandran (1966), who noted a direct relationship between the load of microfilariae of *Brugia malayi* and the initial mortality in the *Ae. aegypti*. Increased mortality resulted when third stage larvae exited the Malpighian tubules and were present in the hemocoel, thorax and head of the females; and might be related to the utilization of tissues or the nutrients present in the body of the females (Kershaw et al. 1953). No such stress was imposed on the infected refractory females by the moribund prelarvae (Sauerman & Nayar 1985).

Differences were found in the egg hatch percentage of susceptible and refractory females in this study with uninfected susceptible females showing a significantly lower percentage of hatched eggs than the uninfected refractory females. The reduction in the percent egg hatch rate of older uninfected refractory females might be due to the monogamous nature of *Ae. aegypti* females (Craig 1967). The percent egg hatch of infected susceptible females was less than the uninfected susceptible females and was possibly due to the *D. immitis* infection resulting in less active females.

In conclusion the present study suggested that the ingestion of the microfilariae decreased the life expectancy and reproductive potentials of *Ae. aegypti* and this effect was more pronounced later in the life of infected susceptible females than in the infected refractory females.

ACKNOWLEDGEMENTS

This study was supported by grant No. AI 17736 from the NIH-NIAID. We wish to thank W. K. Reisen of the Arbovirus Field Station, Bakersfield, California for critical reading of the manuscript. This is part of a thesis submitted to the Graduate School of the University of Florida, IFAS, University of Florida, Gainesville, Florida by Farida Mahmood. University of Florida Experiment Station Journal Series No. 7962.

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EFFECT OF *DIROFILARIA IMMITIS*
(NEMATODA: FILARIOIDEA)
INFECTION ON RATE OF DIURESIS IN SUSCEPTIBLE AND
REFRACTORY STRAINS OF *AEDES AEGYPTI*
(VERO BEACH) (DIPTERA: CULICIDAE)

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ABSTRACT

The effect of *Dirofilaria immitis* (Leidy) infection on the rate of diuresis was investigated for infected and uninfected blood-fed females of highly susceptible and refractory strains of *Aedes aegypti* L. (Vero Beach). The pattern and course of diuresis were similar for both infected and uninfected females of both strains. Infection of Malpighian tubules reduced the rate of diuresis during the peak phase for infected females as compared to that for the corresponding uninfected females. There were no differences between strains as to the rate of diuresis in infected females. Infected susceptible females showed a strong negative linear correlation between the number of developing *D. immitis* and the total amount of fluid excreted during the 90-min observation period, whereas in infected refractory females there was no correlation between the presence of moribund prelarvae and the total amount of fluid excretion. These results suggested that the lower rate of diuresis in both infected susceptible and refractory females was related to damage caused by the developing first stage larvae and moribund prelarvae, respectively.

RESUMEN

Se investigó el efecto de infección de *Dirofilaria immitis* (Leidy) en la tasa de diuresis de hembras infectadas y no infectadas de razas refractarias de *Aedes aegypti* L. (Vero Beach), que se alimentaron con sangre. El patrón y dirección de diuresis fue similar en hembras infectadas y no infectadas de las dos razas. La infección de los tubos de Malpigio redujo la tasa de diuresis durante la fase del auge de las hembras infectadas cuando se comparó con las correspondientes hembras no infectadas. No hubo diferencia entre las razas con respecto a la tasa de diuresis en las hembras infectadas. Hembras susceptibles infectadas demostraron una fuerte correlación lineal negativa entre el número de *D. immitis* en desarrollo y la cantidad total de fluido excretado durante los 90 minutos del período de observación, mientras que en hembras infectadas refractarias no hubo correlación entre la presencia de pre-larvas moribundas y la cantidad total de fluido excretado. Estos resultados sugieren que la baja tasa de diuresis en hembras susceptibles infectadas y en hembras refractarias, está relacionada al daño causado por el desarrollo de la primera etapa de larvas y de larvas pre-moribundas respectivamente.

Soon after female mosquitoes ingest a blood meal, there is rapid excretion of clear urine involving the Malpighian tubules, called diuresis. In species of mosquitoes studied thus far, the process of diuresis follows three phases: the peak phase of very rapid urine elimination during the first 10 minutes, the post-peak phase with a declining rate of elimination during the next 40 min. and the late phase of fairly constant elimination during the last 40 minutes of the 90-minute period (Boorman 1960, Nijhout & Carrow 1978, Williams et al. 1983, Nayar & Bradley 1987). Ingested microfilariae of *Dirofilaria*

immitis (Leidy) develop intracellularly through two molts to the infective stage in the Malpighian tubules of susceptible mosquitoes (Kartman 1953, Taylor 1960, Nayar & Sauerman 1975). Nayar & Bradley (1987) showed that, in *Aedes taeniorhynchus* (Wiedmann) infected with *D. immitis*, the rate of diuresis was significantly reduced during the peak phase of diuresis compared with that of uninfected females. Even greater reduction in secretion rates during peak and post-peak phases of diuresis were observed in infected *Anopheles quadrimaculatus* Say.

We have isolated highly susceptible and highly refractory strains of *Aedes aegypti* L. (Vero Beach) to *D. immitis* infection by the individual sibling mating method of McGreevy et al. (1974). In the highly susceptible strain, *D. immitis* larvae develop normally. The first stage of larval development occurs intracellularly in the primary cells of the Malpighian tubules and the subsequent two stages develop in the lumen (Taylor 1960). On the contrary, in the highly refractory strain the microfilariae become arrested after entering the primary cells of the Malpighian tubules and remain as moribund prelarvae (Nayar & Sauerman 1975). About 50% of the infected females of both strains die during the first 6 days after an infective blood meal (Mahmood & Nayar 1989). Among the remaining females of the susceptible strain, most of the Malpighian tubule cells are damaged due to the development of the first stage larvae, whereas in the refractory strain the proximal and distal cells of the Malpighian tubules are damaged due to the constant movement of moribund prelarvae (Nayar & Sauerman 1975). The present study was designed to investigate the effect of this damage on the process of diuresis in *D. immitis* infected susceptible and refractory females and to compare this process with uninfected females.

MATERIALS AND METHODS

Highly susceptible and refractory strains of *Ae. aegypti* (Vero Beach) used in this study were reared and maintained as described elsewhere (Mahmood & Nayar 1989). All experiments were conducted at $26 \pm 1^\circ$ C under a 12:12 (L:D) photoperiod and at RH 75%.

Experimental protocol, measurements of diuresis in uninfected controls and *D. immitis* infected females of both susceptible and refractory strains, and the rate of infection in infected females were as described by Nayar & Bradley (1987). Diuresis was quantified after the method of Nijhout & Carrow (1978) and modified after the method of Stobbart (1977) by monitoring the loss of weight of blood-fed mosquitoes. Female mosquitoes maintained on a 10% sucrose solution, were given their first blood meal to repletion on an infected dog (peripheral blood count 25 ± 5 microfilariae/ μ l) or (control) on a chicken 4-5 days after emergence. Blood-fed females from both groups were then maintained on a 10% sucrose solution and allowed to lay all their eggs. At 5-7 days after the first blood meal, females from both groups were individually given a second blood meal to repletion on a chicken. Diuresis in these mosquitoes (20 females per group) was measured starting immediately after the second blood meal. After measurement of diuresis, the Malpighian tubules of infected females were dissected and the number of developing larvae was assessed. Rates of weight loss at different times after the infective blood meal were compared using Student's t-test and the total amount of weight loss (diuresis) during the 90 min in relation to parasite burden were compared using linear regression analysis.

RESULTS

The uninfected susceptible females of *Ae. aegypti* took significantly larger second blood meals and showed greater weight loss during 90 min. duration of diuresis as

compared to infected susceptible females (Table 1). There was not a significant weight loss after the second blood meal in refractory uninfected and infected females, the weight loss for the uninfected was greater (3.93 ± 1.12) than for the infected (3.58 ± 1.26) females (Table 1). The pattern and time-course of diuresis were similar in both groups of both strains (Fig. 1). In all four groups, there were significant differences ($P < 0.05$, $n = 40$) in weight loss during the peak phase (0-15 min), and post-peak phase (16-45 min) after feeding (Fig. 1), with the more rapid weight loss occurring within the peak phase (Fig. 1). Infected susceptible and refractory females showed slower rates of diuresis than uninfected susceptible and refractory females (Fig. 1). The rate of diuresis was faster in uninfected susceptible females than in uninfected refractory females, but there were no differences in the rate of diuresis in infected susceptible and refractory females (Fig. 1).

During the initial infection of susceptible and refractory females with *D. immitis* (susceptible females ingested 261.4 ± 58.4 , $\bar{x} \pm \text{sd}$ and refractory females ingested 376.0 ± 87.7) there was no significant difference ($P > 0.05$) in the number of microfilariae ingested; however, there were significant differences ($P < 0.05$) in the number of developing first stage larvae, 5-6 days after initial infection, in the susceptible females (30.0 ± 27.5) and the number of moribund prelarvae (11.5 ± 9.47) in the refractory females. The rate of weight loss was smaller in susceptible females with a greater number of developing first stage larvae of *D. immitis* and showed a correlation coefficient (r) of -0.38 (Fig. 2a), whereas in refractory females there was no correlation between the number of moribund prelarvae and the rate of weight loss (Fig. 2b), the correlation coefficient (r) was -0.15 .

DISCUSSION

These studies showed that *D. immitis* infected refractory and susceptible *Ae. aegypti* females had identical patterns of diuresis and their rates of diuresis were significantly reduced as compared to those for uninfected females of both strains. These lower rates of diuresis in infected *Ae. aegypti* females were similar to those observed in *D. immitis* infected *Ae. taeniorhynchus* and *An. quadrimaculatus* (Nayar & Bradley

TABLE 1. DIFFERENT CHARACTERISTICS OF SUSCEPTIBLE AND REFRACTORY FEMALES OF *Aedes aegypti* (VERO BEACH) INFECTED WITH *DIROFILARIA IMMITIS* DURING DIURESIS. TWENTY FEMALES WERE USED FOR EACH GROUP.

	Uninfected	Infected
	Susceptible	
Mosquito wet body weight (mg)	2.80 ± 0.31^2	2.73 ± 0.27
Weight of blood meal (mg)	4.56 ± 1.34^1	3.33 ± 0.87
Weight loss during diuresis (mg)	$2.42 \pm 0.74^{1,2}$	1.56 ± 0.62
Weight loss percent of blood meal	54.20 ± 14.86^1	44.06 ± 14.87
	Refractory	
Mosquito wet body weight (mg)	2.31 ± 0.48	2.41 ± 0.50
Weight of blood meal (mg)	3.93 ± 1.12	3.58 ± 1.26
Weight loss during diuresis (mg)	1.94 ± 0.42	1.46 ± 0.57
Weight loss percent of blood meal	52.57 ± 15.65^1	41.75 ± 2.07

¹Comparison of uninfected and infected mosquitoes after second blood meal. Mean significantly greater when tested by Student's t-test ($P < 0.05$).

²Comparison of susceptible and refractory mosquitoes.

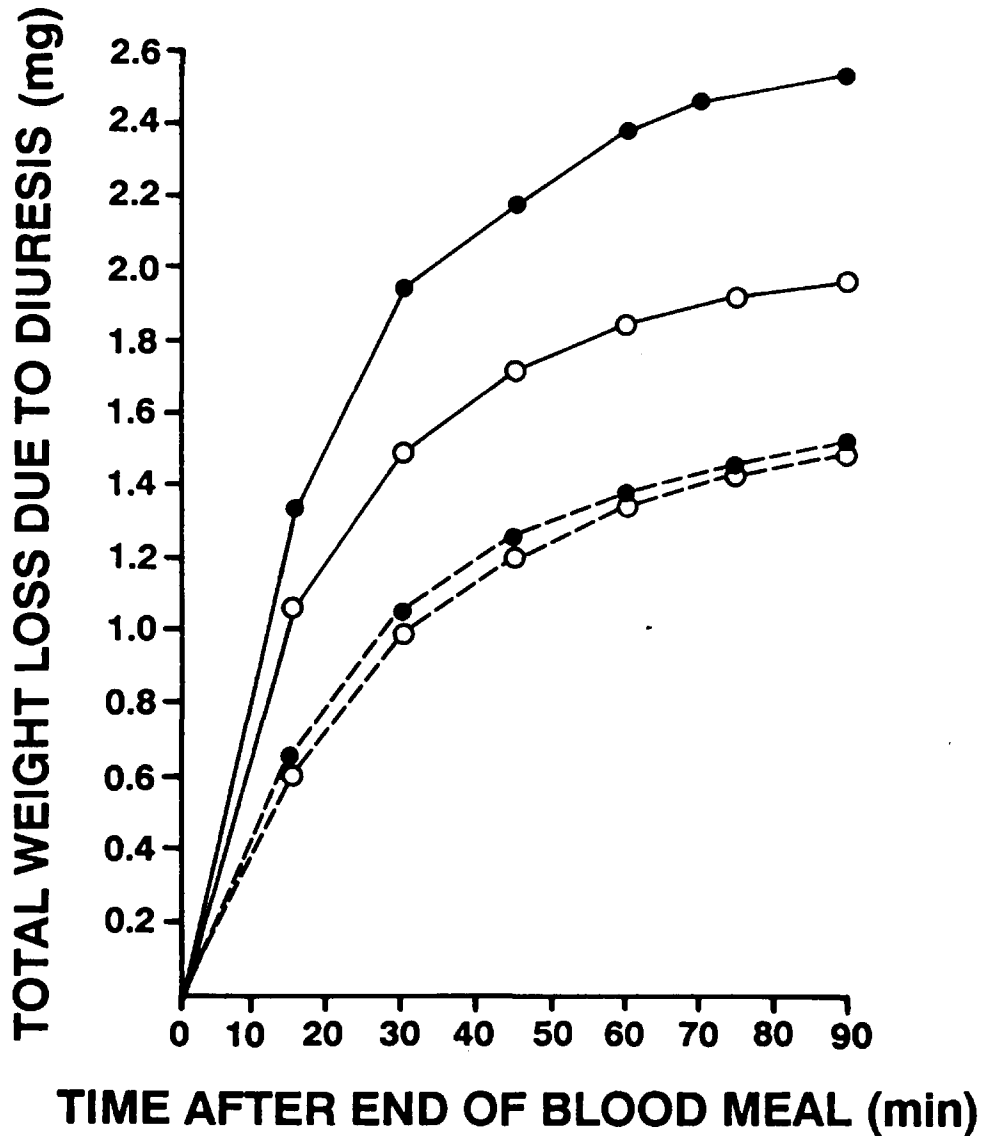


Fig. 1. Time-course of diuresis (mean total weight loss) in females after a blood meal on chicken by uninfected (—) and infected (--) *Aedes aegypti* susceptible (●) and refractory (○) to *Dirofilaria immitis*.

1987). For infected susceptible *Ae. aegypti*, lower rates of diuresis were observed as the number of developing first stage larvae increased. Similar results were recorded for infected *Ae. taeniorhynchus* and *An. quadrimaculatus* (Nayar & Bradley 1987). However, in infected refractory *Ae. aegypti* females the slower rate of diuresis observed could not be related to the number of moribund prelarvae. The impaired rate of diuresis in infected mosquitoes could be due to the damage caused to Malpighian tubules by moribund prelarvae in refractory females and developing first stage larvae in the susceptible females. In *Ae. taeniorhynchus* infected with *D. immitis* prelarvae, the ultrastructure of the Malpighian tubule cells 48 h after the infective blood meal showed significant reduction in microvillar volume, in the percent of microvillar volume occupied by mitochondria and in volume of mitochondria within the microvilli when compared to the uninfected Malpighian tubule cells (Bradley et al. 1984). Palmer et al. (1986) con-

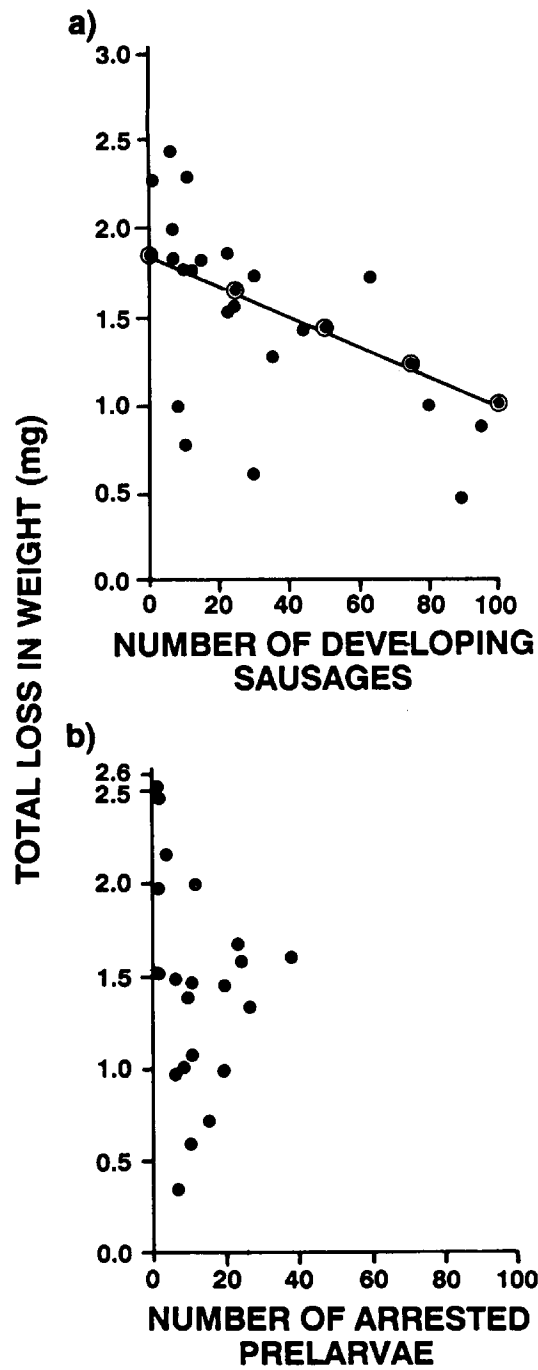


Fig. 2a. Effect of the increasing number of developing larvae of *Dirofilaria immitis* on the total loss in weight during diuresis in infected susceptible female of *Aedes aegypti*.

Fig. 2b. Effect of the increasing number of arrested prelarvae on the total loss in weight during diuresis in refractory *Aedes aegypti*.

firmed these findings in *Ae. aegypti* infected with *D. immitis*, and further showed, that when first stage larvae were ready to molt 6 days after the infective blood meal, the cytoplasmic ground substance was highly disrupted and the cells appeared to be greatly inflated. These authors further concluded that, during the development of *D. immitis* larvae through the first stage, they completely destroy the Malpighian tubule cells in which they reside and after molting, the second stage larvae move to the lumen of the Malpighian tubules. They also suggested that large worm burdens could be responsible for the destruction of the excretory system and vector mortality.

In another study, Bradley & Nayar (1984) examined the rate of fluid excretion, in vitro, using both uninfected and infected *D. immitis* Malpighian tubules of *Ae. taeniorhynchus* and demonstrated that the tubules showed a decline in transport with time following infection and the reduction in transport capacity was proportional to the number of *D. immitis* larvae infecting the Malpighian tubules. A similar phenomenon could be occurring in the infected susceptible *A. aegypti* females. In infected refractory *Ae. aegypti* females, damage to several Malpighian tubule cells inhabited by moribund prelarvae was previously observed (Nayar & Sauerman 1975) and probably is the cause of the reduced rate of diuresis seen in this study.

ACKNOWLEDGEMENTS

This study was supported by a grant from the NIH, NIAID AI-17736. This manuscript is from a thesis submitted to the Graduate School of the University of Florida in partial fulfillment of the requirements for the M. S. degree of Farida Mahmood.

University of Florida, Institute of Food and Agricultural Sciences, Experiment Stations Journal Series No. 7877.

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ABSTRACT

A wettable powder (WP) formulation of *Bacillus sphaericus* 2362 (ABG-6232) and an aqueous suspension of *Bacillus thuringiensis* serovar. *israelensis* (Vectobac 12 AS) were evaluated against *Culex* mosquitoes in a dairy wastewater lagoon in central Florida. *Culex nigripalpus* and *Cx. quinquefasciatus* inhabited the lagoon; the former species comprised >90% of the total *Culex* larvae collected during the sampling periods. Vectobac 12 AS (at 1.17 L/ha) and ABG-6232 (at 1.12 kg/ha) were each applied separately to the lagoon on three different occasions during 1987-1988. Vectobac 12 AS caused a maximum 71-88% larval reduction for only one day posttreatment in the three treatments. ABG-6232 (WP) gave an average larval reduction of 84-92% in the three tests for up to 13 days posttreatment with >50% average reduction of the larvae being maintained for beyond 17 days posttreatment.

RESUMEN

Se evaluó una formulación de polvo humectante de *Bacillus sphaericus* 2362 (ABG-6232) y una suspensión acuosa de *Bacillus thuringiensis* serovar. *israelensis* (Vectobac 12 AS) contra mosquitos *Culex* en una laguna de agua de desperdicio de una lechería en el centro de la Florida. *Culex nigripalpus* y *Cx. quinquefasciatus* habitaban la laguna; la primera especie constituía >90% del total de larvas de *Culex* colectadas durante el período de muestreo. Vectobac 12 AS (a 1.17 L/ha) y ABG-6232 (a 1.12 kg/ha) fueron separadamente aplicados a la laguna en 3 ocasiones diferentes durante 1987-1988. Vectobac 12 AS causó una reducción máxima de larvas de 71-88% solo un día después

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del tratamiento en los tres tratamientos. ABG-6232 causó un promedio de reducción de larvas de 84-92% en las tres pruebas hasta 13 días después del tratamiento con un promedio de >50% de reducción de larvas mantenidas por más de 17 días después del tratamiento.

Wastewater generated on a daily basis at dairy farms, primarily through washing dairy herds and milking barns, collects into large open retention ponds or lagoons. The impounded water contains high contents of solid and dissolved organic materials, providing ideal conditions for mosquito oviposition and larval development.

In the southeastern United States, the dominant species of mosquito in wastewater ponds and lagoons is usually *Culex quinquefasciatus* Say (Steelman & Colmer 1970, Rutz & Axtell 1978, O'Meara & Evans 1983). However, in some wastewater systems in south Florida, *Cx. nigripalpus* Theobald is more abundant than *Cx. quinquefasciatus* (Carlson 1982); the former species is the dominant summer and early fall *Culex* in peninsular Florida (Edman 1974).

In Florida, as in many other parts of the United States, the dairy industry is being encroached upon by rapid urbanization. This results in increasing human contact with mosquitoes breeding in and around the dairy environments and necessitating mosquito control.

Two bacterial agents, *Bacillus thuringiensis* serovar. *israelensis* (*B.t.i.*) and *B. sphaericus*, in a number of laboratory and field studies have proven to be excellent larvicides of a variety of mosquito species world-wide (Ali et al. 1981, Ali & Nayar 1986, Davidson et al. 1981, Lacey et al. 1984, Majori et al. 1987, Mulligan et al. 1980, World Health Organization 1985). For the past several years, *B.t.i.*, in a variety of formulations has been marketed for mosquito control in most parts of the world. However, it has been documented that *B. sphaericus*, in general, is more toxic (equal potency basis) to some mosquito species than *B.t.i.*, and also has the advantage of longer persistence in the treated habitats (DesRochers & Garcia 1984, World Health Organization 1985). As a consequence, *B. sphaericus* is presently being enthusiastically developed by the chemical industry as a mosquito larvicide.

This study reports the effectiveness of an experimental wettable powder (WP) of *B. sphaericus* strain 2362 (ABG-6232) against *Culex* spp. larvae in a dairy lagoon in central Florida. A commercial aqueous suspension of *B.t.i.* (Vectobac 12 AS) was also tested in the same lagoon to compare the degree and longevity of control given by the two microbial mosquito larvicides.

MATERIALS AND METHODS

The dairy lagoon, rectangular in outline, located at approximately 28° 53' N latitude and 81° 41' W longitude, in Dona Vista, Lake County, Florida, was used for this study. It is 102 m long and 15 m wide, with an average water depth of 1 m. The lagoon receives wastewater effluent daily (through gravity flow) from approximately a 400-cow dairy operation via a series of two small settling ponds (each ca. 8 x 8 m). The ponds retain the bulk of the solids which are allowed to dry through evaporation and percolation and periodically cleaned by dredging. The impounded water in the lagoon is occasionally pumped out for pasture irrigation.

Water in the lagoon is usually highly turbid (>100 NTU) and almost neutral (pH 6.9). The lagoon is lined with a thick natural growth of cattails (*Typha* spp.) and water-primrose (*Ludwigia* spp.). Some grasses also border the lagoon. The predominant floating vegetation on the lagoon water consists of Giant duckweed (*Spirodela polyrhiza*) and Pennywort (*Hydrocotyle ranunculoides*).

The *B.t.i.* and *B. sphaericus* used in this study were produced and provided by Abbott Laboratories, N. Chicago, IL. On three separate occasions (October 5, 1987, November 16, 1987, and May 31, 1988), the WP ABG-6232 (812 ITU/mg, lot no. 08-083-BR) was uniformly applied from a boat to the entire surface of the lagoon at a rate of 1 lb/acre (1.12 kg/ha). Similarly, Vectobac 12 AS (1200 ITU/mg, lot no. 15-179-BA) was applied to the lagoon on October 26, 1987, June 20, 1988, and July 7, 1988, at a rate of 1 pt/acre (1.17 L/ha). For each treatment the required amount of spray material was thoroughly mixed with about 3 gal (11.4 L) of water in a bucket and transferred to and applied with a 3.5 gal (13.25 L) pressurized spray can (Solo Backpack) (Solo, Inc. Newport News, VA). A max.-min. thermometer was used at one location in the lagoon to record the water temperature range during each field test.

Immediately prior to and periodically after each treatment, samples of mosquito larvae were collected from the sides of the lagoon at 14 predetermined locations using a 500-ml dipper. The middle area of the lagoon was also sampled from a boat on two occasions but no mosquito larvae were found in the open water. Since there was no comparable habitat in the area to use for an untreated control, the posttreatment larval declines had to be compared with the corresponding prevailing pretreatment population levels to elucidate the percent larval reductions and effectiveness of each treatment. The two small retention ponds containing mostly solids or sludge supported insufficient numbers of mosquito larvae and could not be used as controls. The larval samples were brought to the laboratory for taxonomic identifications and counting.

RESULTS AND DISCUSSION

Larvae of *Cx. nigripalpus* and *Cx. quinquefasciatus* inhabited the lagoon with the former species comprising over 90% of the total larvae on each sampling occasion. The mean number of larvae per dip during the *B. sphaericus* 2362 (ABG-6232) treatments exceeded 350 larvae at the time of pretreatment on each occasion (Table 1). ABG-6232 at 1.12 kg/ha rate of application produced 64-97, 38-93, and 60-85% reductions of larvae for beyond two weeks (14-17 days) in the treatments 1, 2, and 3, respectively. Overall, ABG-6232 gave larval reductions of 84-92% in the three treatments (combined) for up to 13 days, and a greater than 50% reduction of pretreatment larval numbers was maintained for beyond 17 days. The cumulative trend of larval populations and their

TABLE 1. EFFICACY OF *BACILLUS SPHAERICUS* 2362 WETTABLE POWDER (ABG-6232^a) APPLIED AT 1.12 KG/HA AGAINST *CULEX* SPP.^b LARVAE IN A DAIRY WASTEWATER LAGOON IN CENTRAL FLORIDA, 1987-1988.

Mean no. larvae/dip pretreatment	Percent larval reduction posttreatment (days)			
	2-5	6-9	10-13	14-17
	Treatment 1 (October 5, 1987) ^c			
498	94	97	96	64
	Treatment 2 (November 16, 1987) ^d			
363	81	93	77	38
	Treatment 3 (May 31, 1988) ^e			
430	76	85	81	60

^a812 ITU/mg

^bMixture of *Cx. nigripalpus* and *Cx. quinquefasciatus* (>90% *Cx. nigripalpus*).

^cWater temperature: 21-24°C; ^d17-23°C; ^e21-28°C.

declines due to the three *B. sphaericus* treatments combined are shown in Fig. 1. In the pretreatment samples, 3rd and 4th instar larvae were predominant but after the treatments, mature larvae (3rd and 4th instars) declined considerably while the young larvae (1st and 2nd instars) predominated for more than two weeks posttreatment. The prevalence of the young larvae was probably due to their continuous addition as a result of continuous oviposition and egg hatching in the lagoon. These larvae were not exposed to the pathogen for sufficient time to suffer mortality. A similar field observation on asynchronously developing mosquito larvae exposed to *B. sphaericus* was reported by Majori et al. (1987).

Vectobac 12 AS at 1.17 L/ha rate of treatment produced a maximum of 71% (treatment 1), 88% (treatment 2), and 83% (treatment 3) reduction of mosquito larvae within a day after each treatment (Table 2). In treatment 1, the number of larvae was reduced by 14-67% for up to 3 days. In treatment 2, 16-33% reductions of the larval numbers were recorded during the 2-4 days of posttreatment sampling, while in treatment 3, the larval populations returned to the pretreatment levels within 2 days. Overall, for the three treatments combined, *B.t.i.* induced a maximum larval reduction of 84% in one day posttreatment and <36% after 2 days. Third and 4th instar larvae were reduced considerably after the treatments but 1st instar larvae, due to their continuous recruitment, predominated during the pre-, and posttreatment periods (Fig. 1).

This study suggests that appreciable larval reduction (84%) of *Cx. nigripalpus* and *Cx. quinquefasciatus* provided by *B.t.i.* (Vectobac 12 AS) at 1.17 L/ha in the dairy wastewater lasted only for one day posttreatment. Although Vectobac 12 AS had a higher ITU/mg (1200) as compared to the 812 ITU/mg for *B. sphaericus* 2362 (ABG-6232), on equal wt/vol basis, Vectobac 12 AS appeared to produce slightly lower levels of larval control and for a much shorter time than ABG-6232. These data on *B.t.i.* are compatible with some previous mosquito control studies in polluted waters where *B.t.i.* in different formulations had caused 91-100% larval reductions of *Cx. quinquefasciatus* for 1-3 days after treatments at rates ranging from 0.65 to 5.6 kg/ha (Majori et al. 1987). Also, Mulla et al. (1982) reported *Cx. quinquefasciatus* larval reductions of 0, 81 and 91% one day after treatment with Bactimos (WP, 3500 ITU/mg) applied at 0.56, 1.12, and 2.24 kg/ha, respectively, to dairy lagoons in southern California.

The field activity of some potent strains of *B. sphaericus* (including strain 2362) against larvae of a large number of mosquito species in different parts of the world has

TABLE 2. EFFICACY OF *BACILLUS THURINGIENSIS* SEROVAR. *ISAELENSIS* AQUEOUS SUSPENSION (VECTOBAC 12 AS)^a APPLIED AT 1.17 L/HA^c AGAINST *CULEX* SPP.^b LARVAE IN A DAIRY WASTEWATER LAGOON IN CENTRAL FLORIDA, 1987-1988.

Mean no. larvae/dip pretreatment	Percent larval reduction posttreatment (days)			
	1	2	3	4
	Treatment 1 (October 26, 1987) ^c			
111	71	67	14	0
	Treatment 2 (June 20 1988) ^d			
410	88	30	33	16
	Treatment 3 (July 7, 1988) ^e			
41	83	0	—	0

^a1200 ITU/mg

^bPredominantly *Cx. nigripalpus* (*Cx. quinquefasciatus* <5%)

^cWater temperature: 19-24°C; ^d21-27°C; ^e21-28°C.

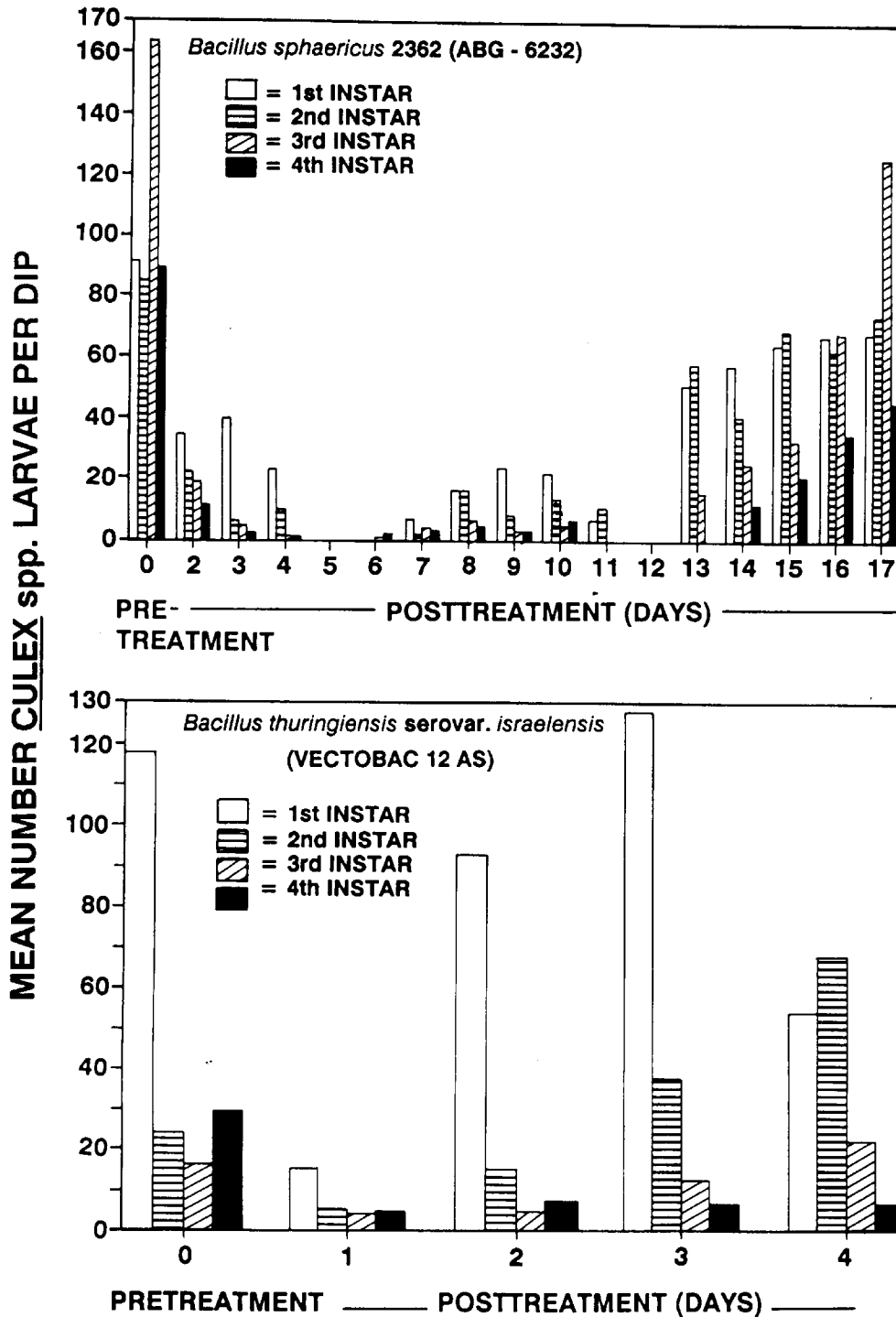


Fig. 1. Pre-, and posttreatment larval trends of *Culex* spp. (predominantly *Cx. nigripalpus*) in a dairy wastewater lagoon treated at 1.12 kg/ha with a wettable powder formulation of *Bacillus sphaericus* strain 2362 (ABG-6232), and at 1.17 L/ha with an aqueous suspension of *Bacillus thuringiensis* serovar. *israelensis* (Vectobac 12 AS), Dona Vista, Lake County, central Florida, 1987-1988.

been documented (World Health Organization 1985). A flowable concentrate (BSP-1, containing 12% primary powder of strain 2362) applied at 20 g/m² provided a satisfactory control of *Cx. quinquefasciatus* for 6 to 10 weeks in cesspits and latrines in the United Republic of Tanzania, while a WP of *B. sphaericus* 2362 applied at 0.25 kg/ha produced 90% larval reduction of *Cx. quinquefasciatus* in polluted waters in Ivory Coast (World Health Organization 1985). Recent studies of Mulla et al. (1988) in dairy wastewater lagoons in California indicated that two primary powder preparations of *B. sphaericus* (ABG-6184) at rates of 0.26 and 0.56 kg/ha gave mediocre and short-term control of *Culex* mosquitoes (*Cx. peus* and *Cx. quinquefasciatus*). However, the level of control and persistence greatly increased as the dosages were increased to 1.12, 2.24, and 4.48 kg/ha. The lower two rates yielded almost 100% control for 4 weeks while the 4.48 kg/ha rate yielded control (99%) for up to 49 days or longer. A flowable concentrate preparation of *B. sphaericus* (BSP-2) yielded complete initial and persistent control of *Culex* larvae for 14-21 days at 2.24, 4.49, and 5.6 kg/ha rates of treatment.

The present study confirms the superiority of *B. sphaericus* 2362 over *B.t.i.* in controlling *Culex* mosquitoes in polluted waters. Only one treatment rate (1.12 kg/ha) of *B. sphaericus* was employed in this study; higher rates of this microbial mosquito larvicide may produce better initial and longer-lasting control as shown by the studies of Mulla et al. (1988). The increased application rate(s) of *B. sphaericus* is feasible and justified in view of the long-lasting control obtained with one treatment, which would save on the costs of site inspections and repeated treatments when less potent and less persistent larval control agents are employed (Mulla et al. 1988). Thus, rapid development of *B. sphaericus* leading to its availability for commercial use in mosquito control programs is deemed necessary.

ACKNOWLEDGEMENTS

The assistance of Columbus Burke, Sr., during the course of this study is appreciated. This is Florida Agricultural Experiment Stations Journal Series No. 10048. Mention of a pesticide or a commercial proprietary product does not constitute an endorsement or recommendation by the University of Florida, nor does it imply registration under FIFRA as amended.

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LIFE HISTORY PARAMETERS OF BARK BEETLES
(COLEOPTERA: SCOLYTIDAE) ATTACKING
WEST INDIAN PINE IN THE DOMINICAN REPUBLIC

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ABSTRACT

An outbreak of pine bark beetles (Coleoptera: Scolytidae) occurred in the central highlands of the Dominican Republic during 1986-1987. Initiation of the outbreak coincided with a period of severe drought. Thousands of native West Indian pines, *Pinus occidentalis* Sw., were killed by beetles attacking the trunk and branches. *Ips calligraphus* (Germar) was the principal mortality agent. Two other bark beetles infested the smaller branches (*Pityophthorus antillicus* Bright) and shoots (*Pityophthorus pinavorus* Bright). Spatial attack pattern, harem size, egg gallery length, egg density, and sex ratio of Dominican *I. calligraphus* populations were similar to values reported from the southeastern United States. However optimal pheromone blends differed between the two populations. Of five pheromone blends tested, the 50% (-)-ipsdienol:50% (+)-ipsdienol plus *cis*-verbenol attracted the most Dominican beetles. *Ips calligraphus* adults were collected throughout the year in pheromone-baited traps and theoretically could complete 11 to 12 generations per year in the Dominican highlands. No other species of *Ips* nor any species of *Dendroctonus* were collected in traps baited with pheromones of the pine bark beetle complex of the southeastern United States. Average tree diameter, tree height, and stand basal area from several infestation sites are presented. Infested pines ranged from 5 to 50 cm in diameter and from 6 to 26 m in height.

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ABSTRACT

An outbreak of pine bark beetles (Coleoptera: Scolytidae) occurred in the central highlands of the Dominican Republic during 1986-1987. Initiation of the outbreak coincided with a period of severe drought. Thousands of native West Indian pines, *Pinus occidentalis* Sw., were killed by beetles attacking the trunk and branches. *Ips calligraphus* (Germar) was the principal mortality agent. Two other bark beetles infested the smaller branches (*Pityophthorus antillicus* Bright) and shoots (*Pityophthorus pinavorus* Bright). Spatial attack pattern, harem size, egg gallery length, egg density, and sex ratio of Dominican *I. calligraphus* populations were similar to values reported from the southeastern United States. However optimal pheromone blends differed between the two populations. Of five pheromone blends tested, the 50% (-)-ipsdienol:50% (+)-ipsdienol plus *cis*-verbenol attracted the most Dominican beetles. *Ips calligraphus* adults were collected throughout the year in pheromone-baited traps and theoretically could complete 11 to 12 generations per year in the Dominican highlands. No other species of *Ips* nor any species of *Dendroctonus* were collected in traps baited with pheromones of the pine bark beetle complex of the southeastern United States. Average tree diameter, tree height, and stand basal area from several infestation sites are presented. Infested pines ranged from 5 to 50 cm in diameter and from 6 to 26 m in height.

RESUMEN

Un brote del escarabajo de la corteza de pinos (Coleóptera: Scolytidae) ocurrió en las tierras altas centrales de la República Dominicana durante 1986-87. El comienzo del brote coincidió con un período de seca severo. Miles de pinos de la Indias Occidentales, *Pinus occidentalis* Sw., fueron matados por los escarabajos atacando el tronco y las ramas. El principal agente de mortalidad fué *Ips calligraphus* (Germar). Otros dos escarabajos infestaron las ramas más pequeñas (*Pityophthorus antillicus* Bright) y los brotes (*Pityophthorus pinavorus* Bright). El patrón espacial del ataque, el tamaño del harem, el largo de la galería de los huevos, la densidad de los huevos, y la proporción del sexo de los huevos de la población Dominicana de *I. calligraphus* fué similar a los valores reportados del sudeste de los Estados Unidos de América. Sin embargo, mezclas óptimas de feromonas fueron distintas entre las dos poblaciones. De cinco mezclas de feromonas probadas, el 50% (-)-ipsdienol:50% (+)-ipsidenol mas *cis*-verbenol atrajo más escarabajos Dominicanos. Se colectaron adultos de *Ips calligraphus* durante el año en trampas cebadas con feromonas y teóricamente pudieran completar de 11 a 12 generaciones por año en las tierras altas Dominicanas. Ninguna otra especie de *Ips* ni ninguna otra especie de *Dendroctonus* se colectaron en trampas cebadas con feromonas del complejo de escarabajos de la corteza de los pinos del sudeste de los Estados Unidos. Se presenta el promedio del diámetro y altura de los árboles, y la base de la población de distintas áreas infestadas.

The Dominican Republic occupies the eastern two-thirds of the island of Hispaniola. It has a mountainous terrain and a maritime tropical climate. The Dominican forests are classified as pine, hardwood, or mixed pine-hardwood. Using 50% tree crown cover as a basis, 38% of Dominican land was categorized as forested in 1980. Seventeen percent of the forested area was planted to pine, 34% was hardwoods, and 49% was mixed (FAO 1981). These forests aid in controlling erosion and protecting watersheds as well as producing lumber, firewood, and charcoal. About 75% of the Dominicans utilize charcoal or firewood for cooking (FAO 1987). During the past several decades, many forests have been lost to uncontrolled cutting, wildfire, hurricanes, and conversion to agriculture (Hartshorn et al. 1981). To limit the rate of deforestation, the Dominican government in 1967 closed all private lumber mills and prohibited cutting trees without a permit. Reforestation efforts have been modest, planting about 6200 ha between 1969 and 1984; the principal species planted were West Indian pine, *Pinus occidentalis* Sw. (Dominican sources), and Caribbean pine, *P. caribaea* Morelet (from Belize and Honduras) (CRIES 1984, FAO 1987).

From late 1986 through mid-1987, an outbreak of bark beetles (Coleoptera: Scolytidae) occurred in the pine forests of the Dominican Republic, killing thousands of native *P. occidentalis* trees. Initiation of the outbreak coincided with severe drought conditions. Infestations occurred primarily in the central highlands of the Cordillera Central where 84% of the country's pine forests occur (CRIES 1984).

Objectives of the present study were to: (1) determine the principal bark beetle species infesting *P. occidentalis*, (2) collect life-history data on each bark beetle species, and in particular compare the *Ips* data with published reports from the southeastern United States to determine if the island population differs substantially from those on the mainland, and (3) gather *P. occidentalis* tree and stand data from the outbreak sites.

Background Information

The most severe bark beetle infestations occurred in forests administered by Plan Sierra, which is a regional program with headquarters in San José de las Matas, Province of Santiago. Initiated in 1979, Plan Sierra is mandated to develop and integrate

into the national economy a mountainous region covering about 200,000 ha in Santiago and Santiago Rodriguez Provinces. The forestry component of Plan Sierra provides for harvesting and management of the natural forests as well as for reforestation. Plan Sierra has mapped, inventoried, and prepared forest management plans for more than 3000 ha of pine forests under its jurisdiction (Kastberg 1982).

Few published reports exist on *P. occidentalis*, which is native only to the islands of Hispaniola and Cuba. In the Dominican Republic, where it is the only native pine, it grows on poor sites at elevations from 800 to more than 3000 m (Critchfield & Little 1966, Hartshorn et al. 1981). In Cuba, it occupies dry, rocky sites at elevations from 900 to 1500 m; individual trees reach 102 cm in diameter at breast height (DBH, 1.4 m above groundline) and 41 m in height (Smith 1954).

Species of both six-spined and five-spined *Ips* bark beetles have been reported from the Dominican Republic. However, much taxonomic confusion still exists over the actual species present. For example, the six-spined *I. interstitialis* was collected in the Dominican Republic in 1967 (Lanier 1972). However, the six-spined *Ips* recovered during a 1969-1970 survey of the Dominican forest insect and disease problems were reported as *I. calligraphus* (FAO 1971). It is possible that both species could occur on the island of Hispaniola. The taxonomic status of these six-spined *Ips* is still in debate. Lanier (1972) recognizes *I. interstitialis* (Eichhoff), which is distributed from Central America to southern Arizona, as distinct from *I. calligraphus*, which is mostly North American in distribution. However, Wood (1982) placed *I. interstitialis* in synonymy with *I. calligraphus*. Similarly, the five-spined *Ips grandicollis* (Eichhoff) is reported to occur in the Dominican Republic by Wood (1982) and has been collected from *P. occidentalis* in Haiti as well (Billings 1985). However, the taxonomic certainty of these reports is now in question because all specimens reported as *I. grandicollis* by Garraway (1986) from nearby Jamaica were later found to be *Ips cribricollis* (Eichhoff) by Lanier (1987). Here too, Wood (1982) placed *I. cribricollis* in synonymy with *I. grandicollis*. However, Lanier (1987) considers these two species as distinct forms, with *I. grandicollis* being mostly North American in distribution and *I. cribricollis* being mostly from Central America.

No specimens of *Dendroctonus* bark beetles, which are important pests in Central and North America, have been recovered from the Dominican Republic or any other Caribbean island to our knowledge. Two other bark beetle species in the genus *Pityophthorus* infest *P. occidentalis* in the Dominican Republic: *Pityophthorus antillicus* Bright (Bright 1981) and *Pityophthorus pinavorus* Bright (Bright 1985).

MATERIALS AND METHODS

Eight major outbreak areas between 400 and 1000 m of elevation were visited in the Provinces of Santiago and Santiago Rodriguez during a 2-week period in November 1987 and a 1-week period in April 1988. Several insect, tree, stand, and site characteristics were recorded at each site. At each location, three to five beetle-killed trees were inspected from the groundline to the ends of several branches to determine the bark beetle species present. Beetle specimens were collected and identified, and notes were taken on the egg galleries of each species. For the *Ips* species encountered, we measured the distance between male attack sites, harem size, egg gallery length, and egg density (see details on methods in Haack et al. 1987). The adult sex ratio was calculated from specimens reared from infested trees and from beetles caught in pheromone traps.

The seasonal occurrence of *I. calligraphus* was monitored near San José de las Matas from October 1986 through September 1987 using 18 "stove pipe" traps. The traps were made of 20-cm-diameter, white PVC pipe, that was cut into 1-m lengths and drilled with more than 100 holes each. Traps were capped to exclude rain, fitted with

a water-filled container in the bottom to capture beetles, and suspended vertically. A pheromone lure, containing a racemic mixture of ipsdienol (Celamerck Inc., Ingelheim, Germany), was placed inside each trap and changed monthly. In general, beetles were collected and counted weekly.

In November 1987, a test was conducted to determine what blend of the two ipsdienol enantiomers was most attractive to the local population of six-spined *Ips* (later determined to be *I. calligraphus*). Ipsdienol and *cis*-verbenol are the two major components of the aggregation pheromone of *I. calligraphus* (Renwick & Vité 1972, Vité et al. 1978). The six treatments were: 2% (+):98% (-), 25% (+):75% (-), 50% (+):50% (-), 75% (+):25% (-), 98% (+):2% (-), and a blank ethanol control. All mixtures were prepared with the same amounts of total ipsdienol (8 mg) and *cis*-verbenol (8 mg). The pheromones were diluted in ethanol to a quantity of 110 μ l and deployed in closed, polyethylene vials (release rate ca. 34 μ gm/day at 22°C). Twenty-four sticky traps (51 cm by 66 cm; DeWill Inc., Chicago, Illinois) were installed near San José de las Matas, six in each of four locations. At every location each treatment was assigned to one of the six traps. The total number of *I. calligraphus* adults on each trap was recorded after eight days.

In April 1988, a second pheromone study was conducted in the same outbreak region to determine if any of the other major bark beetle species common to the pine forests of the southern United States were present, i.e., *Dendroctonus frontalis* Zimmermann, *I. calligraphus*; *I. grandicollis*, and *I. avulsus* (Eichhoff). Multiple-funnel barrier traps (Phero-Tech Inc., Vancouver, British Columbia) were baited with a combination of pheromones specific to these four beetle species [400 μ l of frontalin, 250 ml of pine turpentine, 8 mg of *cis*-verbenol, 8 mg of racemic ipsenol, and 8 mg of racemic ipsdienol were deployed in polyethylene vials or tubing; see Borden (1982) for details on pheromones of each species]. One trap was placed in each of four pine stands near San José de las Matas, with each trap being baited with all pheromones. Responding insects were collected after 5 days and identified.

We collected data on (1) average DBH, height, and basal area of several forest compartments in which outbreaks occurred [using data from Kastberg (1982)], and (2) height and diameter measurements of more than 1000 beetle-killed pines from seven outbreak areas (Plan Sierra, unpublished data). In the region administered by Plan Sierra, more than 600 forest compartments (covering about 3000 ha) have been delineated and inventoried (Kastberg 1982). These stands are representative of *P. occidentalis* forests in much of the Dominican central highlands. Each forest compartment was classified into one of four categories by Kastberg (1982): (1) young pine, average DBH < 8 cm; (2) actively growing pine, average DBH > 8 cm with active height and diameter growth; (3) mature pine, average DBH > 8 cm, but with little height and diameter growth, and (4) open stand, average DBH > 8 cm, usually mature trees, basal area typically < 5 m²/ha.

RESULTS AND DISCUSSION

Outbreak Site Conditions

The outbreak sites ranged in size from several scattered trees to large forested areas of several hundred hectares. No exact figures are available on the total area affected. Most pines were attacked and killed during the last quarter of 1986 and the first half of 1987. Rainfall at San José de las Matas is usually bimodal (Fig. 1). A severe drought affected the region during the second half of 1986 and apparently was the principal environmental stress that initiated the outbreak. In other pine-growing regions of the country, where drought conditions were mild, outbreaks did not occur. Throughout the

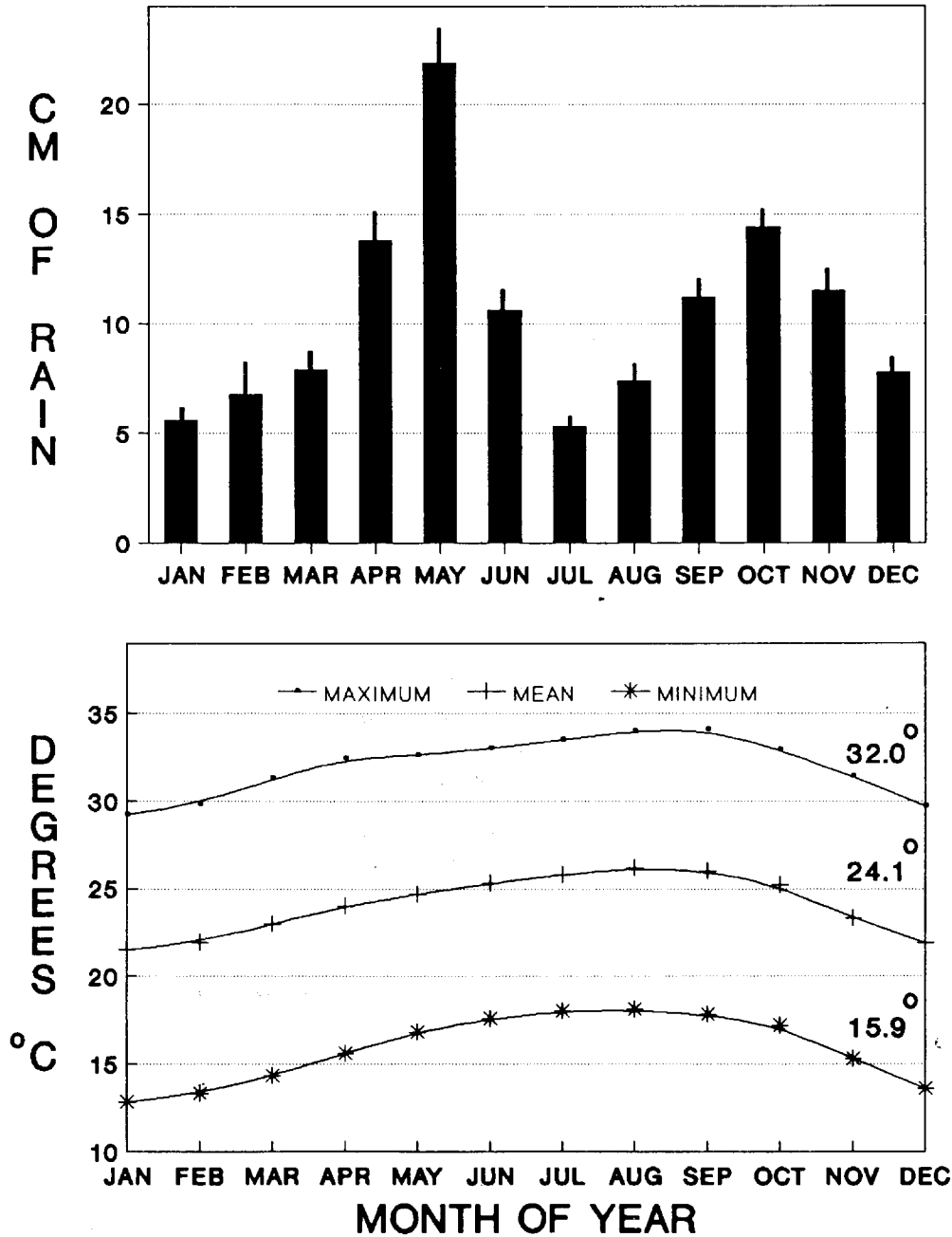


Fig. 1. Mean monthly rainfall in centimeters (top; vertical bars = 1 standard error of the mean) and mean daily maximum, mean, and minimum temperatures in °C by month (bottom) for San José de las Matas (elevation about 500 m) during the period 1931-1986 (Source: Plan Sierra, unpublished climatological records). The three temperatures (along the right margin) represent the mean annual maximum, mean, and minimum temperatures based on the same data set.

world, outbreaks of pine bark beetles often occur during or soon after periods of drought (Haack & Mattson 1989, Mattson & Haack 1987).

Practically all outbreak sites consisted of mature or nearly mature *P. occidentalis* stands; few trees died in stands classified as young pine by Kastberg (1982). In sites with nearly 100% tree mortality, soils were shallow and coarse textured, and had much exposed rock. Similarly, bark beetle outbreaks in Central America have been most severe in overstocked and overmature stands growing on poor soils (Schwerdtfeger 1955, Beal et al. 1964, Yates 1972, Vité et al. 1975, Billings 1982, Wilkinson & Haack 1987).

Causal Agents and Within-Tree Distribution

The following species of bark beetles were associated with every dead or dying *P. occidentalis* tree inspected (N = 32): *Ips calligraphus*, *Pityophthorus antillicus*, and *Pityophthorus pinavorus*. In all currently infested trees, *I. calligraphus* appeared to have attacked before the *Pityophthorus* species, based on developmental stage and gallery patterns of the brood.

The three bark beetle species attacked distinct portions of the tree. *Ips calligraphus* colonized the entire trunk and branches down to diameters of 4 cm. *Pityophthorus antillicus* was found only in the crown where it inhabited branches of 1-5 cm in diameter. Its gallery system consisted of a central nuptial chamber in the phloem tissue from which 4-6 gallery arms radiated in a star-shaped pattern, indicating that these beetles are harem polygynous (see Kirkendall 1983). Bright (1981) states that *P. antillicus* has only been recovered from the Dominican Republic. *Pityophthorus pinavorus* inhabited the central pith region of foliage-bearing shoots. These beetles entered the twig from 2 to 4 cm distal to the needle-bearing portion of the shoot. This species has been collected in the Dominican Republic and in Florida where it was found on or in shoots of slash pine, *Pinus elliottii* Engelman (Bright 1985). Such resource partitioning has been recorded for other complexes of pine bark beetles in the southeastern United States (Paine et al. 1981, Foltz et al. 1985), Mexico (Perry 1951), Central America (Vité et al. 1975, Wilkinson & Haack 1987), and Jamaica (Garraway 1986).

Based on the age distribution of developing brood, *I. calligraphus* attacked first in the upper trunk near the base of the crown. Subsequent attacks proceeded upwards into the crown and downwards along the trunk. In Florida, where *I. calligraphus* is typically the first bark beetle to infest slash pine, a similar attack pattern was reported (Foltz et al. 1985).

In addition to the bark beetles described above, galleries of one or more unidentified species of sapwood-infesting ambrosia beetles (Scolytidae and/or Platypodidae) were present along the lower trunk. Possibly these were galleries of *Xyleborus volvulus* (F.), a tropical polyphagous species that was frequently collected with pheromone-baited traps (see below). No gallery systems or brood of any other *Ips* or any species of *Dendroctonus* were observed.

Interpopulational Comparisons

Overall, life history parameters of *I. calligraphus* were very similar between Caribbean and North American populations. For example, the average distance between male attack sites (nuptial chambers) was 9.7 cm (range: 5-16 cm, N = 104 nuptial chambers) in the present study, compared with 9.2 cm in Florida (Haack et al. 1987). Considering each gallery arm to represent one female, *I. calligraphus* harem size averaged 3.4 females per male (range: 2-5, N = 108 nuptial chambers) in the Dominican Republic, 2.8 in Jamaica (Garraway 1986), 3.2 in Florida (Haack et al. 1987), and 3.1 in Texas (Cook et al. 1983). The average length of egg gallery constructed by Dominican female beetles was 13.7 cm (range: 7-20, N = 364 egg galleries) compared with 13.3 cm

in Florida (Haack et al. 1987). Egg density (eggs per unit length of gallery) values ranged between 2 to 4 eggs/cm of gallery ($N = 364$ egg galleries) for Dominican *I. calligraphus* populations. These values are similar to reports for Florida populations (Haack et al. 1984a, 1984b, 1987). Egg density is a rather "plastic" variable, tending to increase with increasing inner bark (phloem) thickness. Phloem thickness of *P. occidentalis* ranged from 1 to 3 mm, which is similar to the range found in slash pine (Haack et al. 1984a), the principal host tree of *I. calligraphus* in Florida. The sex ratio of emerging brood adults in the Dominican Republic was approximately 1:1 (male:female, $N = 84$) whereas the sex ratio of adults collected from pheromone traps was about 1:3 ($N = 294$) in November 1987 and 1:2.2 ($N = 487$) in April 1988. Similar values have been reported from Jamaica (Garraway 1986) and North America (Cook et al. 1983, Haack et al. 1987, Renwick & Vité 1972, Vité et al. 1978). The small degree of variability in the above life-history parameters, especially considering that four different pine species were involved, suggests that these traits are rather fixed and may change only slowly in discrete populations of *I. calligraphus*.

Seasonal Flight and Voltinism

Flight of *I. calligraphus* occurred during every month of the year, with the generally decreasing trap catches reflecting the overall decline in outbreak severity during the sampling period (Fig. 2). Year-round flight also occurs in Florida, where a threshold temperature for *I. calligraphus* flight was estimated to be about 20°C (Haack 1985). Given a similar threshold temperature for Dominican populations, the warm temperatures at San José de las Matas (Fig. 1) will obviously support flight throughout the year.

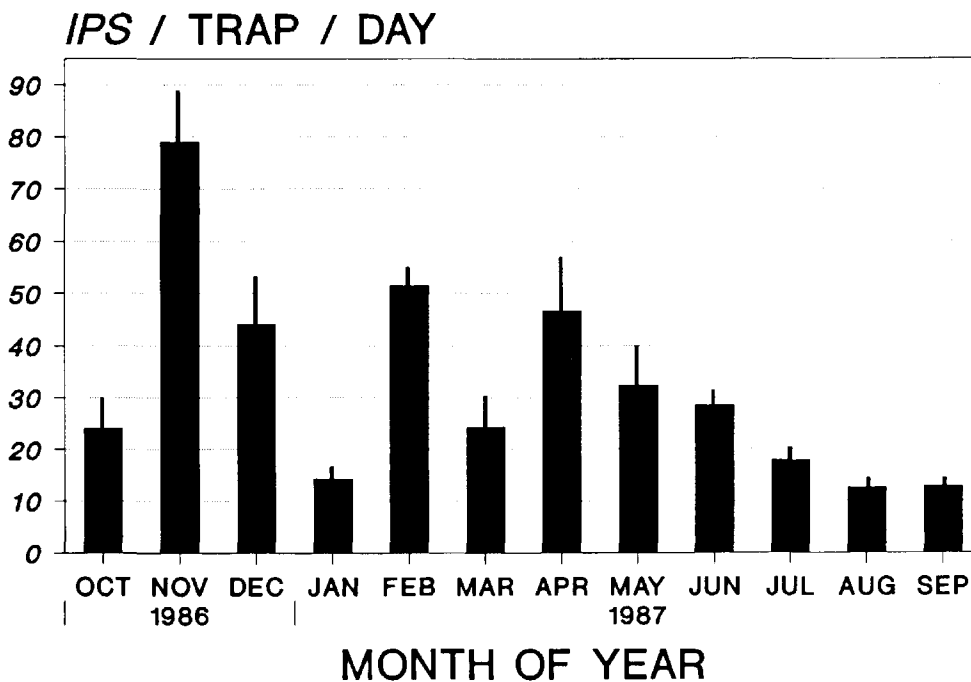


Fig. 2. Mean daily catch of *Ips calligraphus* adults per trap by month from October 1986 through September 1987 ($N = 102,980$ beetles and 18 traps); vertical bars = 1 standard error of the mean.

Florida populations of *I. calligraphus* complete one generation every 457 degree days above a threshold temperature of 10°C (Haack 1985). Assuming similar thermal requirements for Dominican *Ips* and given that the mean annual temperature of San José de las Matas is 24.1°C (Fig. 1), Dominican *Ips* could complete more than 11 generations per year: $[(24.1^{\circ}\text{C}-10^{\circ}\text{C}) 365 \text{ days/year}]/457 \text{ degree-days/generation} = 11.3 \text{ generations/year}$. Given year-round flight and the ability to complete nearly one generation per month makes this beetle a serious threat to Dominican forests whenever stressed by such causes as drought, fire, and hurricane damage.

Pheromone Studies

The results from the ipsdienol blend study were similar at all four trapping locations, and overall more than 60% of the 638 *I. calligraphus* collected were on traps baited with the 50% (+)/50% (-) blend (Fig. 3). In studies by Vité et al. (1978) in Texas, nearly pure (-)-ipsdienol was most attractive. Such a marked difference between these two populations of *I. calligraphus* suggests that evolutionary change in pheromone biology is taking place. Lanier & Burkholder (1974) indicate that such pheromonal changes can lead to speciation. Similar differences in optimal pheromone blends have been recorded for *Ips pini* (Say) populations from the eastern and western parts of its North American range (Lanier et al. 1972, 1980), as well as for discrete populations in British Columbia (Miller et al. 1989).

In addition to *I. calligraphus* being recovered from the sticky traps in the above study, five species of Buprestidae and two other species of Scolytidae were collected. The buprestids were: *Actenodes bellula* Mannerheim, *Buprestis hispaniolae* Fisher, *Chrysobothris chlorosticta* Thomson, *Chrysobothris megacephala* Laporte & Gory, and *Chrysobothris tranquebarica* (Gmelin). The two scolytids were *Pityophthorus annectens* LeConte and *Xyleborus volvulus* (F.).

In the multi-species pheromone study only *I. calligraphus* were recovered (N = 487). That is, no *Dendroctonus* nor any other *Ips* species were collected. The existence of *I. cribricollis* in the region cannot be ruled out, however, since the components of its pheromone are not known, and therefore we may not have presented all compounds necessary to attract it. Furthermore, since the pheromones of *I. calligraphus* are slightly inhibitory to *I. grandicollis* (Borden 1982), we may have repelled members of the latter species by placing all pheromone baits on the same traps. In addition to collecting *I. calligraphus*, one female specimen of *Thanasimus dubius* (F.) (Coleoptera: Cleridae), an important bark beetle predator, was captured. However, no individuals of another *Ips* predator, *Temnochila virescens* (F.) (Coleoptera: Trogositidae), were observed or caught in either of the two pheromone studies.

Host Trees

All infested pines were *P. occidentalis*. Young plantations of *P. caribaea* occurred in the outbreak region, but were not attacked by *I. calligraphus*. Nevertheless, six-spined *Ips* have attacked and killed *P. caribaea* in Central America (Yates 1972, Billings 1982) as well as other exotic pines in Jamaica (Garraway 1986).

Data on mean DBH, height and basal area for stands in which outbreaks occurred are presented in Table 1. These stands were visually similar to *P. occidentalis* stands throughout the Dominican highlands. Because mean DBH and height were broadly similar among actively growing, mature, and open pine stands, more than 90% of the pine forests can be considered nearly mature or mature (Table 1). This type of skewed age structure probably facilitated the *Ips* outbreak because older trees are often more susceptible to bark beetle attack during periods of environmental stress (Mattson & Addy 1975).

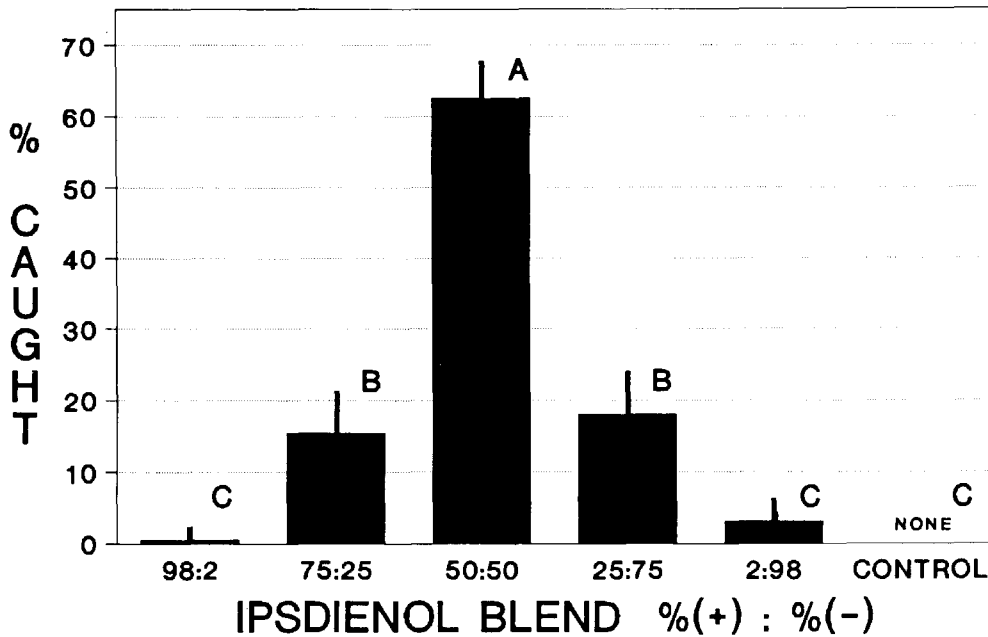


Fig. 3. Percent of all *I. calligraphus* adults ($N = 638$) collected on pheromone traps (4 traps/treatment) baited with various blends of (+) and (-)-ipsdienol; vertical bars = 1 standard error of the mean. Means followed by the same letter are not significantly different at the $P < 0.05$ level (Duncan's multiple range test).

In seven compartments, total height and DBH were recorded for all beetle-killed pines ($N = 1112$ trees). In each compartment, almost every tree was killed and thus the measurements represent nearly a complete census of the seven stands. Frequency distributions are presented by height and DBH (Fig. 4). Average height and DBH of these trees were 16 m (range = 6-26 m) and 21 cm (range = 5-50 cm), respectively, and compare closely with the average values presented for mature pine stands in Table 1.

Ips bark beetles are often considered secondary forest pests in North America, attacking primarily logging slash and unhealthy trees (Wood & Stark 1968). However, under circumstances such as widespread drought, *I. calligraphus* has the potential to

TABLE 1. CHARACTERISTICS OF *PINUS OCCIDENTALIS* FOREST STANDS NEAR SAN JOSÉ DE LAS MATAS (CA. 3000 HA) IN WHICH *IPS* OUTBREAKS OCCURRED.

Forest type ¹		Stand parameter ²			
Type	Area (%)	DBH (cm)	Ht (m)	BA (m ² /ha)	N
Growing pine	39	18 (12-23) b ³	15 (10-19) a	12 (6-19) a	33
Mature pine	43	22 (17-27) a	16 (12-20) a	12 (6-18) a	45
Open stand	9	23 (19-28) a	16 (12-22) a	4 (3-5) b	3

¹Description for each forest type presented in text. Area values from Kastberg (1982) as a percent of all forested lands classified as pine.

²DBH = diameter at breast height, Ht = height, BA = basal area, N = number of stands sampled.

³Overall means are given followed by the range of individual stand means in parentheses. Means followed by the same letter (within columns) are not significantly different at the $P < 0.05$ level (Duncan's multiple range test).

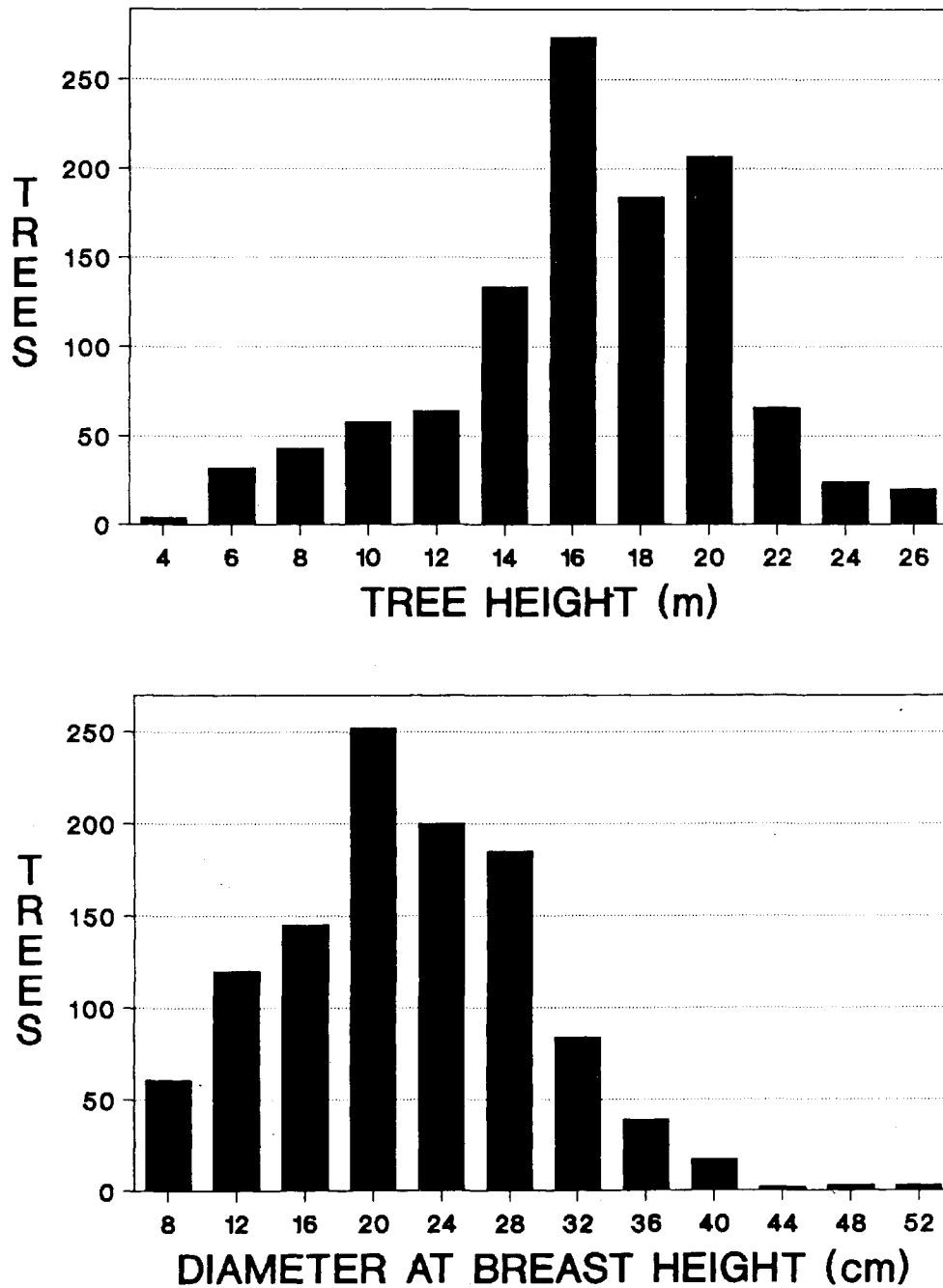


Fig. 4. Height (top) and diameter (bottom) distributions of *Ips*-killed *Pinus occidentalis* trees (N = 1112) (Source: Plan Sierra, unpublished sawmill records).

reach outbreak proportions as it did in Jamaica following a drought in 1980 (Garraway 1986) and as reported in the present study.

ENDNOTE

The authors wish to thank the U.S. Agency of International Development and Partners of the Americas for foreign travel support; Plan Sierra for lodging and local

travel; José Gonzales, Luis Mendosa, Luis Tejada, José Dominguez, and Teresa Gil of Plan Sierra for technical and field assistance; Bertil Kastberg of Swedforest Consulting for providing forest inventory data; Stephen Teale (State University of New York, Syracuse) and Phero-Tech Inc., Vancouver, British Columbia, for donating pheromone lures; DeWill Inc., Chicago, Illinois, for donating the sticky traps; Stanley Wellso (USDA at Purdue University, West Lafayette, Indiana) for identifying the Buprestidae; Gerald Lanier (State University of New York, Syracuse) for identifying the *Ips*; Thomas Atkinson (University of Florida, Gainesville) for identifying the *Pityophthorus* and *Xyleborus*; and Gerald Lanier and Robert Wilkinson (University of Florida, Gainesville) for their critical reviews of an earlier draft of this manuscript. Mention of a commercial or proprietary product does not constitute an endorsement by the U.S. Department of Agriculture. Voucher specimens of the Scolytidae have been deposited with the Florida Division of Plant Industry, Gainesville.

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A SURVEY OF INSECTS OF THE FLORIDA KEYS:
POST-PLEISTOCENE LAND-BRIDGE ISLANDS:
INTRODUCTION

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ABSTRACT

This paper introduces a series investigating the fauna of selected insect and arthropod groups occurring in south (subtropical) Florida, especially in the Florida Keys. Characteristics of the region are summarized. Collections were made continuously with malaise and flight-intercept traps for 1 year or more in 21 hardwood hammock or pineland habitats, and by other methods. Based on numbers of species of trees and shrubs, a prediction is made that a conservative total of at least 5,000 insect species should occur in south Florida. Six generalizations about the insect fauna are suggested for future testing.

RESUMEN

Este papel introduce una serie que investiga la fauna de grupos selectos de insectos y de artrópodos que ocurren en el sur (subtropical) de la Florida, especialmente en los Cayos de la Florida. Se summarize las características de la región. Se hicieron colecciones continuas usando trampas "malaise" y de interceptoras de vuelos, por un año o más en habitaciones de "hardwood hammock" o de pino, y también por otros métodos. Basado en el número de especies de árboles y arbustos, se hace una predicción conservadora de que por lo menos 5,000 especies deben de ocurrir en el sur de la Florida. Se sugieren seis generalizaciones para pruebas futuras sobre la fauna de insectos.

It has long been realized that southern Florida has a most interesting biota. The climate is subtropical. The southwest trending string of islands, the Florida Keys, are

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It has long been realized that southern Florida has a most interesting biota. The climate is subtropical. The southwest trending string of islands, the Florida Keys, are

young, and have had a dynamic history. They have experienced several cycles of submergence and emergence. Their uppermost bedrock limestones and oolites were deposited about 100,000 yr BP, during the late Pleistocene, at the time of high (Sangamon interglacial) sea levels (Hoffmeister 1974). During the last glacial, about 80,000 to 15,000 yr BP, the Keys were a broadly continuous land mass or land bridge on the southern end of the Florida submarine shelf, extending out to the Dry Tortugas, 110 km west of Key West. The present islands were formed over the past 10,000 years as sea levels rose because of the melting of the continental Wisconsinan glacial ice sheets (Hoffmeister & Multer 1968, Holmes 1985). During this process the land bridge biota retreated to the decreasing area of the islands. Much of this biota of south Florida and the Keys is West Indian in origin. It has mostly arrived by over-water dispersal to south Florida through rafting, being carried by birds, or by storm winds (Darlington 1938).

The Keys have been important in the development of the equilibrium theory of island biogeography (e.g. MacArthur & Wilson 1967, Simberloff 1974, 1976a, 1976b, Simberloff & Wilson 1969, 1970, Wilson & Simberloff 1969). Some recent studies have continued to investigate the composition and dynamics of the insect faunas of the Keys, notably the ants (Deyrup et al. 1988) and the scavenging scarab beetles (Peck & Howden 1985). Many Keys insect records are in the series of volumes "Arthropods of Florida." Important summaries linking Keys insects and habitats to the biogeography of the rest of Florida are those of Blanton & Wirth (1979) and Woodruff (1973).

A remarkable growth in human population and activity has occurred in south Florida in the past 30 years. Much of this has been at the expense of native habitats and their biotas. Few baseline data are available to document or evaluate change in insect faunas in south Florida. This is of concern to land managers who must make decisions about protected lands and habitats under their care and administration. Of the 218 invertebrate species listed in Franz (1982) as being rare or endangered in Florida, 28 of these are terrestrial species that occur in the US exclusively in subtropical Florida.

There is a growing tendency to incorporate data from south Florida in discussion of zoogeography of Caribbean insects. Three authors have done so in the recent book edited by Liebherr (1988). Donnelly (1988) provides a framework of Antillean geology.

This study was undertaken to investigate the species composition and distribution of selected groups of insects and other arthropods in native habitats in south Florida, with the belief that this fauna is still very poorly known.

METHODS

A variety of collecting methods was employed to sample the insect faunas from 1981 to 1986. Most important was the use of 15 large-area intercept or flight intercept traps, combined with Townes-style Malaise trap heads (Peck & Davies 1980). These were operated for a year or more each in 18 native closed canopy hardwood hammock forests and in 3 open pineland forests from November 1984 to December 1986. The advantage of these traps is that they can sample insects continuously at all times of day or night and in all weather conditions. They are most effective for beetles, but other insects are also caught in the trough below or the trap head above, each of which was filled with non-evaporating ethylene glycol. The catches of these traps were harvested at 3 month intervals, at which time supplementary collections were made in the same and additional sites with UV blacklight traps, by sifting or washing forest litter and soil and placing the samples in Tullgren extractors, or with baited pitfall traps.

Study sites were predominantly native, closed-canopy, hammock forests or open pineland forest. Principal study sites are indicated in Figure 1 and 2. These were in the Metro-Dade Park and Recreation Board system at Old Cutler Hammock, Mattheson Hammock, and forest in the Charles Deering Estate. Everglades National Park sites

were in Royal Palm Hammock, Palma Vista Hammock, and two pineland sites on Long Pine Key. Sites in the Florida State Park system were forests in Grossman Hammock in Chekika State Recreation Area, Lignum Vitae Key Botanical Reserve, John Pennekamp Coral Reef State Park, Bahia Honda State Park, and Long Key State Recreation Area. Sites protected by the US Fish and Wildlife Service were in Key Deer and Crocodile Lake National Wildlife Refuges on Key Largo, and Watsons Hammock and Cactus Hammock on Big Pine Key, and Sugarloaf and No Name keys. Other hammock sites were located in Weiner (1981) and were sampled on Sugarloaf Key, Cudjoe Key, Fat Deer Key, Key Vaca (Marathon), Middle Torch Key, Big Torch Key, northern Big Pine Key, and Stock Island Botanical Gardens.

RESULTS

Over the sampling period from 1981 to 1986, an estimated 500,000 insects were collected at over 50 locations. The results will form a projected series of publications. It is hoped that other entomological specialists will also contribute to an eventual understanding of the south Florida insect fauna, its species composition, origin, and distribution. Collection residues are available for study by others and are in the collections of the Canadian National Collection, Biosystemics Research Centre, Agriculture Canada, Ottawa (Acari and Hymenoptera); Alberta Provincial Museum, Edmonton, Canada (aculeate Hymenoptera); American Museum of Natural History, New York (spiders and Hemiptera); American Entomological Institute, Gainesville, Florida (Ichneumonidae); and the Field Museum of Natural History, Chicago, Illinois (bulk residues, especially litter samples and Malaise trap Diptera). Where appropriate, data may be included from the extensive holdings of the Florida State Collection of Arthropods, DPI, Gainesville, Florida.

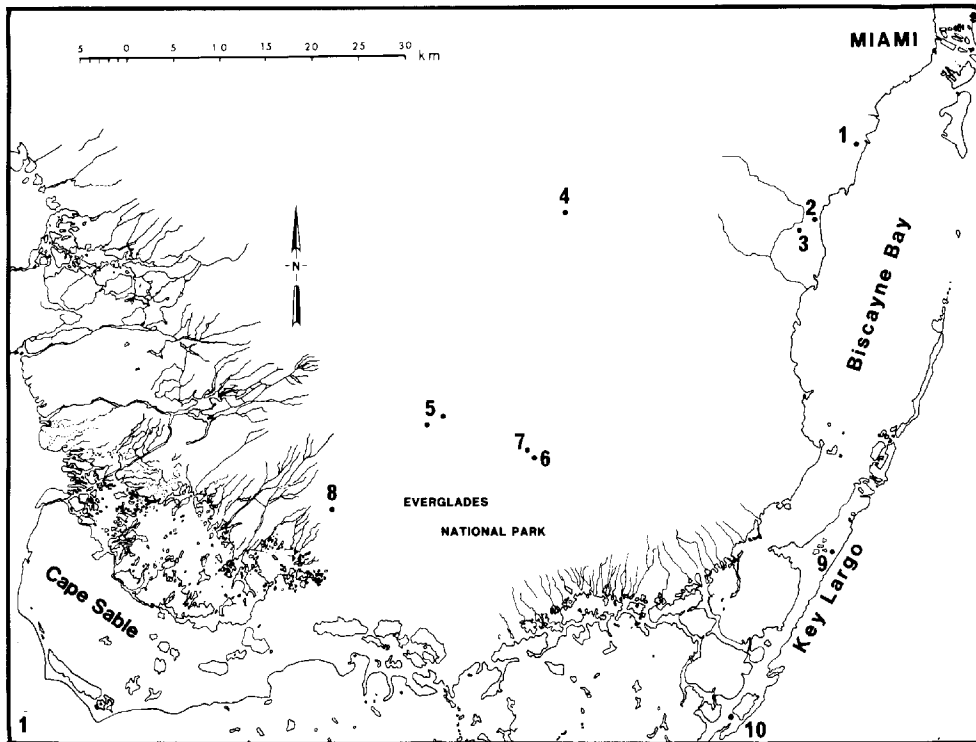
DISCUSSION

“West Indian” Biota.

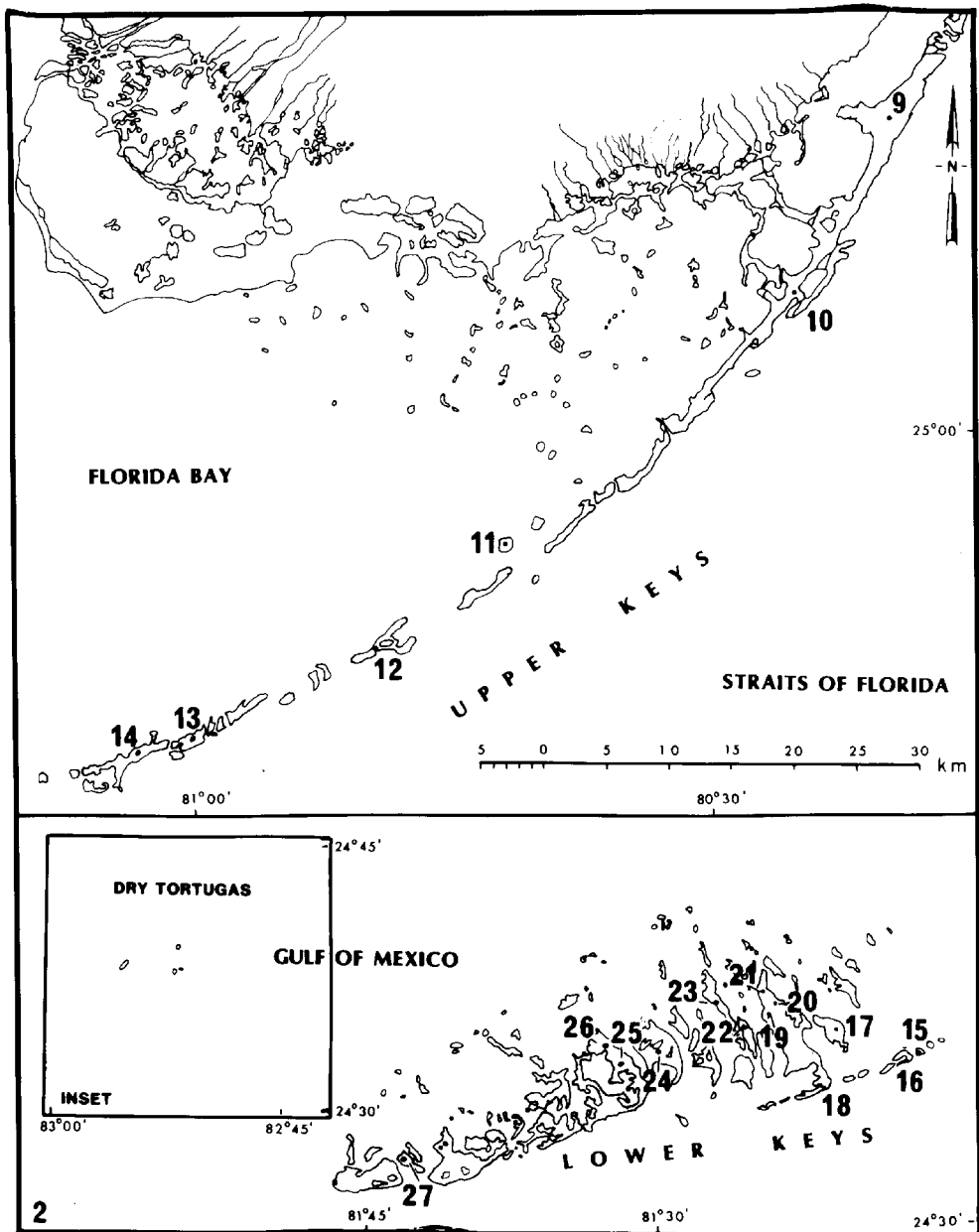
The insect fauna of Florida may be the most diverse of any state or province north of Mexico. This study investigates selected groups of insects and other arthropods in south Florida, principally in the native West Indian vegetation of the hardwood hammock forests of south Florida and the Keys. “Hammock” is an Amerindian term applied in Florida to groups of evergreen hardwood trees having a West Indian distribution and occurring in distinct “tree islands” surrounded by contrasting vegetation, typically either pinelands, or swamplands. Hammocks are a feature typical of south Florida. The ultimate goal of this study is to investigate the biogeographic affinities of the insects living in habitats dominated by a West Indian flora. It should not be assumed *a priori* that all the insects are “West Indian”. It has already been found that the scavenging scarab beetle fauna of south Florida, with 35 species, is predominantly derived from the temperate North America fauna, but contains two native Caribbean species and seven species which probably are introduced (Peck & Howden 1985).

How many insect species are in south Florida?

At the start, it is necessary to state that we do not know how large the south Florida insect fauna is. It has not been catalogued. I do not even know of an estimate for the size of the insect fauna of Florida as a whole. But it is possible to make an estimate for south Florida, and it is based on the richness of the flora. The richness of an insect fauna has both a direct and indirect relationship with the diversity of the flora. The



Figs. 1 and 2. Generalized maps of south Florida and the islands of the Florida Keys. The main chain of the Keys is now connected by a series of highway embankments or bridges (not shown). The primary sampling localities in this study are indicated on the maps by the following numbers. All are West Indian hardwood hammock forest unless otherwise indicated. 1. Matheson Hammock, 9800 Old Cutler Road, South Miami. 2. Deering Estate Park, 167th St. SW and 72 Ave, South Miami. 3. Old Cutler Hammock, 7900 SW 176th St., South Miami. 4. Grossman Hammock, Chekika State Recreation Area, 168th St. and SW 237 Ave. 5. Long Pine Key, (open pinelands forest), Everglades National Park. 6. Royal Palm Hammock (=Paradise Key) (not to be confused with Royal Palm at Collier Seminole State Park, Monroe County), Everglades National Park. 7. Palma Vista Hammock, 1.5 km NW Royal Palm Hammock, Everglades National Park. 8. Mahogany Hammock, Everglades National Park. 9. North Key Largo, Section 35. 10. South Key Largo, John Pennekamp Coral Reef State Park. 11. Lignum Vitae Key. 12. Long Key. 13. Fat Deer Key. 14. Key Vaca (Marathon, Section 1). 15. Ohio (=Sunset) Key. 16. Bahia Honda Key. 17. No Name Key. 18. Cactus Hammock, Big Pine Key. 19. Watsons Hammock, Big Pine Key. 20. Watson Boulevard (open pine-palm forest), Big Pine Key. 21. No Name Road (Section 4, mangrove-hardwood transition forest), Big Pine Key. 22. Middle Torch Key. 23. Big Torch Key. 24. Cudjoe Key. 25. Kitching Hammock (Section 25), Sugarloaf Key. 26. Section 23, Sugarloaf Key. 27. Stock Island Botanical Garden.



number of insect species dependent on a plant species is partly determined by the size of the geographic range of the host plant, its general abundance within that range, the evolutionary time to originate such associations, and the size (structural complexity) of the host. Trees support more insect species (because they offer more "niches") than do shrubs, herbs, monocots, or ferns. For instance, a study of insect species found on angiosperm trees in Britain and European Russia found an average of 109 and 74 species per tree genus respectively (Southwood 1961).

A plant species in Britain frequently is host to more than 50 insect species (Strong & Levin 1979, Lawton & Schroder 1977). Few data are available for subtropical lands or islands. Southwood (1960); summarized data for trees on Hawaii and found from 1.8 to 41 species of insects (averaging 40 species) obligatorily restricted to a single tree species and a total of from 5.6 to 155 insect species (averaging 123 species) associated in some way with each tree species. Gagné (1979) found at least 162 insect taxa on two tree species in Hawaii. On the Mediterranean island of Cyprus, Southwood (1961) reported 3.4 species of Heteroptera and Auchenorrhyncha alone per tree species. Stork (1987) found about 3000 insect species in 10 individual trees in Borneo. Erwin (1983) estimated around 160 species of canopy beetles specific to a tropical tree species in Panamanian moist, seasonal forests.

These figures may be too high to apply directly to south Florida. The trees are small. The canopy of a hardwood hammock seldomly exceeds 25 m in height on the mainland or 15 m in the Keys. The late Pleistocene history of the area allows inadequate time for speciation, but abundant time for immigration from the West Indies. Panama represents a continental tropical seasonal moist forest, famous for its rich insect diversity. Cyprus and Borneo are large islands and close to surrounding continental (or shelf) source areas. Hawaii is an exceptionally remote archipelago where much *in situ* speciation over more time has enriched the plant-feeding fauna. Simberloff (1976b) examined the arboreal arthropods (mostly insects) of nine mangrove islands in the Keys. Each single-tree island contained from 12 to 30 species and larger mangrove islands had from 63 to 103 species, from a total pool of about 500 species. But few of these are obligatorily associated with mangroves [See Strong et al. (1984) for additional discussion of plant-insect interactions].

The subtropical Florida flora contains over 100 genera of native woody plants (Tomlinson 1980). The insect species pools have not been measured on any of these plants in subtropical Florida. However, if there were an average of 10 specialist phytophagous insect species per plant genus, we have a possible species pool of 1,000 native herbivore insect species in subtropical Florida. This is not an unreasonable estimate based on the above averages and because sub-tropical mainland faunas are probably more diverse than those of the temperate mainland or of tropical oceanic islands. The actual number would be expected to be higher because there are additional generalist plant feeders, and many additional non-arborescent plant species (65% of the total flora is herbaceous (Long & Lakela 1971)) which are hosts for additional insects. On top of this is the fact that more than half of any insect fauna is composed of additional predatory and decomposer-scavenger species. This could give a total of some 5,000 insect species, but this seems conservative because over 6,000 insect species are claimed for Mount Desert Island, Maine, USA (Proctor 1946). Even if the actual number is more or less than 5,000 the point is that the fauna is probably rich, but very poorly known.

Climate of south Florida.

The most important factor which probably limits the northward distribution of most of the subtropical insects may be minimum winter temperatures. Tomlinson (1980) suggests that for most wide-ranging native tropical trees it is the average 12°C (54°F)

January isotherm, which forms a U shaped band extending inland some 20-40 km from the coast, and running south from Cape Canaveral (= Kennedy) on the east coast and up the west coast to Tampa. Most of Dade and Monroe counties are within this zone. The main climatic seasons are a long, hot and wet summer from May to September, and a dry and cooler winter and spring from November to March. Average maximum temperatures at Miami are about 32°C (90°F) and average minimums of around 10°C (50°F) with a record minimum of -2°C (27°F). Rainfall is seasonal and averages 152 cm (60 inches) at Miami, and decreases to the southwest along the more arid Keys to 97 cm (38 inches) at Key West, with 80% of the rainfall occurring from May to October.

Patterns of distribution and origin.

Several patterns of species distribution or abundance may be expected to occur in the insects of south Florida. Many of these should parallel patterns found in the flora. I accentuate patterns from the flora because its species distributions are well known, and distributional changes through time are better documented in the fossil record.

Certainly, for the flora, the richest part of the state is the subtropical southern tip, including the Florida Keys. Here there are 130 species of native trees alone, more than in any other biogeographic region of the United States or Canada. Of these, 18 (12.5%) are temperate species, at the southern limits of their distribution, with wider distributions in the eastern United States. The remaining 112 species (87.5%) are at their northern distributional limits, and have an otherwise tropical distribution (Tomlinson 1980). Only one of these subtropical Floridian trees is considered to be an endemic: *Acacia pinetorum* Hermann. The other tropical species are thought to have originated outside of Florida and to have dispersed there in the Tertiary or Pleistocene by one of three routes (Tomlinson 1980).

1. A temperate route. This was from temperate North America and down the Florida peninsula. Some trees used this route to reach the Caribbean. There is fossil pollen of *Fagus*, *Nyssa*, and *Liquidambar* from the Oligocene of Puerto Rico (Graham & Jarzen 1969), and *Quercus*, *Rhus*, and *Fraxinus* occur natively in Cuba.

2. A tropical overseas route. This is from the south, across the sea gap of the Straits of Florida. It accounts for the high proportion of trees with fleshy or otherwise edible fruits or small seeds and sticky fruits (e.g. *Pisonia*), all dispersed by birds. Also important is dispersal by winds and sea currents of floating or rafting propagules, especially during tropical storms (Darlington 1938). Caribbean lands were also much more extensive and the sea gaps narrower during the low sea levels accompanying Pleistocene glacials [see especially Campbell (1978) for emergent Caribbean lands during glacials]. Single recent dispersal events were once suggested by the sole US records of *Xanthoxylum flavum* Vahl., *Catesbaea parviflora* Sw., and *Jacquemontia jamaicensis* (Jacq.) (historical plaque on Bahia Honda Key), but these are now known from other islands (Long & Lakela 1971).

3. A tropical land route. This is from Central America and Mexico via the Gulf States. It was most important in earlier epochs, and the species usually differentiated in Florida after dispersal. This route may account for the presence of *Diospyros* and *Asimina* (paw-paw) as relicts in Florida. Comparatively little information is available on the ancestral distribution of Caribbean plants (Graham 1976).

Control of "peninsular" distribution patterns.

In addition to climate as discussed above, the "peninsula effect" is frequently considered to be of importance in the distribution of Florida's organisms. It is a decline in species richness from the base to the tip of the peninsula because of increased extinctions

and decreased immigration along the peninsula (Simpson 1964). This alone would suggest an impoverished fauna and flora in the Keys. Means and Simberloff (1987) have examined herpetofaunal distributions in Florida and find that there is no peninsula effect as such, but that faunal richness is related to habitat richness. The southwardly decline of the herpetofauna is related to the progressive decline of (1) rivers and streams, (2) acid wetlands, (3) mesic hardwood forests, (4) pinelands, and (5) winter rains for breeding or larval overwintering. The southward decline of terrestrial habitats in general is a result of low elevation and more extensive wetlands, over extensive areas: the "everglades effect" (Means & Simberloff 1987). Counter to these trends is the progressive increase to the south of the native tropical hardwood forests. All these (and probably other factors) will control the distributions of Florida insects (see also Blanton & Wirth 1979).

Expectations

Some generalized conclusions can be suggested about the insect fauna of south Florida. Future studies will test these predictions.

1. The fauna is comparatively rich for the small land area of subtropical south Florida.

2. A smaller component of the insect fauna has come from the north, from elsewhere in the United States. A larger component has arrived by over-water dispersal from tropical America. The exact proportion will vary according to the vagility of the taxon.

3. Comparatively few species will be endemic to the subtropical parts of south Florida. This is because the area is geologically young, and has been more open to invasion of species from elsewhere than to the isolation and origin of local species.

4. More species will be found in the subtropical mainland of south Florida than in the Keys, because of its greater area, more favorable (wetter) climate, and greater habitat diversity (especially of soils and aquatic or sub-aquatic environments).

5. Most insect species of south Florida are comparatively vagile and will occur elsewhere in the circum-Caribbean lowlands or in the lowlands of the islands of the West Indies. For instance, a large number of Caribbean species of butterflies have entered south Florida, but few have gone the other way (Brown 1978). In lygaeid bugs 24 species have come into Florida from the West Indies, but only 9 species have gone from Florida to the West Indies (Slater 1988).

6. Because the insect fauna is vagile, it will be eurytopic, and its trophic associations will be more general. Fewer species-specific host plant or other feeding associations will occur. Slater (1988) has noted that 27% of West Indian species of lygaeid bugs also occur in Florida and generally throughout the southern U.S. and into Central America. These, however, tend to be "oligophagous" but on "weed" species.


ACKNOWLEDGMENTS

We thank the following for permits to study the insect faunas in the areas under their protection: Pete Dingler and Rob Line, Metro-Dade County Park and Recreation Department; J. A. Stevenson, Florida Department of Natural Resources, Division of Recreation and Parks; John M. Morehead (Superintendent), Gary Hendrix (Director of Research), and Pat Tolle (Management Technician), Everglades National Park; Donald J. Kosin, Jack Watson, and Deborah Holle, (Managers) National Key Deer and Crocodile Lake Wildlife Refuges. William and Ellen Peck generously provided long-term logistical support on Big Pine Key. Field work was partly supported by operating grants from the Natural Sciences and Engineering Research Council of Canada. The manuscript was improved by comments from Howard Frank, M. C. Thomas, W. W. Wirth, and anonymous reviewers.

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A SURVEY OF INSECTS OF THE FLORIDA KEYS:
COCKROACHES (BLATTODEA), MANTIDS (MANTODEA),
AND WALKINGSTICKS (PHASMATODEA)

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ABSTRACT

A survey of cockroaches, mantids, and walkingsticks in native forests in south Florida found 15 species, from a total of about 40 (15 of which are introduced) which occur in all of Florida. Three cockroach species are added to the Florida fauna. *Compsodes schwarzi* (Caudell), previously known from Mexico and Texas, is reported from Florida for the first time. *Neoblatella detersa* (Walker) and *Symploce morsei* (Hebard), both known from elsewhere in the West Indies, are reported for the United States for the first time. The only introduced species found to have invaded native habitats is the

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ABSTRACT

A survey of cockroaches, mantids, and walkingsticks in native forests in south Florida found 15 species, from a total of about 40 (15 of which are introduced) which occur in all of Florida. Three cockroach species are added to the Florida fauna. *Compsodes schwarzi* (Caudell), previously known from Mexico and Texas, is reported from Florida for the first time. *Neoblatella detersa* (Walker) and *Symploce morsei* (Hebard), both known from elsewhere in the West Indies, are reported for the United States for the first time. The only introduced species found to have invaded native habitats is the

parthenogenetic cockroach *Pycnoscelus surinamensis* (Linnaeus). *Parcoblatta fulvescens* (Saussure & Zehnter) has invaded from the southeastern United States. The other 13 species are Neotropical (Caribbean or Mexican) in origin.

RESUMEN

Se hizo una encuesta de cucarachas, come-piojas, e insectos palos en bosques nativos del sur de la Florida, encontrándose 15 especies de un total de cerca de 40 (15 de las cuales son introducidas) que ocurren en toda la Florida. Se añaden tres especies de cucarachas a la fauna de la Florida. Se reporta por primera vez a *Compsodes schwarzi* (Caudell) de la Florida, previamente conocida de México y Texas. Se reporta por primera vez de los Estados Unidos a *Neoblattella detersa* (Walker) y a *Symploce moresei* (Hebard), ambas conocidas de las Indias Occidentales. La única especie introducida que se ha encontrado invadiendo habitaciones naturales es la cucaracha partenogenética *Pycnoscelus surinamensis* (Linnaeus). *Parcoblattaa fulvescens* (Saussure & Zehnter) ha invadido desde el sudeste de los Estados Unidos. Las otras 13 especies son Neotropicales (del Caribe o Mejicanas) de origen.

A survey of some of the insect fauna was made in south Florida, mostly between 1984 and 1986, in about 30 sites, mostly in the Florida Keys (see Peck 1989 for details). Most collections were made with continuously collecting "large area window traps" or "flight intercept traps" (see Peck & Davies 1980) in closed canopy West Indian hardwood hammock forests. The purpose was to contribute to understanding the species composition of these poorly known habitats. This paper reports on the cockroaches, mantids, and walkingsticks found to walk or fly into the traps used in the survey. Voucher specimens are in the collections of the first author; the Florida State Collection of Arthropods, Gainesville; The National Museum of Natural Sciences, Ottawa, Canada; and in the Lyman Entomological Museum of Macdonald College, McGill University, Ste Anne de Bellevue, Quebec, Canada H0A 1C0. Detailed specimen data are available from the first author. Most determinations can be easily made with the keys in Helfer (1972). The only previous survey of these insects from south Florida is that of Rehn & Hebard 1912, 1914a).

RESULTS

The Cockroaches (Blattodea)

Sixty-five species of cockroaches are known from the continental United States (Pratt 1988). Keys to most of the genera are in Rehn (1950). Distributional data and references are given by Princis (1962-1971). Twenty-eight of these species are known from Florida, and another 5 species may occur there. Of these, about 15 species were probably introduced by man. Of the native species, 11 are known or may be expected in south Florida (Hebard 1917, Helfer 1972, Rehn & Hebard 1912, 1914a). Eleven species were found in this study. The (probably) native species *Latiblatella rehni* Hebard, *Phoetalia* (= *Leurolestes*) *pallida* (Brunner) and *Hemiblabera tenebricosa* Rehn & Hebard were expected but not found. Three species were found to be new records for Florida.

Family Blaberidae

Pycnoscelus surinamensis (Linnaeus), The Surinam cockroach.

Seventy-two specimens were taken throughout south Florida in the Deering Estate,

Old Cutler Hammock, Long Pine Key (open pinelands), Grossman Hammock, south Key Largo, Fat Deer Key, Key Vaca, Ohio Key, Bahia Honda Key, No Name Key, Big Pine Key (No Name Road, Watsons and Cactus Hmocks), Middle Torch Key, Cudjoe Key, and Sugarloaf Key (Sec. 25). Adults were present throughout the year but most abundant from August to December. The species is circumtropical and was probably spread by man from Asia. It is established in natural habitats in the U.S. from Florida to Texas. The species is parthenogenetic, thelytokous and ovoviviparous (Roth 1967). Florida probably was occupied by multiple invasions from Central or South America (Parker et al. 1977).

Family Blattidae

Eurycotis floridana (Walker), The stinking cockroach.

Twelve specimens were taken on Long Pine Key (open pinelands), Big Pine Key (Watsons Hammock) and Big Torch Key. Adults were present only from March to June. These are flightless cockroaches which must walk into flight intercept traps. The species is distributed from the Keys to Georgia and Mississippi.

Family Polyphagidae

Compsodes schwarzi (Caudell), Schwarz's cockroach.

One specimen was caught in open pineland forest in Long Pine Key, Everglades National Park, 28.VIII-5.IX.1986 (identification confirmed by L. Roth; specimen deposited in FSCA). The species is otherwise known only from northwestern Mexico, Arizona, and Brownsville, Texas. This is the first record for Florida. A much smaller species, *Compsodes cucullatus* (Saussure & Zehntner) has been collected, apparently only once, at Paradise Key (= Royal Palm Hammock) (Blatchley 1920). It was described from Guatemala and may have been introduced.

Family Blattellidae

Cariblatta lutea minima Hebard, The least yellow cockroach.

One hundred sixty-eight specimens were found, mostly in hardwood hammock forests, in south Florida and the Keys in Long Pine Key (open pinelands), Royal Palm Hammock, Grossman Hammock, south Key Largo, Fat Deer Key, Key Vaca, No Name Key, Big Pine Key (Cactus and Watson's Hammocks), Big Torch Key, Cudjoe Key, Sugarloaf Key, and Stock Island. Adults occur throughout the year but were most abundant from May to September. This subspecies is restricted to south Florida, the Keys and Cuba. The subspecies *C. lutea lutea* (Saussure & Zehntner) ranges from central Florida to North Carolina, and Louisiana. The subgenital plates of the two seem to be distinctive and do not intergrade. They may represent two specific taxa (L. Roth, personal communication).

Chorisoneura texensis Saussure & Zehntner, The small yellow Texas cockroach.

Four specimens were found only on the south Florida mainland in hardwood hammock forests in Royal Palm Hammock (Everglades N.P.) and Grossman Hammock (Chekika Recreation Area). Three of these were from November to February, and one was collected between May and August. The species ranges from Texas to North Carolina and to south Florida.

Euthlastoblatta gemma (Hebard), The shortwing gem cockroach.

Five specimens were found only in hardwood hammock forests of the Keys; on Big Pine Key (Cactus and Watson's Hammocks), Big Torch Key and Cudjoe Key. Adults were caught only from August to February. The species ranges from Florida and Georgia to Texas, and the Bahamas. Princis (1965) transferred the species from the genus *Aglaopteryx*. Another species, *E. diaphana* (Fabricius), has much the same distribution (Princis 1962-1971).

Ischnoptera deropeltiformis (Brunner), The dark wood cockroach.

This was the most frequently found cockroach. Two hundred twenty-eight specimens were taken in south Florida and the Keys, in the Deering Estate, Long Pine Key (pinelands), Royal Palm Hammock, Grossman Hammock, south Key Largo, Fat Deer Key, No Name Key, Big Pine Key (Watson's Hammock), Middle Torch Key, Big Torch Key, Cudjoe Key, and Sugarloaf Key. The species ranges from the Keys north to New Jersey, and west through Indiana to Kansas and Texas.

Neoblatella detersa (Walker)

Forty-five specimens were found in south Florida and the Keys, in Old Cutler Hammock, the Deering Estate, Long Pine Key (pinelands), Royal Palm Hammock, south Key Largo, No Name Key, Middle Torch Key, Big Torch Key, Cudjoe Key, and Sugarloaf Key (identification confirmed by L. Roth; specimens deposited in FSCA). Adults were present in all seasons of the year. The species was previously known with certainty only from Jamaica and Haiti (Princis 1959, 1962-1971; Rehn & Hebard 1927: 74). It had been reported earlier from Homestead, Lakeland, and Everglades, Florida (Rehn & Hebard 1914a: 379, 1914b: 98), but these determinations were later stated to be misidentifications of *Latiblatella rehni* Hebard (Hebard 1917: 38, Rehn & Hebard 1927: 76), which otherwise occurs in the Bahamas and Cuba. We found no material with the characters of *L. rehni*.

Parcoblatta fulvescens (Saussure & Zehnter), The fulvous wood cockroach.

Twenty-four specimens were found in mainland and Keys forests on Long Pine Key (pinelands), south Key Largo, Middle Torch Key, and Cudjoe Key. Adults were present throughout the year but most abundant between June and August. The species is known to range from the Keys to New York and west to Iowa and Texas.

Plectoptera poeyi (Saussure), The Florida beetle cockroach.

Seventy-seven specimens were found only in the Keys, in hardwood hammock forests on Fat Deer Key, Vaca Key, Big Pine Key (Cactus Hammock and No Name Road), Middle Torch Key, Cudjoe Key and Sugarloaf Key. Adults were present in similar numbers in all seasons of the year. This small beetle-like species is known only from Florida and Cuba.

Symploce morsei (Hebard)

Twenty specimens were found only in the Keys in hardwood hammock forests, on south Key Largo, No Name Key, Middle Torch Key, and Cudjoe Key (identification confirmed by L. Roth; specimens deposited in FSCA). Adults were present throughout the year. The species is otherwise known only from the Bahamas (Roth 1984). These are the first U.S. records.

Mantids (Mantodea)

Twenty species of mantids are known from the United States, of which 6 occur in Florida but only four are known from south Florida (Gurney 1951, Helfer 1972, Rehn & Hebard 1914a). They are only rarely taken in flight intercept traps.

Mantoida maya Saussure & Zehntner, The little Yucatan mantid.

Twenty-seven specimens were found in south Florida and the Keys at the Deering Estate, Long Pine Key (open pinelands), south Key Largo, Vaca Key, Big Pine Key (No Name Road, Watson's and Cactus Hammocks), No Name Key, Big Torch Key, and Middle Torch Key. Adults occurred between June and September. The species occurs in south Florida and the Yucatan Peninsula of Mexico.

Gonatista grisea (Fabricius), The grizzled mantid.

Only 4 specimens were found, on Royal Palm tree trunks at the Deering Estate, in August. The species ranges from South Carolina, through Florida, to Cuba.

Thesprotia graminis (Scudder), The grass-like mantid.

Only seven specimens were taken in open pinelands on Long Pine Key in August. The species ranges from Florida to Mississippi.

Walkingsticks (Phasmatodea)

Twenty-six species of walkingsticks are known from the United States of which up to 5 may occur in Florida, but only four are known from south Florida (Rehn & Hebard 1914a). *Manomera tenuescens* (Scudder), *M. brachypyga* Rehn & Hebard, and *Aplopus mayeri* Caudell were expected in the Keys and south Florida but were not found in this survey.

Anisomorpha buprestoides (Stoll), The two-striped walkingstick

Many specimens were found under boards, but few were collected in flight intercept traps. Records are from Long Pine Key (open pinelands) and in hammock forest in south Key Largo, Big Pine Key (No Name Road), and Middle Torch Key. Adults were found from August to January. The species ranges from south Florida to southeastern Georgia.

Biogeographical Considerations

A total of 15 species of cockroaches, mantids, and walkingsticks was found in native habitats in south Florida. This is out of a total of about 40 species in these groups (15 of which are introduced) which occur in all of Florida. These groups of insects are predominantly tropical in distribution and diversity. Only one introduced species, *Pycnoscelus surinamensis* was found to have invaded native habitats. Only *Parcoblatta fulvescens* has many related species in the United States north of Florida. It may have colonized from that direction. All the other genera have more species in the West Indies or in circum-Caribbean and other Neotropical countries. The ancestral colonizations for these were most probably either across the Caribbean, or along the northern coast of the Gulf of Mexico. For eight of these this colonization occurred sufficiently in the past that their contemporary descendant species distributions are now limited to the southern United States or northern Mexico. The remaining five species (*N. detersa*, *P. poeyi*, *S.*

morsei, *M. maya*, and *G. grisea*) still have native distributions including the West Indies or southern Mexico.

ACKNOWLEDGEMENTS

We thank the following for permits to study the insect faunas in the areas under their protection: Pete Dingler and Rob Line, Metro-Dade County Park and Recreation Department; J. A. Stevenson, Florida Department of Natural Resources, Division of Recreation and Parks; John M. Morehead (Superintendent), Gary Hendrix (Director of Research), and Pat Tolle (Management Technician), Everglades National Park; Donald J. Kosin, Jack Watson, and Deborah Holle (Managers), National Key Deer and Crocodile Lake Wildlife Refuges. William and Ellen Peck generously provided long-term logistical support on Big Pine Key. Field work was partly supported by operating grants to the first author by the Natural Sciences and Engineering Research Council of Canada. Louis M. Roth generously helped verify and correct our determinations of the cockroaches, examined the manuscript, and suggested useful literature.

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AMITERMES FLORIDENSIS, A NEW SPECIES AND
FIRST RECORD OF A HIGHER TERMITE IN THE
EASTERN UNITED STATES
(ISOPTERA: TERMITIDAE: TERMITINAE)

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ABSTRACT

Alates, soldiers, workers, and brachypterous nymphs of *Amitermes floridensis* n. sp. from St. Petersburg, Florida, U.S.A., are described for the first time. Distribution records, biological notes, and significance of *A. floridensis* are reported.

RESUMEN

Se describen por primera vez los alados, los soldados, los obreros y las ninfas braquípteras, de *Amitermes floridensis* n. sp. de St. Petersburg, Florida, U.S.A. Se reporta los registros de la distribución, apuntes biológicos, y la significancia de *A. floridensis*.

During the course of routine termite identifications and a survey of Florida termites, several collections of a few wings and alates of an undetermined species of Termitidae from St. Petersburg, Florida, were noted (Scheffrahn et al. 1988). These specimens were of considerable significance as no member of this large family (ca. 1600 spp., Edwards and Mill 1986) had ever been collected in the eastern United States. The original specimens, however, were in poor condition and the absence of soldiers further hampered identification.

On July 2, 1988, swarming alates of this termite were captured near a previous collection site. Immediately, termite control operators in the St. Petersburg area were asked to collect any dark-winged alates they encountered during the course of their work. Two subsequent collecting expeditions were also undertaken. These actions yielded additional alates and, for the first time, foragers. The species is assigned to the genus *Amitermes* as established and defined by Silvestri (1901, 1903). We name this new species *Amitermes floridensis* n. sp., the etymology of which is derived from its unexpected and apparently confined geographical distribution in Florida. We herein provide: 1) a description of *Amitermes floridensis* n. sp., 2) notes on its distribution and biology, and 3) a discussion of the significance of this finding.

Amitermes floridensis, new species

SOLDIER (Fig. 1 A-D). Measurements, in mm by ocular micrometer, adapted from Light (1927, 1930, 1932)

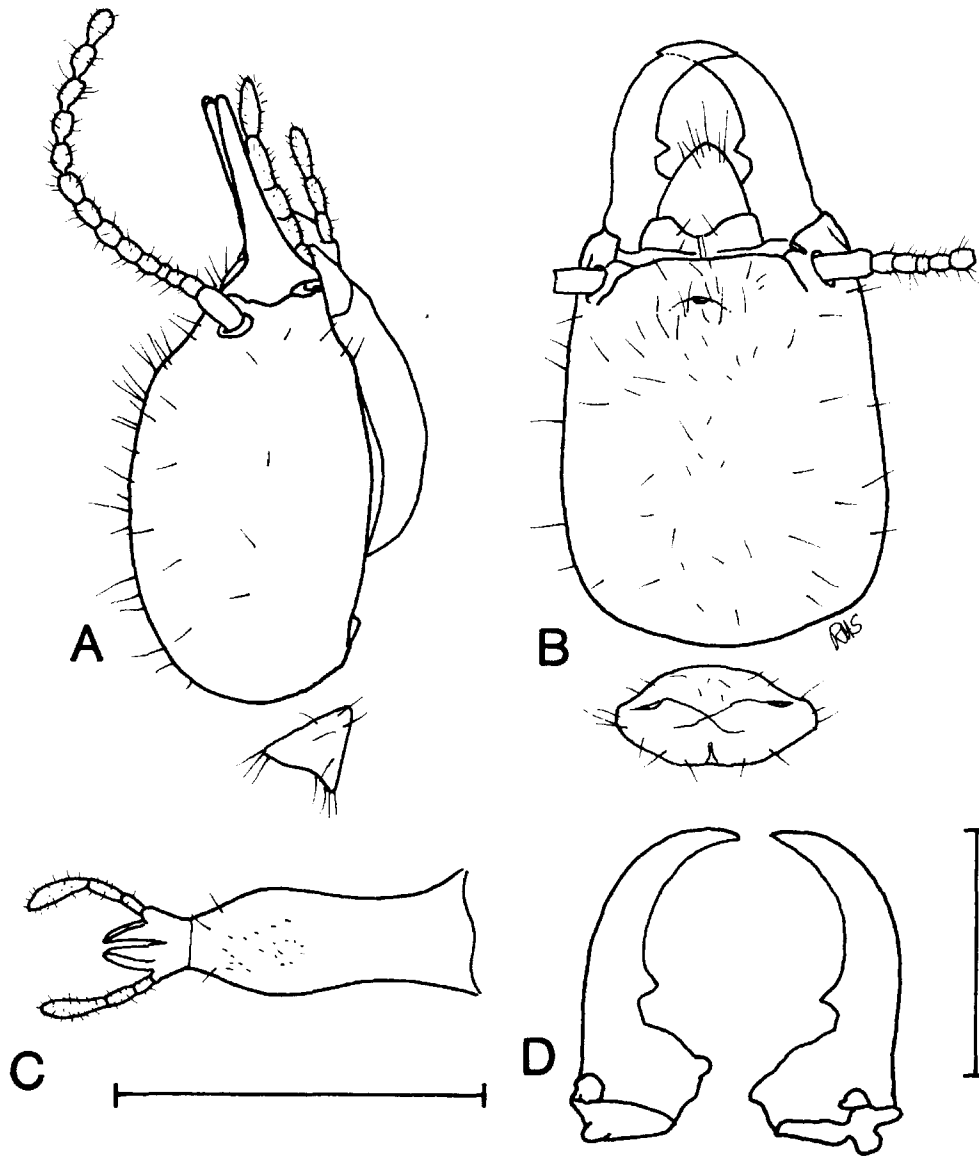


Fig. 1. *A. floridensis* n. sp. soldier. Head and pronotum, lateral (A) and dorsal (B) views; labium (C), ventral view; and mandibles (D), dorsal view. Horizontal bar = 1 mm for A-C; vertical bar = 0.5 mm for D.

Description. Head capsule light yellow with sparsely scattered setae; head length 1.14 to base of mandibles, minimum head width 0.76 at antennal sockets, maximum head width 0.90 near posterior end; fontanelle barely visible (at 50X) on frons just posterior to antennal sockets, surrounded by setae up to 0.16 long; frontal gland visible in interior of head capsule, as wide as distance between lateral mandibular articulations in front, narrowing toward posterior edge of head capsule.

Antennae light yellow, with 14 segments (= subsegments); second segment about half as long as first; third and fourth together slightly longer than second; fourth shorter than third.

Mandibles yellowish brown, 0.70 long from lateral articulation to tip; near-circular curve from marginal tooth to tip, minimum mandibular curvature 0.08 measured from

inside surface between tip and marginal tooth to an imaginary line extending from lateral articulation to tip. Single marginal tooth lying near proximal third of each mandible and projected perpendicular from inner edge; tooth projected distinctly from inner edge of mandible, anterior face of tooth cut more roundly from edge than the more squarely cut posterior face.

Labrum triangular, rounded at tip; dorsal surface with ca. eight long setae projecting anteriorly; tip ending level with marginal teeth of mandibles.

Clypeus with medial cleft along anterior margin that forms dividing groove in clypeus.

Gula narrow in middle, widest (0.29) in anterior half; contraction index (min. width ÷ max. width) 0.76.

Pronotum 0.56 wide; sharply elevated anteriorly and with long setae scattered along entire margin.

Measurements in mm (n = 28)	Range	Mean	S.D.	Holotype
1. head length to mandibles	1.07-1.22	1.136	0.038	1.15
2. min. head width at antennae	0.72-0.82	0.764	0.023	0.77
3. max. head width	0.83-0.96	0.899	0.035	0.88
4. head index (= 3 ÷ 1)	0.74-0.86	0.791	0.031	0.77
5. head contraction index (= 2 ÷ 3)	0.80-0.89	0.850	0.020	0.88
6. mandible length	0.67-0.77	0.703	0.021	0.69
7. head-mandible index (= 6 ÷ 1)	0.58-0.67	0.619	0.026	0.60
8. min. mandible curvature	0.07-0.09	0.082	0.006	0.09
9. mand. curvature index (= 8 ÷ 6)	0.10-0.13	0.116	0.009	0.12
10. gular length	0.58-0.75	0.682	0.038	0.70
11. min. gular width	0.20-0.25	0.223	0.014	0.22
12. max. gular width	0.26-0.31	0.294	0.012	0.26
13. gular cntr. index (= 11 ÷ 12)	0.67-0.86	0.757	0.054	0.84
14. pronotum width	0.51-0.60	0.564	0.023	0.56

Diagnosis. Mandible dentition can be used to categorize the Nearctic and Neotropical *Amitermes* soldiers into two convenient groups: those with marginal teeth directed perpendicular from the surface of the inner edge of the mandible and having a distinct anterior face, and those whose teeth are directed posterior and lack a well defined anterior face (e.g. *A. emersoni* Light). The former group includes *A. floridensis*, *A. wheeleri* (Desneux), *A. excellens* Silvestri, *A. brevicorniger* Silvestri, *A. amifer* Silvestri, and *A. foreli* Wasmann. Of these, *A. floridensis* most closely resembles *A. wheeleri* in mandibular structure and overall size; however, mandibles are shorter and stouter in the larger *A. wheeleri* soldiers. *Amitermes floridensis* is the smallest species of this group. Alates of *A. wheeleri* are larger than *A. floridensis*.

ALATE (Figs. 2 E-H and 3 I-J).

Description. Body length about 4.2 with dorsum generally brownish black; venter yellowish white with partial pigmentation of some sternal plates. Head capsule and pronotum darkest, covered densely with setae.

Compound eyes very slightly elliptical; ocelli round from anterolateral aspect, about two-thirds their diameter from eyes; fontanelle egg-shaped, about length of ocellus.

Postclypeus bilobed, twice as wide as long; labrum pointed at apex.

Wing membrane translucent, smoky black, and punctate, setae mostly on margins and costal veins, but occurring throughout; 2 anterior-most veins (radius and radial sector) well pigmented throughout entire length, inner vein of pair darker; median vein near center of wing branching once and becoming lighter near apex; cubitus with 10 branches and ca. 5 subbranches reaching posterior margin and apex, proximal 4-5

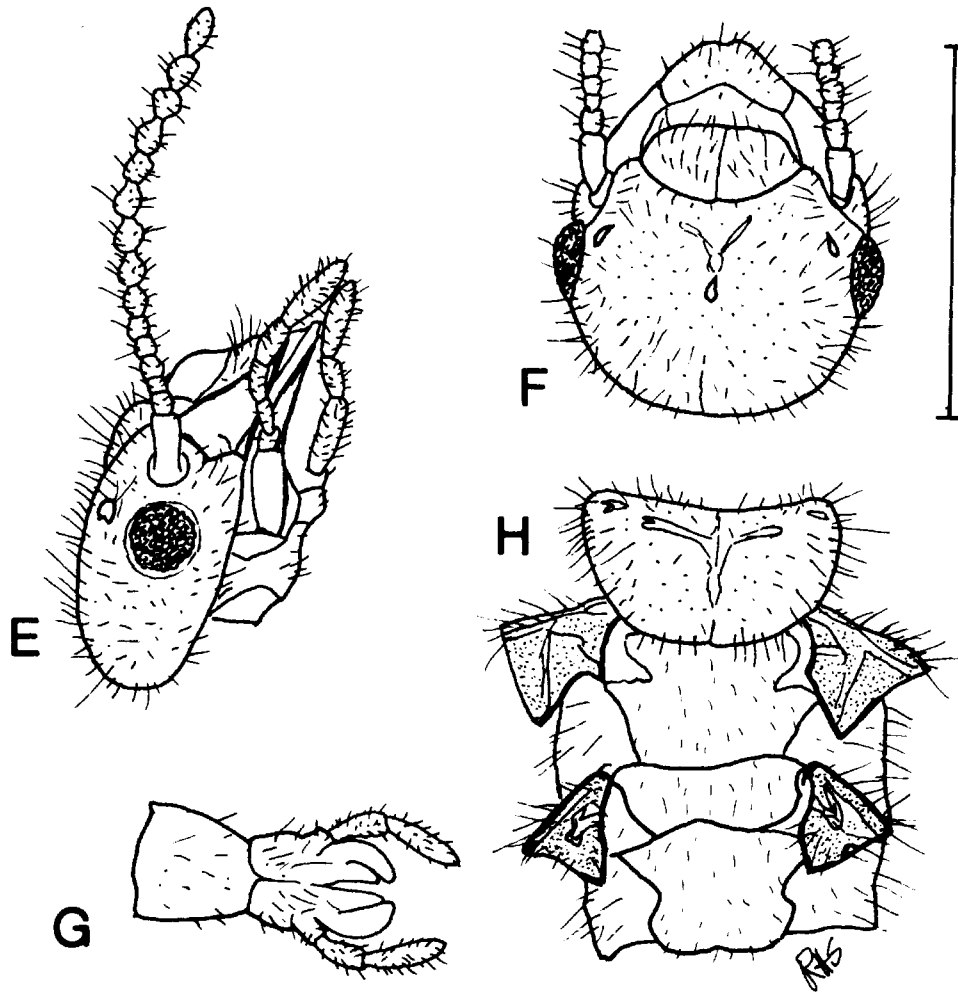


Fig. 2. *A. floridensis* n. sp. alate. Head, lateral (E) and dorsal (F) views; labium (G), ventral view; and thorax with wing scales (H), dorsal view. Bar = 1 mm.

branches thicker and darker than rest; forewing scale slightly shorter than length of pronotum, hindwing scale two-thirds size of forewing scale.

Antennae with 15 segments, centers of segments dark, becoming lighter near articulations; third segment shortest.

Pronotum about twice as broad as long; anterior margin nearly straight, posterior margin with small cleft at midline.

Measurements in mm (n = 12)	Range	Mean	S.D.	Morphotype
1. length with wings	8.29-9.59	8.958	0.36	9.33
2. right forewing length	7.06-7.65	7.342	0.21	7.58
3. overall length	3.85-4.60	4.221	0.24	4.60
4. head length to mandibles	0.62-0.72	0.665	0.025	0.68
5. head width at eyes	0.87-0.92	0.898	0.016	0.91
6. eye, long diameter	0.17-0.19	0.180	0.007	0.19
7. postclypeus length	0.20-0.24	0.215	0.014	0.23
8. postclypeus width	0.38-0.43	0.408	0.015	0.42

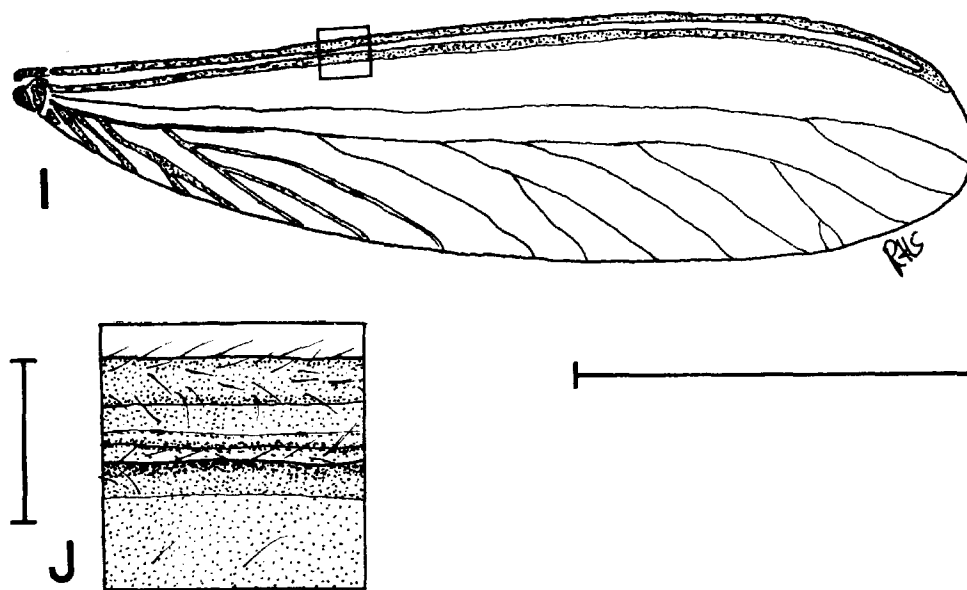


Fig. 3. *A. floridensis* n. sp. right forewing (I), dorsal view; and magnified inset (J) for enclosed area. Horizontal bar = 3 mm for I; vertical bar = 0.2 mm for J.

9. postclypeal index (= 7 ÷ 8)	0.49-0.56	0.528	0.026	0.55
10. pronotum length	0.38-0.42	0.405	0.013	0.41
11. pronotum width	0.69-0.77	0.739	0.023	0.74

Diagnosis. *Amitermes floridensis* most closely resembles alates described as *A. beaumonti* Banks by Snyder (1924). Although not collected with soldiers, he assigned these alates based on their sympatry with and their relative size to soldiers of *A. beaumonti* originally described from Panama by Banks (1918). Although alates are similar, *A. floridensis* soldiers differ from those of the slightly larger *A. beaumonti* as the latter's marginal tooth rests on the apical third of the mandible. The tooth of *A. beaumonti* is well marked with a posterior face but grades off into the anterior edge of the mandible (Banks 1918, Light 1932).

WORKER

Description. Head white, not more than 0.92 wide; thorax white and narrow, pronotum width 0.49. Viscera and gut contents visible; dark brown matter in gut appears grey through abdominal wall.

Measurements in mm (n = 14)	Range	Mean	S.D.
1. head length with labium	0.87-1.00	0.938	0.042
2. head width	0.79-0.92	0.860	0.032
3. clypeus length	0.18-0.23	0.201	0.014
4. clypeus width	0.33-0.40	0.361	0.018
5. pronotum length	0.18-0.28	0.224	0.029
6. pronotum width	0.45-0.54	0.489	0.036
7. total length	2.80-3.70	3.264	0.272

BRACHYPTEROUS NYMPH

Description. More intensely white than workers, especially abdomen, where gut contents not as visible as in worker; structurally similar to workers, but with extended abdomen; about 1.5 times as long as workers; wing pads conspicuous.

Measurements in mm (n = 8)	Range	Mean	S.D.
1. head length	0.98-1.03	1.014	0.021
2. head width	0.81-0.84	0.824	0.009
3. pronotum width	0.67-0.78	0.724	0.039
4. overall length	3.60-5.12	4.426	0.51
5. forewing pad length ^a	0.93-1.13	1.006	0.083

^an=7, one specimen was last instar nymph with pad length of 2.10.

Holotype Soldier. Florida: Pinellas Co., St. Petersburg. 11-VII-1988 (Coll. R. H. Scheffrahn). [Florida State Collection of Arthropods, Fla. Dept. Agric. Cons. Serv., Div. Plant Ind., Gainesville, FL].

Morphotype Alate. Florida: Pinellas Co., St. Petersburg. 2-VII-1988 (Coll. J. R. Mangold). [Florida State Collection of Arthropods].

Paratype Soldiers. [Florida State Collection of Arthropods; National Museum of Natural History, Washington, D.C.; American Museum of Natural History, New York, N.Y.]

Paratype Alates. [Florida State Collection of Arthropods; National Museum of Natural History, Washington, D.C.; American Museum of Natural History, New York, N.Y.]

Distribution. The type locality and only known distribution of *A. floridensis* is in the city of St. Petersburg, Pinellas Co., Florida. Specimens of *A. floridensis* have been collected from ten sites in a ca. 15 km² area in the central and western sections of the city bounded to the north by Montrose Blvd, to the south by Third Ave. South, to the west by 37th St., and to the east by First St.

Biology. Foraging groups of *a. floridensis*, composed of workers, soldiers, and brachypterous nymphs, have been collected in shaded and sunlit locations in wood debris (*Mangifera indica* L., *Albizia lebbek* (L.) Benth., and *Pinus elliotii* Engelm.) in contact with the soil or in their subterranean galleries connected to the wood. In one case, an alate was collected with foragers in tunnels built on the undersurface of flat patio stones on soil adjacent to a home. In another instance, foragers and an alate wing were taken from a heavily mined 0.6 m section of header board in the framework of a private residence (S. Shelton pers. comm.). Several other structural infestations have been reported but not yet substantiated with voucher specimens. *Amitermes wheeleri* and *A. minimus* Light have been reported to attack structural lumber in the southwestern states (Light 1934a). Foraging routes of *A. floridensis* are lined with dark brown, nearly black carton matrix, characteristic of this genus. The carton also forms small chambers in the larger voids of heavily mined wood.

Soldier proportions of *A. floridensis* in foraging groups are relatively small as is characteristic of other Nearctic *Amitermes* spp. (Scheffrahn, unpubl.). A total of 8 foraging groups excavated nearly intact were counted for a combined total of 1,715 workers (W), 71 soldiers (S, 4.1%), and 8 brachypterous nymphs (N). The 3 largest groups were composed of the following: 1) 598 W, 34 S, and 2 N; 2) 474 W, 17 S, and 2 N; and 3) 411 W, 3 S, and 1 N.

Reproductive and brood centers of *A. floridensis* colonies, as with other species of *Amitermes* lacking epigeal structures, are not traceable from foraging areas and have not been found. Colonies do, however, cohabitate foraging territories and compete for food resources with *Reticulitermes* spp. (Rhinotermitidae). We found a ca. 12 cm diam.

limb lying on the ground infested by foragers of both *Reticulitermes flavipes* (Kollar) and *A. floridensis*. When the limb was broken open and foragers intermingled from previously intact and segregated galleries, interspecific combat immediately ensued demonstrating the potent agonistic tendencies of both *A. floridensis* soldiers and workers toward their larger competitors.

Dispersal flights of *A. floridensis* occurred on mid-summer afternoons (ca. 1200-1600 hrs) following a heavy shower or during a lingering light rain after a shower. Of other Nearctic *Amitermes*, only *A. minimus* has flight habits similar to *A. floridensis* (Nutting 1969). The earliest seasonal alate flight of *A. floridensis* was recorded on July 2 and the latest August 2, both in 1988. The dark wings and atypical flight season of *A. floridensis* alates have entertained the curiosity of termite control operators in St. Petersburg for over 20 years, but a careful appraisal of the specimens in question was not pursued until now (P. Amick, pers. comm.).

DISCUSSION

The genus *Amitermes* Silvestri consists of nearly 100 species world-wide (Scheffrahn & Su 1987) and ranks as the largest genus in the subfamily Termitinae. Of all isopteran genera, only *Nasutitermes* (Nasutitermitinae) and *Odontotermes* (Macrotermitinae) are more diverse. *Amitermes floridensis* brings to nine the number of Nearctic *Amitermes* species, all of which occur in the United States. Seven Neotropical species, now including *A.* (= *Synhamitermes* Holmgren) *brevicorniger* Silvestri, (E. Ernst, Swiss Tropical Institute, pers. comm.), have been described in the genus. Nearctic congeners found nearest to Florida include *A. wheeleri*, *A. minimus*, and *A. parvulus* Light which occur in the semiarid southwest, eastward to southcentral Texas (Light 1932). *Amitermes beaumonti* and *A. cryptodon* Light, the nearest Neotropical species, have been collected from the Yucatan Peninsula of Mexico (Light 1934b).

The discovery of *A. floridensis* brings to 16 the number of described species of Isoptera in Florida (Scheffrahn et al. 1988). The known termite fauna of Florida, until now, has consisted exclusively of members of the "lower" families, i.e. Kalotermitidae and Rhinotermitidae, as defined by Wilson (1976). Although quite a number of the Termitidae or "higher" termites are found throughout the islands of the Bahamas and Antilles (Snyder 1956), it is surprising that none of these species occurs in Florida, especially in its most southern extremity. The absence of *Amitermes* spp. from the Antillean fauna suggests that the genus invaded Florida from a mainland Nearctic route along a Gulf Coast corridor and that *A. floridensis* may be a relict of a once expanded Nearctic distribution. The likelihood that *A. floridensis* is recently introduced seems remote. Members of the Termitidae do not lend themselves to human-aided establishment outside their native distribution. This is demonstrated by the report that only one termitid, *Nasutitermes walkeri* (Hill), has been regarded, with reservation, as having become established in a new location (New Zealand) from a remote native (Australian) habitat (Gay 1967).

ACKNOWLEDGEMENTS

We are grateful to the following persons for their help in collecting *A. floridensis* n. sp. and assisting the authors during field work in St. Petersburg: Breck, Phil, and Tony Amick, Amick and Son, Inc.; Bill Barrs, Van Waters & Rogers; Mrs. Bench and Mr. Hood, homeowners; Billie Chapman, Chapman Pest Control, Inc.; Arthur Dales and Bruce Sibson, Rentokil, Inc.; John Helm and Sam Frontera, Terminix International; Steve Hobelmann, Hobelmann Exterminating Service; Steve Shelton, Exterm-A-Tech; Ellen Thoms, Dow Chemical; and supervisory personnel at United Aluminum Products

of St. Petersburg. We also thank Robin Giblin-Davis, Peter Luykx, Alan Meerow, Michael Rust, James Tsai, and F. W. Howard (who translated the abstract into Spanish) for their review of this paper, no. 9571 of the Florida Agric. Expt. Stn. Journal Series.

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NOTES ON CRITICAL CHARACTER STATES IN
TELMATOTREPHEs (HETEROPTERA: NEPIDAE)

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ABSTRACT

In his 1972 revision of *Telmatotrephe*s Stål, Lansbury discussed four character states he considered important in understanding the systematic position of the genus in the family. We examine the distribution of those characters across the Nepidae and find two of Lansbury's conclusions to be invalid. Short respiratory siphons are found in seven nepid genera, including *Telmatotrephe*s, and not two as supposed by Lansbury. Paired sulci on the prothoracic venter are not unique to *Telmatotrephe*s but are also found in *Nepa* Linnaeus. Vestigial, coriaceous metathoracic wings and clubbed egg respiratory horns without a plastron meshwork remain as valid diagnostic character states for *Telmatotrephe*s as hypothesized by Lansbury.

RESUMEN

En la revisión de *Telmatotrephe*s Stal en 1972, Lansbury expuso cuatro caracteres que él consideraba importantes para entender la posición sistemática del género en la familia. Nosotros examinamos la distribución de esos caracteres en los Népidos y encontramos que dos de las conclusiones de Lansbury son inválidas. Siete géneros de nepid tienen sifones respiratorios cortos, incluyendo a *Telmatotrephe*s, y no los dos supuestos por Lansbury. Parejas de sulci en el venter protorácico no son exclusivos de *Telmatotrephe*s, pues también se encuentran en *Nepa* Linnaeus. Vestigios de alas coriáceas metatorácicas y cuernos de huevos respiratorios en maza sin malla de plastrón, se mantiene como un carácter diagnóstico válido para *Telmatotrephe*s como Lansbury hipotizó.

During our studies of nepid genera of the world, anticipating a cladistic analysis, we reviewed Lansbury's (1972) revision of *Telmatotrephe*s Stål wherein he compared this genus to other genera within the family. Because our data and conclusions differ somewhat from his, and because some of the nepid genera we studied are rare in collections, hence known only to a few workers, we present some notes that should be of interest to those involved with the taxonomy and phylogeny of Nepomorpha.

Lansbury concluded his revision of the genus *Telmatotrephe*s with a discussion of four character states he believed to be important in understanding the systematic position of *Telmatotrephe*s in the Nepidae (p. 285):

1. Short caudal respiratory siphons.
2. Prominent spiracular apertures on the venter of the prothorax.
3. Coriaceous, vestigial metathoracic wings.
4. Incomplete plastron meshwork on respiratory horns of eggs.

According to Lansbury, short respiratory siphons were found in only one nepid species outside of *Telmatotrephe*s, i.e., *Borborophyes erutus* Montandon (subsequently placed in its own genus, *Montonepa*, by Lansbury in 1973). The other three character states Lansbury regarded as unique to *Telmatotrephe*s.

During a recent visit to the National Museum of Natural History (NMNH), one of us (SLK) observed that four monotypic Ethiopian genera represented in the Raymond Poisson Collection: *Borborophilus* Stål, *Paranepa* Montandon, *Nepita* Poisson, and *Nepella* Poisson, also had short siphons. Poisson's 1965 catalogue of Ethiopian Nepidae confirmed those observations and listed precise siphon measurements (Poisson 1965, pp. 230-231) which are summarized in Table 1. In addition to the Ethiopian genera and the Oriental *M. erutus*, we also observed that the Palearctic *N. hoffmanni* Esaki possesses a short siphon (also noted by Esaki 1925, p. 314). Thus, short respiratory siphons are shared by seven known nepid genera and not two as supposed by Lansbury.

The "spiracular apertures" (Lansbury's terminology) of *Telmatotrepes* are paired sulci lateral to the median prosternal ridge and posteromedial to the coxal cavities (Lansbury 1972, Figs. 2, 16, 34, 41, 56). They are deep, glabrous, and distinct from the surrounding propleura and sternum. Two aperture shapes are evident in *Telmatotrepes* (Lansbury 1972, p. 271): elongate in the Neotropical species and triangular in the Oriental species. A survey of the synoptic collections of Nepidae in the NMNH and the Polhemus Collection revealed that paired sulci on the venter of the prothorax are also found in *Nepa* Linnaeus but absent in all other nepid genera. The sulci of *N. cinerea* Linnaeus (Fig. 1), *N. sardiniensis* Hungerford (similar to *N. cinerea*), and *N. apiculata* Uhler (Fig. 3) are narrowly triangular and thus somewhat intermediate in shape between the Oriental and Neotropical *Telmatotrepes*. *N. hoffmanni* has broadly triangular sulci (Fig. 2) which closely resemble those of the Oriental *Telmatotrepes*. In short, ventral paired prothoracic sulci are not unique to *Telmatotrepes* but are instead found in both *Telmatotrepes* and *Nepa*.

It should be noted that these sulci have nothing to do with spiracular openings as assumed by Lansbury (1972). Dissection of specimens of *N. apiculata* reveals that internally each sulcus ends anteriorly in an apodeme and not in a spiracular opening (Fig. 4). As noted by Hamilton (1931, p. 1091 and Plate I) in his description of adult *N. cinerea*, and McPherson & Packauskas (1987, p. 683) in their description of nymphal *N. apiculata*, the most anterior pair of spiracles is found ventrally in the membrane between the pro- and mesothorax and not in the area of the sulci. The tracheal system of

TABLE 1. RELATIVE LENGTHS OF SHORT RESPIRATORY SIPHONS IN NEPIDAE.

Taxon	Body length	Siphon length	Body/Siphon
<i>Nepa hoffmanni</i> (Esaki) ^{1,5}	21.5-23 mm	3 mm	>7
<i>Borborophilus afzelii</i> (Stål) ^{2,5}	15-17	3-4.5	>3.77
<i>Paranepa primitiva</i> (Montandon) ^{2,5}	15-17.5	3.5-4	>4
<i>Nepita djaloni</i> Poisson ^{2,5}	13-14	2.75-3	>4
<i>Nepella pauliani</i> Poisson ^{2,5}	18.5	2	9.25
<i>Montonepa erutus</i> (Montandon) ^{3,5}	14.25	0.9	15.83
<i>Telmatotrepes sculpticollis</i> Stål ⁴	31-32	6	>5
<i>T. ecuadorensis</i> Lansbury ⁴	22.8	unknown	?
<i>T. grandicollis</i> Kuitert ^{4,5}	25-27	4.5-5.5	>4.9
<i>T. chinensis</i> Lansbury ⁴	25.5	4.5	5.67
<i>T. breddini</i> Montandon ^{4,5}	30	8	3.75
<i>T. carvalhoi</i> De Carlo ⁴	25	2	12.5

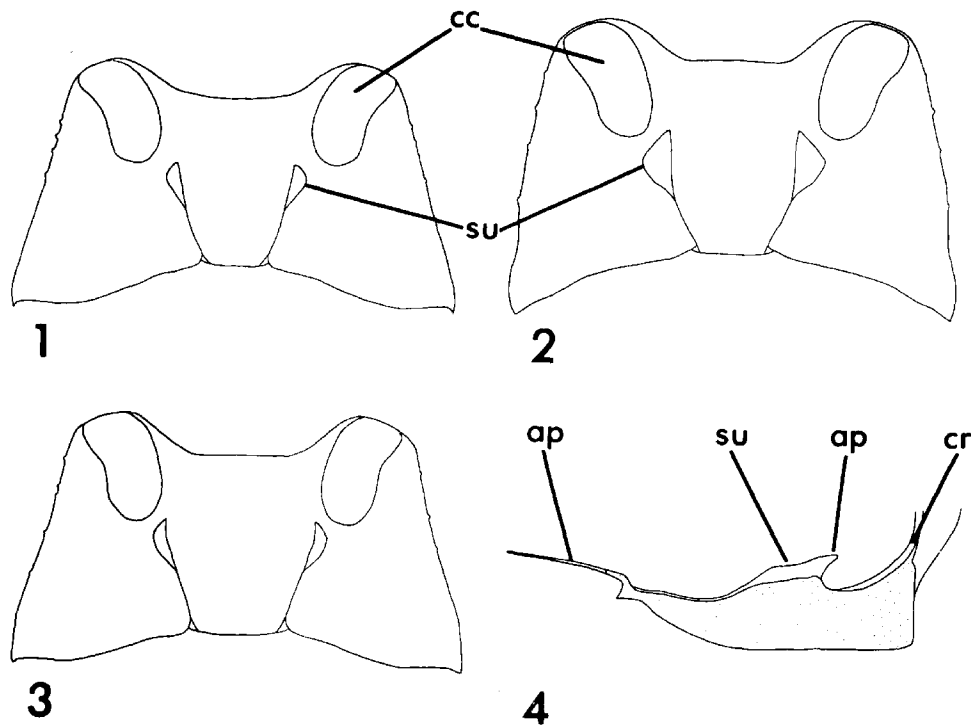
¹Esaki 1925, p. 314

²Poisson 1965, pp. 230-231

³Lansbury 1973, p. 111

⁴Lansbury 1974, pp. 273, 277, 279, 280, 282, 283

⁵Personal observation



Figs. 1-3. Venter of prothorax: 1. *Nepa cinerea*. 2. *Nepa hoffmanni*. 3. *N. apiculata*.
 Fig. 4. Internal midlongitudinal view of sulcus of *N. apiculata*.
 Abbreviations: ap, apodeme; cc, coxal cavities; cr, coxal rim; su, sulcus.

Nepa was studied earlier and figured in detail by Brucher (1916) and Poisson (1924), who found the same arrangement of spiracles.

All specimens of *Telmatotrephes* examined by Lansbury had leathery, vestigial metathoracic wings. Reduced, membranous metathoracic wings seem to occur frequently in the Nepini, e.g., *Montonepa erutus* and *Borborophyes mayri* Stål (Lansbury 1973, pp. 111 and 113), *Nepa dollfusi* Esaki (Esaki 1928, p. 437), *N. hoffmanni*, and *Laccotrephes pseudoampliatius* Poisson (both personal observation). However, truly vestigial, leathery metathoracic wings appear to be unique to *Telmatotrephes*.

Eggs of two of the six currently recognized species of *Telmatotrephes* have been examined. Hinton (1961, pp. 240-241) studied the eggs of *T. breddini* Montandon. Eggs of *T. grandicollis* Kuitert were described by Lansbury (1972, p. 273) and found to be indistinguishable from those of *T. breddini*. In both instances the respiratory horns of the eggs were clubbed and lacked a plastron meshwork on the inner margin. Nowhere else in the Nepidae thus far studied are these two egg character states found (i.e., *Paranepa*, *Nepa*, *Laccotrephes* Stål, *Cercotmetus* Amyot and Serville, and *Ranatra* Fabricius, Hinton 1961, 1962; *Goondnomdanepa* Lansbury, 1974; *Curicta* Stål, personal observation); those of *Austronepa* Menke and Stange, *Borborophilus*, *Borborophyes* Stål, *Montonepa*, *Nepella*, and *Nepita* remain unknown. Thus, they so far appear to be truly diagnostic for the genus *Telmatotrephes*.

In conclusion, we have invalidated two of the four conclusions reached by Lansbury about character distribution in *Telmatotrephes* and other nepine genera. Short respiratory siphons are found in seven genera, including *Telmatotrephes*, and not two as supposed by Lansbury. Paired sulci on the prothoracic venter are not unique to *Telmatotrephes* but are also found in *Nepa*. Vestigial, coriaceous metathoracic wings and clubbed

egg respiratory horns without a plastron meshwork remain as valid diagnostic characters for *Telmatotrephes*.

ACKNOWLEDGEMENTS

We would like to thank Dr. Richard Froeschner of the NMNH who generously provided the senior author access to the Poisson Collection of Ethiopian Nepidae. Specimens studied at the NMNH included, *Borborophilus afzelii* Stål, *Paranepa primitiva* Montandon, *Nepita djaloni* Poisson, *Nepella pauliani* Poisson, *Montonepa erutus* (type collection), *Laccotrephes pseudoampliatus*, and many other species of African *Laccotrephes*. Specimens of *N. apiculata* examined are in the Southern Illinois University Entomological Collection, those of *Nepa cinerea*, *N. hoffmanni*, *Telmatotrephes grandicollis* Kuitert, *T. breddini* Montandon, *Borborophyes mayri* Stål, and *Nepella pauliani* are in the Polhemus Collection (University of Colorado Museum at Englewood).

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A SECOND SPECIES OF FOSSIL *STENOTABANUS*
(DIPTERA: TABANIDAE)
IN AMBER FROM THE DOMINICAN REPUBLIC

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ABSTRACT

Stenotabanus woodruffi n. sp. is described and figured from a single female embedded in amber from the Dominican Republic. This species is compared with similar species of Tabanidae, living and fossil, known from the Greater Antilles.

RESUMEN

Stenotabanus woodruffi n. sp. se describe e ilustra a partir de una hembra incrustada en ambar de la República Dominicana. Además, esta especie es comparada con otros tabánidos similares conocidos, vivientes y fósiles, en las Antillas Mayores.

In 1986, Dr. Robert E. Woodruff received on loan a small piece of amber from J. Brodzinsky, which he showed to the senior author. The coincidence of discovering that another horse fly in amber from the same source existed and was being described by Lane and Poinar caused us to compare notes and exchange information with mutual benefit. There seems to be no need to repeat here the introductory and literature review provided in the preceding description of *Stenotabanus brodzinskyi* Lane, Poinar and Fairchild (1988).

Stenotabanus woodruffi sp. nov.

A small yellowish brown species with apically fumose wings, a nearly parallel-sided frons, bicolored third antennal segments, and a patterned mesonotal integument.

Female. Length of right wing 8.2 mm, left wing incomplete apically. Body length about 9.0 mm. Venation normal, all marginal cells open except anal closed, no appendix at fork of 3rd vein, stigma brownish. Apical third of wing somewhat infuscated, darker anterior to 3rd vein and veins broadly but diffusely brown margined. Basicosta sharply pointed, without macrosetae like those on adjoining costa. Costa, subcosta, and R beset with strong, short, dark setae. Halteres with slender pale stem and oval, dark brownish knob. Legs slender, the tibiae not flattened nor inflated. Tibiae with a definite but short fringe of nearly erect hairs. Hind tibiae without terminal spurs, but with sparse longer dark hairs interspersed among a fringe of short pale hairs. Mid tibiae with 2 strong terminal spurs. Fore tibiae without spurs. Tarsal claws simple, paired on all legs where the tarsi are preserved.

Head with eyes and frontal area somewhat obscured by overlying cracks, but frons narrow, index about 8.3, narrower below with a divergence index of about 2.0, (indices derived from the accompanying camera lucida drawings, Fig. 1, 2). Frontal callus cla-

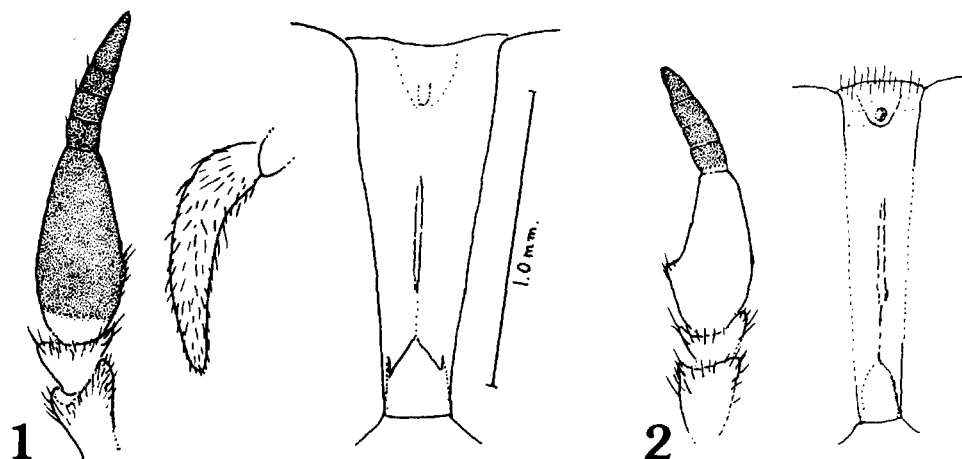


Fig. 1. *Stenotabanus brodzinskyi* L., P. and F. holotype. F, frons, antenna and left palpus. Fig. 2. *Stenotabanus woodruffi* n. sp. holotype F, frons and right antenna. All figures to same scale, shown at right of Fig. 1.

vate, apparently attached above to a slender ridge-like median callus. Vertex with a tubercle, bearing vestiges of at least 2 ocelli; upper third of frons and vertex densely beset with long black hairs. Post-orbital hairs sparse, pale, and difficult to see. Eyes bare, no pattern evident. Palpi and proboscis partially obscured, apparently subequal in length, the second palpal segment slender though not thread-like. Antennae with basal plate of third segment pale brownish, with a sharp dorsal angle, and considerably longer than contrasting black 4-annulate terminal portion; scape and pedicel concolorous with basal plate, but covered with relatively long dark hairs. Surface color pattern of thorax and abdomen, if any, not preserved. Abdomen yellowish brown, darker terminally, without clear integumental pattern. Thoracic integument light brown, with a broad central dark stripe and a pair of dorsolateral dark stripes separated from median dark area by narrow pale stripes. Scutellum concolorous with mesonotum anteriorly, but posterior portion darker. Legs light yellowish brown, all tarsi, distal half of fore tibiae and tip of fore femora notable darker brown.

Holotype female No. 10543, Dominican Republic, J. Brodzinsky collector. To be deposited in U. S. National Museum of Natural History.

DISCUSSION

The visible characters of this specimen place it in the subfamily Tabaninae and the tribe Diachlorini, where it appears quite similar to some elements of the catch-all genus *Stenotabanus*. Some of the important head characters, such as the condition of the frontal calli, palpi, and proboscis are not well displayed, but possibly some further cutting of the amber might reveal these structures more clearly. Its small size and general appearance seem much like some modern species from the Greater Antilles, but the combination of visible character states is not precisely like any living species with which we are familiar. The wing pattern resembles that of *Stenotabanus mellifluus* J. Bequaert from Cuba, but that species is much larger and has more slender unicolorous antennae and no vestiges of ocelli. The specimen has been compared carefully by both of us with the holotype of *Stenotabanus brodzinskyi*. It differs from that species by being much paler in color of integument, with only parts of mesonotum, tarsi, and

annulate part of antennal flagellum black. The frons is considerably narrower and less convergent below, the annulate portion of the antennal flagellum is relatively shorter, the basal plate broader, and the dorsal angle markedly more acute. The smoky wing apex of *woodruffi* also separates it from *brodzinskyi*. These character states can best be appreciated by reference to the accompanying figures of both species, drawn by the senior author with the aid of a camera lucida on a Wild binocular microscope, while the amber pieces were immersed in colorless mineral oil.

We take great pleasure in dedicating this important paleontological find to Dr. Robert E. Woodruff, who not only recognized the importance of this fossil and enable us to study it, but declined co-authorship. He also read and made astute suggestions on the several drafts of this paper.

COMMENTS

The discovery of two distinct but obviously similar species of tabanids in amber believed to be at least 25 million years old is an extraordinary occurrence considering the rarity of fossil Tabanidae. That these specimens show no character states that would separate them generically from a group of living sympatric and mainly precinctive Antillean species suggest that evolution in this group of Diptera has been much slower than in those groups of animals, such as horses, elephants, and primates, whose differentiation is believed to have occurred during the geologically abrupt changes of the Pleistocene.

ENDNOTE

Contribution No. 717, Bureau of Entomology, Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, FL 32602.

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POLYGyny IN HYBRID IMPORTED FIRE ANTS

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ABSTRACT

The occurrence of polygyny in hybrid fire ants from Mississippi was initially indicated by the clustering behavior of the workers around queens. Polygyny was demonstrated by the rate of oviposition of isolated queens, and dissection of samples of queens for the presence of sperm in the spermatheca. The colonies were identified as *S. invicta*/*S. richteri* hybrids by gas chromatograph analyses of venom alkaloids and cuticular hydrocarbons.

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RESUMEN

La ocurrencia de hormigas de fuego híbridas polígamas de Mississippi fue inicialmente indicado por el comportamiento de agregación de los obreros alrededor de las reinas. Se demostró poligamia por la tasa de oviposición de reinas aisladas, y por la disección de muestras de reinas para determinar la presencia de esperma en la espermatocita. Se identificaron las colonias como híbridos de *S. invicta*/*S. richteri* usando análisis cromatográfico de gas de los alcaloides del veneno e hidrocarburos cuticulares.

The imported fire ants, *Solenopsis invicta* Buren and *S. richteri* Forel, are agricultural pests that affect several important crops. In addition, high population densities and the very aggressive nature of the fire ants pose well documented health hazards to some humans and animals occupying the same habitat (reviewed by Adams, 1986). The ants are found in 10 southeastern states and Puerto Rico and infest about 93,120,000 ha (Lofgren 1986).

Within the past 15 years, two important discoveries have been made by researchers working with the imported fire ants. The first discovery was polygyny (multiple functional queens) in *S. invicta* populations in Mississippi (Glancey et al. 1973). Since this initial report, polygyny has been reported from *S. invicta* colonies in Texas, Louisiana, Georgia, Florida, Oklahoma, Arkansas, and Alabama (Hung et al. 1974, Fletcher 1983, Lofgren & Williams 1984, Banks & Wojcik unpublished). Polygyny is known to occur in other species of *Solenopsis* in North and South America (Banks et al. 1973, Summerlin 1976, Jouvenaz et al. in press).

The second important discovery was the occurrence of viable hybrids of *S. invicta* and *S. richteri* (Vander Meer et al. 1985, Ross et al. 1987a). The hybridization phenomenon was first detected through biochemical characters (Vander Meer et al. 1985), with subsequent recognition of morphological characters (J. C. Trager unpublished). Subsequent studies by Diffie et al. (1988) and Vander Meer and Lofgren (unpublished) have shown that the hybrid has an extensive range in northeastern Mississippi, northern Alabama, and northwestern Georgia. The expanse of territory occupied by the hybrid as well as its reproductive viability (Ross et al. 1987a) have raised concerns about the possibility of range expansion of hybrid fire ants.

We report here evidence for polygynous hybrids of *S. invicta* and *S. richteri* in Mississippi, a unique situation which could further complicate the control of the imported fire ants in the United States.

MATERIALS AND METHODS

While collecting imported fire ants in northern Mississippi for studies requiring queen-rite colonies, BMG and DPW found what appeared to be multiple queen colonies. To collect a queen from a mound, a shovel-full of tumulus containing ants from the mound was scattered on the pavement. Any dealates which evoked a clustering behavior (a response to queen pheromones) were suspected of being mated (Glancey et al. 1975). When suspected polygynous colonies were recognized, the dealates were collected and placed in vials, and a sample of the colony was shoveled into a quart jar or 5 gal buckets. The buckets were lined with Fluon[®] (Banks et al. 1981) to prevent escape of the ants. We found what appeared to be polygynous colonies at 3 separate locations. Each colony contained 2 or more dealated females. At the first location, on the shoulders of the frontage road, 1/2 mi east of US 82 and Alt US 45 junction, Lowndes Co. (ca. 14 miles W of Columbus), we collected 19 mounds of which 4 had several dealated females. The 4 mounds were within a 100 ft stretch of road. At the second location, on US 45, 1/2 mi south of Lauderdale (Lauderdale Co.), we collected 2 colonies, both with several deal-

ates. At the third location, 1/4 mi south of location #2, we collected 6 colonies of which one had several dealates.

To test whether or not these 7 colonies were indeed polygynous, dealates were collected and subjected to a 5 hr quantitative oviposition bioassay (Fletcher et al. 1980). After the oviposition bioassay, 11 of the queens from one nest, 7 from another nest, and 4 from a third nest were dissected and a spermathecal examination made.

The hybrid status of these colonies was verified using the methods of Vander Meer et al. (1985) and is briefly summarized here. Pooled samples of worker ants (50-100) from each colony were placed in a vial and soaked in hexane (HPLC grade, Burdick and Jackson, Muskegon, MI) for ca. 24 hr. After soaking, the solvent was transferred to a clean vial and saved for chemical analysis. Ethanol (70%) was added to the vial containing the ants to preserve a taxonomic sample. The hexane solution was analyzed for species-specific venom alkaloids and hydrocarbons by gas chromatography on a Varian[®] 3700 gas chromatograph equipped with a flame ionization detector. A 30 m DB-1 fused silica capillary column was used to separate the components of interest. The temperature program (Ross et al. 1987a) was 150° to 285° C at 5 min. with a final temperature hold of 3 min.

RESULTS AND DISCUSSION

All of the isolated dealates laid sufficient eggs in the oviposition bioassay to meet the criteria of Fletcher et al. (1980) for polygyny. All of the dissected queens contained sperm and were mated. The GC patterns of both the venom alkaloids and hydrocarbons showed that 26 of 27 collected colonies were hybrid colonies (Figure 1). The one exception was a polygynous *S. invicta* colony (from site 2).

This finding of hybrid polygynous imported fire ant colonies is interesting for several reasons. First, the occurrence of these colonies demonstrates some of the variability in the hybrid. Of the 26 hybrid colonies collected at these three locations, 20 colonies were apparently monogynous. Secondly, the finding of hybrid polygynous colonies, coupled with the widely scattered occurrence of polygyny throughout the range of *S. invicta* in North America, suggests that polygyny in *S. invicta* in North America has not arisen de novo as postulated by Ross et al. (1987b), but is in fact part of the *S. invicta* genome which is being expressed in North America. Polygyny in *S. invicta* has not been documented in South America, but we assume it occurs because polygyny has been observed in other *Solenopsis* spp. in South America (Jouvenaz et al. in press, Wojcik, Lofgren, & Jouvenaz unpublished). A generally accepted assumption is that the original introduction of the imported fire ants into North America occurred with only a few queens for each species (Tschinkel & Nierenberg 1983) which would limit the original North American gene pool. The presence of diploid males in monogynous and polygynous colonies is evidence that inbreeding is taking place in *S. invicta* (Ross & Fletcher 1985). This inbreeding may be the mechanism by which the polygynous phenotype is being expressed. One year after our initial discovery, we returned to the original collection area, collected samples, and found that the hybrid multiple queen colonies were still present.

The occurrence of polygynous *S. invicta* and *S. invicta*/*S. richteri* hybrid colonies could pose problems in efforts to control these fire ants. Current research is being directed toward the formulation or discovery of more species-specific control methods. These efforts have centered on the use of pheromones and the search for specific pathogens from their native homelands in South America. Our recent discoveries raise concern whether a species-specific pathogen of *S. invicta* will also be effective against the hybrid. In addition, would a toxic bait formulated with the species-specific pheromones of *S. invicta* be effective for control of the hybrid? Control of the polygynous pest ant *Monomorium pharaonis* with bait toxicants is difficult and inconsistent (Newton &

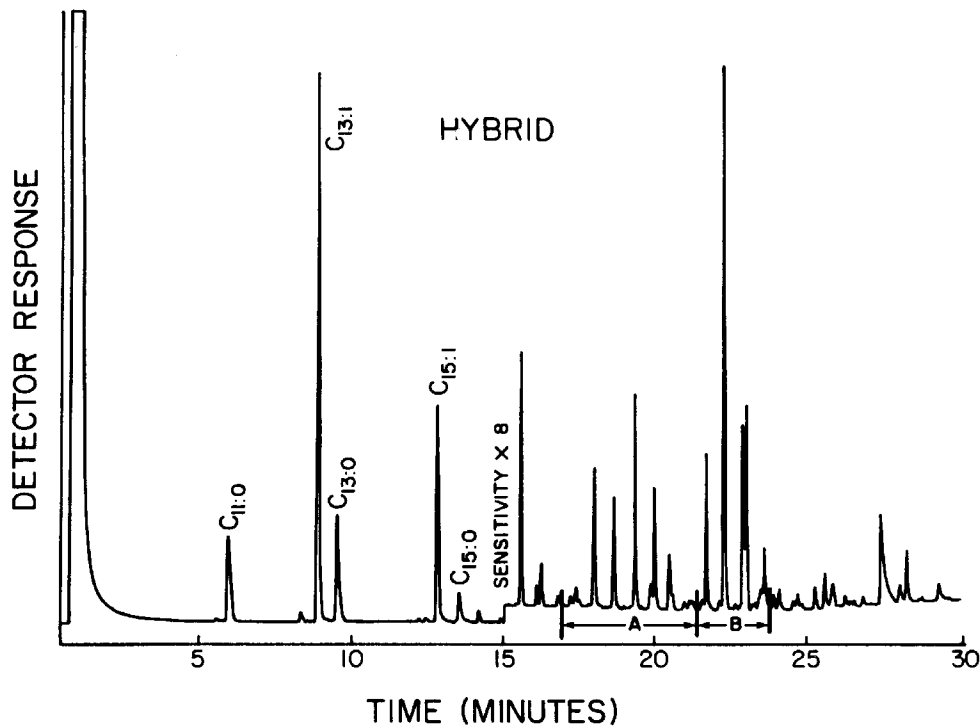


Fig. 1. Gas chromatogram of a hexane soak of hybrid worker ants. Venom alkaloids are designated by the chain length and the double bond status of the 6-alkyl or alkenyl group of the piperidine alkaloids associated with *S. richteri* and *S. invicta* (i.e. C_{13:1} is 2-methyl tridecenyl piperidine). *S. richteri* associated hydrocarbons are defined by the components above A, and those associated with *S. invicta* are defined by the components above B. See Vander Meer et al. (1985) and Ross et al. (1987) for detailed comparison of the hybrid and parent chemistry.

Coombes 1987). A recent report (Glancey et al. 1987) indicates that control of polygynous *S. invicta* populations with Amdro[®] bait has been less effective than that of monogynous populations. The rapid changes in this insect's ability to survive through polygyny and hybridization warrants continuous investigation into its strategies for survival and efforts for its control.

ENDNOTE

This article represents the results of research only. Mention of a proprietary product does not constitute an endorsement or recommendation for its use by the USDA.

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EYE COLOR CHANGES DUE TO PIGMENT MIGRATION IN
SOME SPECIES OF HETEROPTERA AND HOMOPTERA

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ABSTRACT

Changes in eye color in response to light and darkness were observed in *Trigonotylus doddi* (Distant) (Heteroptera: Miridae), *Saccharosydne saccharivora* Westwood, *Perkinsiella saccharicida* Kirkaldy (Homoptera: Delphacidae), and *Cyrtoda melichari* Van Duzee (Homoptera: Flatidae). Histological examinations of the eyes of *P. saccharicida* revealed that pigments were condensed in a zone proximal to the crystalline cones when light-adapted, and dispersed distally into the region of the cones when dark-adapted. This adaptation is believed to occur primarily in nocturnal insects or species that are active by day and night. Eye color changes were not observed in 23 additional species of Heteroptera and Homoptera collected in Southern Florida, including *Unerus colonus* (Uhler) (Homoptera: Cicadellidae), which is reported for the first time from the United States.

RESUMEN

Se observaron cambios en el color del ojo como respuesta a la luz o la oscuridad en *Trigonotylus doddi* (Distant) (Heteróptera: Mírida), *Saccharosydne saccharivora* Westwood, *Perkinsiella saccharicida* Kirkaldy (Homóptera: Delphacida) y *Cyrtoda melichari* Van Duzee (Homóptera: Flátida). Examines histológicos de los ojos de *P. saccharicida* revelaron que los pigmentos fueron condensados en una zona próxima a los conos cristalinos cuando adaptados a la luz, y dispersados distalmente en la región de los conos cuando adaptados a la oscuridad. Se cree que esta adaptación primariamente ocurre en insectos nocturnos o en especies los cuales son activos día y noche. No se observaron cambios en los colores de los ojos en 23 especies adicionales de Heteroptera y Homoptera colectadas en el sur de Florida, incluyendo *Unerus colonus* Uhler (Homoptera: Cicadellidae), la cual especie se registra por primera vez en los Estados Unidos.

Migration of screening pigments of the compound eye in response to changing light conditions is known in species of various insect orders, including Heteroptera (Bedau 1911) and Homoptera (Howard 1981), and has been explained as follows (Bernhard & Ottoson 1960, Walcott 1975): In the superposition eye, in response to light, a photochemical process takes place which induces the pigments to travel in secondary pigment cells to form a dense band proximal to the crystalline cones, optically isolating each ommatidium. In darkness, the pigments migrate distally in these cells into the cone area, so that light entering any one facet may act on the retinula cells of neighboring ommatidia. By varying the amount of light entering the photoreceptor cells, the screening pigment migration system is analogous to the pupil mechanism of vertebrates (Hoglund

& Struwe 1970, Stravenga & Kuiper 1977). The color of insect eyes is often largely determined by the screening pigments, thus changes in the position of pigments are seen externally as changes in the color of the compound eyes.

Our current interest in this mechanism is that although the color of the eyes is generally not included in taxonomic descriptions of Heteroptera and Homoptera, this character may be useful in field identifications.

Also, since photomechanical changes in the eyes associated with light and dark conditions are more pronounced in nocturnal than diurnal insects (Bernhard & Ottoson 1960, Parker 1932), simple observations for eye color changes as described in this paper can provide clues as to this aspect of an insect's natural history, as was the case with the American palm cixiid, *Myndus crudus* Van Duzee (Howard 1981).

Here we report observations of several species of Heteroptera and auchenorrhynchous Homoptera collected near Ft. Lauderdale, Florida to, determine whether their eyes undergo externally visible color changes in response to light and dark conditions. We selected one of the species, the sugarcane planthopper, *Perkinsiella saccharicida* Kirkaldy (Homoptera: Delphacidae), for histological study of this mechanism.

MATERIALS AND METHODS

Live true bugs, leafhoppers, and planthoppers were separated from sweepnet samples or collected by hand from foliage during daylight hours at the Ft. Lauderdale Research and Education Center. They were held in glass vials and the eyes examined under a dissecting microscope in a well-lit laboratory at ca. 25°C. The vials with the insects were then placed in a dark chamber for periods of several hours. They were removed briefly to the light ca. every 10-15 min and examined under a microscope for a change in eye color. Insects which exhibited a change in eye color in response to a dark period were left in the light for 1/2 to several hours and re-examined to determine whether the eye color had returned to its light-adapted condition. These tests were repeated about five times with each insect species.

Pigment migration was studied histologically in the sugarcane planthopper. Twenty sugarcane planthoppers were collected from sugarcane and divided into two groups of 10 each. One group was placed in the dark chamber and the other exposed to light. After an hour, at which time there were pronounced differences in eye color between the two groups, the insects were fixed immediately in Bouin's solution and the compound eyes removed, dehydrated in a tertiary butanol and toluene series (Sass 1958), embedded in paraplast, then sectioned with a microtome at 12 µm. The sections were mounted on microscope slides and the paraffin removed with a xylene bath. Examinations were made with a compound microscope at 100 X. Voucher specimens are in the Florida State Collection of Arthropods or the authors' collections.

RESULTS

Eye color changes were observed in the following species (names followed by the eye color in light-darkness, respectively): Heteroptera, Miridae: *Triognotylus doddi* (Distant), light gray-maroon (Fig 1, a & b); Homoptera, Delphacidae: West Indian canefly, *Saccharosydne saccharivora* Westwood (Delphacidae), yellow-dark purple (intermediate stage-orange); sugarcane planthopper, light gray-dark gray; Homoptera, Flatidae: *Cyarda melichari* Van Duzee, adult, light gray-maroon, nymph, white-dark red.

The changes in eye color were not timed precisely, but it was observed that at the same temperature the change from light to dark adaptation took less than 10 minutes in *T. doddi* and more than 30 minutes in the West Indian canefly.

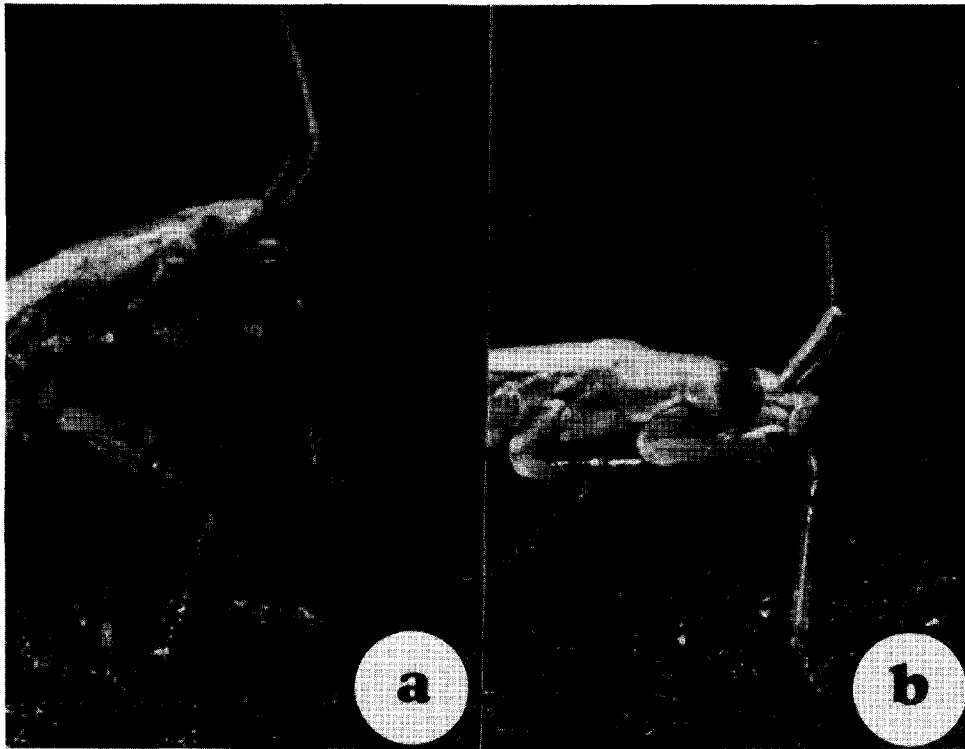


Fig. 1(a). *Trigonotylus doddi* with light-adapted eyes, and (b) dark-adapted eyes.

Examinations of sections of the compound eyes of the sugarcane planthopper showed that the externally visible difference in color between the light- and dark-adapted eyes is related to distal-proximal migration of pigments. When the eye is light-adapted, the pigments are condensed in a zone proximal to the crystalline cones (Fig. 2a). When dark-adapted, the pigments are dispersed into the zone of the crystalline cones (Fig. 2b), and probably because of the greater proximity of pigments to the cuticle, the eye appears darker externally. This is the same kind of mechanism observed previously in the American palm cixiid (Howard 1981), and is undoubtedly similar in the other Heteroptera and Homoptera species in which we observed eye color changes in response to light and darkness.

We were unable to detect color changes in the eyes of 23 other species of Heteroptera and Homoptera that we examined. These included: Heteroptera, Alydidae: *Stenocoris* sp., Pentatomidae: *Mormidea pama* Rolston; Homoptera, Cicadellidae: *Aceratagallia sanguinolenta* (Provancher), *Acinopterus angulatus* Lawson, *Agallia albidula* Uhler, *Balclutha incisa* (Matsamura), *B. hebe* (Kirkaldy), *Chlorotettix rugicollis* Ball, *C. minimus* Baker, *Empoasca* sp., *Graminella villica* (Crumb), *Homalodisca insolita* (Walker), *Hortensia similis* (Walker), *Oncometopia nigricans* (Walker), *Polyamia obtecta* (Osborn & Ball), *Protalebrella brasiliensis* (Baker), *Stragania robusta* (Uhler), *Texananus excultus* (Uhler), *Unerus colonus* (Uhler), *Xerophloea viridis* (F.) Fulgoroidea: *Acanalonia latifrons* (Walker), *Cyrpoptus reineckeii* Van Duzee, and *Stobaera concinna* (Stal), all of which were collected in open fields. The 7 specimens of *U. colonus* collected July 12, 1983 at the Ft. Lauderdale Research and Education Center by D. M. Beatty using a sweepnet over mixed vegetation represent the first U.S. record of this neotropical species.

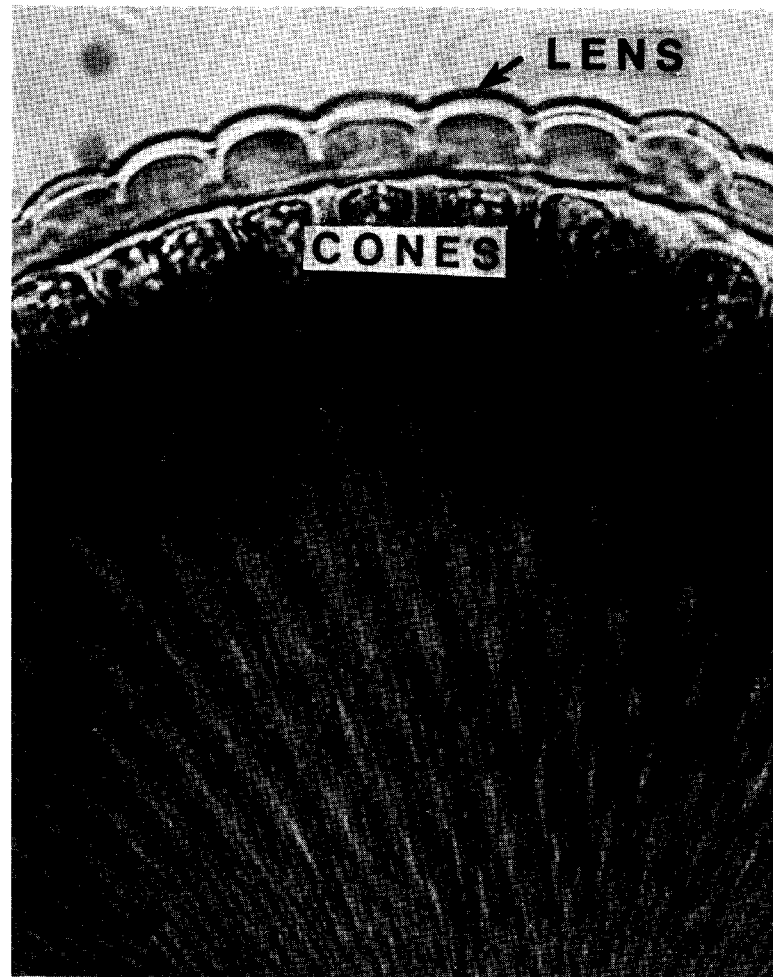
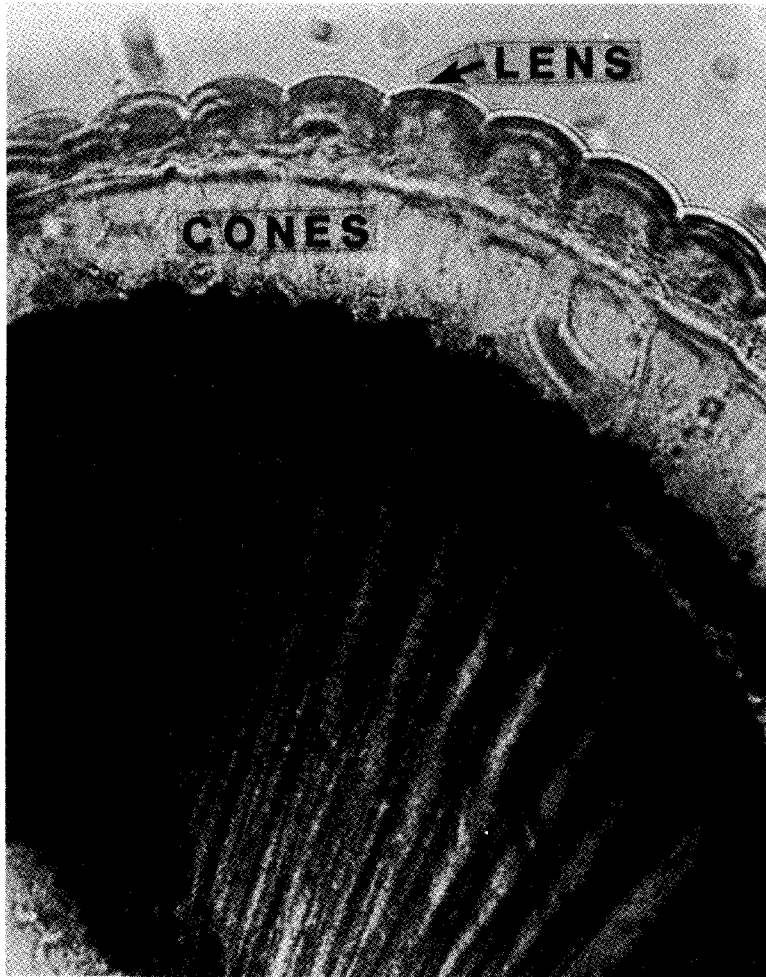


Fig. 2. Long sections of eyes of *Perkinsiella saccharicida*. (a) Light-adapted eye: pigment granules within secondary pigment cells are aggregated into a dense band enclosing ends of cones (b) Dark-adapted eye: pigment granules disperse distally into regions of cones.

The relatively slow migration of distal eye pigments inward in the light and outward in darkness occurs commonly in moths and other nocturnal insects (Bernhard & Ottoson 1960 Parker 1932). The American palm cixiid (Howard 1981), the West Indian canefly (Guagliumi 1953, Metcalfe 1968) and the sugarcane planthopper (Perkins 1903) are all to some degree active both day and night. The bugs and leafhoppers that we observed that did not undergo eye color changes probably are diurnal species with apposition eyes. Taxonomists might note that in Heteroptera and Homoptera in which the externally viewed eye color of the live insects changes in response to light and darkness, the eye color of the dead, dried specimens is generally that of the dark-adapted eye.

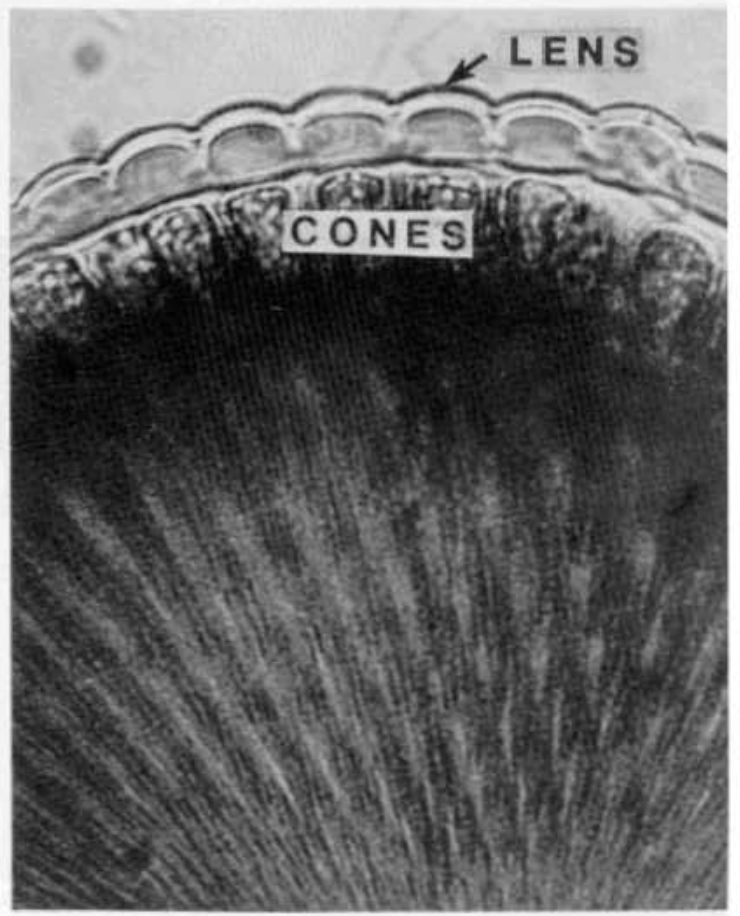
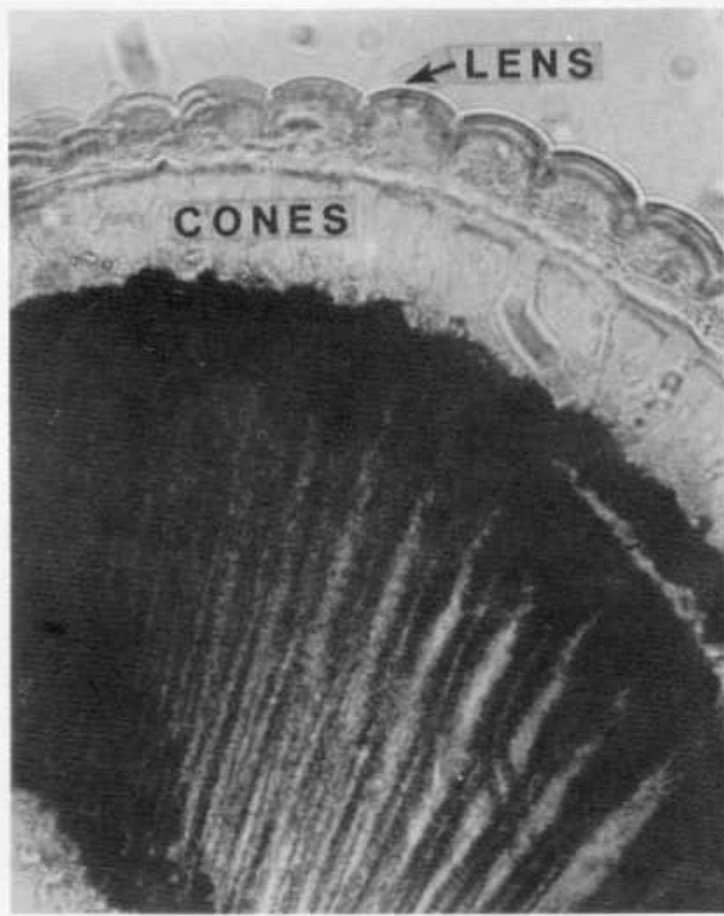
ACKNOWLEDGMENTS

We wish to thank J. V. DeFilippis for photography, D. M. Beatty for collecting insects, and J. P. Kramer and T. J. Henry of the Insect Identification and Beneficial Insects Introduction Institute, USDA, for confirming the identification of *Unerus colonus* and *Trigonotylus doddi*, respectively. We thank Rudolf Scheffrahn (University of Florida), Lionel Stange (Florida Department of Agriculture and Consumer Services) and George Steyskal (U.S. Department of Agriculture) for reviewing the manuscript. Richard M. Baranowski (University of Florida), Lois B. O'Brien (Florida A&M University), Joseph C. Schaffner (Texas A&M University) and the late eminent entomologist, Reece I. Sailer (University of Florida) reviewed an earlier version of the manuscript. This paper is published as Florida Agriculture Experiment Station Journal Series No. 9929 and Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Bureau of Entomology Contribution No. 707.

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SIMPLE AND INEXPENSIVE ELECTRONIC DEVICE FOR AUTOMATIC RECORDING AND ANALYSIS OF INSECT ACOUSTICAL ACTIVITY

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ABSTRACT

An apparatus has been developed for monitoring the timing and duration of cricket calling song, using a simple electronic device coupled to an Apple II microcomputer. The calling activity of up to three insects can automatically be recorded and stored to magnetic disc. An analysis program determines the percent of time spent calling for each half-hour block of a 24-hour recording period. A graphical representation of the temporal pattern of calling is also an available option. Other microcomputers can be used with minor modification of the connections, and the ancillary electronics required for this purpose are inexpensive and readily constructed.

RESUMEN

Presentamos un aparato electrónico para medir dos aspectos del canto de grillos: la distribución temporal y la duración. El aparato es conectado al minicomputador "Apple II". Este montaje puede grabar hasta tres insectos y pone automáticamente en disco magnético los resultados. Un programa de análisis determina el porcentaje de tiempo en canto por cada media-hora en un período de 24-horas. También se puede representar gráficamente el patrón temporal del canto. Se puede adaptar el aparato para usarlo con otras marcas de minicomputadores usando electrónicas baratas y fáciles.

Although much is known of the mating behavior of crickets (Orthoptera: Gryllidae), few studies have been conducted on diel patterns of calling in this diverse insect group (Walker 1983). Male crickets call to attract sexually receptive females, and the timing and duration of acoustic signalling activity are crucial to male reproductive success. In many species, males appear to call throughout most of the night, placing practical limitations on the use of standard observational sampling methods (Altmann 1974) which can often be extremely laborious. Consequently, some researchers have employed electronic sound relay devices to monitor cricket calling (e.g., Cade 1981, Sakaluk et al. 1987, Rost & Honegger 1987). The construction of such instruments, however, can be prohibitively expensive or beyond the technical expertise of most researchers. Accordingly, we have developed an inexpensive electronic addition to the Apple[®] II series microcomputer which simultaneously records the calling of up to three insects and stores the data directly to disk. An associated analysis program determines the proportion of time spent calling by each male for each half-hour of recording time, and presents the results in a printed table. A graphics program permits the calling activity of each male to be plotted as a function of real time.

HARDWARE AND CONSTRUCTION

The requirements are an Apple II+ computer with 48K of memory, a single disk drive, and a CRT monitor. If a printer is available, the programs can make use of it,

but this feature is not essential. To record as a function of real time, the computer must be equipped with a clock. Finally, a simple electronic circuit is required to convert the electrical impulses from the three microphones into signals appropriate to the inputs available at the Apple's game port. This and the requisite programming complete the requirements for the system.

The electronic circuit required for interfacing the computer with the microphones is illustrated in Figure 1. There are three identical channels ($n = 1, 2$ and 3), each consisting of an audio amplifier Q_{n1} , a comparator Q_{n2} and a timer Q_{n3} . Aside from a common audio amplifier bias adjustment (R_2) and power source, no other parts are shared by the channels. The audio amplifier and comparator are packaged with four identical amplifiers to a chip, so only one chip is needed for all three channels. The timer (Q_{n3}) is a dual circuit, so two chips and sockets are needed, leaving one unused unit. The 10.2 x 10.3 cm prototype card (Radio Shack 276-154A) on which the circuit is connected, mates with a plug which is wired as shown in Figure 2. Each channel has an auditory sensitivity and time delay adjustment located on the front panel, along with an indicator light to show when the channel is active.

The microphones used are electret versions (Radio Shack) and require application of voltage. The use of a 1K resistor (R_{n1}) gives the highest electrical output for a given

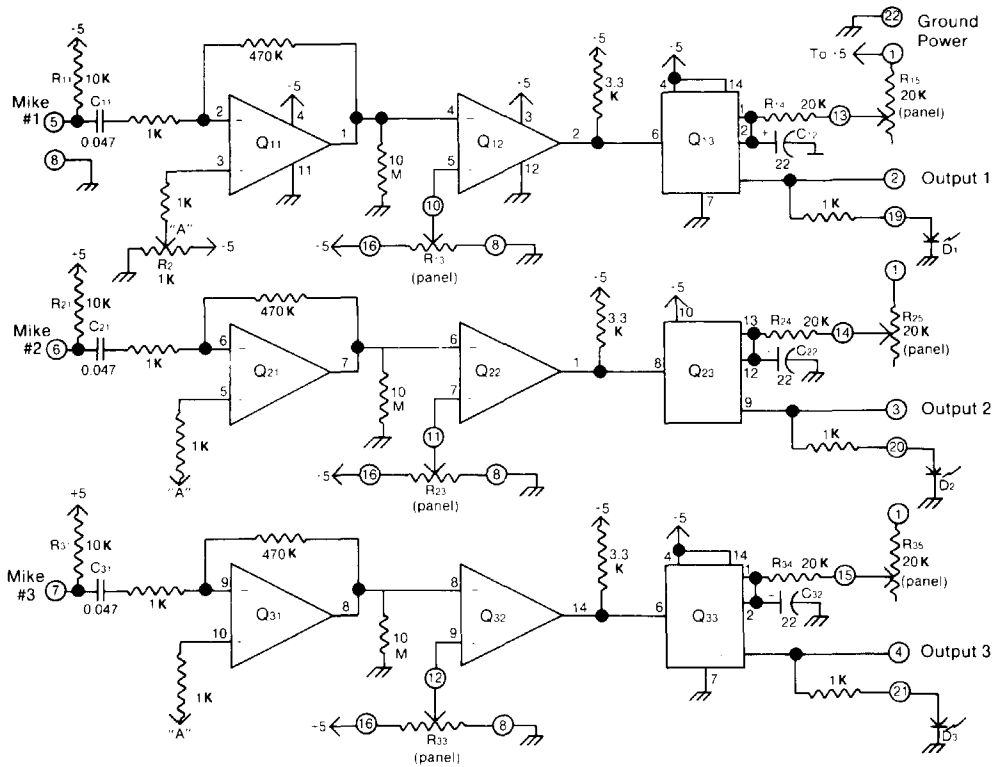


Fig. 1. A schematic diagram of the interface electronics, as constructed on a 44-pin edge-connector prototype card. Connection numbers (in circles) refer to the pins on the edge connector. All integrated circuits are commercial DIP versions and are mounted in sockets. Resistors are 1/4 W 5% tolerance and are given in ohms, kilohms (K) and mehoohms (M); capacitors are in microfarads. C_{n1} (C_{11}, C_{12}, C_{13}) is a disc ceramic, while C_{n2} is a tantalum (observe polarity); 15 V ratings are ample. Variable resistors are 10-turn ceramic trimmers; all but R_2 are mounted on the front panel and connected through the edge connector. Power is drawn from the computer via the games connector; about 40 mA is required at 5 volts.

sound input, which is maximized since distortion is of no concern to the present study. Q_{n1} is an audio amplifier with a gain of 470X. The positive excursions of the audio signal carry the input of the comparator Q_{n2} across its threshold value (adjustable by panel-mounted R_{n3}), producing a negative-going pulse at the input of Q_{n3} . This is a timer which, when tripped, produces a positive 5 V signal at its output for a duration determined by R_{n5} (panel mounted) in series with R_{n4} . This timer is normally adjusted to produce a 1-second pulse. Increasing the values of R_{n4} , R_{n5} or C_{n2} will increase the time period should a greater range be desired. Light emitting diodes (LEDs) D_{n1} are used to visualize the operation of the circuit, and are valuable during initial adjustment and monitoring.

The interface circuits are mounted in a metal box (14.8 x 20.1 x 4.2 cm) with the adjustable resistors and LEDs mounted on the front panel and the microphone connectors and cable to the computer extending from the rear. The latter connections are made via a DB-19 connector which is wired in accordance with the joystick input of the Apple IIe and IIc computers; if one of these computers is used, the computer cable should be wired pin for pin to the corresponding DB-19 connector. The Apple II+ requires a connector which plugs into the game port on the main board and is routed out of a ventilation slot in the rear of the computer. This connector system can also be used with the Apple IIe, but not with the IIc or Laser. The interface box draws about 40 mA at 5 volts from the host computer, which is well within the design limits of the port.

The connections between the edge connector and the interface box are shown in Figure 2. J_1 - J_3 are sub-miniature phone jacks which mate with corresponding plugs on the shielded microphone cables. J_4 is the 44-pin edge connector for the circuit board, of which only the 22 numbered pins are used. J_5 is a DB-9 female connector mounted on the interface box, mating to a corresponding male connector on the cable to the computer. J_6 is a 16-pin DIP header which mates with the games connector in the Apple II+ or IIe. The off-board components from Figure 1 are also indicated in this schematic diagram.

PROGRAMS

Since BASIC is the resident language in the Apple II series, it was chosen for these programs; the disk operating system is DOS 3.3. Programs are available to: 1) record events, 2) determine the proportion of time spent singing by each male for each half-hour block of recording, and 3) produce a graph of the temporal distribution of calling. In addition, a file transfer program and a program to read, display and set the clock are included. All of these programs can be accessed from the main menu which is displayed upon booting the disk, and all but the file management program return to this menu upon completion. The main menu is part of the HELLO program which is automatically run when the program disk is booted.

Upon entry to the data collection program EVENTS, the clock is read to the nearest second to obtain the time and date. The system collects data by examining the three inputs and recording the time at which a change in activity is detected at any one of them. The 1-second timers ensure that no "on" event is missed during the time required to read the clock and store a record to memory. The timers are not re-triggerable, however, and actually drop out for a brief period even in the presence of continuous audio activity (substitution of an N74123 retriggerable monostable multivibrator would eliminate the "drop out"). Thus the program loop that monitors the inputs takes about three readings per second, and these three must agree before a change of state is recorded. When a change in any of the three inputs occurs, the clock is read and the time (in seconds since midnight) and the values of each input (1 = on, 0 = off) are stored to an array in memory. This array has provisions for 1300 such records, and the program will terminate automatically before this limit is exceeded.

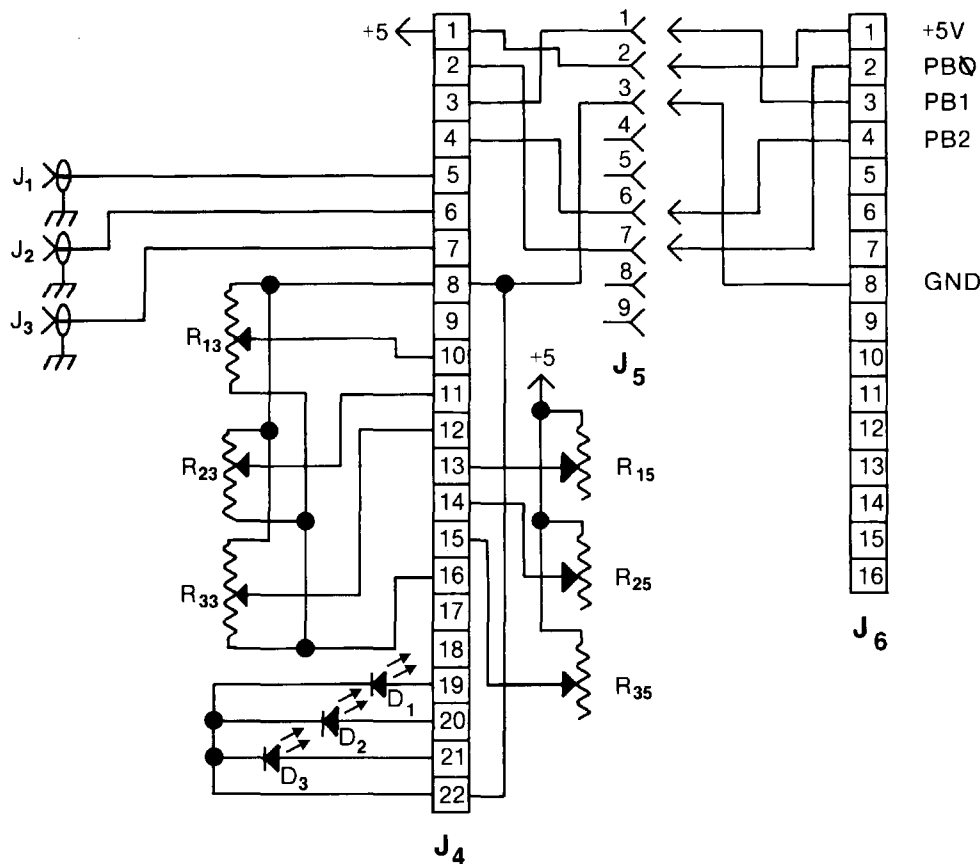


Fig. 2. Wiring diagram of the interface box. J_1 - J_3 are subminiature phone jacks, J_4 is the card socket, J_5 is a DB-9 male connector for output to the computer, and J_6 is a 16-pin DIP header required for connection to the main board on the Apple II+. Also shown are the off-board components from Figure 1. The LEDs are mounted in Beckman 89B trimmer holders to provide shielding from ambient light.

The program normally terminates at the end of a user-defined recording interval. Alternatively, unlimited recording may be specified, or the program may be terminated by keyboard entry regardless of the preset values. When the program terminates, the data are automatically transferred to the disk if a file name is specified in advance, without operator intervention. A default filename is taken from the clock when the program initializes, in the form of the date and year. Thus a set of data which were obtained starting on April 15, 1988 will be stored to a file called APR15/88. The default file name can be modified to any legal name, or no selection entered, in which case the program waits for the operator to supply a name at termination or opt not to store the data at all. As a protection against storing new data over old, the program searches the data disk for a file with the proposed name. If one is found, the new file name has an "X" appended to it, such as APR15/88X. This process is repeated until the new name (with an appropriate number of X's) is unique. The only way to remove a data file from disk is by using the DELETE command from BASIC or from the filer.

Upon termination of the recording program, control is passed back to the main menu. Normally, the analysis program would be selected at this time. This program (LIST.EVENTS) is menu driven, with routines for listing the raw data to the screen or printer, determining the proportion of time spent singing by each male for each half-hour block, listing the array of 48 half-hour blocks to the screen or printer, and

saving the array to disk for later display and/or graphical analysis. The analysis program discards any data recorded before the start of the first even half hour, analyzes data collected over the subsequent 24 hours, and discards any data after the 24-hour period. For this reason, the default time for data recording is set to 24.5 hours, ensuring a full 24 hours of usable data. In the analysis, the time at which singing begins is recorded and, when singing stops, the difference in time is added to the running total for that channel. At the end of the half-hour period, the time spent calling by each male is divided by 1800 seconds to determine the percent of time spent calling (rounded off to the nearest 0.1%) for that block. To enable analysis of files which contain less than 24 hours of data, the array is initially cleared to an impossible value (-1%) to distinguish "no singing" from "no data" in that period.

The analysed data are stored to disk with a file name consisting of the original raw data file name and an appended "#" sign, to assist in associating each results file with its raw data file. Upon terminating the program, the graphics program (GRAPH.EVENTS) is normally selected. This program accesses the results file, can list it to screen or printer in the same manner as the analysis program, and produces a high-resolution CRT bar graph which plots calling time (as a percent of time available) versus the time of day for each channel. Periods for which no data are available (flagged as -1%) are indicated on the graph.

CALIBRATION

Before data collection, it is first necessary to calibrate the apparatus. As an initial adjustment, the threshold of the comparators is set with the microphones removed, shorting the inputs. R_{n3} is adjusted until the associated LED is just extinguished. When the microphone is replaced, ambient noise will usually trigger the circuit, so a further decrease in sensitivity is required until the LED is off except when deliberately stimulated. At this point, the timer duration can be set (R_{n5}); this is best done with a calibrated oscilloscope at the output of the timer, or at the positive terminal of the LED. We adjusted each of the timers to a duration of 0.9 seconds. The microphones are then installed in the recording chambers, which are rectangular plastic shoe boxes (29.5 X 15.0 cm at the base and 8.5 cm high), appropriately ventilated and with a microphone inserted through a hole.

The process of adjusting the sensitivities is simplified by having a standard sound source that can be placed in the recording chamber instead of an insect, and which generates the same sound level in every chamber. This is accomplished using a high-frequency speaker (Realistic[®] piezo tweeter 40-1383), that can be placed in the chamber and driven in parallel with the computer's internal speaker. Due to the high frequencies involved, a program in machine language (TONE) was used to produce pure tones of adjustable frequency, duration and interpulse delay; the latter two determine the pulse repetition rate. This program is called by a BASIC program, MAKE.TONES, which displays the default parameters, accepts changes and POKE's them to memory, and calls TONE. The modified parameters subsequently can be stored as part of TONE for future use. It should be possible to simulate a wide variety of insect calls with this program, although it is intended for calibration purposes, unlike the systems of Walker (1982) and Campbell & Forest (1987). To permit the signal amplitude to be varied, an 8-ohm potentiometer is used (Realistic[®] L-Pad 40-.980), wired such that one side of the L-Pad provides a constant impedance to the computer cable while the speaker is connected between the wiper and the grounded side.

TEST RESULTS

To test for uniformity of response across the three channels, an experiment was

performed in which the three microphones were bundled together and placed in the same chamber with a single male cricket, *Gryllodes supplicans* Walker (Orthoptera: Gryllidae). Over a 24-hour recording period, there were several half-hour blocks during which singing was continuous (100%), many blocks in which there was no singing, and many with intermediate values. Only 13 of the 48 half-hour periods showed any difference between channels, with the greatest error being a 0.6% (10.8-second) difference in a period of low activity (0.6, 1.0 and 0.4% for the three channels, respectively). Ten of the 13 periods had a difference of only 0.1-0.2% (1.8-3.6 seconds). Careful alignment of the circuits with respect to sensitivity and timer duration resulted in a second trial in which only 10 of the 48 half-hour periods showed any difference between channels, with the error never exceeding 0.2% (3.8 seconds).

Because the crickets frequently change their location within the recording chambers, sensitivities must be adjusted such that microphone response does not vary as a consequence of such movement. To determine if the placement of the microphone relative to the cricket had any influence on microphone response, the three microphones were placed in different locations in the same chamber and oriented in different directions. In a 24-hour recording period, 11 of the 48 sampling periods showed a difference between channels, with the error never exceeding 0.3% (5.4 seconds).

Finally, the apparatus was set up for an experiment employing three recording chambers, each containing a single male *G. supplicans* and provisioned with ample food, water and shelter. Microphone cables, approximately three meters in length, permitted the chambers to be widely separated, thereby preventing acoustical activity in one cage from being detected at adjacent microphones. The results of this experiment are shown in Figure 3. Although there was some variation between males, calling activity peaked shortly after "lights off", remained constant throughout most of the dark portion of the photoperiod, and ceased shortly before "lights on". These results conform closely to field observations of *G. supplicans* (Sakaluk 1987).

DISCUSSION

The ease and accuracy of data collection using our apparatus make possible a range of experiments which would be extremely laborious or essentially impossible using standard observational sampling methods (Altmann 1974). Three crickets can be monitored for acoustical activity continuously over a 24-hour period, and the system measures not only the duration of activity, but its temporal distribution. The use of half-hour analysis periods was an arbitrary choice; appropriate program modifications can provide any appropriate interval.

For some studies, the restriction to three channels of input may be a limitation. The interface electronics will support a fourth channel involving no additional active components, since an unused section of each chip is available. The Apple II+ has a cassette input, similar to the pushbutton inputs, which is mapped to a specified memory location (49256, \$C060) and could be specified as PB3. However, this input is capacitor coupled and will not respond to direct current, so that the Apple main circuit board would have to be modified to enable use of this input.

It should also be possible to use a parallel interface card such as the Apple Parallel Interface Card to access up to eight inputs, using one digit for each input. If used in conjunction with the three or four inputs available through the games/cassette inputs, a total of 12 event channels could be monitored, with a corresponding increase in the complexity of the interface circuit. Alternatively, by employing an appropriate multiplexing circuit, a single input line could be used to signal a change in activity (i.e., on or off) while three others would be sufficient to specify which channel of the eight was being monitored. In either scheme, a more efficient data storage system would be

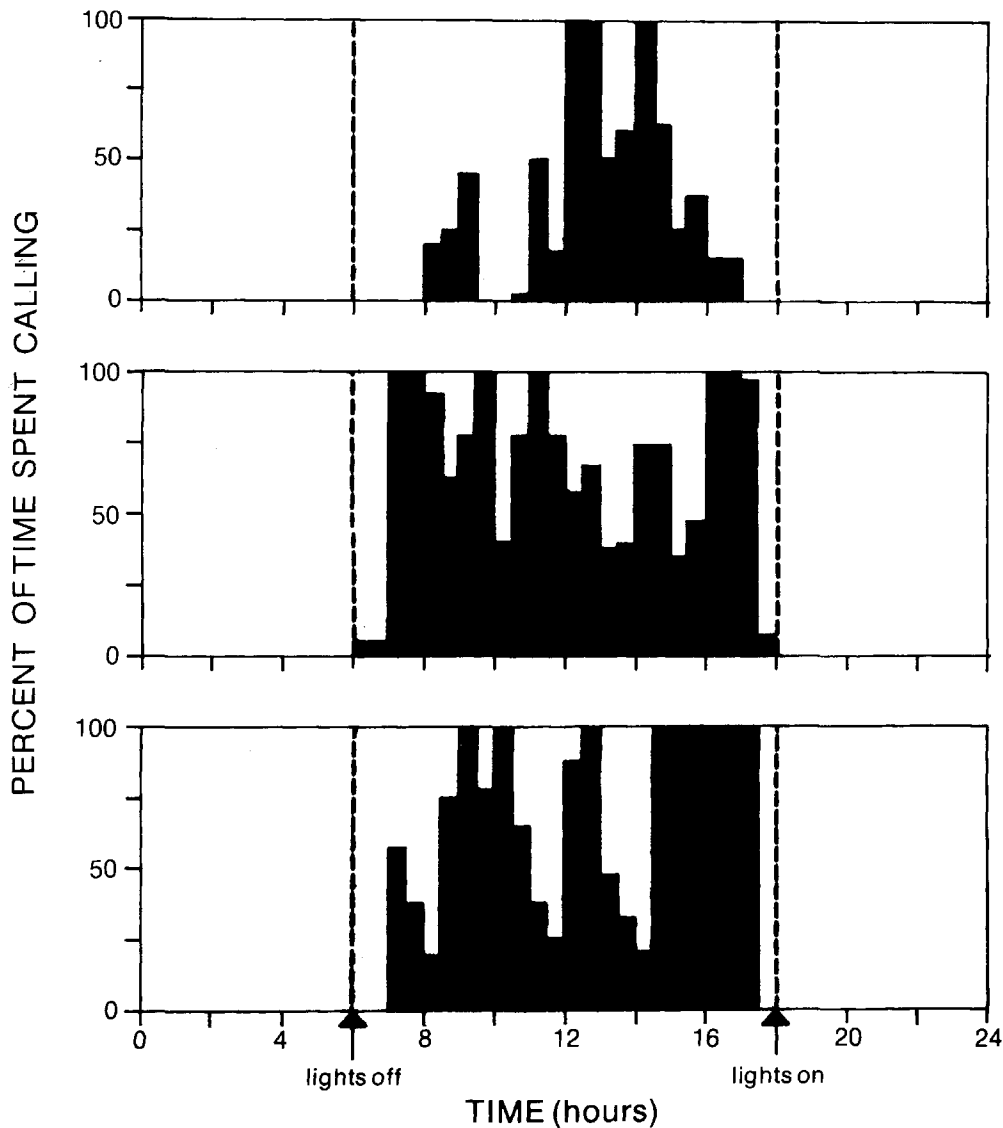


Fig. 3. Temporal pattern of calling of three decorated crickets, *Grylodes supplicans*, monitored over a 24-hour period. Calling time is shown as a percent of the total time available for each half-hour block.

required. At present, the data are stored as an array of three integers, requiring six words per record. Since only one bit is required to specify the information for each channel, it would be possible with additional programming to compress 16 channels of data into a single integer representation (two 8-bit words).

Most of these modifications would, of course, be unnecessary with the purchase of a more powerful (and more expensive) computer. However, our selection of the Apple II+ was deliberate, since we sought to utilize a common and inexpensive computer that is often found in departmental stockrooms, having been retired from more demanding service. In fact, the existence of this computer and similar computers as surplus items, or at low cost on the used market, is an attractive feature of this apparatus. The authors would be pleased to correspond with others interested in the further development or implementation of this system. Since the programs are too long for publication, we would be happy to supply listings or copies of them on request.

ACKNOWLEDGEMENTS

GWK was supported by a grant from the National Institute of Health. We thank Angelo Capparella for providing the Spanish translation of the abstract, and an anonymous reviewer for helpful comments on the manuscript.

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COMPARATIVE ENERGETICS OF TWO SPECIES OF
DROSOPHILA IN FLORIDA

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ABSTRACT

The metabolic rates of wild-caught adult female *Drosophila melanogaster* measured at 22°C are significantly greater than those of sympatric *Drosophila simulans*. Similarly, the temperature-specific metabolic rates, measured at 18, 22, and 25°C, in laboratory-reared granddaughters of the wild-caught *D. melanogaster* are greater than those of the laboratory-reared granddaughters of the wild-caught *D. simulans* females. These genetically encoded differences in metabolic rate between the two species may be related to differences in fecundity and seasonality.

RESUMEN

La tasa de metabolismo de hembras salvajes atrapadas de *Drosophila melanogaster* medidas a 22°C fué significativamente mayor que aquellas de *Drosophila simulans* simpátricas. Similarmente, la tasa de metabolismo de temperatura específica, medidas a

ACKNOWLEDGEMENTS

GWK was supported by a grant from the National Institute of Health. We thank Angelo Capparella for providing the Spanish translation of the abstract, and an anonymous reviewer for helpful comments on the manuscript.

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COMPARATIVE ENERGETICS OF TWO SPECIES OF
DROSOPHILA IN FLORIDA

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ABSTRACT

The metabolic rates of wild-caught adult female *Drosophila melanogaster* measured at 22°C are significantly greater than those of sympatric *Drosophila simulans*. Similarly, the temperature-specific metabolic rates, measured at 18, 22, and 25°C, in laboratory-reared granddaughters of the wild-caught *D. melanogaster* are greater than those of the laboratory-reared granddaughters of the wild-caught *D. simulans* females. These genetically encoded differences in metabolic rate between the two species may be related to differences in fecundity and seasonality.

RESUMEN

La tasa de metabolismo de hembras salvajes atrapadas de *Drosophila melanogaster* medidas a 22°C fué significativamente mayor que aquellas de *Drosophila simulans* simpátricas. Similarmente, la tasa de metabolismo de temperatura específica, medidas a

18, 22, y 25°C, en nietas de hembras salvajes de *D. melanogaster* criadas en el laboratorio, fué mayor que el de nietas de hembras salvajes de *D. simulans* criadas en el laboratorio. Estas diferencias del código genético en la tasa de metabolismo entre las dos especies pudieran estar relacionadas a diferencias de fecundidad y estacional.

Drosophila melanogaster Meigen and *Drosophila simulans* Sturtevant are sibling species that can be separated only by genital characteristics of males and the shapes of egg respiratory filaments (Sturtevant 1921). Both species are cosmopolitan and are found throughout the continental United States (Sturtevant 1921). However, collecting experience indicates that their geographic and seasonal distributions differ (unpublished observations). *Drosophila simulans* is primarily a southern species, uncommon in collections from latitudes above 30°N. *Drosophila melanogaster*, although occurring in the southern United States, has a more northerly distribution. Both species are found in north-central Florida: *D. simulans* is common throughout the year, but *D. melanogaster* is less abundant and appears primarily during the spring and fall. In seeming accord with this distributional difference, life histories also differ. Under laboratory conditions, oviposition of *D. melanogaster* begins on the first or second day after eclosion, builds to a peak of about 120 eggs per day on days 7-9, then declines (Giesel et al. 1982a, b). Female lifespan is 20-40 days, depending on culture temperature. In contrast, *D. simulans*'s reproductive output is about 60% lower on a per-day basis, with no obvious age-related peak, and females may live for 40-60 days depending on culture temperature (Murphy et al. 1983).

Given the the positive correlations between metabolic rate and fitness among populations of *D. melanogaster* (Marsteller 1985), and between fecundity and metabolic rate among genotypes of *D. simulans* (unpublished observations), we expected *D. melanogaster* to have a higher rate of metabolism than *D. simulans*. Here we test this hypothesis using flies collected in Gainesville, Florida.

MATERIALS AND METHODS

Two samples of flies were taken from Gainesville, Florida during the fall of 1988. The first, collected September 28 and 29, consisted of 4 female *D. melanogaster* and 13 female *D. simulans*; the second, collected on October 27-29, included 13 female *D. melanogaster* and 30 female *D. simulans*. The flies were attracted to traps containing fermenting bananas. Isofemale lines were established from each collected female. Cultures were maintained at 11-h light:13-h dark and 23-24°C in vials containing 15 ml of medium consisting of corn meal, sucrose, and brewers yeast. Cultures were supplemented with live yeast.

Rates of metabolism at 22°C of the surviving wild-caught October females were determined 2 or 3 days following their capture. In addition, we measured the rates of metabolism of laboratory-reared granddaughters of the females collected in September and October. Three granddaughters were paired with single males from each isofemale line following eclosion and then were placed in separate vials of fresh medium. Four days later, the females were transferred to metabolism chambers and incubated in the dark at 18°C, 22°C, or 25°C for approximately 6 h.

Rates of metabolism were determined on individual flies held in the dark using "closed system" metabolic chambers (Vleck 1987) consisting of disposable 30 cc syringes. Complete darkness, which may reduce flight and other locomotory activities, was assured by sealing the metabolic chambers in an incubator. At the end of a run, approximately 6 h, the fractional O₂ concentration of the syringe gas was determined with an Ametek Applied Electrochemistry S-3A Oxygen Analyzer (Pittsburgh) supplied with a model

N-22M Sensor. A 6-h run was chosen because our previous measurements indicate that the magnitude of the decrease in oxygen fraction allows accurate measurement and that body weight and metabolic rate do not decrease during this period of time. Three or 4 syringes without flies were treated exactly as were experimental syringes and served as controls for each series of measurements. A more complete description of our method of metabolic rate measurement is found in Giesel et al. (1989).

Oxygen consumption (\dot{V}_{O_2}) in $\mu\text{l/h}$ was calculated using the following equation (Vleck 1987)

$$\dot{V}_{O_2} = V(FI_{O_2} - FE_{O_2}) / (1 - FE_{O_2})t,$$

where V is the initial volume of dry CO_2 -free room air in the syringe at STP, FI_{O_2} and FE_{O_2} are the O_2 fractions within the syringe at the beginning and end of the run, and t is the duration of the run in hours.

The flies were dried for 3 days in a 60° oven and weighed to the nearest 0.002 mg using a Cahn electrobalance. Metabolic rates were adjusted with analysis of covariance (as recommended by Packard & Boardman 1987) to a common body weight of 0.50 mg, the average dry weight of all flies in this study. Size variation of the analyzed flies (Table 1) emphasizes the need to adjust for differences in size. The significance of species differences was tested with 1-tailed t -tests.

RESULTS

The average rates of metabolism of field-collected October females measured at 22°C , $3.79 \mu\text{l O}_2/0.5 \text{ mg}\cdot\text{h}$ in *D. melanogaster* and $3.26 \mu\text{l O}_2/0.5 \text{ mg}\cdot\text{h}$ in *D. simulans*, were significantly different ($P < 0.05$).

Similar species differences in rates of metabolism measured at 22°C were obtained for laboratory-reared granddaughters from both the September and October samples. In the September sample, average rates of metabolism of *D. melanogaster* and *D. simulans* were $6.4 \mu\text{l O}_2/0.5 \text{ mg}\cdot\text{h}$ and $4.4 \mu\text{l O}_2/0.5 \text{ mg}\cdot\text{h}$, respectively ($P < 0.0001$).

TABLE 1. DRY WEIGHTS (mg) OF FLIES ANALYZED. SYMBOLS ARE \bar{x} = MEAN, s = STANDARD DEVIATION, AND n = SAMPLE SIZE. DRY WEIGHTS CAN BE CONVERTED TO LIVE WEIGHTS WITH THE FOLLOWING EQUATIONS: FOR *DROSOPHILA MELANOGASTER*, LIVE WEIGHT = $0.147 + 2.730 \times$ DRY WEIGHT; AND FOR *DROSOPHILA SIMULANS*, LIVE WEIGHT = $0.050 + 2.507 \times$ DRY WEIGHT (UNPUBLISHED DATA).

	\bar{x}	s	n
Field-collected (October 1988)			
<i>D. melanogaster</i>	0.339	0.110	6
<i>D. simulans</i>	0.306	0.079	28
Laboratory-reared (September 1988 collection)			
<i>D. melanogaster</i>	0.531	0.090	12
<i>D. simulans</i>	0.523	0.056	41
Laboratory-reared (October 1988 collection)			
<i>D. melanogaster</i>	0.515	0.061	29
<i>D. simulans</i>	0.505	0.061	54

In the October sample, average rates of metabolism of *D. melanogaster* and *D. simulans* were $6.5 \mu\text{l O}_2/0.5 \text{ mg}\cdot\text{h}$ and $6.1 \mu\text{l O}_2/0.5 \text{ mg}\cdot\text{h}$, respectively ($P < 0.05$). Adult female *D. melanogaster* also have higher rates of metabolism at 18°C and 25°C than do adult female *D. simulans* ($P < 0.05$, Figures 1 and 2).

The reasons for the large deviation between the metabolic rates of field-collected and laboratory-reared flies of the same species were not investigated but may be due to (1) acclimation differences, if field temperatures were higher than laboratory rearing temperatures or (2) nutritional differences, if, as the data in Table 1 suggest, field-collected flies were food-limited as larvae.

DISCUSSION

The rates of metabolism measured in this study are not "standard rates of metabolism" (Hill and Wyse 1989), as the experimental protocol did not preclude locomotory activity. Although the flies were incubated in complete darkness to reduce activity, diel cycles in oxygen consumption still persist (Anderson et al., in press). Such rhythmic changes in oxygen consumption may represent variation in locomotory activity that corresponds to activity cycles in nature. This qualification should not invalidate the species comparison because measurements were made on both species exposed to the same conditions.

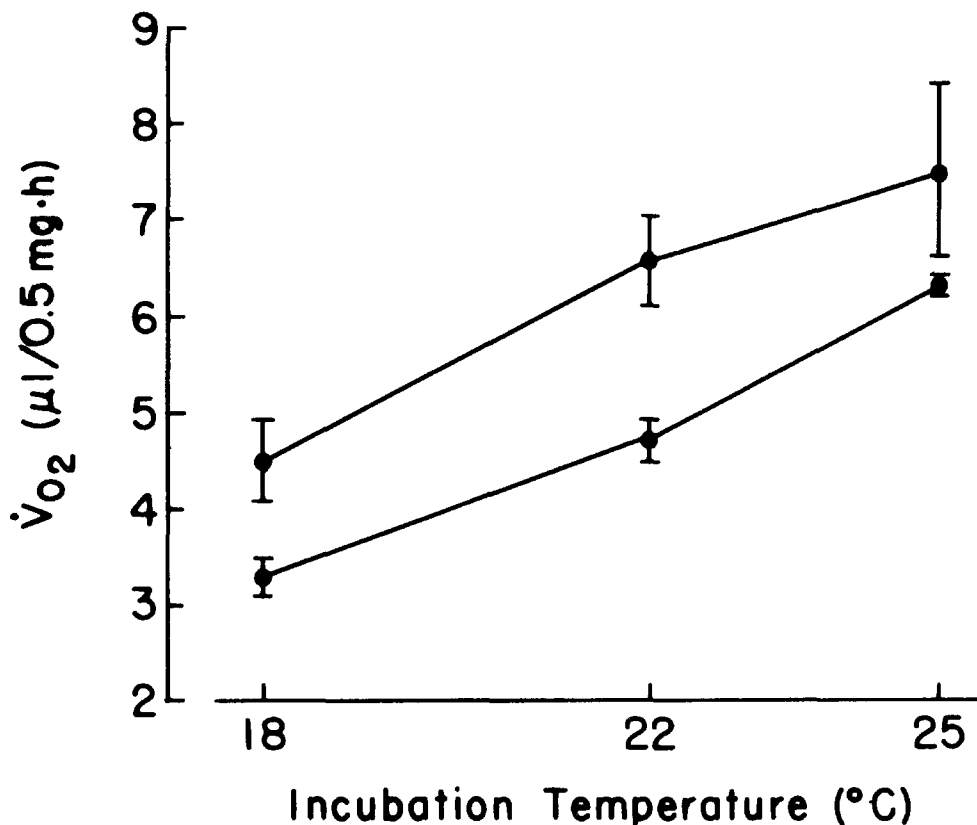


Fig. 1. Average metabolic rates of granddaughters of September wild-caught females measured at 18, 22 and 25°C , \pm standard error. Upper line—*D. melanogaster*, lower line—*D. simulans*.

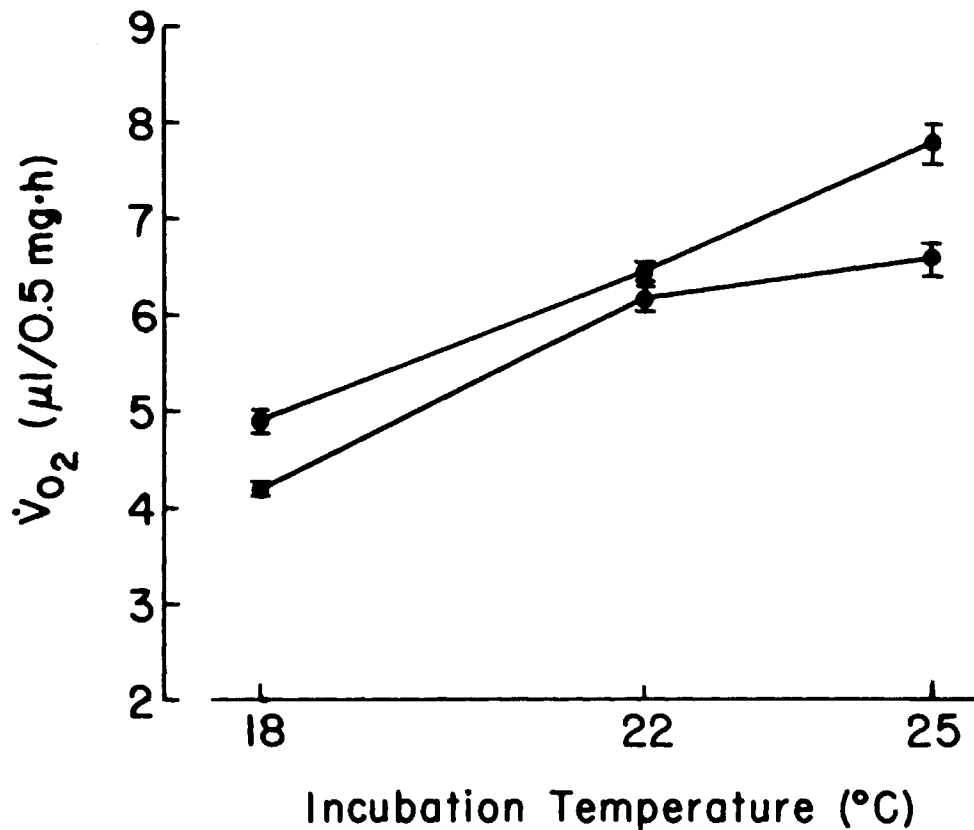


Fig. 2. Average metabolic rates of granddaughters of October wild-caught females measured at 18, 22 and 25°, \pm standard error. Upper line—*D. melanogaster*, lower line—*D. simulans*.

Metabolic rates of *D. melanogaster* are higher than those of *D. simulans*, an observation that is consistent with a previous comparison of these species (Anderson et al., in press). Because the same relative rates were found in wild-caught females and their laboratory-reared granddaughters, this difference must be highly heritable. For some important morphological characters such as wing length and body size, within-species population differences in wild-caught flies dwindle, disappear, or are even reversed in their laboratory-reared descendants, casting doubt on the extent of genetic determination and selectability of the trait (Prout 1958, Levins 1969).

The persistent and genetically encoded difference in metabolic rates between the two species may be related to fecundity and seasonality differences. *Drosophila melanogaster* has higher per-day fecundity than does *D. simulans* but has a much shorter life-span. *Drosophila melanogaster*'s higher rate of metabolism may be necessary to support a higher rate of egg production but may result in reduced longevity. Rate of metabolism is positively correlated with rate of egg laying during the first few days of reproduction (Marsteller 1985 and unpublished observations). Also, individuals of *D. melanogaster* are most common in the late fall and early spring in Florida. High rates of metabolism may be required for rapid larval development and high fecundity, both of which build populations quickly during short yearly population flushes. *Drosophila simulans* is commonly observed during every month in Florida. High rates of fecundity are apparently not as critical to population persistence as is the ability to produce eggs over a long period of time. A low metabolic rate may be sufficient to

maintain *D. simulans*'s characteristic oviposition rate and may enhance chances of an extended lifespan, particularly during periods of food deprivation.

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MOLE CRICKET PHONOTAXIS: EFFECTS OF INTENSITY
OF SYNTHETIC CALLING SONG (ORTHOPTERA:
GRYLLOTALPIDAE: *SCAPTERISCUS ACLETUS*)

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ABSTRACT

The sound pressure level of the natural call of *S. acletus* is 70 to 90 dB (measured at 15 cm). Within this range louder males attract many more conspecifics than do quieter males. Because traps that broadcast simulated calling songs at >90 dB catch enormous numbers of mole crickets, the upper limit of greater phonotaxis to higher sound levels is important to sound trap design. In three series of tests of traps broadcasting synthetic calling songs differing by 12 dB, the louder trap captured 3 to 9 times as many mole crickets as the quieter one. The effect was significantly greater in trials of 94 vs 106 dB and of 106 vs 118 dB than in trials of 116 vs 128 dB, but we failed to find the upper limit we were seeking. At all intensities a greater proportion of females than males landed within 0.76 m of the speaker.

RESUMEN

La presión del sonido del llamado natural de *S. acletus* es de 70 a 90 dB (medido a 15 cm). Dentro de esta gama, los machos que emiten sonido más alto atraen muchos más coespecíficos que los machos más callados. Debido a que las trampas que emiten cantos simulados a >90 dB capturan cantidades enormes de grillotopos, el límite superior de más fonotaxis a niveles de sonidos altos es importante en el diseño de trampas de sonido. En tres series de pruebas con trampas emitiendo cantos sintéticos diferenciando por 12 dB, la trampa más alta capturó de 3 a 9 veces más grillotopos que la más baja. El efecto fué significativamente mayor en pruebas de 94 contra 106 dB y de 106 contra 118 dB que en las pruebas de 116 contra 128 dB, pero fracasamos en encontrar el límite alto que estábamos buscando. A todas las intensidades, hubo una mayor proporción de hembras que de machos que estaban dentro de 0.76 m del autoparlante.

Trapping flying mole crickets (*Scapteriscus* spp.) that land near electronic renditions of mole cricket songs is an effective means of monitoring flight activity and of securing specimens for research (Walker 1982, 1988). The numbers captured, sometimes thousands in less than 1 hr, are great enough to suggest that sound traps could be useful in control of pest mole crickets.

An important finding from previous studies of mole cricket phonotaxis is that the more intense the call, the greater the number of mole crickets attracted to it. This is true with natural variation in the loudness of calling mole crickets, 70 to 90 dB SPL (sound pressure level re 20 μ Pa measured at 15 cm above the sound source) (Forrest 1983). It is also true with experimentally varied electronic imitations of mole cricket calls. Ulagaraj & Walker (1975) reported that at SPL's between 70 and 106 dB the numbers of mole crickets captured, relative to a 100 dB standard, approximately dou-

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bled with each 6 dB increase. Above 106 dB, increases in captures were slight and not statistically significant. However, Forrest (1980), using improved sound generating equipment and more replication, found that a 6 dB increase within the range 101 to 111 dB gave a 5.7-fold increase in numbers caught (95% C.I. = 5.2 to 6.3). Forrest & Green (1989) showed that this degree of increase was predicted by a simple physical model based on flying mole crickets choosing the sound source that had the greatest SPL at their sound receptors.

The studies reported here extend the upper range of SPL's tested to 128 dB, 10 dB higher than any used more than once by Ulagaraj & Walker (1975) and 17 dB above the range used by Forrest (1980). Unlike the previous studies, our traps captured mole crickets landing as far as 1.83 m from the sound source and segregated the catch into those landing within the 0.76-m radius of a standard mole cricket trap (Walker 1982) and those landing up to 1.07 m farther out. We hoped to find the limits of higher intensity resulting in greater catch and to determine if very high intensities decreased the relative frequency of those landing within the standard catching area.

METHODS

Two mole cricket traps, each consisting of a 3.66 m diameter circular swimming pool with a 1.52 m diameter child's wading pool placed at center, were installed 2 m apart at University of Florida's Green Acres Farm, near Gainesville. Enough water was added to cover the bottoms of the pools. From the center of each trap, identical battery-powered sound synthesizers broadcast simulated calling song of *Scapteriscus acletus* (2.7 kHz carrier turned on and off at 50 Hz with a 50% duty cycle; see Walker 1982). SPL's of the two units were set 12 dB apart, using a Bruel & Kjaer model 2219 sound level meter 15 cm above the sound source. Sound synthesizers were switched on at sunset and off ca. 2 hr later, after *S. acletus* flights had ceased. Mole crickets that landed within the pools swam about on the water's surface until removed, sexed, and counted.

Tests were run nightly, weather permitting, 8 May to 4 June 1980. In each series of tests, the location of the high SPL broadcast was switched between the two traps at least every second night; synthesizers were alternated between high- and low-intensity duty nightly. The first series of tests (8 to 13 May, n=6) compared 106 and 118 dB. The substantial differences in catches, contrasting with the results of Ulagaraj and Walker (1975), led us to use 94 and 106 dB for the second series (14 to 24 May, n=9). The synthesizers for these two series were standard "artificial crickets" (Walker 1982). In the third series (26 May to 4 June, n=6), we used more powerful versions of the same device to compare 116 and 128 dB. These "super crickets," made by William Oldacre, the designer of the standard ones, had more batteries, a larger amplifier, and two 7.5 cm speakers 1 cm apart. Intensity was measured 15 cm above the 1 cm bridge between the two speakers. Hearing protectors were required when measuring intensities above 106 dB.

RESULTS

Traps with higher sound levels caught significantly more *S. acletus* than similar traps operated 12 dB lower (Fig. 1). The high range tests (116 vs: 128 dB) produced catch ratios (no. in high dB trap/no. in low dB trap) that were significantly lower than the ratios of the other two ranges (chi square, $P < 0.001$). Within the low and medium range tests (94 vs 106 and 106 vs 118), but not in the high range tests, females showed a significantly stronger preference for the high dB trap than did males. The catch ratios for males and females in the low range tests were 6.7 and 9.1, respectively. Corresponding values in medium and high range tests were 7.9 and 10.1, and 2.6 and 2.9.

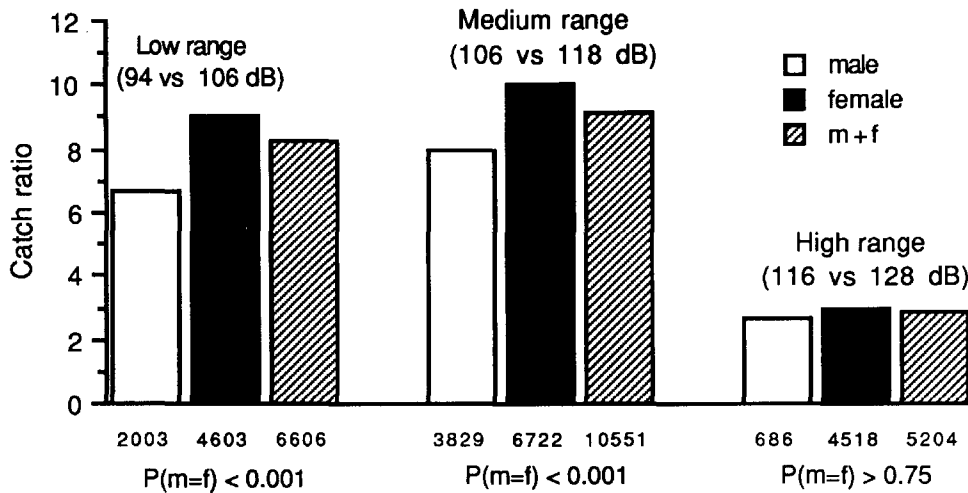


Fig. 1. Relative effectiveness of paired traps baited with synthetic *S. acletus* calls differing by 12 dB. Bars show catch ratios—i.e., (no. *S. acletus* caught in high dB trap)/(no. caught in low dB trap). Total captures and probabilities of male ratio equalling female ratio (chi square) are at bases of bars.

The majority of mole crickets captured landed within the 0.76-m radius of a standard mole cricket trap (Table 1). In the low and medium range tests, the catch ratios were significantly higher than for mole crickets captured landing farther out. In the high range tests, the higher catch ratio was for the outer ring.

In both traps in every comparison, females were significantly more concentrated in the central 1.5 m of the trap than were males (Fig. 2). Landing density ratios—i.e., the density (no./m²) in the inner circle of the trap divided by the density in the outer ring—were 2.5 to 5.6 for males and 4.8 to 14.3 for females.

In the low and medium range tests, landings of males and females in the trap with the higher SPL were significantly more concentrated centrally than landings in the trap with the lower SPL (chi square, $P < 0.05$). In the high range tests, this effect disappeared for males ($P > 0.10$) and reversed for females ($P < 0.001$) (Fig. 2).

TABLE 1. NUMBERS AND CATCH RATIOS (NO. CAUGHT IN HIGH dB TRAP/NO. CAUGHT IN LOW dB TRAP) FOR *SCAPTERISCUS ACLETUS* CAUGHT IN 1.83 M DIAM SOUND TRAPS BROADCASTING AT SPL'S DIFFERING BY 12 dB.

Test range	Inner circle (0.76m radius)			Outer ring (0.76-1.83 m)		
	Low	High	Catch ratio	Low	High	Catch ratio
94 vs 106 dB	371	4002	10.8 ^a	345	1888	5.5
106 vs 118 dB	514	5593	10.9 ^a	522	3922	7.5
116 vs 128 dB	761	1902	2.5	581	1960	3.4 ^b

^aCatch ratio higher than in outer ring (chi square; $P < 0.001$).

^bCatch ratio higher than in inner circle (chi square; $P < 0.001$).

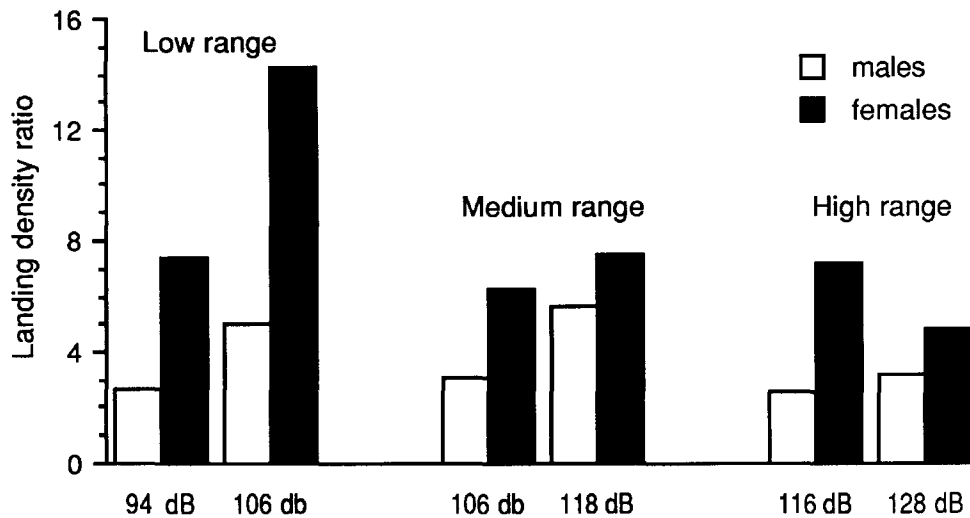


Fig. 2. Relative densities of *S. acletus* landing in central and outer portions of traps baited with synthetic *S. acletus* calls. For each SPL in each range, bars show landing density ratios—(landing density in central circle)/(landing density in outer ring)—for males and females. In every trap females were significantly more concentrated centrally than were males (chi square, $P < 0.001$).

DISCUSSION

We failed in our quest of a limit to higher intensities catching more *S. acletus* (Fig. 1). The reduction in the degree of effect in tests of 116 vs 128 dB can be attributed to intensity effects diminishing at such high SPL's, to crickets attracted to the louder trap landing in the adjacent softer trap, or to our use of two-speaker artificial crickets. Whether SPL's above 128 dB would be even more effective is probably of little practical importance, because equipment to produce such SPL's is not readily available and because of potential problems with hearing damage, noise-nuisance complaints, and law suits.

Our data on landing patterns confirmed a phenomenon reported in earlier studies—viz., males are more dispersed in their landing sites relative to the sound source than are females (Forrest 1981, Matheny et al. 1983). Males landing at the sound of another male are probably less likely to benefit from entering the calling male's burrow than are females; however, the only study of behavior of mole crickets landing near a burrow found no significant sexual difference in the frequency of entering (Forrest 1983).

Effects of SPL on landing patterns seem complex (Fig. 2), and our switching to two-speaker synthesizers for the 116 vs 128 dB tests makes it unprofitable to compare those results with results from tests in the other two ranges. In the 94 vs 106 and in the 106 vs 118 tests, the landing density ratios of both males and females were significantly greater at the higher SPL. That this was a relative rather than an absolute effect is shown by comparing landing density ratios at 106 dB paired with 94 dB and with 118 dB (Fig. 2). For both males and females the ratios at 106 dB differed under these two conditions (chi square, $P < 0.001$). A possible reason for higher landing density ratios at the higher intensity is that a portion of the crickets landing in the low dB trap were attracted to the high dB trap but landed a few meters away. Matheny et al. (1983), who studied landing patterns about a single sound source, reported that landing densities 3 m from the sound source were still 10 to 20% of those within 0.75 m. The edge of the low SPL sound trap in our experiments was only 3.83 m from the synthesizer in the

high intensity trap. Any "cross-catching" that occurred would diminish the landing density ratio in the low SPL trap more than in the high SPL trap (because many more cross-caught crickets would land in the low intensity trap). Cross catch would also reduce the catch ratios shown in Fig. 1.

ACKNOWLEDGEMENTS

We thank Jackie Belwood and Pat Parkman for criticizing the manuscript. Fla. Agric. Exp. Stn. Journal Series No. R-00008.

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NEW CHILEAN *ITAMUTON*
(HYMENOPTERA: ICHNEUMONIDAE: MESOSTENINI)
REARED FROM *ELICURA LITIGATOR*
(NEUROPTERA: MYRMELEONTIDAE)

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ABSTRACT

Itamuton stangei n. sp. attacks pupae of the central Chilean antlion, *Elicura litigator* Navas. It is the first New World species of Ichneumonidae known to parasitize Myrmeleontidae. *Itamuton stangei* n. sp. is described from males and females. It resembles the sympatric *I. rufitibia* (Spinola) but is shorter and stouter in bodily proportions and has less strongly projecting propodeal cristae.

RESUMEN

Itamuton stangei n. sp. ataca las pupas del mirmeleóntido centro-chileno, *Elicur litigator* Navas. Es esta la primera vez que un icneumonídeo haya sido criado en el Nuevo Mundo, como parásito de Myrmeleóntido. *Itamuton stangei* n. sp. se asemeja a la especie simpátrica, *Itamuton rufitibia* (Spinola), pero tiene el cuerpo más corto y robusto y las crestas del propodeo menos proyectantes.

Itamuton Porter (1987) ranges through subequatorial South America with species in the Andean Puna (*I. townesorum* (Porter)), in the Peruvian West Andean slopes and Coastal Desert (*I. occidentis* (Porter)), in central and south-central Chile (*I. rufitibia* (Spinola)), and also across the ecotone at the austral end of South America between *Nothofagus* forest and Patagonian Steppe (*I. magallanes* (Porter)).

This genus belongs to the Subtribe Ischnina of the Tribe Mesostenini (Townes 1969). Its diagnostic features include the filiform female antenna; the long malar space (0.6-1.6 as long as basal width of mandible); the little elevated but sharp occipital carina; the dorsally much narrowed areolet; the reclivous 2nd recurrent vein that is outbulged on its upper 0.5; the axillus vein which runs close to the anal margin of its wing; the unarmed lower prepectus; the conspicuous notauli that reach 0.5 or more the mesoscutal length; the prominent and polished groove that descends from the hind coxal base; the more or less traceable basal and apical transverse carinae of the propodeum on which the apical trans-carina reaches far forward medially; the elongate propodeal spiracle; the absence of a lateral tooth at the base of the petiole; and the sparsely setose female 2nd gastric tergite.

Itamuton stangei provides the 1st host data for its genus and is the only New World ichneumonid known to parasitize Myrmeleontidae. However, most ischnine genera exploit lepidopterous hosts (Porter 1967, 1987), so that *I. stangei* may constitute a trophic novelty within its genus. Certainly, the high Andean *I. townesorum* (Porter) and the subantarctic *I. magallanes* (Porter) inhabit areas where Myrmeleontidae are

unlikely to occur. Furthermore, species of the related genera *Phycitiplex* and *Oecetiplex* do parasitize Lepidoptera in such families as Phycitidae and Psychidae.

KEY TO THE SPECIES OF *ITAMUTON*

1. Mesoscutum mat with some dully shining areas, its sculpture consisting of small punctures and of fine wrinkling; malar space 0.9-1.1 as long as basal width of mandible 2
- 1'. Mesoscutum highly polished with abundant small and sharp punctures that have at least narrow smooth interspaces; malar space 0.7-1.6 as long as basal width of mandible 3
2. Ovipositor upcurved; temple 0.4-0.5 as long as eye in dorsal view; no red markings on gaster; female flagellum with a white band; female gaster wholly black *I. townesorum* (Porter)
- 2'. Ovipositor very slightly upcurved; temple 0.2-0.3 as long as eye in dorsal view; gaster with red extensively on at least tergites 1-3; flagellum without a white band; female gaster with white on tergite 4 and those succeeding *I. occidentis* (Porter)
3. Flagellum without a white band: ground color of 2nd and following gastric tergites pale red with some brownish suffusion; wings hyaline; malar space of female 1.4-1.6 as long as basal width of mandible, of male 1.1-1.3 as long as basal width of mandible; ovipositor gently upcurved, its nodus high and its tip in profile straight or slightly concave from nodus to apex *I. magallanes* (Porter)
- 3'. Flagellum with a white band; gastric tergites with ground color black; malar space of female 0.7-0.9 as long as basal width of mandible, of male 0.6-0.7 as long as basal width of mandible; ovipositor straight with a low but distinct nodus and convex in profile between nodus and apex 4
4. Malar space in female 0.6-0.7 as long as basal width of mandible; temple in female 0.2-0.3 as long as eye in dorsal view; mesoscutum 0.8-0.9 as long as wide; female propodeum 0.4-0.5 as long as high in lateral view, male propodeum 0.7 as long as high; propodeal cristae of female broadly subcuneate and little projecting; female postpetiole 1.7-2.2 as wide apically as long from spiracle to apex; male 2nd gastric tergite stout and gradually widened toward apex, 0.6 as wide apically as long *I. stangei* n. sp.
- 4'. Malar space in female 0.8-0.9 as long as basal width of mandible; temple of female 0.4-0.5 as long as eye in dorsal view; mesoscutum about as long as wide; female propodeum with projecting cristae and 0.6-0.7 as long as high, male propodeum 0.8 as long; female postpetiole 1.2-1.4 as wide apically as long from spiracle to apex; male 2nd gastric tergite parallel-sided, slender, 0.3-0.4 as wide apically as long *I. rufitibia* (Spinola)

Itamuton stangei Porter, New Species
(Fig. 1, 2)

FEMALE: *Color*: antenna black with weak brown staining and with a ventrally duller and partly interrupted white band on flagellomeres 4-5 and base of 6; head, mesosoma, and gaster black with white markings as follows: narrow band on facial orbit and lower 0.3 of frontal orbit; narrow band on hind orbit except near top and bottom; large but unattached blotch in malar space; small round blotch medially a little before base of mandible; pair of transverse marks on dorsum of pronotal collar; narrow stripe externally on pronotal humerus; much of tegula; triangular blotch on basal angle of scutellum;

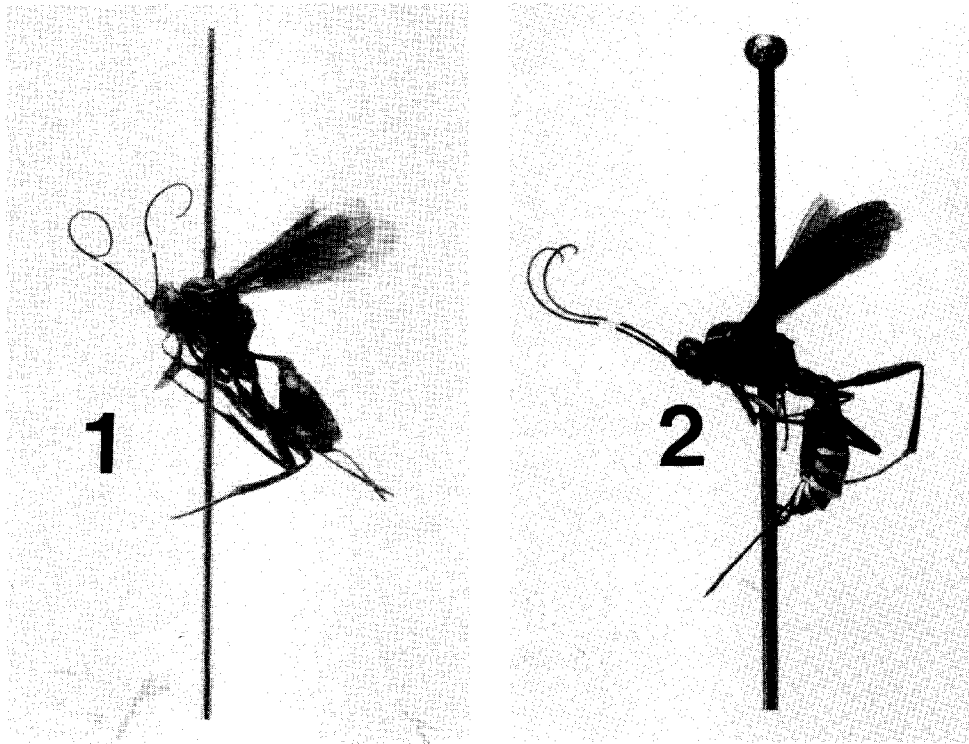


Fig. 1. *Itamuton stangei*, ♀ Holotype. Lateral view of whole insect at 5.6X enlargement.

Fig. 2. *Itamuton rufitibia*, ♀. Lateral view of whole insect at 5.6X enlargement.

broad band on apex of 3rd gastric tergite; very broad band on apical 0.3-0.5 of 4th tergite (even broader laterally); narrower but complete and laterally widened band on apex of 5th tergite: complete, dorsally much narrowed but laterally widened apical band on 6th tergite; and a broad band laterally on 7th tergite; legs black with pale brown to orange-brown on front femur apically, dorso-apically, and over a large area posteriorly, on all of fore tibia; dully on apices of front tarsomeres 1-4; restrictedly near apex of mid femur, extensively and varying to pale orange on much of mid tibia except for the irregularly dusky apex, dully on apices of mid tarsomeres 1-4; and with hind leg shining black on coxae, trochanters, and femur, and duller black on tibia and tarsus as well as with rather prominent pale brown areas toward apex of tarsomeres 1-4; wings infumate.

Length of fore wing: 5.0-6.0 mm. *Mesosoma and gaster:* short and robust. *Flagellum:* 1st segment 5.0 as long as deep at apex. *Malar space:* 0.6-0.7 as long as basal width of mandible. *Temple:* 0.2-0.3 as long as eye in dorsal view; abruptly receding and a little rounded. *Mesoscutum:* short and broad, 0.8-0.9 as long as wide; notauli sharp and reaching 0.4-0.6 the length of mesoscutum; surface highly polished with many small to medium sized sharp punctures whose intervals vary from a little to definitely longer than diameter of the punctures. *Propodeum:* very short and high, only 0.4-0.5 as long as high; basal face steeply declivous in profile; areola much wider than long; cristae broadly subcuneate and not much projecting. *First gastric tergite:* postpetiole strongly expanded, 1.7-2.2 as wide at apex as long from spiracle to apex; dorsal longitudinal carinae weak or absent; petiole broad and flat, broader than high in cross-section. *Ovipositor:* sheathed portion 0.4-0.5 as long as fore wing; tip between nodus and apex with profile distinctly convex (more so than in *I. rufitibia*).

MALE: *Color:* antenna black with a white band dorsally on more or less of segments 11-15, without a white spot on scape; head mesosoma, and gaster black with profuse white markings as follows: 1st segment of maxillary palpus; most of basal 0.5 of clypeus; orbits, broadly below and more narrowly dorsad as well as with a break anteriorly at bottom of eye but otherwise extending into most of malar space; broad but medially a little interrupted band on pronotal collar; broad band on humeral margin of pronotum; tegula; subalarum; very large triangular blotch in anterior corner of scutellum that reaches 0.5 length of scutellum laterally; large blotch on and below propodeal crista; very broad bands on apical 0.3 or more of gastric tergites 4-7; and a large blotch apicad on clasper; legs black with orange to pale brown on much of front femur (especially above and toward apex); fore tibia bright pale orange-brown; and with a little brown staining, especially near apex, on tarsomeres of all legs as well as with the following white: large dorsal and dorso-lateral blotch on fore and mid coxa; ventro-lateral 0.5 or more of fore and mid trochanter; blotch ventrally on fore and mid trochantellus; large dorso-anterior basal blotch on hind coxa; as well as on hind tarsomeres 1 (about apical 0.3 above) and 3-4 (entirely); wings hyaline with faint dusky staining toward apex.

Length of fore wing: 6.3 mm. *Flagellum:* 1st segment 3.3 as long as deep at apex; with linearly subelliptic to bacilliform tyloids on segments 13-16 (tyloids mostly follow longitudinal axis of their segments). *Malar space:* 0.7 as long as basal width of mandible. *Temple:* 0.5 as long as eye in dorsal view. *Propodeum:* a little longer and lower than in female but unusually short and high (in comparison to *I. rufitibia*), about 0.7 as long as high in lateral view; cristae broadly and a little tubercularly subcarinate, a little less projecting than in many males of *I. rufitibia*; surface behind basal transcarina a little more coarsely rugose than in *I. rufitibia*. *First gastric tergite:* slightly widened apicad postpetiole 0.7 as wide apically as long from spiracle to apex. *Second gastric tergite:* shining but micro-reticulate with small, very faint punctures that emit long and mostly overlapping setae; stout and expanded gradually from base to apex; 0.6 as wide apically as long.

TYPE MATERIAL. Holotype ♀: CHILE, Santiago Province, Parque Nacional Río Clarillo, 1-I-1989, R. B. Miller and L. A. Stange. Paratypes: 4, ♀ and 1 ♂, same locality as holotype, 31-I-1989, 20-29-II-1989, R. B. Miller and L. A. Stange. Holotype in Florida State Collection of Arthropods at Gainesville. Paratypes in Florida State Collection of Arthropods at Gainesville (1 ♀ and 1 ♂), Miller collection (1 ♀), Porter collection (♀), and in the American Entomological Institute at Gainesville, Florida (1 ♀).

RELATIONSHIPS. This species is similar to the common central Chilean *Itamuton rufitibia* (Spinola), from which it may be distinguished by its much shorter and higher mesosoma, less projecting propodeal cristae, and more robust gaster. *Itamuton stangei* might have originated from the *I. rufitibi* stock either by vicariance or (given its remarkable similarity to the commoner species) by sympatric speciation accompanying a host shift. It is also possible that *I. stangei* represents no more than a host race of *I. rufitibia*.

FIELD NOTES. The type locality is a well watered subandean ravine in the Precordillera near Santiago. Its flora includes both xeric elements (e.g., *Acacia*, *Cactaceae*) and mesic to hygrophile plants (*Lithraea*, *Schinus*, *Peumus*, *Maytenus*, and, at stream-side, *Gunnera*). The plant community at Río Clarillo thus represents a mixture of semidesertic and relict Valdivian taxa. This type of habitat is found in central Chile wherever there are protected sites with permanent water.

Miller and Stange (personal communication) explained that the antlion, *Elicura litigator* Navas, abounds in Chile at Río Clarillo and in other localities, from Coquimbo Province on the north to Llanquihue Province in the south. The larva of *Elicura* is a generalized predator found in all types of situations where the soil is loose and sandy. The antlion larvae make their cocoons wherever they may be upon reaching maturity. The cocoons are camouflaged with soil fragments and situated either partially or wholly embedded in the substrate. *Elicura* thus offers a host easily accessible for short-ovipos-

itored ichneumonids that attack holometabolous pupae on or in the topmost soil layers. Indeed, Miller and Stange found that some 25% of the *Elicura* pupae collected by them were or had been parasitized. Since numerous moth larvae pupate in the same type of microhabitat as *Elicura*, it is easy to see how *Itamuton stangei* could have switched from ancestral lepidopterous hosts to the more apomorphic exploitation of Neuroptera that pupate on or in the soil.

SPECIFIC NAME. For Dr. Lionel A. Stange of the Florida State Department of Agriculture and Consumer Services (Division of Plant Industry at Gainesville).

DISCUSSION

Itamuton stangei appears to be a sibling species of the much collected *I. rufitibia* (central and south-central Chile and east to the Atlantic Coast in Patagonian Argentina). Its utilization of myrmeleontid hosts thus may have evolved recently, assuming that parasitism of Lepidoptera is the plesiomorphic life style among the other *Itamuton* (as is true for the whole Subtribe Ischnina). In contrast, the Old World ischnine genus *Myrmeleonostenus*, which ranges from Mediterranean Europe to Australia, is well known as an antlion parasite (Townes 1969, Gauld 1984). *Myrmeleonostenus* forms a well-differentiated complex of species not closely related to *Itamuton* (e.g., *Itamuton* possesses a prominent and polished groove descending from the hind coxal insertion and this characteristic is absent in *Myrmeleonostenus*). *Myrmeleonostenus* has the mesosoma and gaster very long and slender; whereas, in *Itamuton stangei* the gaster is robust and the mesosoma foreshortened. In this way, *I. stangei* might seem better adapted than its Old World ecological equivalent for pupating within globular antlion cocoons. However, Miller and Stange reported that pupae of *I. stangei* fill only about 0.3 the available space within *Elicura* cocoons parasitized.

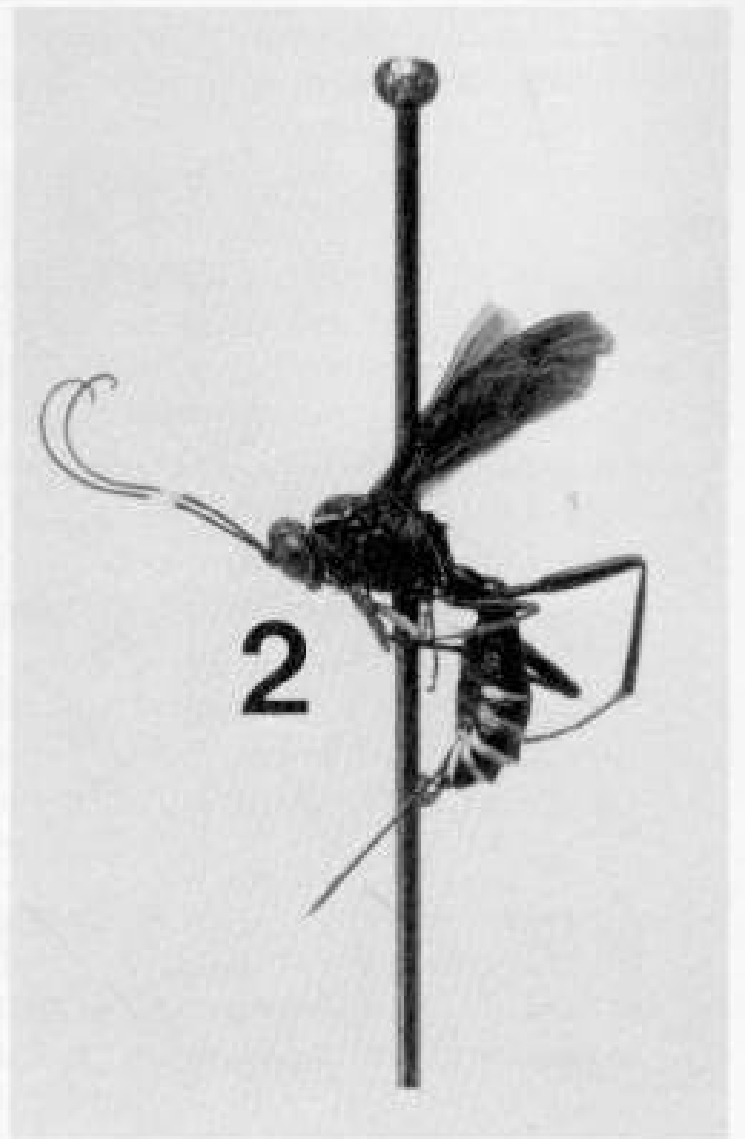
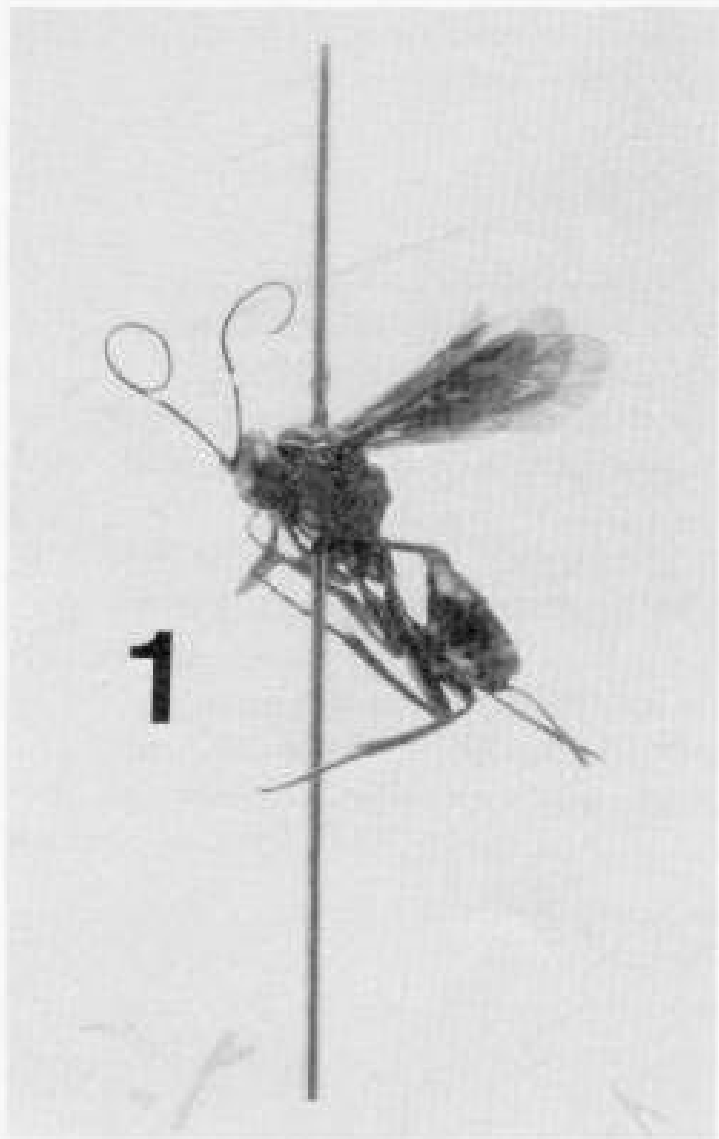
ACKNOWLEDGMENTS

The specimens and life history data here expounded were obtained by Mr. R. Bruce Miller and Dr. Lionel A. Stange during fieldwork in Chile supported by the Division of Plant Industry of the Florida Department of Agriculture and Consumer Services. Mr. Jeffrey Lotz of the DPI took the photographs that illustrate this study. The author also is indebted to Fordham University for the Faculty Fellowship award that made the present work possible. This research continues investigation begun under United States National Science Foundation Grant BSR-8313444.

Contribution No. 718, Bureau of Entomology, Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, FL 32602.

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COMPSOCRYPTUS OF THE NORTHERN CARIBBEAN WITH
DESCRIPTION OF A NEW SPECIES FROM HISPANIOLA
(HYMENOPTERA: ICHNEUMONIDAE)

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ABSTRACT

Compsocryptus (Ichneumonidae: Mesostenini) is centered in the Sonoran Region of western North America and Middle America but has disjunct species in southern South America, in Florida, and on some of the northern Antilles. *Compsocryptus stangei* n. sp. is the 1st *Compsocryptus* reported from Hispaniola. It differs from other Caribbean and south Floridian congeners by the following combination of characters: body shining black, wings dark with yellow blotches, gaster red, and thorax generally shining with narrow but prominent smooth intervals among the punctures. *Compsocryptus fasciipennis* (Brullé) of Florida and Cuba has yellow wing markings but a uniformly blue-black ground color on the gaster, mesosoma, and head. *Compsocryptus orientalis* Alayo & Tzankov (described from Cuba and here cited also from the Bahamas) has the wings almost uniformly dark and a subdued bluish-purple ground color. In both the foregoing species the thoracic punctures are dense with inconspicuous smooth interspaces.

RESUMEN

Compsocryptus (Ichneumonidae: Mesostenini) alcanza su máxima diversidad en la Región Sonorense del oeste de Norteamérica y en Mesoamérica. Tiene, además, especies aisladas en el sur de Sudamérica, en Florida, y en varias islas del Mar Caribe. *Compsocryptus stangei* n. sp. es el primer *Compsocryptus* de ser reportado de Hispaniola. Se diferencia de otras especies geográficamente vecinas por la siguiente combinación de características: cuerpo negro brillante, alas oscuras con manchas amarillas, gáster rojo, y el tórax en general reluciente debido a la presencia de intervalos lisos estrechos pero conspicuos entre los puntos. *Compsocryptus fasciipennis* (Brullé) de Florida y Cuba tiene las alas con manchas amarillas pero el gaster, mesosoma y la cabeza son de un color uniforme negro-azulado. *Compsocryptus orientalis* Alayo & Tzankov (descrito de Cuba pero aquí citado también de las Bahamas) se destaca por sus alas casi totalmente negras y el color algo purpúreo-azulado del cuerpo. En ambas especies antecedentes, el punteado del tórax es tan denso, que revela muy pocos intervalos lisos.

GENUS *COMPSOCRYPTUS* ASHMEAD

This conspicuous genus, recently diagnosed by Townes (1962) and by Porter (1986), can be recognized by its upcurved ovipositor, nearly square areolet in which the anterior veinlet is about as long as the mesal veinlet, and by having the axillus vein as close to the submediella as to the posterior margin of its wing.

Although most diverse in the Sonoran Biogeographic Province, *Compsocryptus* has presumably relict species in south Florida and on several north Caribbean islands, in addition to *C. fuscofasciatus* (Brullé) of the Peruvian Coastal Desert and to *C. melanosigma* (Brullé) of the Argentine Chaco (Porter 1986).

Compsocryptus females often are collected while crawling on the ground in weedy places and probably attack lepidopterous pupae in soil or leaf litter. Indeed, the only species which has been reared, *C. melanosigma*, attacks the noctuid lepidopteran genera *Alabama* and *Pseudaletia* which do pupate at or just below ground level.

KEY TO THE CARIBBEAN SPECIES OF *COMPSOCRYPTUS*

1. Flagellum black; gaster red; occipital carina not raised and flange-like laterally; female mesoscutum shining but with small subadjacent to adjacent punctures; male mesoscutum largely smooth and shining with many punctures separated by polished intervals; lower metapleuron shining, in female with adjacent to confluent punctures so as to appear longitudinally substriate, in male smooth and shining with large and numerous but mostly well separated punctures 1. *Compsocryptus stangei* n. sp.
- 1'. Flagellum yellow on at least basal 0.3; gaster bluish black; occipital carina laterally elevated into a definite flange; female mesoscutum sublustrous, very closely and confluent micro-puncto-reticulate; male mesoscutum densely punctate with few polished interstices; lower metapleuron of both sexes grossly puncto-reticulate 2
2. Fore wing with a broad postmedian yellow cross band: male mesoscutum shining with narrow refulgent punctural interstices; lower 0.5 of female mesopleuron strongly to coarsely puncto-reticulate but without coarse longitudinal wrinkling 3. *Compsocryptus fasciipennis*
- 2'. Fore wing mostly to wholly infumate: male mesoscutum with surface dully shining and with only a few polished interstices between the very dense punctures; lower 0.5 of female mesopleuron with puncto-reticulation traversed by coarse longitudinal wrinkles 2. *Compsocryptus orientalis*

1. *Compsocryptus stangei* Porter, NEW SPECIES

(Fig. 1, 2, 6)

FEMALE. Color: antenna black, duller apicad and more shining basad, with dull brown below, especially toward apex; head and mesosoma shining black except for brown staining in antennal scrobes and on mandible; gaster a little dull red with black on most of petiole, vaguely on apex of postpetiole as well as with irregularly developed blackish staining on succeeding tergites; legs with coxa, trochanters, and femur shining black with a little brown at base of femur and with tibia and tarsus dull black except for some dull brown suffusion that is best developed on fore leg; wings deeply infumate with a broad submedian yellow cross-band on fore wing extending from upper corner of median cell, across much of discocubital cell, over much of 1st brachial cell, through basal 0.5 of 2nd discoidal cell to hind margin of wing on base of 2nd brachial cell and about apical 0.3 of anal cell, as well as with a broad postmedian band which traverses hind wing at level of the intercubital both basad and apicad (most extensively).

Length of fore wing: 8.4-8.8 mm. **Flagellum:** stoutly setaceous, rather strongly flattened below on preapical segments; 1st segment 3.4-3.6 as long as deep at apex. **Temple:** at mid-height 0.60-0.64 as long as eye; strongly receding and gently rounded-off. **Occipital carina:** fine and sharp throughout, not flange-like laterally. **Clypeus:** weakly raised and a little asymmetric in profile. **Malar space:** 1.0-1.2 as long as basal width of mandi-

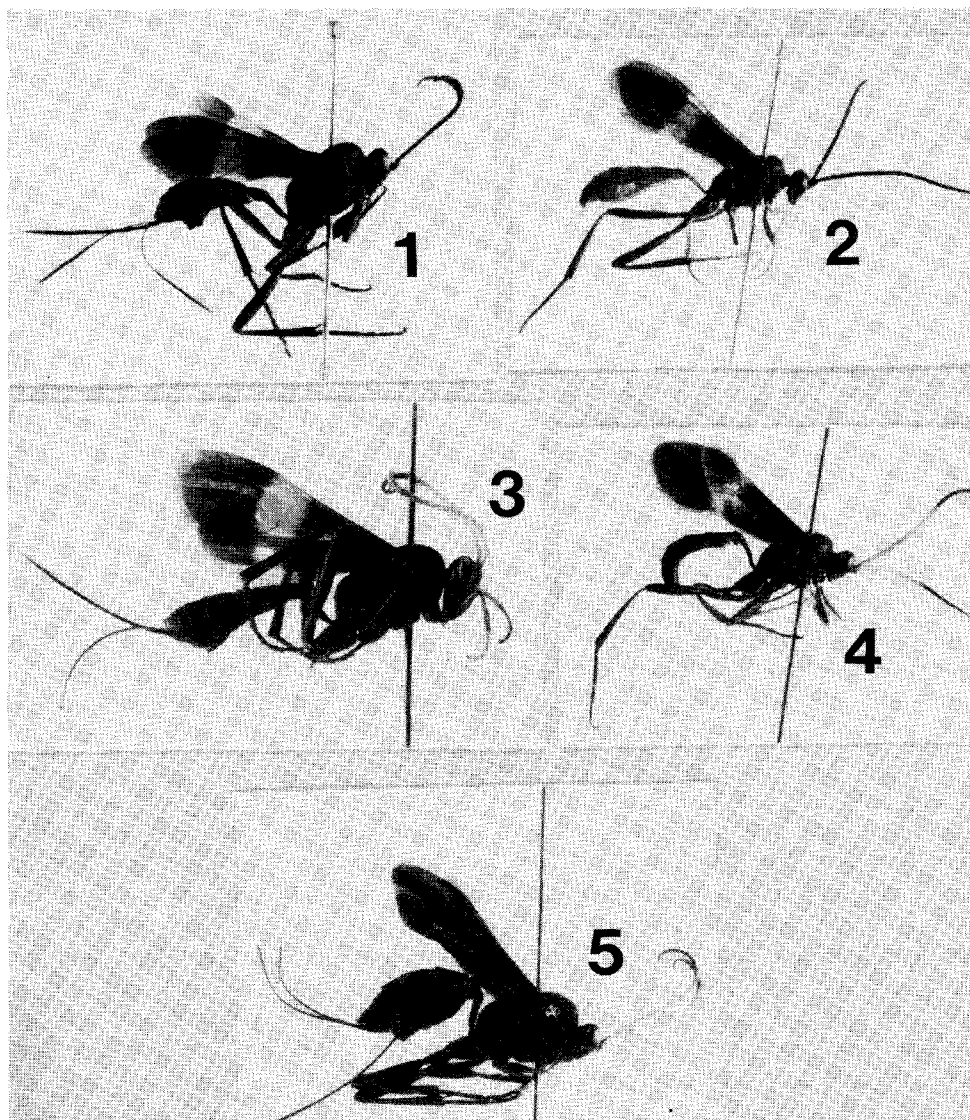


Fig. 1. *Compsocryptus stangei*, ♀. Lateral view of whole insect, showing habitus and color pattern. (Holotype).

Fig. 2. *Compsocryptus stangei*, ♂. Lateral view of whole insect, showing habitus and color pattern. (Paratype).

Fig. 3. *Compsocryptus fasciipennis*, ♀. Lateral view of whole insect, showing habitus and color pattern.

Fig. 4. *Compsocryptus fasciipennis*, ♂. Lateral view of whole insect, showing habitus and color pattern.

Fig. 5. *Compsocryptus orientalis*, ♀. Lateral view of entire insect, showing habitus and color pattern.

ble. *Mesoscutum*: surface brightly shining with very abundant small to medium sized punctures that average briefly subadjacent to adjacent but which display prominent but narrow polished interstices; notauli finely traceable about 0.4 the length of mesoscutum. *Mesopleuron*: disc on upper 0.5 shining, mostly with fine longitudinal striation and with small, dense, briefly subadjacent to confluent punctures which do not become coarse and on lower 0.5 with dense, strong, irregular to longitudinal wrinkles and larger, denser, and in part reticulately intercalated punctures (except becoming shinier and with well separated punctures toward prepectal carina below). *Lower metapleuron*: shining, with abundant, medium sized, adjacent to confluent punctures, so as to appear more or less longitudinally substrate. *Propodeum*: basal transcarina traceable throughout, sometimes strong and sharp and sometimes weak and irregular; apical transcarina sometimes distinct throughout and always developed sublaterally into low, asymmetrically cuneate cristae; surface rather finely reticulo-rugose distad of the basal transcarina. *Second gastric tergite*: sublustrous with uniformly developed very fine reticulo-aciculation and abundant, tiny, shallow punctures, which are mostly subadjacent and emit short but extensively overlapping setae. *Ovipositor*: sheathed portion 0.6-0.69 as long as fore wing.

MALE. *Color*: differs from female as follows: fore and mid femur irregularly dull yellow on and near apices: fore and mid tibia pale but opaque yellow; fore and mid tarsus with dull yellow on at least the basal segments; wings less deeply, more brownish infumate than in female, the fore wing often with irregular yellowish staining in proximal 0.5 of basal and subjacent cells as well as with a broad submedian yellow cross band about as in female, the hind wing rather pale brown with some yellowish toward proximal end of basellan cell and with most of its postmedian 0.3 hyaline or faintly yellowish.

Flagellum: long but rather stout, with a long taper toward apex. *Malar space*: 1.0 as long as basal width of mandible. *Mesoscutum*: largely smooth and shining with abundant but mostly well separated punctures and polished punctural interstices. *Mesopleuron*: on upper 0.5 of disc with extensive polished interstices separating the sharp and numerous but well spaced punctures, on lower 0.5 of disc with dense and strong irregular to longitudinal wrinkles and with larger punctures than on dorsal 0.5 which also are dense and in part reticulately confluent. *Lower metapleuron*: mostly smooth and polished with many large and deep punctures which are well separated on anterior 0.5 of metapleuron, but denser and mingled with longitudinal to reticulate wrinkling on the apical 0.5. *Propodeum*: basal transcarina often sharp and unusually high throughout; apical transcarina represented only by its sublateral cristae which are small but broadly and bluntly projecting.

TYPE MATERIAL. Holotype ♀: DOMINICAN REPUBLIC, Monte Cristi Province, 9 km N. Villa Elisa, 4-VI-1986, R. B. Miller and L. A. Stange. Paratypes 8 ♂: DOMINICAN REPUBLIC, Monte Cristi Province, 9 km N. Villa Elisa, 4-VI-1986, R. B. Miller and L. A. Stange, 9 km N. Monte Cristi, 17-VI-1986, R. B. Miller and L. A. Stange; San Cristóbal Province, San Cristóbal, 19-VI-1986, C. Nunez, insect flight interception trap; Constanza, 3-4000 ft, 21-VII-1938, P. J. Darlington; Cordillera Central, foothills south of Santiago, 28-VI-1938, P. J. Darlington; Mt. Diego de Ocampo, 3-4000 ft, 28-VI-1938, P. J. Darlington. Holotype in Florida State Collection of Arthropods. Paratypes in Florida State Collection of Arthropods (3 ♂), American Entomological Institute (1 ♂), and Museum of Comparative Zoology (4 ♂).

RELATIONSHIPS. *Compsocryptus stangei* differs strongly from its relatives in Cuba, the Bahamas, and south Florida. Some diagnostic features include the red gaster, comparatively elongate 1st flagellomere, uniformly low occipital carina, more shining and less densely puncto-rugose mesoscutum and mesopleuron, as well as its much less strongly sculptured lower metapleuron and propodeum. Since many other *Compsocryptus* differ by far less prominent characters so that "several of the species are difficult

to distinguish" (Townes 1962: 279), it may be conjectured that *C. stangei* has had a long evolutionary history in isolation on Hispaniola.

FIELD NOTES. The specimens collected by Miller and Stange came from semiarid scrub in which the most conspicuous plants were arborescent cacti and *Acacia* spp. Such habitat preference is normal for the principally xerophilous genus *Compsocryptus*.

SPECIFIC NAME. For Dr. Lionel A. Stange of the Florida Department of Agriculture and Consumer Services, whose vast field experience in the Neotropics continually reveals new or unexpected species.

2. *Compsocryptus orientalis* Alayo & Tzankov
(Fig. 5)

FEMALE. *Color*: scape and pedicel shining reddish to yellowish brown; flagellum yellow on segments 1-13 (apical 2-3 segments more or less dusky and 1st segment brownish basad); head, mesosoma, and gaster deep purplish to bluish black with shining brown on most of mandible; fore coxa, trochanters, and femur deep purplish black with more or less of apical 0.4 of femur yellowish on its front face, fore tibia dull purplish black with much dull yellow below and anteriorly; fore tarsus shining dark brown to black; mid and hind legs mostly black, with purplish staining well developed on coxa, trochanters, and femur but duller on tibia and tarsus; fore and hind wing deeply infumate, sometimes with an inconspicuous yellow area near base of stigma.

Length of fore wing: 8.8-11.3 mm. *Flagellum*: stoutly setaceous and flattened below subapically; 1st segment 2.6-3.0 as long as deep at apex. *Temple*: at mid-height 0.73-0.78 as long as eye in lateral view. *Occipital carina*: elevated laterally into a conspicuous flange. *Clypeus*: weakly convex and about symmetrically raised in profile. *Malar space*: 1.0-1.2 as long as basal width of mandible. *Mesoscutum*: surface nearly mat with multitudinous small and sharp, adjacent to a little reticulately confluent punctures, whose interstices are cariniform; notauli traceable about 0.5 length of mesoscutum, weak. *Mesopleuron*: sublustrous; disc on upper 0.5 with granular puncto-reticulation and on lower 0.5 with puncto-reticulation traversed by coarse longitudinal wrinkling (except for a shining and discretely punctate area toward prepectus ventrad). *Lower metapleuron*: very coarsely reticulo-rugose throughout. *Propodeum*: basal transcarina traceable throughout and areola broader than long in position; apical transcarina more or less detectable throughout and forming broad but low subcuneate cristae; whole surface distad of basal transcarina grossly reticulo-rugose. *Second gastric tergite*: mat, surface with uniform and very delicate micro-reticulation and innumerable tiny, shallow punctures, that emit rather long, recumbent, and much overlapping setae. *Ovipositor*: sheathed portion 0.71-0.79 as long as fore wing.

MALE. *Color*: differs from female as follows: fore tibia pale yellow; fore tarsus with 1st segment yellowish and following segments dusky; mid tibia dull blackish with pallid yellow on basal 0.3; fore wing infumate with obscure yellowish staining just below base of stigma, toward base of 2nd discoidal cell (near 1st recurrent), and a little in anal cell; hind wing more pallidly infumate than forewing, obliquely yellowish on basal 0.3 of radiell cell and nearly hyaline on much of cubitell and discoidell cell, especially beyond nervellus both proximally and distally.

Occipital carina: slightly less elevated than in *C. fasciipennis*. *Mesoscutum*: surface dully shining with a few polished ridges between the punctures.

MATERIAL EXAMINED. 8 ♀ and 1 ♂: BAHAMAS, Eleuthera Island, Rainbow Bay, 1-VII-1988, R. W. and D. B. Wiley; Rum Kay, IX-16-1934 (Cambridge, Gainesville: FSCA and AEI).

RELATIONSHIPS. *Compsocryptus orientalis* shares many features with the partially sympatric *C. fasciipennis*. The two probably may be regarded as sister species, because

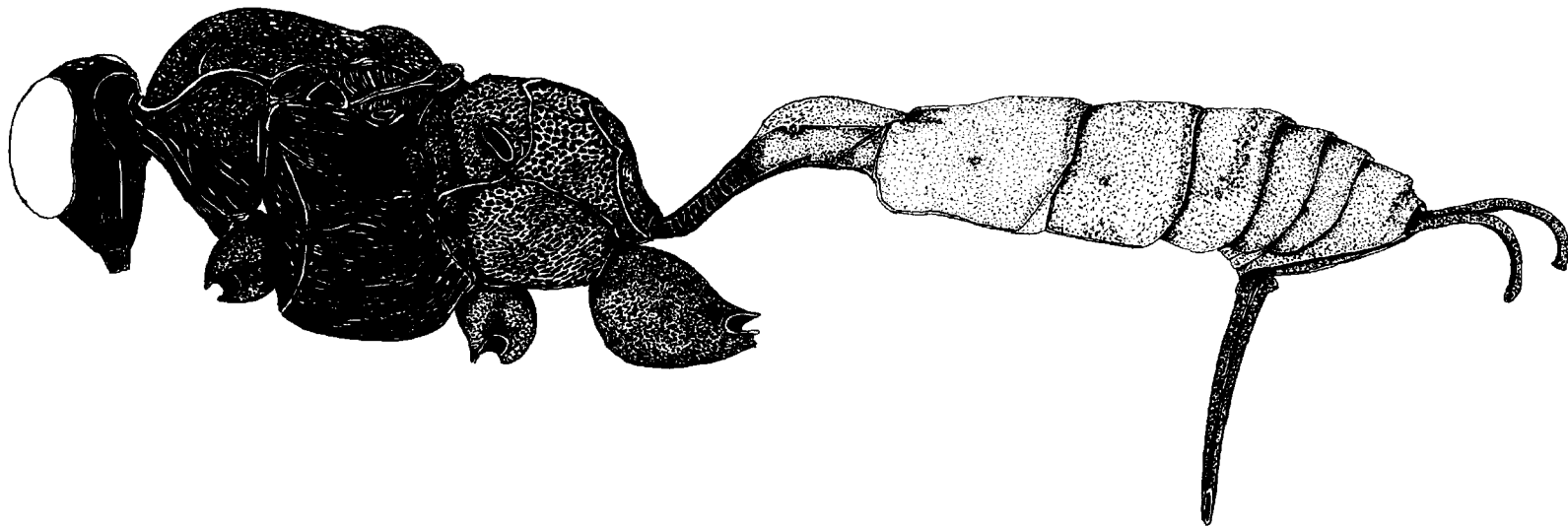


Fig. 6. *Compsocryptus stangei*, ♀. Drawing of head and body in lateral view, showing structural details and color pattern. (Holotype).

each one morphologically is far closer to the other than to any of the rest of the known *Compsocryptus* species. *Compsocryptus orientalis*, nonetheless, easily may be distinguished from *C. fasciipennis* by its almost uniformly dark wings, slightly shorter temple, slightly less convex clypeus, duller and more strongly sculptured mesopleuron with longitudinal wrinkling on its lower 0.5, and by its moderately longer ovipositor.

Both *C. orientalis* and *C. fasciipennis* differ from *C. stangei* by the characters discussed under that species.

FIELD NOTES. Alayo and Tzankov (1947) comment that *C. orientalis* inhabits coastal localities near Santiago de Cuba and that it flies toward evening during June and July. With exception of the 1 February record for Rum Kay, this species seems to show similar habits on the Bahamas.

Since *C. fasciipennis* occurs throughout the year in all parts of Cuba and has reached south Florida and the Keys (where it is most common from October to April but may be found even in summer), this species shares only a narrow zone of sympatry with *C. orientalis* and, even here, is but briefly synchronous with the related taxon. These *Compsocryptus* thus show two modes of competitive exclusion and seem to have arisen allopatrically by habitat division. During late Tertiary and Pleistocene climatic fluctuations, Cuba and the Bahamas were connected overland when cooler episodes reduced the level of the ocean as more water became trapped in the Polar Ice Caps and glaciers. In contrast, warm periods allowed the ice to melt, the ocean to rise, and the Bahaman-Cuban land connection to be broken. Such events provide an ideal scenario for allopatric speciation.

The Wileys report that specimens collected by them on Eleuthera were netted in second-growth Bahaman scrub, an open woodland dominated by *Acacia*, *Metopium*, *Swietenia*, and other tropical Caribbean halophobes. Specimens were netted in cleared areas and at the woods edge. This corroborates the already noted tendency for *Compsocryptus* to occur in disturbed habitats (Porter 1986).

3. *Compsocryptus fasciipennis* (Brullé)

(Fig. 3, 4, 5)

FEMALE. *Color*: Head, body, and wings refulgently bluish black; antenna yellow with dusky staining on its apical 0.3; wings each with a conspicuous transverse orange-yellow band.

Length of fore wing: 8.0-11.7 mm. *Flagellum*: robustly setaceous and quite strongly flattened below subapically; 1st segment 2.6-2.9 as long as deep apically. *Temple*: at mid-height 0.65-0.75 as long as eye in lateral view. *Occipital carina*: elevated laterally into a rather high flange. *Clypeus*: convex, moderately strongly and a little asymmetrically raised in profile. *Malar space*: 1.1-1.2 as long as basal width of mandible. *Mesopleuron*: more shining than in *C. orientalis*; disc on upper 0.5 moderately strongly puncto-reticulate with most punctures distinct and separated in part by some very narrow shining interstices; on lower 0.5 of disc with stronger puncto-reticulation varying to coarse but not gross reticulate wrinkling but without coarse longitudinal wrinkles. *Lower metapleuron*: strongly to coarsely puncto-reticulate (not as strongly so as in *C. orientalis*). *Propodeum*: basal trans-carina more or less traceable throughout; areola approximately as wide as long; median longitudinal carinae often faintly defined; apical trans-carina varying from complete and strong to weak and sometimes medially absent, sublaterally always forming a low but projecting broad and bluntly cuneate crista; surface distad of basal trans-carina strongly reticulo-rugose but less coarsely so than in *C. orientalis*. *Ovipositor*: sheathed portion 0.65-0.67 as long as fore wing.

MALE. Differs from female as follows: *Clypeus*: a little more strongly raised in profile than in female. *Propodeum*: basal trans-carina averaging higher than in female, arched forward to a short median abscissa or almost a point; cristae broad and weakly subcuneate. *Second gastric tergite*: smooth and polished with multitudinous tiny punctures that emit long and much overlapping setae.

MATERIAL EXAMINED. Many ♀ and ♂ from subtropical Florida, including the Miami area and Everglades National Park, as well as the Keys from Key Largo to Key West. (Cambridge, Gainesville: FSCA and AEI).

RELATIONSHIPS. As previously explained, *Compsocryptus fasciipennis* closely resembles the Cuban *C. orientalis*. The best proof of their specific differentiation derives from the fact that both occur sympatrically in the Santiago region of Cuba but show no evidence of hybridization or intergradation in the zone of contact.

FIELD NOTES. This large and brilliantly colored ichneumonid is 1 of the most conspicuous Hymenoptera in south Florida and the Keys. Porter (1986) indicated that its normal flight period extends from October to May, that the species frequents disturbed habitats with much herbaceous vegetation (especially *Bidens*), and that it may be collected both by hand net and by insect flight interception traps.

COLLECTIONS

Material for this study was examined in the following institutional collections, which are listed below according to the cities where they are located and the abbreviated designations by which they are known.

CAMBRIDGE. MCZ. Museum of Comparative Zoology, Harvard University, Cambridge, MA 02138.

GAINESVILLE. AEI. American Entomological Institute (Townes Collection) 3005 SW 56th Avenue, Gainesville, FL 32608.

———. FSCA. Florida State Collection of Arthropods, Bureau of Entomology, Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, FL 32602.

ACKNOWLEDGMENTS


This research derives from work done under National Science Foundation Grant BSR-8313444 (1984-'87) and during a Fordham University Faculty Fellowship awarded for the academic year 1989-'90. The Florida State Collection of Arthropods, the American Entomological Institute, and the Museum of Comparative Zoology generously provided indispensable facilities for study of their ichneumonid collections. I am especially grateful for the generous support of Drs. Frank M. Carpenter and James M. Carpenter at the Museum of Comparative Zoology, of Drs. Henry and Marjorie K. Towses at the American Entomological Institute, and of Drs. Howard V. Weems, Jr. and Lionel A. Stange at the Florida State Collection of Arthropods.

Mr. Thomas J. O'Neill (Fordham College 1987) of New Seabury, Massachusetts prepared the drawing of *Compsocryptus stangei*. Mr. Jeffrey Lotz of the Florida Department of Agriculture and Consumer Services (Division of Plant Industry) took the photographs of *Compsocryptus fasciipennis*, *C. orientalis* and *C. stangei*.

Contribution No. 719, Bureau of Entomology, Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, FL 32601.

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- TOWNES, H. K. 1962. Ichneumon-flies of America north of México: Subfamily Gelinae, Tribe Mesostenini. Bull. U. S. Natl. Museum 216(3): 1-602.



COLEOPTERA OF BERMUDA

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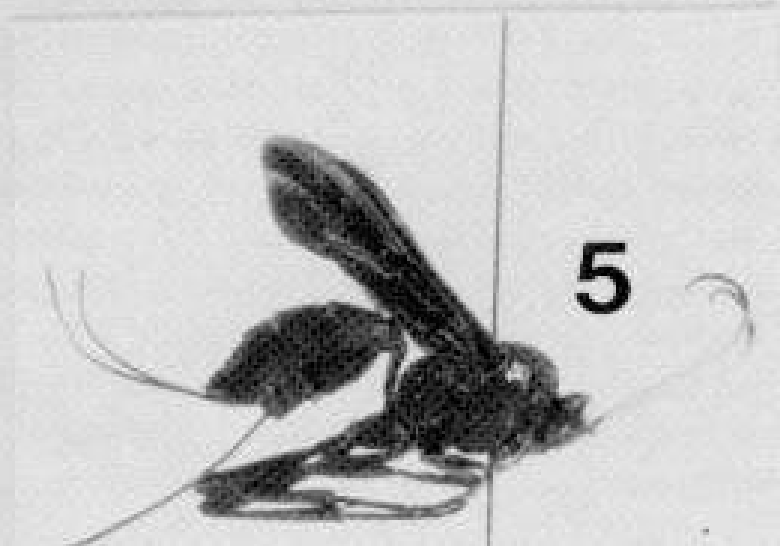
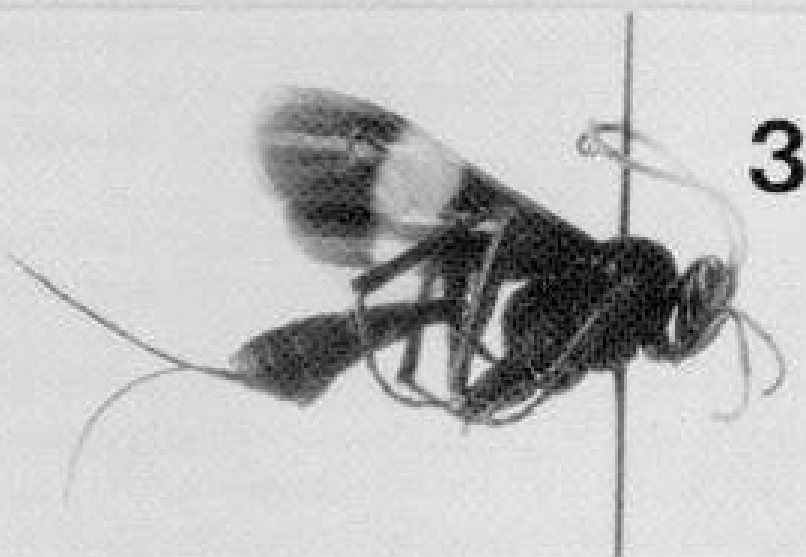
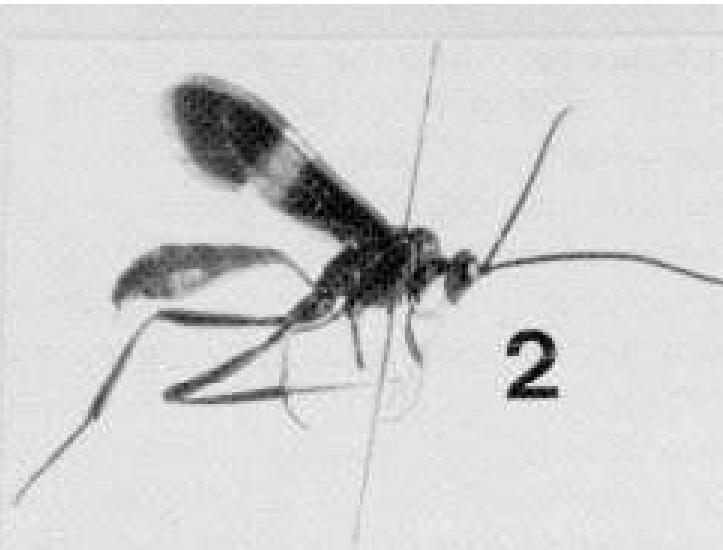
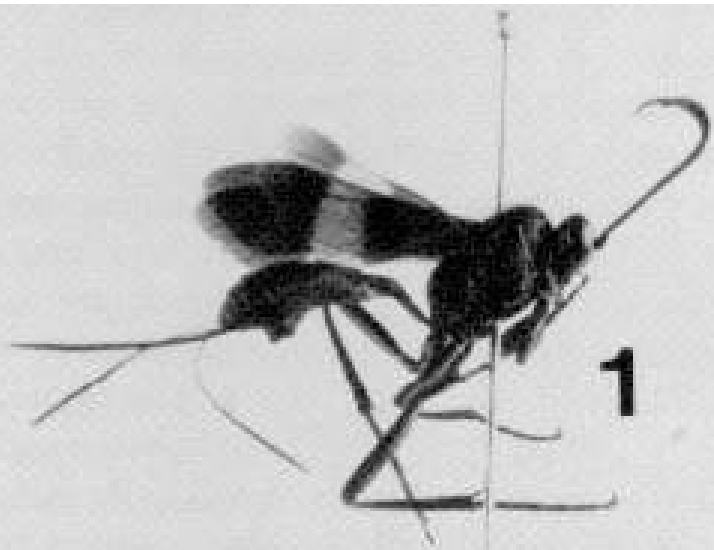
ABSTRACT

A new survey of Bermuda's insects was initiated in 1987. Two hundred and twenty-eight species of Coleoptera (beetles), in 44 families, are found in the Bermuda Department of Agriculture and Fisheries collection, or are reported in the literature. One hundred and twenty-six are new Bermuda records. Sixty-five of the species listed may not be established on the islands; twenty-four are interceptions, and the rest are probably misidentifications or species which were once present but are no longer established. Approximately 41% of the beetles are cosmopolitan or tropicopolitan species, a further 34% occur in eastern or southeastern North America, and 20% originate from the Caribbean region. There are no known endemics.

RESUMEN

Se inició en 1987 una nueva encuesta de los insectos de las Bermudas. Doscientas veinte y ocho especies de Coleópteros (escarabajos) en 44 familias se encuentran en la colección del Departamento de Agricultura y Pesca, o son reportados en la literatura. Ciento veinte y seis son nuevos registros para las Bermudas. Sesenta y cinco de las especies listadas pudieran no estar establecidas en las islas; veinte cuatro son intercepciones, y el resto son probablemente identificaciones erróneas o especies que estuvieron presente pero que ya no están establecidas. Aproximadamente el 41% de los escarabajos son especies cosmopolitas or tropicopolitanas, el 34% ocurre en las zonas este o sudeste de Norteamérica, y el 20% se origina de la región del Caribe. No hay especies endémicas.

Bermuda is a small archipelago in the North Atlantic. Seven main islands and numerous smaller ones lie in a fishhook-shaped cluster centered at 32°18' N, 64°46' W. The closest land is Cape Hatteras, North Carolina, USA., 1040 km to the west-northwest. Total land area is approximately 54 km² with a maximum elevation of only 74 m. The



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Bermuda is a small archipelago in the North Atlantic. Seven main islands and numerous smaller ones lie in a fishhook-shaped cluster centered at 32°18' N, 64°46' W. The closest land is Cape Hatteras, North Carolina, USA., 1040 km to the west-northwest. Total land area is approximately 54 km² with a maximum elevation of only 74 m. The

climate is mild and frost-free due to the nearby Gulf Stream. Rainfall is distributed fairly evenly throughout the year and averages 1420 mm annually. Vegetation is lush and subtropical. The human population is dense on nearly all of the land; there are approximately 60,000 residents.

Due to its small size, isolation, and geologically young age, Bermuda's native terrestrial flora and fauna are depauperate. There are few endemic species and no known endemic Coleoptera; nearly all the beetles have been introduced accidentally by human activity. Approximately 41% of the Coleoptera are cosmopolitan or tropicopolitan species, a further 34% occur in eastern or southeastern North America, and 20% originate from the Caribbean region.

Kevan (1981) presents a historical review of our knowledge of terrestrial arthropods in Bermuda from the earliest mention of insects in 1603 through the early 1900s. The most complete and reliable species lists are given by Jones (1876) and Verrill (1902). Ogilvie (1928) reviewed these and other early accounts of insects in Bermuda and published a "complete" list of Bermuda's insects, including seventy-eight species of Coleoptera. Eight additional species were reported in a supplementary list published by Waterston (1940), and one new record appears in Hughes & Schuster (1986).

In the late 1940s and early 1950s, Bermuda's dominant tree species, *Juniperus bermudiana* L., was nearly wiped out by an infestation of scale insects, *Carulaspis minima* (Targgioni-Tozzetti) and *Insulaspis newsteadi* (Sulc) (Challinor & Wingate 1971). The Bermuda Department of Agriculture and Fisheries (BDAF) imported forty-four species of Coccinellidae in an attempt to control this outbreak. Bennett & Hughes (1959) and Bennett et al. (1985) list these species and others brought in over the years for biological control.

BDAF has maintained an insect collection since 1923. Many specimens collected by Lawrence Ogilvie between 1923 and 1927 are still found there. Since then, additions to the collection have been sporadic. Major contributions were made by Dr. I. W. Hughes between 1954 and 1975, and Francis Monkman between 1964 and 1971. Kevin Monkman, an Entomologist employed from 1983 to 1986, also made additions. As a result of an initiative by Dr. I. W. Hughes in 1977, a beginning was made of a modern reappraisal of the Bermudian insect fauna. This resulted in the publication of a comprehensive account of the orthopteroid fauna of the islands by Kevan (1980). In 1987 the project was revived by the senior author and an attempt was made to survey the remainder of Bermuda's insects, upgrade the BDAF collection, and transfer most of it to the new Bermuda Natural History Museum (BNHM). A small reference collection will be maintained at the BDAF laboratory in Paget. Thousands of new specimens were added and a major effort was made to get the entire collection identified. Determinations of Coleoptera were made with the help of the junior author and twenty other specialists. Additional reports are planned to cover other insect groups.

The following list of two hundred and twenty-eight species in forty-four families includes all the Coleoptera currently found in the BDAF collection as well as those reported by Jones (1876), Verrill (1902), Ogilvie (1928), Waterston (1940) and Hughes & Schuster (1986). Of the coccinellids that were brought in for biological control, only the established species are listed. Sixty-five records are tentative, including twenty-four interceptions; most of the rest are probably misidentifications, but some may represent species that were present at one time, but are no longer established. One hundred and twenty-six new Bermuda records are reported. The list is arranged alphabetically by family, and by genus and species within families. Common names are from the approved list of the Entomological Society of America.

Voucher specimens are in the collections at BNHM in Flatts, and BDAF in Paget.

ALLECULIDAE

Hymenorus obscurus Say

(Jones 1876, Ogilvie 1928). Rare (Jones 1876). No specimens in BDAF collection. May no longer be established.

ANOBIIDAE

Caenocara sp. New Record

One specimen collected in 1951 on *Cycas revoluta* Thunberg infested with mealybugs.

Cryptoramorphus sp. New Record

Two specimens collected May 1987, St. Paul's Church, Paget Parish, while beating trees and shrubs. One additional specimen collected May 1987, Botanical Gardens, Paget Parish while sweeping. Species is apparently undescribed.

Lasioderma serricorne (F.)

(Verrill 1902, Ogilvie 1928). Cigarette beetle. In papaya seeds from Florida, gelatin boxes, citrus pulp, etc. Common in stored products. Cosmopolitan.

Nicobium castaneum (Olivier) New Record

Two specimens collected July 1956, Hamilton, Pembroke Parish in a wooden box. Known from Europe and North America.

Oligomerus sp.

(= *Oligomerus obtusus* Lec.; Waterston 1940). First collected June 1939 in woodwork. In June 1987 collected from maple flooring in Paget Parish.

Tricorynus herbarius (Gorham)

(*Catorama herbarium* Gorh.; Ogilvie 1928). In upholstery, books, and various foodstuffs and stored products. Common. Neotropical.

ANTHICIDAE

Anthicus cervinus LaFerte New Record

One specimen collected June 1966, Botanical Gardens, Paget Parish, with vapour lamp. A common species in eastern USA.

Anthicus ephippium LaFerte New Record

Three specimens collected August 1967, Warwick Pond, Warwick Parish, in a light trap. Widespread in North America.

ANTHRIBIDAE

Araecerus fasciculatus (De Geer)

(Verrill 1902, Ogilvie 1928). Coffee bean weevil. Reared from bananas in July 1925. Adults collected by sweeping grass on Nonsuch Island, St. George's Parish, Aug. 1967. One specimen intercepted on orchids from Thailand July 1987. Cosmopolitan.

BOSTRICHIDAE

Amphicerus bicaudatus (Say) New Record

Apple twig borer. One specimen collected December 1982 in Paget Parish. May not be established. Known from eastern North America.

Rhyzopertha dominica (F.) New Record

Lesser grain borer. First collected June 1966, Paget Parish, in chicken feed. Distributed by commerce throughout the world.

Xylopsocus capucinus (F.) New Record

One specimen collected July 1941, Paget Parish, under dead bark of *Delonix regia* (Bojer) Rafinesque. Widely distributed in all tropical regions by commerce.

BRUCHIDAE

Acanthoscelides obtectus (Say)

(= *Bruchus obtectus* Say; Verrill 1902, Ogilvie 1928). Bean weevil. Last collected in 1983, no locality given. Attacks *Phaseolus* spp. seeds. Cosmopolitan.

Bruchus chinensis L.

(Verrill 1902, Ogilvie 1928). No specimens in BDAF collection. Possibly misidentified or no longer established. A cosmopolitan insect with many hosts.

Bruchus pisorum (L.)

(Verrill 1902, Ogilvie 1928). Pea weevil. No specimens in BDAF collection. Reported to be destructive to seeds of Fava and broad beans (Ogilvie 1928). *B. pisorum* is restricted to *Pisum* sp., Fava and broad beans are host to *B. rufimanus* Boheman.

Bruchus quadrimaculatus F.

(Ogilvie 1928). No specimens in BDAF collection. Reported to be destructive to stored beans (Ogilvie 1928).

Callosobruchus maculatus (F.) New Record

Cowpea weevil. First collected September 1950. Common in dried beans. Cosmopolitan.

Caryedon serratus (Olivier)

(= *Pachymerus gonager* (F.); Ogilvie 1928). Intercepted in seeds from India, 1924. Not established. Tropicopolitan. Spread through plantings of *Tamarindus* sp.

Caryobruchus gleditsiae (L.) New Record

Larvae develop in palm seeds. Adults first collected in October, 1987 in a light trap and a Malaise trap on Berry Hill Road, Paget Parish. Found in seeds of *Sabal bermudana* L. H. Bailey, June 1988, Nonsuch Island, St. George's Parish. Seventy one (7.3%) of a total of 971 *S. bermudana* seeds collected in Sept. 1988 on Nonsuch Island had round holes in the seed coat indicating parasitism by *C. gleditsiae*. Known from the West Indies, Florida, and Gulf Coast States.

Pygiopachymerus lineola (Chevrolat) New Record

Intercepted in *Cassia javanica* L. seeds from Trinidad Feb. 1935 and April 1968. Not established. Known from Costa Rica to Brazil.

BUPRESTIDAE

Buprestis aurulenta L. New Record

Golden buprestid. Collected in a house May 1967, Paget Parish. Not established. Known from western USA and Canada.

Buprestis salisburyensis Herbst

(= *Buprestis decora* F.; Jones 1876, Ogilvie 1928, = *Ancylocheira decora* (F.); Verrill 1902). No specimens in BDAF collection. Probably misidentified or no longer established. Known from eastern USA and Canada.

Buprestis lineata (F.) New Record

Collected from a bookshelf 1950, Tuckers Town, St. George's Parish. Not established. Known from eastern USA and Canada.

Chrysobothris tranquebarica Gmelin

(= *Chrysobothris impressa* F.; Verrill 1902, Ogilvie 1928). No specimens in BDAF collection. Probably no longer established. Known from Florida and the West Indies.

CANTHARIDAE

Caccodes oceaniae Bourgois New Record

First collected May 1987, Admiralty House Park, Pembroke Parish, while beating trees and shrubs. Subsequent collections Sept. 1987, Berry Hill Rd., Paget Parish, and Botanical Gardens, Paget Parish. Recorded from the New Hebrides.

CARABIDAE

Agonum punctiforme (Say)

(Verrill 1902, Ogilvie 1928, = *Platynus punctiformis*; Jones 1876). Not common. Occasionally in light traps or under stones. Occurs in eastern North America.

Anchomenus cincticollis (Say)

(Ogilvie 1928, m = *Platynus cincticollis*; Jones 1876). No specimens in BDAF collection. Possibly misidentified or no longer established. Known from eastern North America.

Notiobia prob. *terminata* (Say) New Record

First collected Sept. 1966, Mount Hill, Pembroke Parish. Now widespread and common in light traps in the fall. *N. terminata* is an eastern North American species.

Perigona nigriceps Dejean New Record

First collected October 1987 in light traps at Spittal Pond, Smith's Parish, and Berry Hill Road, Paget Parish. Widespread in USA.

Pristonychus complanatus Dejean

(Jones 1876, = *Laemosthenes complanatus* Dej.; Ogilvie 1928). Fairly common, most specimens collected from soil. This species is native to north Africa and western Europe, but it has been introduced into North America.

Stenolophus lineola (F.)

(= *Agonoderus lineola* F.; Jones 1876, Ogilvie 1928). Common in light traps. Known from southeastern USA.

Stenolophus plebejus Dejean New Record

Two specimens collected Feb. 1988 in light traps at Spittal Pond, Smith's Parish, and Berry Hill Rd., Paget Parish. Occurs in eastern North America.

CERAMBYCIDAE

Achryson surinamum (L.)

(= *Achryson* sp., Ogilvie 1928). No specimens in BDAF collection. Known from North, Central, and South America and the West Indies.

Anelaphus cinereum (Olivier) New Record

One specimen collected on a building at the Botanical Gardens, Paget Parish, in 1955; a second specimen from a light trap in Smith's Parish, 1955. Known from Florida and the West Indies.

Curtomerus flavus (F.) New Record

First collected in a house, Sept. 1967, Mount Hill, Pembroke Parish. Now widespread and common. Known from Florida, Mexico, South America, and the West Indies.

Eburia stigma (Olivier) New Record

Intercepted in floor boards from USA, no date given. Known from Florida, Mexico, Costa Rica, and the West Indies.

Eburia quadrigeminata (Say) New Record

Intercepted on furniture from England Dec. 1949. Not established. An eastern North American species.

Leptostyloides assimilis (Gahan) New Record

One specimen collected Aug. 1973, Hamilton Parish. Known from Mexico and the West Indies.

Leptostyloides praemorsus (F.)

(Ogilvie 1928). At lights and in dead wood. Larvae destructive to *Delonix regia* trees (Ogilvie 1928). Common. Known from Mexico and the West Indies.

Monochamus titillator (F.)

(Ogilvie 1928). Southern pine sawyer. No collections since 1928. Not established. Known from eastern USA and the West Indies.

Oeme rigida (Say)

(= *Oeme linearis* Harris; Ogilvie 1928). Collected at a light in 1950. Reared from dead *Cupressus* sp., Feb. 1986, Hamilton Parish. Known from eastern USA.

Plectromerus dentipes (Olivier) New Record

First collected 1950 on *Juniperus bermudiana*. One specimen from a house July 1970, Bailey's Bay, Hamilton Parish. Known from Florida to Louisiana and Cuba.

Styloleptus posticalis (Gahan) New Record

First collected June 1950 from wood of *Juniperus bermudiana*. Also April 1967, Mount Hill, Pembroke Parish, at a light. A West Indian species.

Urgleptes quadaloupensis (Fleutiaux & Sallé) New Record

First collected Feb. 1967, Botanical Gardens, Paget Parish. Now widespread but not common. A West Indian species.

CERYLONIDAE

Euxestus erithacus Chevrolat New Record

One specimen collected Aug. 1987, Mullet Bay Rd., St. George's Parish, on *Turnera ulmifolia* L.; a second specimen collected July 1988, Berry Hill Rd., Paget Parish, in a house. Known from Mexico and the West Indies.

CHRYSOMELIDAE

Agelastica alni (L.)

Intercepted on *Rosa* sp. from Holland, Jan. 1933. Not established. Known from North America and Europe.

Altica sp. near *fuscoaenea* Melsheimer New Record

Collected in a light trap, July 1971, Ferry Reach, St. George's Parish.

Altica spp.

(= *Graptodera chalybea* (Illiger), *Haltica ignita* (Illiger); Verrill 1902; = *H. amaena* Horn, *H. chalybea* (Illiger), *H. ignita* (Illiger); Ogilvie 1928). Specimens from Botanical Gardens, Paget Parish, 1925; Devonshire Marsh, Devonshire Parish, 1955; and near Camden House, Paget Parish, 1955.

Calomicrus sp. or near New Record

Intercepted on *Protea* sp. from South Africa May 1967. Not established.

Chaetocnema brunnescens Horn New Record

First collected Aug. 1966, Spittal Pond, Smith's Parish, on *Conocarpus erecta* L. leaves. Also on *C. erecta* Aug. 1967, Nonsuch Island, St. George's Parish, and July 1987, airport, St. George's Parish. A West Indian species.

Chaetocnema sp. prob. *confinis* Crotch

(= *Chaetocnema apricaria* Suff.; Ogilvie 1928). Sweetpotato flea beetle. Reported to be injurious to leaves of sweet potato, Irish potato, tomato, and eggplant (Ogilvie 1928). Common on leaves of sweet potato, *Ipomoea batatas* (L.), leaves. A North American species.

Chaetocnema denticulata Illiger New Record

Toothed flea beetle. One specimen collected April 1967, Botanical Gardens, Paget Parish. Known from eastern USA.

Chaetocnema sp. near *perplexa* Blake New Record

One specimen collected Aug. 1987, Spittal Pond, Smith's Parish, while sweeping.

Chirodica elongata Baly New Record

Intercepted on *Protea* sp. from South Africa, May 1967. Not established.

Chrysomela polita L. New Record

Collected on cabbage in 1949, Pembroke Parish. Not established. A European species.

Epitrix hirtipennis (Melsheimer)

(=*E. parvula* (F.); Verrill 1902, Ogilvie 1928). Tobacco flea beetle. Reported as injurious to leaves of sweet potato, Irish Potato, morning glory and related plants during the summer (Ogilvie 1928). Common on Irish potato, *Solanum tuberosum* L., leaves May 1969, Southampton Parish. Known from eastern USA.

Leptinotarsa decemlineata (Say)

(Waterston 1940). Colorado potato beetle. Intercepted on Irish potatoes Dec. 1940. Not established. Known from North America and Europe.

Phyllotreta sp.

(Ogilvie 1928). No specimens in BDAF collection. Possibly misidentified or no longer established.

CICINDELIDAE

Cicindela trifasciata LeConte

(Hughes & Schuster 1986, =*Cicindela tortuosa* Dej.; Jones 1876, Verrill 1902, Ogilvie 1928). Once very common in summer (Jones 1876). Now rare in intertidal and supratidal beach habitats. Most recently collected at Hungry Bay, Paget Parish, June 1956 and Whale Bone Bay, St. George's Parish, October 1970. Known from southeastern USA.

CLERIDAE

Necrobia rufipes (DeGeer)

(Verrill 1902, Ogilvie 1928). Redlegged ham beetle. Larva damages hams and bacons (Verrill 1902). No specimens in BDAF collection. Probably no longer established. Cosmopolitan.

Tarsostenus univittatus (Rossi) New Record

Collected from mahogany lumber June 1969, Pembroke Parish. Not established. Cosmopolitan.

COCCINELLIDAE

Azya orbiger Mulsant

(Bennett et al. 1985, =*A. luteipes* Mulsant; Bennett & Hughes 1959). Feeds on scales. 15,000 imported from Trinidad in 1956-57. Larvae covered with wax. Neotropical, but intentionally established in several parts of the world.

Chilocorus cacti (L.)

(Bennett & Hughes 1959, Bennett et al. 1985). Feeds on scales, especially *Comstockiella sabalis* (Comst.). Imported from Cuba and Jamaica in 1948 and 1951. Known from southern USA to South America.

Clitostethus arcuatus (Rossi)

(Bennett et al. 1985). Feeds on *Metaleurodicus cardini* (Back), a whitefly on fiddlewood, *Citharexylum spinosum* L. A European species.

Coccinella septempunctata (L.) New Record

Intercepted on Christmas trees from Washington, USA in Dec. 1987. Not established. Palearctic, but established in USA.

Cryptolaemus montrouzieri Mulsant

(Bennett & Hughes 1959, Bennett et al. 1985). Mealybug destroyer. Imported in large numbers from Australia via Trinidad in 1956-57. Rare in Bermuda. Native to Australia, but intentionally established in many parts of the world.

Cycloneda munda (Say)

(= *Coccinella munda* L.; Ogilvie 1928). Feeds on aphids. Once common, now very rare. Known from eastern North America.

Decadiomus sp.

(? = *Scymnus* sp., Bennett et al. 1985). An undescribed species. Common on *Pittosporum* sp. and *Cycas revoluta* when infested with mealybugs; also collected by sweeping.

Diomus terminatus (Say)

(= *Scymnus terminatus* Say.; Ogilvie 1928). Fairly common in sweepnet samples. Known from eastern USA.

Exochomus californicus Casey New Record

Intercepted on Christmas trees from Oregon, USA in Dec. 1987. Not established. Known from west coast USA.

Exochomus jamaicensis Sicard

(Bennett & Hughes 1959, Bennett et al. 1985). Very common. Feeds primarily on aphids. Imported from Jamaica in 1951. Previously known only from Jamaica.

Hippodamia tredecimpunctata tibialis (Say) New Record

Thirteenspotted lady beetle. Intercepted on vegetables from USA Oct. 1946. Not established. Nearctic.

Microweisea suturalis (Schwarz)

(Bennett & Hughes 1959, Bennett et al. 1985). On *Juniperus bermudiana*. Feeds on scales. Imported from California in 1949. Known from California, USA.

Naemia seriata seriata (Melsheimer) New Record

Three specimens collected in 1955 at "Camden Marsh", Paget Parish (now filled in). One adult collected Nov. 1987 at Spittal Pond, Smith's Parish, a larva collected July 1987 also at Spittal Pond. Very rare. East coast USA from Rhode Island to Texas.

Rhyzobius lophanthae (Blaisdell)

(Bennett et al. 1985, = *Lindorus lophanthae*; Bennett & Hughes 1959). Primarily on *Juniperus bermudiana*. Common. Feeds on scales. Imported from Australia in 1947-48, and 1951. Known from eastern North America.

Rodolia cardinalis (Mulsant)

(Bennett & Hughes 1959, Bennett et al. 1985, = *Novius cardinalis* Muls.; Ogilvie 1928). Vedalia. Feeds on cottony cushion scale, *Icerya purchasi* Mask. Imported from California in 1902. Native to Australia, but intentionally established in many parts of the world.

Scymnus (Pullus) creperus Mulsant

(? = *Scymnus* sp.; Bennett & Hughes 1959, Bennett et al. 1985). Occasionally in sweepnet samples. Known from southeastern USA.

Scymnus (Scymnus) floralis (F.)

(? = *Scymnus* sp.; Bennett & Hughes 1959, Bennett et al. 1985). Very common. Often collected while sweeping or beating. Feeds on aphids. A West Indian species.

CORYLOPHIDAE

Sericoderus sp.

(Ogilvie 1928). No specimens in BDAF collection. Reported from decaying bananas (Ogilvie 1928). Possibly misidentified or no longer established.

CRYPTOPHAGIDAE

Ephistemus sp. New Record

Three specimens collected in a light trap, Oct. 1987, Berry Hill Rd., Paget Parish.

CUCUJIDAE

Ahasverus advena (Waltl) New Record

Foreign grain beetle. In raw peanuts Jan. 1967, Mount Hill, Pembroke Parish. Cosmopolitan.

Cryptolestes ferrugineus (Stephens)

(= *Laemophlaeus pusillus* Schonh.; Ogilvie 1928). Rusty grain beetle. From stored flour. No collections since 1924. Cosmopolitan.

Oryzaephilus mercator (Fauvel) New Record

Merchant grain beetle. In flour 1955, Botanical Gardens, Paget Parish, and in raw peanuts Jan. 1967, Mount Hill, Pembroke Parish. Cosmopolitan.

Oryzaephilus surinamensis (L.)

(= *Silvanus surinamensis* L.; Verrill 1902, Ogilvie 1928) Sawtoothed grain beetle. In dry dog food and other stored products. Cosmopolitan.

CURCULIONIDAE

Acalles sp. New Record

On beach or strand plants. First collected 1955, Botanical Gardens, Paget Parish. On *Conocarpus erecta* at Spittal Pond, Smith's Parish, August 1968, and on *Tamarix* sp. at Ferry Reach, St. George's Parish, May 1987.

Anchonus spp.

(Verrill 1902, Ogilvie 1928). At least two species. On beach or strand plants. Also collected under bark, in soil, and at lights. Fairly common.

Anthonomus juniperinus (Sanborn) New Record

First collected March 1987 on *Juniperus bermudiana*, but probably established years before. Feeds on fungus. Widespread and common. Known from southeastern USA and Oregon.

Anthonomus irroratus Dietz New Record

First collected March 1987, but probably established years before. Common. Feeds on Surinam cherry, *Eugenia uniflora* L. and secondarily on guava. Collected in houses, light traps, Malaise traps, and on *E. uniflora*. Known from Florida, Mexico, Cuba, and Puerto Rico.

Artipus sp. New Record

Intercepted from Jamaica on *Casuarina* sp. June 1960. Not established.

Brachyomus octotuberculatus (F.) New Record

Intercepted from Trinidad in peppers, March 1987. Not established. Known from northeastern South America and Trinidad.

Cosmopolites sordidus (Germar)

(Ogilvie 1928). Banana root borer. Ogilvie (1928) reported this species was of serious

importance in Bermuda only where bananas were grown in unsuitable soil or situations where the plants were otherwise weakened. Last collected in 1955, may no longer be established. Pantropical.

Diaprepes famelicus (Olivier)

(= *Diaprepes esuriens* Gyl.; Verrill 1902, Ogilvie 1928). Very common. Known locally as the "donkey beetle." Adults eat notches from leaves of loquats, roses, sweet peas, citrus, etc. Larvae feed on roots of citrus and probably other plants. Occasionally a pest of potatoes. Known from the Lesser Antilles.

Epicaerus imbricatus (Say)

(Verrill 1902, Ogilvie 1928). Imbricated snout beetle. Reported to be destructive to onions, cabbages, and other crops (Verrill 1902). No longer a pest. No specimens in BDAF collection. Possibly no longer established. Known from eastern USA and Mexico.

Euscepes porcellus Boheman New Record

One specimen collected Sept. 1983, on sweet potato, *Ipomoea batatas* (L.), Devonshire Parish. Known from Florida, Central America, and the West Indies.

Euscepes postfaciatus (Fairmaire)

(Waterston 1940). West Indian sweetpotato weevil. Causes loss to sweet potato tubers, *Ipomoea batatas* (L.), when left too long in the ground (Waterston 1940). Known from the West Indies, South America, California, Hawaii, Tahiti, and the Old World.

Exophthalmus vittatus (L.) New Record

Intercepted from Jamaica, June 1956. Not established. A Jamaican species.

Himatium sp. New Record

Intercepted from South Africa on *Protea* sp., June 1967. Not established.

Hypera postica (Gyllenhal) New Record

First collected in 1945. Common on *Medicago hispida* Gaertner on Nonsuch Island, St. Georges's Parish, February 1967. An Old World species which has spread throughout North America.

Lepyryus sp.

(Jones 1876, Ogilvie 1928). Common in summer (Jones 1876). No specimens in BDAF collection. Possibly misidentified or no longer established.

Listroderes difficilis Germain New Record

Several specimens collected June 1966, Mount Hill, Pembroke Parish, at a light. Immigrant from South America, probably via USA. May not be established. Native to southern South America, but now widespread in southern USA.

Nanus uniformis Boheman New Record

Collected on dead palm leaves in Paget Parish, 1955. A West Indian species also found in Florida and Central America.

Otiorryhynchus sulcatus F.

(Ogilvie 1928). Black vine weevil. Intercepted on plants from England, 1925. Not established. Native to Europe, but now widespread in North America.

Pantomorus cervinus (Boheman) New Record

On *Conocarpus erecta* at Spittal Pond, Smith's Parish, July 1968. Widespread in both Old and New Worlds.

Rhynchophorus ferrugineus F.

(Waterston 1940). Intercepted on seeds of *Elaeis guineensis* Jacquin from India in 1931. No specimens in BDAF collection. Not established. An oriental species.

Sitona hispidulus (F.) New Record

Clover root curculio. One specimen collected July 1982, Pembroke Parish. May not be established. An Old World species now widespread in North America.

Sitona lineatus (L.)

(= *S. lineata* L.; Ogilvie 1928). Pea leaf weevil. Large number collected on Nonsuch

Island, St. George's Parish, February 1967 on *Medicago hispida*, and while sweeping grasses in Paget Marsh, March 1968. Recent collections from Spittal Pond, Smith's Parish, and Stokes Point, St. George's Parish, Jan. 1988. Immigrant from Europe now established on east and west coasts of North America.

Sitophilus granarius (L.)

(= *Calandra granaria* (L.) in part; Verrill 1902, Ogilvie 1928). Granary weevil. Last collected in 1924 from a grocery store. Probably not established. Cosmopolitan.

Sitophilus oryzae (L.)

(= *Calandra oryzae* (L.); Jones 1876, Verrill 1902, Ogilvie 1928). Rice weevil. In chicken feed, macaroni and other stored products. Common. Cosmopolitan.

Sitophilus zeamais Motschulsky

(= *Calandra granaria* (L.) in part; Ogilvie 1928). Maize weevil. Recorded as early as 1622 as destructive to stored corn (Ogilvie 1928). Common in stored corn and macaroni. Cosmopolitan.

Sphenophorus venatus vestitus Chittenden

(= *Sphenophorus reticulaticollis* Boh., Ogilvie 1928). Not uncommon in 1928. Now rare. Probably an immigrant from eastern North America.

Tomolips sp. New Record

First collected March 1966, Hayden House, Sandy's Parish, in an old cedar.

DERMESTIDAE

Anthrenus flavipes LeConte New Record

(= *Anthrenus vorax* Waterh.; Waterston 1940). Furniture carpet beetle. From damaged upholstered furniture and bristles of a paint brush. Cosmopolitan.

Anthrenus scrophulariae (L.)

(Verrill 1902, Ogilvie 1928). Carpet beetle. No specimens in BDAF collection. Cosmopolitan.

Anthrenus verbasci (L.)

(Verrill 1902, Ogilvie 1928). Varied carpet beetle. No specimens in BDAF collection. Cosmopolitan.

Attagenus unicolor (Brahm)

(= *A. piceus* Olivier; Verrill 1902, Ogilvie 1928). No specimens in BDAF collection. Cosmopolitan.

Cacoleptus sp. New Record

One specimen collected in 1951, no locality given. A genus found in the Neotropics.

Cryptorhopalum sp. New Record

One specimen collected in a house July 1966, Mount Hill, Pembroke Parish. A genus found in the Neotropics.

Dermestes lardarius L.

(Verrill 1902, Ogilvie 1928). Larder beetle. No specimens in BDAF collection. Cosmopolitan.

Dermestes maculatus De Geer New Record

Hide beetle. Several specimens collected in 1982, Warwick Parish. Cosmopolitan.

Orphinus fulvipes (Guerin-Meneville) New Record

One specimen collected June 1987, St. George's Parish, in a house. Cosmopolitan.

DRYOPIDAE

Pelonomus sp. near *obscurus* LeConte New Record

Collected in a light trap July 1967, Smith's Parish.

DYTISCIDAE

Rhantus calidus (F.) New Record

One specimen collected August 1956, from a pond near Horseshoe Bay, Southampton Parish.

Thermonectus ornatcollis Aubé

(Jones 1876, Verrill 1902, Ogilvie 1928). No specimens in BDAF collection. Possibly misidentified or no longer established.

ELATERIDAE

Agriotes sp.

(Jones 1876, Verrill 1902, Ogilvie 1928). Reported to be common by Jones (1876) and Verrill (1902). No specimens in BDAF collection. Probably misidentified or no longer established.

Anoplischius sp. New Record

Intercepted on citrus from Florida, Jan. 1934. Not established.

Conoderus amplicollis (Gyllenhal) New Record

Gulf wireworm. First collected Sept. 1966, Mount Hill, Pembroke Parish. In soil or at lights. A pest species found in southeastern USA.

Conoderus sp. possibly *castanipes* (F.) New Record

First collected June 1964, Mount Hill, Pembroke Parish. Most collections from sweeping or in light traps.

Monocrepidius lividus De Geer

(Verrill 1902, Ogilvie 1928). No specimens in BDAF collection. Probably misidentified or no longer established.

HELODIDAE

Cyphon sp. New Record

Three specimens collected as follows: May 1987, St. Paul's Church, Paget parish, while beating trees and shrubs; and Nov. and Jan. 1988, Devonshire Marsh, Devonshire Parish.

HETEROCERIDAE

Neoheterocerus angustatus (Chevrolat) New Record

Collected in a light trap at Warwick Pond, Warwick Parish, Aug. 1967. Known from the West Indies, Florida, and Louisiana.

HISTERIDAE

Carcinops sp. New Record

One specimen from rotting papaya May 1966, Botanical Gardens, Paget Parish.

Hypocaccus sp. prob. *apricarius* Erichson

(Ogilvie 1928). One specimen on seaweed Oct. 1924, Paget Parish. No subsequent collections. *H. apricarius* is a New World species.

HYDROPHILIDAE

Berosus infuscatus Leconte

(Waterston 1940). Common water beetle in Pembroke Marsh (Waterston 1940). Ad-

ditional collections from Devonshire Marsh, Devonshire Parish, Camden Marsh, Paget Parish (now filled in), and in a light trap Berry Hill Rd., Paget Parish. Found in southern Canada, USA, and Central America.

Cercyon depressus Stephens New Record

One specimen collected Oct. 1987, Berry Hill Rd., Paget Parish. Found along east coast USA from Massachusetts to Virginia.

Cercyon litoralis (Gyllenhal) New Record

Three specimens collected July 1959, no locality given. A coastal species found from Nova Scotia to Virginia.

Cercyon praetextatus (Say) New Record

One specimen collected August 1967, Warwick Pond, Warwick Parish, in a light trap. Widespread in North and Central America, and in the West Indies.

Cyclonotum sp.

(Ogilvie 1928). No specimens in BDAF collection. Possibly misidentified or no longer established.

Dactylosternum abdominale (F.)

(Ogilvie 1928). From Devonshire Marsh, Devonshire Parish, and on a building 1955, Botanical Gardens, Paget Parish. A common pantropical species.

Enochrus hamiltoni (Horn) New Record

Collected April 1966, Spittl Pond, Smith's Parish, and August 1967, Warwick Pond, Warwick Parish, in a light trap. Found from Nova Scotia to Florida, and Texas to California.

Enochrus ochraceus (Melsheimer) New Record

First collected August 1967, Warwick Pond, Warwick Parish, in a light trap. Subsequent collections October 1987, Berry Hill Rd., Paget Parish, in a light trap; and January 1988, Devonshire Marsh, Devonshire Parish, while sweeping. Occurs in eastern USA, Central America, and the West Indies.

Tropisternus lateralis nimbatus (Say) New Record

First collected 1955, Devonshire Parish, in a drainage ditch. Also February 1966, Camden Marsh, Paget Parish (now filled in). *T. lateralis* is a common species with numerous subspecies; *T. l. nimbatus* occurs in southeastern Canada and eastern USA.

LAMPYRIDAE

Photinus sp.

(Jones 1876, Verrill 1902, Ogilvie 1928). Introduced by Governor Lefroy before 1876. Seen but not collected by Ogilvie in June 1927. No recent sightings, probably no longer established.

LATHRIDIIDAE

Eufallia seminiveus (Motschulsky) New Record

Intercepted in wicker baskets Nov. 1980. Not established. Known from USA, Mexico, and Puerto Rico.

LYCTIDAE

Lyctus africanus Lesne New Record

In shipment of doors Nov. 1966 and mahogany lumber July 1969, Pembroke Parish. Probably not established. Cosmopolitan.

MORDELLIDAE

?Mordellistena sp. New Record

One specimen collected May 1987, Bermuda Aquarium, Smith's Parish, on *Pittosporum* sp.

MYCETOPHAGIDAE

Typhaea stercorea (L.) New Record

Hairy fungus beetle. First collected Oct. 1987 in light traps at Berry Hill Rd., Paget Parish, and Admiralty House Park, Pembroke Parish. Feeds on fungal hyphae. Cosmopolitan.

NITIDULIDAE

Carpophilus hemipterus (L.) New Record

One specimen collected May 1967, BDAF laboratory, Paget Parish. Probably not established. Cosmopolitan.

Carpophilus sp. a

(= *Carpophilus dimidiatus* F.; Ogilvie 1928). Reported by Ogilvie (1928) as common in decaying bananas. *C. dimidiatus* is a New World species.

Carpophilus sp. b New Record

First collected May 1966, Botanical Gardens, Paget Parish, in strawberries. Also from rotting papaya and in a house.

Conotelus sp. New Record

First collected Mar. 1966, Botanical Gardens, Paget Parish. Now common in flowers, especially morning glory, *Ipomea purpurea* (L.).

Cybocephalus gibbulus Erichson

Imported from Japan via Trinidad 1958-60 (Bennett et al. 1985). No recoveries and no specimens in BDAF collection. Probably not established. A Japanese species.

Cybocephalus sp.

Imported from Trinidad in 1955 for control of *Pseudaulacaspis pentagona* (Targioni-Tozzetti). Established and contributes to control (Bennett and Hughes 1959, Bennett et al. 1985). Recent collections Oct. 1987, Botanical Gardens, Paget on *Sabal bermudana* infested with *Comstockiella sabalis* (Comstock), and Jan. 1988, Warwick on *Nerium oleander* L. infested with *P. pentagona*.

Glischrochilus quadrisignatus (Say) New Record

One specimen collected Oct. 1948, St. George's Parish. probably not established. Known from temperate North America.

Haptoncus luteolus (Erichson)

(Ogilvie 1928, = *Epuraea luteola* Ev.; Verrill 1902). Common in decaying fruits and in light traps. Widespread in the New World.

Stelidota sp. nr. *geminata* (Say) New Record

First collected in May 1966, Camden, Paget Parish, in rotting papaya. Also from rotting citrus. *S. geminata* is a New World species.

Urophorus humeralis (F.) New Record

First collected in 1955 in rotten watermelon. Large numbers in canteloupe June 1966, Southampton Parish. Known from the Old World and Puerto Rico.

OEDEMERIDAE

Nacerdes melanura (L.)

(= *Nacerda melanura* L.; Ogilvie 1928). Wharf borer. Several collections at lights and from houses. Adults active in June. Cosmopolitan.

Oxycopis vittata (F.) New Record

Collected in 1955, Botanical Gardens, Paget Parish, in a light trap; and July 1988, Tucker's Town, St. George's Parish, at a light. A West Indian species.

PASSALIDAE

Passalus punctiger Serville New Record

Intercepted on potted *Cryptostegia grandiflora* R. Brown from Trinidad Dec. 1950. Not established. A Neotropical species.

PHALACRIDAE

Acylomus calcaratus Casey New Record

One specimen collected May 1987, Devonshire Bay, Devonshire Parish. Common in southeastern USA.

Olibrus sp.

(Ogilvie 1928). No specimens in BDAF collection. Possibly misidentified or no longer established.

Phalacrus politus Melsheimer New Record

First collected by L. Ogilvie Sept. 1925, Camden Marsh, Paget Parish, but not reported by him (Ogilvie 1928). Common in sweepnet samples. Size quite variable. Known from eastern USA.

PTILIIDAE

Achratrichis sp. New Record

Two specimens collected Sept. and Oct. 1987, Berry Hill Rd., Paget Parish, in a Malaise trap.

PTILODACTYLIDAE

Ptilodactyla nanoderma Johnson & Freytag New Record

First collected Aug. 1967, Warwick Pond, Warwick Parish, in a light trap. One additional specimen Oct. 1987, Spittal Pond, Smiths Parish, in a light trap. Species previously known from midwestern USA (Kansas, Indiana).

PTINIDAE

Ptinus fur (L.)

(Verrill 1902, Ogilvie 1928). Whitemarked spider beetle. Destructive to dried animal substances (Verrill 1902). No specimens in BDAF collection. Cosmopolitan.

Gibbium aequinoctiale Boieldieu New Record

Three specimens collected May 1987, Nov. 1987, and Mar. 1988 in BDAF offices, Paget Parish. Cosmopolitan.

RHIZOPHAGIDAE

Bactridium sp. New Record

Intercepted on *Protea* sp. from South Africa June 1967. Not established.

SCARABAEIDAE

Ataenius gracilis (Melsheimer) New Record

First collected Oct. 1987, Berry Hill Rd., Paget Parish in a light trap. Known from eastern North America.

Ataenius havanensis Balthasar New Record

First collected Oct. 1987, Spittal Pond, Smith's Parish, at a black light. Known from the West Indies and Florida Keys.

Ataenius spretulus (Haldeman) New Record

First collected Oct. 1987, Berry Hill Rd., Paget Parish, in a light trap. Widespread in North America.

Ataenius sp. New Record

First collected June 1956 on *Conocarpus* sp. Several subsequent collections in light traps.

Aphodius fimetarius (L.)

(Jones 1876, Verrill 1902, Ogilvie 1928). Rare (Jones 1876). No specimens in BDAF collection. Possibly misidentified or no longer established. Native to Europe, but distributed by commerce to many parts of the world.

Aphodius granarius (L.) New Record

One specimen collected Mar. 1968, Paget Marsh, Paget Parish, while sweeping in grass. Native to Europe, but distributed by commerce to many parts of the world.

Aphodius lividus (Olivier)

(Ogilvie 1928). Common in light traps. Cosmopolitan in tropical and subtropical areas.

Aphodius ruricola Melsheimer

(Jones 1876, Verrill 1902, Ogilvie 1928). Rare (Jones 1876). No specimens in BDAF collections. Possible misidentified or no longer established. Known from eastern North America.

Cyclocephala sp. New Record

One specimen collected Jan. 1983, Paget Parish.

Ligyrrus gibbosus Dejean

(Verrill 1902, Ogilvie 1928, = *L. juvenicus* (Oliv.); Jones 1876). Reported to be the most common beetle on the islands (Jones 1876). Injurious to sweet potatoes and various other crops (Verrill 1902). No specimens in BDAF collection. Probably *L. cuniculus*. Known from USA and Mexico.

Ligyrrus cuniculus (F.)

(= *L. tumulosus* Burmeister; Verrill 1902, Ogilvie 1928). Known locally as "hardbacks". At lights in the summer. Once very common, now less so. Known from the West Indies and Florida.

Macrodactylus subspinosus (F.)

(Waterston 1940). Rose chafer. Intercepted on *Rosa* sp. from USA June 1939. Not established. Known from eastern North America.

Popillia japonica Newman

(Waterston 1940). Japanese beetle. Intercepted from USA in 1939. A single live adult was collected on *Lathyrus odoratus* L., June 1940 in St. George. Not established. Native to Japan, but established in eastern North America.

Psammodyius sp.

(Verrill 1902). No specimens in BDAF collection. Probably misidentified or no longer established.

Trox scaber L.

(Jones 1876, Ogilvie 1928). Rare (Jones 1876). No specimens in BDAF collections. Possibly misidentified or no longer established. Known from most of the USA and southern Canada.

Trox suberosus (F.)

(Jones 1876, Ogilvie 1928. Not common. All collections from lights. Cosmopolitan.

SCOLYTIDAE

Coccotrypes carpophagus (Hornung) New Record

One specimen collected July 1987, Paget Parish, in a house; three additional specimens Oct. 1987, Berry Hill Rd., Paget Parish, in a light trap. Widely distributed in both New and Old World tropics and subtropics.

Coccotrypes distinctus (Motschulsky) New Record

First collected Dec. 1965, Botanical Gardens, Paget Parish, on *Sabal causiarum* (O. F. Cook) Beccari. Occasionally in houses. Known from Florida, Honduras, Puerto Rico, British Guiana, Hawaii, Micronesia, and Ceylon.

Coccotrypes sp. possibly *cyperi* (Beeson)

(= *C. dactyliperda* F.; Ogilvie 1928). From fallen fruits of *Sabal bermudana*. No collections since 1925. *C. cyperi* occurs in Florida, Central America, West Indies, and from Java to India.

Cryphalus sp. New Record

Intercepted on *Nerium oleander* from Japan 1956. Not established.

Hypothenemus eruditus Westwood New Record

One specimen collected Feb. 1986, Smith's Parish, on *Cupressus* sp. Nearly cosmopolitan.

Hypothenemus seriatus (Eichhoff) New Record

Several specimens collected Aug. 1965 on *Morus* sp., Pembroke Parish. Known from southeastern USA to Brazil, Hawaii, Australia, Indonesia, and Madagascar.

Hypothenemus squamosus (Hopkins) New Record

Several specimens collected Oct. 1987 from pods of *Tamarindus* sp. Botanical Gardens, Paget Parish. Known from southern Florida, Mexico, and Cuba.

Hypothenemus sp. New Record

One specimen collected July 1987, Paget Parish, in a garden.

Xyleborinus saxeseni (Ratzeburg) New Record

One specimen collected July 1987, Penhurst Park, Smith's Parish, in a Malaise trap. Widespread in both New and Old Worlds.

STAPHYLINIDAE

Acrotona sp. New Record

Several specimens collected in a Malaise trap October 1987, Berry Hill Rd., Paget Parish.

Aleochara puberula Klug New Record

Two specimens collected in a light trap October 1987, Berry Hill Rd., Paget Parish. Cosmopolitan.

Anotylus insignitus (Gravenhorst) New Record

Several specimens collected May 1966, Camden, Paget Parish, in rotting fruit. Also in a light trap March 1988, Berry Hill Rd., Paget Parish. A pantropical and subtropical species.

Atheta coriaria (Kraatz)

(Ogilvie 1928). From decaying bananas and papaya. Native to Europe, immigrant to North America.

Cafius bistratus (Erichson)

(Ogilvie 1928, Hughes & Schuster 1986). Under beached seaweed or debris along shoreline. On beach April 1988, Shelly Bay, Hamilton Parish. Known from the Atlantic coast of North America and the West Indies.

Cafius subtilis Cameron New Record

One specimen collected 1959, no location given. A West Indian species.

Carpelimus sp. a New Record

One specimen collected in BDAF Laboratory, Paget Parish, June 1987.

Carpelimus sp. b New Record

First collected in a light trap in October 1987, on Berry Hill Rd., Paget Parish.

Coproporus hepaticus (Erichson) New Record

One specimen collected 1955, Paget Parish, in bananas. Known from the neotropics and subtropics.

Coproporus pulchellus (Erichson) New Record

One specimen collected Sept. 1987, Paget Parish, in a Malaise trap. A second specimen from a light trap Oct. 1987, Berry Hill Rd., Paget Parish. Known from the Neotropics and subtropics.

Creophilus maxillosus (L.)

(= *C. villosus* Kirby; Jones 1876, Verrill 1902, Ogilvie 1928). No specimens in BDAF collections. Known from Eurasia, North and Central America, and northern Africa.

Diestota sp. New Record

First collected May 1966, Paget Parish, from rotting papaya. Also from canteloupe.

Diochus schaumii Kraatz New Record

One specimen collected in a light trap in October 1987, Berry Hill Rd., Paget Parish. A North American species.

Gabronthus thermarum (Aube) New Record

One specimen collected Nov. 1987, Berry Hill Rd., Paget Parish, in a house. A pantropical and subtropical species.

Lithocharis nigriceps Kraatz New Record

First collected in light traps in October 1987, Berry Hill Rd., Paget Parish; and Spittal Pond, Smith's Parish. Also from cabbage March 1988, Trimmingham Hill, Paget Parish. Native to the Old World tropics and Eurasia; an immigrant to North America.

Lithocharis ochracea (Gravenhorst) New Record

First collected in light traps in October 1987, Berry Hill Rd., Paget Parish, and Admiralty House Park, Pembroke Parish. A pantropical species known also from Eurasia and North America.

Lithocharis spp.

Females difficult to identify to species. Probably *L. nigriceps* and *L. ochracea*. Most specimens from light traps.

Philonthus hepaticus Erichson New Record

One specimen collected Nov. 1987, Berry Hill Rd., Paget Parish in a light trap. Known from North, Central and South America and the West Indies.

Philonthus longicornis Stephens New Record

One specimen collected May 1966, Botanical Gardens, Paget Parish, in strawberries. Cosmopolitan.

Platystethus spiculus Erichson New Record

One specimen collected Nov. 1966, Devonshire Parish on sweet potato. Also collected Sept. 1973, Botanical Gardens, Paget Parish, while sweeping grass. A neotropical species.

TENEBRIONIDAE

Alphitobius diaperinus (Panzer) New Record

Lesser mealworm. First collected 1955, Sandy's Parish. In light traps and in houses. Large numbers in a poultry house, Dec. 1987, Paget. Cosmopolitan stored products pest.

Alphitobius laevigatus (F.)

(Ogilvie 1928). Black fungus beetle. Several collections from houses in Paget and Pembroke Parishes. Cosmopolitan stored products pest.

Blapstinus metallicus (F.)

(Jones 1876, Verrill 1902). Rare (Jones 1876). From under decaying rubbish on the shore (Verrill 1902). Recent collections: May 1966, in a lilly field, Devonshire Parish, and from Horseshore Bay dunes, Southampton Parish, Jan. 1988. A North American species.

Diaperis affinis Laporte

(Jones 1876, Verrill 1902, Ogilvie 1928). No specimens in BDAF collection. Probably misidentified.

Diaperis maculata (Olivier) New Record

Under dead bark on a stump July 1987, Admiralty House Park, Pembroke Parish. Also Oct. 1987, Spittal Pond, Smith's Parish, in a light trap. Known from eastern North America, the West Indies, and Panama.

Gnatocerus cornutus (F.) New Record

Broadhorned flour beetle. One specimen collected May 1967, Botanical Gardens, Paget Parish. Almost cosmopolitan.

Neomida bicornis (F.)

(= *Hoplocephala viridipennis* F.; Ogilvie 1928). No collections since 1925. May not be established. Known from North America and the West Indies.

Opatrinus pullus (Sahlberg)

(Ogilvie 1928, ? = *Opatrinus* sp.; Jones 1876, ? = *O. anthracinus*; Verrill 1902). Under stones and dead bark. Common. Known from Central America, Florida, and the West Indies.

Palorus subdepressus (Wollaston) New Record

Depressed flour beetle. One specimen collected Oct. 1987, Spittal Pond, Smith's Parish, at a light trap. A widely spread stored products pest.

Phaleria picipes Say

(Hughes & Schuster 1986). In light traps. Adults and larvae associated with seaweed where they feed as scavengers. Known from North America and the West Indies.

Phaleria punctipes LeConte New Record

One specimen collected 1955, Grape Bay, Paget Parish, under seaweed. Known from North America and the West Indies.

Phaleria testacea Say

(Jones 1876, Verrill 1902). Rare (Jones 1876). Found under decaying rubbish on the shore (Verrill 1902). No specimens in BDAF collection. Probably misidentified or no longer established. Known from North America and the West Indies.

Tenebrio molitor L.

(Verrill 1902). Yellow mealworm. No specimens in BDAF collection. Cosmopolitan stored products pest.

Tribolium castaneum (Herbst)

(Ogilvie 1928, = *T. ferrugineum* F.; Verrill 1902). Red flour beetle. From stored flour and rat poison. Cosmopolitan stored products pest.

Tribolium confusum Jacquelin du Val

(Verrill 1902, Ogilvie 1928). Confused flour beetle. In turtle food at pet store. Cosmopolitan stored products pest.

ACKNOWLEDGMENTS

We are grateful to the following scientists for providing identifications:

Arnett, R. H. Florida State Collection of Arthropods (Oedemeridae)

- Barr, W. F. Univ. of Idaho (Buprestidae, Cleridae)
 Booth, R. G. British Museum, Natural History (Mordellidae, Nitidulidae in part)
 Bright, D. E. Agriculture Canada (Scolytidae)
 Chemsak, J. A. Univ. of California (Cerambycidae)
 Cox, M. L. British Museum (Chrysomelidae in part)
 Davidson, R. Carnegie Museum (Carabidae in part, Cicindelidae)
 Dogger, J. R. U. S. Dept. of Agriculture (Elateridae)
 Frank, J. H. Univ. of Florida (Staphylinidae in part)
 Gordon, R. D. U. S. Dept. of Agriculture (Cantharidae, Coccinellidae, Scarabaeidae, Tenebrionidae in part)
 Hoffman, R. Radford Univ., Va. (Carabidae in part)
 Kingsolver, J. M. U. S. Dept. of Agriculture (Bruchidae, Cryptophagidae, Dermestidae, Heteroceridae, Histeridae, Lathridiidae, Lyctidae, Mycetophagidae, Nitidulidae in part, Ptiliidae, Rhizophagidae)
 Madge, R. British Museum, Natural History (Dryopidae, Ptinidae, Staphylinidae in part)
 Spangler, P. J. Smithsonian Institution (Hydrophilidae)
 Spilman, T. J. U. S. Dept. of Agriculture (Bostrichidae, Tenebrionidae in part)
 Steiner, W. E. Smithsonian Institution (Cerylonidae, Phalacridae)
 Stribling, J. B. visiting scientist U.S. Dept. of Agriculture (Helodidae, Ptilodactylidae)
 Werner, F. G. Univ. of Arizona (Anthicidae)
 White, R. E. U.S. Dept. of Agriculture (Anobiidae, Anthribidae, Chrysomelidae in part)
 Whitehead, D. R. U. S. Dept. of Agriculture (Curculionidae)

We would also like to thank A. G. Wheeler, Jr., E. R. Hoebeke, and N. E. Woodley for reviewing the manuscript, Joelle Hendrickson for assistnace with the collection, and Penny Hill for searching out old records.

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PETREJOIDES SALVADORAE SP. NOV. (COLEOPTERA:
PASSALIDAE) FROM EL SALVADOR

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ABSTRACT

Petrejoides salvadorae sp. nov. is described from cloud forest at 2300m (El Trifinio). It is closely related to *P. reyesi* Schuster from Honduras.

RESUMEN

Se describe *Petrejoides salvadorae* sp. nov. de bosque nebuloso a 2300m altura (El Trifinio). Muestra parentesco cercano a *P. reyesi* Schuster de Honduras.

In the recent description of *Petrejoides reyesi* (Schuster 1988), I mentioned the existence of a similar, undescribed species from Cerro Montecristo (El Trifinio), El Salvador. At that time I had hesitated to describe it, having seen only 1 specimen. Since then I have seen 2 more specimens, all very similar, herein described (for specialized terminology see Reyes-Castillo, 1970).

Petrejoides includes 13 described species (Castillo & Reyes-Castillo 1984, Reyes-Castillo & Schuster 1983, Schuster 1988). Only 4 are known from south of the Isthmus of Tehuantepec; only 1, *P. subrecticornus* (Kuwert), from El Salvador. This latter species is cited from Guatemala, El Salvador and Costa Rica (Castillo & Reyes-Castillo 1984). Nevertheless, Guatemala and El Salvador are each represented by only 1 specimen, both collected in the last century. I have collected for 13 years in Guatemala and have not seen this species (Schuster 1985). It could, however, exist in wet Caribbean lowland forests similar to the Caribbean lowland forests of Costa Rica where it is most abundant (Castillo & Reyes-Castillo 1984). In Costa Rica, it is found from sea level to 800m altitude.

Petrejoides salvadorae sp. nov.

Fig. 1

Head. Anterior border of labrum very concave, anterior angles only slightly rounded; behind anterior border is a glossy, bare concavity similar to that of *Verres*. Clypeus inclined, almost trapezoidal, the fronto-clypeal suture straight mesally (Fig. 1), well marked throughout; anterior border sublinear, a slight median indentation present in at least 1 specimen, anterior angles sharp and directed downward; rugose throughout or partially smooth along anterior border. External tubercles large, rounded and directed forward.

Frontal area short, without frontal ridges or inner tubercles. Frontal fossae glabrous or with few hairs. Median frontal structure of the "falsus" type; center horn elongate with pointed apex almost reaching clypeus, without median longitudinal groove; lateral ridges at right angles to median horn, terminal tubercles rounded and pronounced,

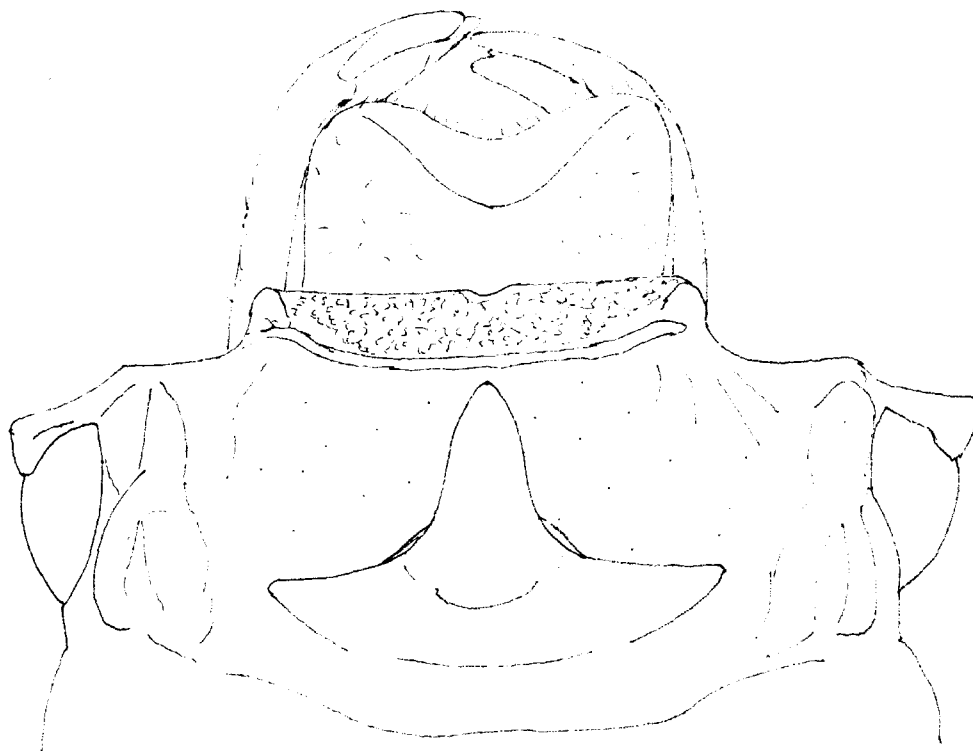


Fig. 1. Head, holotype of *Petrejoidea salvadorae*. Dorsal view.

more "massive" and elevated more posteriorly than in *P. reyesi*. Occipital groove well marked, concave and terminating in frontal fossa.

Anterior 1/2 of supraorbital ridge bituberculate, posterior 1/2 bifurcate. Anterior cephalic angle rounded or slightly protruding. Canthus swollen distally with apex rounded, protruding slightly beyond lateral border of eye. Eyes small, the dorsal width of an eye 1/13 - 1/14 head width.

Ligula between insertions of labial palps slightly protruding, pubescent with punctations. Lateral lobes of mentum with anterior external border rounded, whole surface punctate and pubescent, lateral border straight. Medial basal mentum with setae and punctations more abundant on posterior margin, anterior margin convex, not biconvex. Hypostomal process narrow, without lateral depression. Infraocular ridge smooth, glabrous, widened anteriorly.

Superior and median apical teeth of mandible protruding beyond inferior tooth. Dorsal tooth occupies more than 1/2 mandible length. Internal tooth of left mandible bifid.

Thorax. Lateral pronotal fossa without punctations. Marginal pronotal groove narrow, without punctations laterally, a few punctations anteriorly. Prosternum rhomboidal, posterior apex truncated though narrower than in *P. reyesi*.

Lateral margins of mesosternum rugose opaque. Mesoternal shield with few or no punctations. Anterior angles of metasternum pubescent. Metasternal disc delimited by 26 to 39 punctations in each lateral posterior side. Marginal fossa very narrow, glabrous or with scarce, short setae and weak punctations.

Anterior elytral profile convex; elytral striations marked uniformly with punctations, somewhat heavier in lateral striations. Punctations distinctly heavier than those of *P. reyesi*.

Legs. Femur I with anterior-ventral groove distinctly marked for at least 4/5 of anterior border, posterior 1/2 of ventral face pubescent. Dorsal ridge covered with hair, extends total length of tibia II.

Abdomen. Marginal groove of last sternite complete.

Dimensions (mm). Total length, tip of mandibles to tip of elytra 26.0-218.4, \bar{x} = 27.6; elytral length 14.8-16.0 \bar{x} = 15.4. This species. *P. reyesi* and *P. guatemalae* are the largest members of the genus.

Materials examined. Three specimens:

Holotype: EL SALVADOR, Metapán, Co.: Miramundo, Hda. Montecristo, 16-IV-1972, Altitude 2300, S. & L. Steinhauser, (collectors #3050), cloud forest. Deposited in the Florida State Collection of Arthropods, Gainesville, Florida.

Paratypes: 1) same location and collection data, 29-IV-1972, #3069. In my collection temporarily. Will be deposited with holotype.

2) "Trifinio." (This refers to essentially the same area as the other specimens). 27-VII-1960. Deposited in the Instituto de Ecología, Xalpa, Mexico.

Etymology. Refers to the country from which the only specimens are known, El Salvador.

Distribution. Known only from the Trifinio area of El Salvador near the juncture of that country with Guatemala and Honduras. This is an isolated montane cloud forest area with other endemic passalid species, e.g., *Ogyges politis* (Hincks). Except for passalids collected at Trifinio, most passalids known from El Salvador are lowland species (Hincks 1953). Hopefully, other high mountain areas can be explored before rampant deforestation leads to extinction of undescribed species.

Affinities. *P. salvadorae* is distinctly related to *P. guatemalae* Reyes-Castillo & Schuster and *P. reyesi*, forming a coherent biogeographic unit of montane cloud forest species in northern Central America. These species are in the "orizabae" group of Castillo & Reyes-Castillo (1984). *P. salvadorae* can be differentiated from other *Petrejoides* by the following modification in the key of Castillo & Reyes-Castillo (1984):

1. Posterior 1/2 of supraorbital ridge bifurcate. Dorsal ridge of tibia II long.
... "orizabae" group 2
- 1'. Posterior 1/2 of supraorbital ridge not bifurcate. Dorsal ridge of tibia II short, if long, then infraocular ridge absent .. "laticornis" & "recticornis" groups
2. Clypeus partially or totally rugose and opaque, trapezoidal or almost trapezoidal with fronto-clypeal suture curved or straight. Internal tubercles absent 3
- 2'. Clypeus smooth and glossy throughout, rectangular. Internal tubercles present 3 in C. & R-C
3. Labrum with a glabrous depression or concavity behind its mid-anterior border, clypeus totally rugose. EL SALVADOR *P. salvadorae*
- 3' Labrum without a distinct depression behind anterior border, clypeus partially rugose 4
4. Clypeus trapezoidal rugose and opaque throughout except for narrow glossy anterior margin; fronto-clypeal suture indistinct medially. Lateral ridges of median frontal structure at right angles to longitudinal body axis. Femur I with anterior-ventral groove indistinct or absent. Body length 24.5-32 mm. GUATEMALA *P. guatemalae* Reyes-Castillo & Schuster
- 4'. Clypeus almost trapezoidal, rugose and opaque only in posterior-medial

area; fronto-clypeal suture curved and distinct throughout. Lateral ridges of median frontal structure curve slightly forward. Femur I with anterior-ventral groove distinct. body length 27.530 mm. HONDURAS

..... *P. reyesi* Schuster

ACKNOWLEDGMENTS

I thank Bob Woodruff (Florida State Collection of Anthropods Gainesville, Florida) and Pedro Reyes-Castillo (Instituto de Ecología, Mexico) for Loan of specimens. Pedro Reyes-Castillo and Camelia Castillo provided advice, and the Instituto de Ecología, Mexico, and the Universidad del Valle de Guatemala provided support for the project. Kalara Schuster helped edit the manuscript.

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SCIENTIFIC NOTES
 REDISCOVERED SPECIES AND REVISED KEY TO THE
 FLORIDA THIEF ANTS (HYMENOPTERA: FORMICIDAE)

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A series of seven specimens of the thief ant, *Solenopsis trunctorum* Forel, was collected by the junior author in February 1988 in mixed hardwood-pine litter adjoining an old field habitat 2-3 mi SW of Archer in Alachua Co., FL. This species had been reported from Florida by Smith (1979), but no specimens from the state were known despite an extensive search by the senior author. *Solenopsis trunctorum* was therefore not included in the taxonomic revision by Thompson (1989) for the Florida thief ants. The emended key which follows includes *Solenopsis trunctorum*, but retains figure references from Thompson (1989). The specimens will be deposited in the Florida State Collection of Arthropods, Gainesville, FL.

Key to workers of Florida thief ant species

- 1. Large, reddish brown species (HL 0.56-0.58; HW 0.50-0.52; WL 0.68-0.70) *trunctorum* Forel
- 1'. Distinctly smaller, yellow or dark-bodied species (HL and HW 0.48 or less, WL 0.32-0.68) 2
- 2. Petiolar node (Fig. 23) placed somewhat anterior to the petiolar-postpetiolar juncture so that the petiole has a distinct slender posterior peduncle; body either uniformly dark brown or with lighter reddish brown head and/or thorax; arboreal *picta* Emery
- 2'. Petiolar node placed near the petiolar-postpetiolar juncture (Fig. 15); body usually pale yellow, or if dark, then the appendages are pale; subterranean (except one yellow arboreal species) 3
- 3(2'). Head, thorax and gaster dark brown; appendages pale brown to pale yellow; (Fig. 13-16) *nickersoni* Thompson
- 3'. Usually entire body pale yellow to somewhat darker yellow, but one species (*carolinensis*) often with moderate infuscation on head and gaster 4
- 4(3'). Eyes small (length \leq 0.02 mm), most of eye area the same color or only slightly darker than the rest of the head; head with distinct median strip free of punctures and hairs which is weakly impressed forming longitudinal furrow (Fig. 30) 5
- 4'. Eyes normal size (length at least 0.03 usually 0.04 mm); eye area mostly brown to black; head without median strip free of hairs and punctures 6

- 5(4). Head narrow, elongate (Fig. 26) and flat (HI 72-81) (Fig. 25); very small species (HTL 0.61-0.69 mm) *tennesseensis* M. R. Smith
- 5'. Head proportionately not as narrow, only slightly oblong and convex ventrally (HI 89-94) (Fig. 29); medium-sized species (HTL 0.76-0.83 mm) *tonsa* Thompson
- 6(4'). Large species (HTL 0.84-1.14 mm); head, from above, nearly square (HI 91-100) with numerous (ca. 200) hairs arising from punctures which, lie in parallel rows (Fig. 18); head in lateral view with distinctly convex ventral margin *pergandei* Forel
- 6'. Smaller species (HTL 0.64-0.80); head clearly oblong (HI 82-92) with far fewer (< 100) hairs which do not lie in parallel rows; head in lateral view not greatly convex ventrally 7
- 7(6'). Eye longer than broad, nearly oval, but wider anteriorly giving a slightly almond shape; eyes with one black facet anteriorly followed by a central yellow area with a second smaller black facet at the posterior eye corner; body entirely light brownish yellow or with gaster slightly infuscated; arboreal *corticalis* Forel
- 7'. Eye nearly circular, facets light-colored, and surrounded by black line, or by uniform black areas that are not concentrated at the anterior and posterior eye corners; body yellow to brownish yellow with or without infuscation; subterranean 8
- 8(7'). Eye normal sized (0.04 mm); body yellow to brownish yellow; promesopleural suture, below mesothoracic spiracle, only slightly darker than rest of thorax and shaped like a half-boomerang, the tapered dorsal end of the suture extends posteriorly but does not encircle the spiracle; thorax, in profile, with flattened area before and after the metanotal groove (Fig. 5, but not completely aligned) *carolinensis* Forel
- 8'. Eye smaller (0.030-0.035 mm); body clear yellow; promesopleural suture somewhat hourglass-shaped with a reddish orange outline which extends to encircle the spiracle; dorsum of thorax smoothly curved, not flattened before and after the metanotal groove (Fig. 1) *abdita* Thompson

Contribution No. 722. Bureau of Entomology, Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, FL 32602.

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NEW RECORD FOR *ANASTREPHA MONTEI* (DIPTERA:
TEPHRITIDAE) FROM NORTHEASTERN MEXICO

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The genus *Anastrepha* Schiner has a widespread distribution including southern Texas and Florida in the United States, Mexico, Central and South America, and the Caribbean Islands (Stone 1942). To date, more than 190 species of *Anastrepha* are recognized (Steyskal 1977, Foote 1980, Norrbom 1985, Steck & Wharton 1988), of which 13 species were reported to occur in Mexico (Stone 1942). Recently, 19 additional species have been recorded for Mexico, including *A. montei* Costa Lima (Aluja et al. 1987, Hernandez 1989).

The population phenology of *A. ludens* (Loew) is currently being monitored with McPhail traps placed on its native host, yellow chapote, *Sargentia greggii* Watson (Plummer et al. 1941), and several cultivated hosts. The study is being conducted in central Tamaulipas, Mexico (23-24° North latitude, and 99-99° 30' West longitude). One adult *A. montei* was captured in this area near Ciudad Victoria, Tamaulipas, in late August 1987. The specimen was identified by Dr. Allen L. Norrbom (USDA-ARS Systematic Entomology Laboratory) who also confirmed the absence of prior records of *A. montei* in northeastern Mexico.


Before the report of Aluja et al. (1987) the northernmost known distribution of *A. montei* was San Mateo, Costa Rica (Stone 1942) at about 10° North latitude. With the present report, the known distribution of *A. montei* is expanded more than 1000 km northwest from Chiapas. Cassava [*Manihot dulcis* (Gmelin) Pax and *M. esculenta* Crantz] is the only recorded host of *A. montei*. The larvae of *A. montei* feed inside the seed capsules of their hosts (Stone 1942). *Manihot esculenta* is a very important food crop, particularly in Africa (Nartey 1978). The specimens trapped by Aluja et al. (1987) were caught in the vicinity of cassava plants. In our case, a single female was trapped in a yellow chapote stand. Although there may be some cassava located in private gardens, it is not cultivated in this region of Tamaulipas, which suggests the possibility of additional host plants for *A. montei*.

We thank M. Rose, R. A. Wharton, L. A. Rodriguez, and B. Overholt, Texas A & M University for their review of this manuscript. It is approved as TA No. 24332 by the Texas Agricultural Experiment Station, College Station, Texas.

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REDUCED FECUNDITY IN *NEODIPRION MERKELI*
(HYMENOPTERA: DIPRIONIDAE) ASSOCIATED WITH
FEEDING ON JUVENILE SLASH PINE FOLIAGE


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The slash pine sawfly, *Neodiprion merkelii* Ross, periodically causes heavy defoliation of 5- to 10-yr-old typical slash pine, *Pinus elliottii* Engelm. var. *elliottii*, plantations in the Southeastern Coastal Plain (Wilkinson 1971). Eggs are laid in the current year's (juvenile) needles located in the apical 1/2 of growth flushes (Wilkinson & Popp 1989) and larval instars 1 & 2 feed on the outer (mesophyll) tissue of this immature foliage. In contrast, instars 3-6 feed on all tissues of the previous year's (mature) foliage, dispersing to other trees if the supply of mature foliage is exhausted. Late-instar larvae often are forced to feed on juvenile foliage during outbreaks when mature foliage is gone (unpublished studies). Preference for feeding on mature foliage of pine and hemlock (*Tsuga*) has been reported in a number of northern *Neodiprion* spp. (e.g., Wilkinson et al. 1966; Hard 1971; All & Benjamin 1975; Niemela et al. 1982). A compound [13-keto-8(14)-podocarpin-18-oic acid] present in the juvenile foliage of 2 species of pine has been shown to deter feeding of 3 *Neodiprion* spp. (Ikeda et al. 1975, Niemela et al. 1982). Reduced fecundity and other deleterious effects have resulted from rearing larvae solely on juvenile foliage of pine (Erlandson 1967) and hemlock (Hard 1971).

During Sept. 1965, several thousand instar 4-6 *N. merkelii* were collected from a large, outbreak population infesting 7- to 8-yr-old plantations in Taylor Co. (NW peninsular FL). Larvae were laboratory-reared to the cocoon stage on cut-branches bearing both juvenile and mature foliage and misted daily with water (all feeding instars imbibe free water). Forewing length (to nearest 0.05 mm) and fecundity (no. full-sized, green eggs present) were determined for each of 50 ♀♀ emerged during Oct. 1965 and data were analyzed by correlation-regression procedures (SAS 1985; Fig. 1, A).

Following a June 1966 outbreak in a 6-year-old plantation in Glades Co. (S FL), 5 cocoons were dug from the soil under each of 20 trees. Half of the sample trees were

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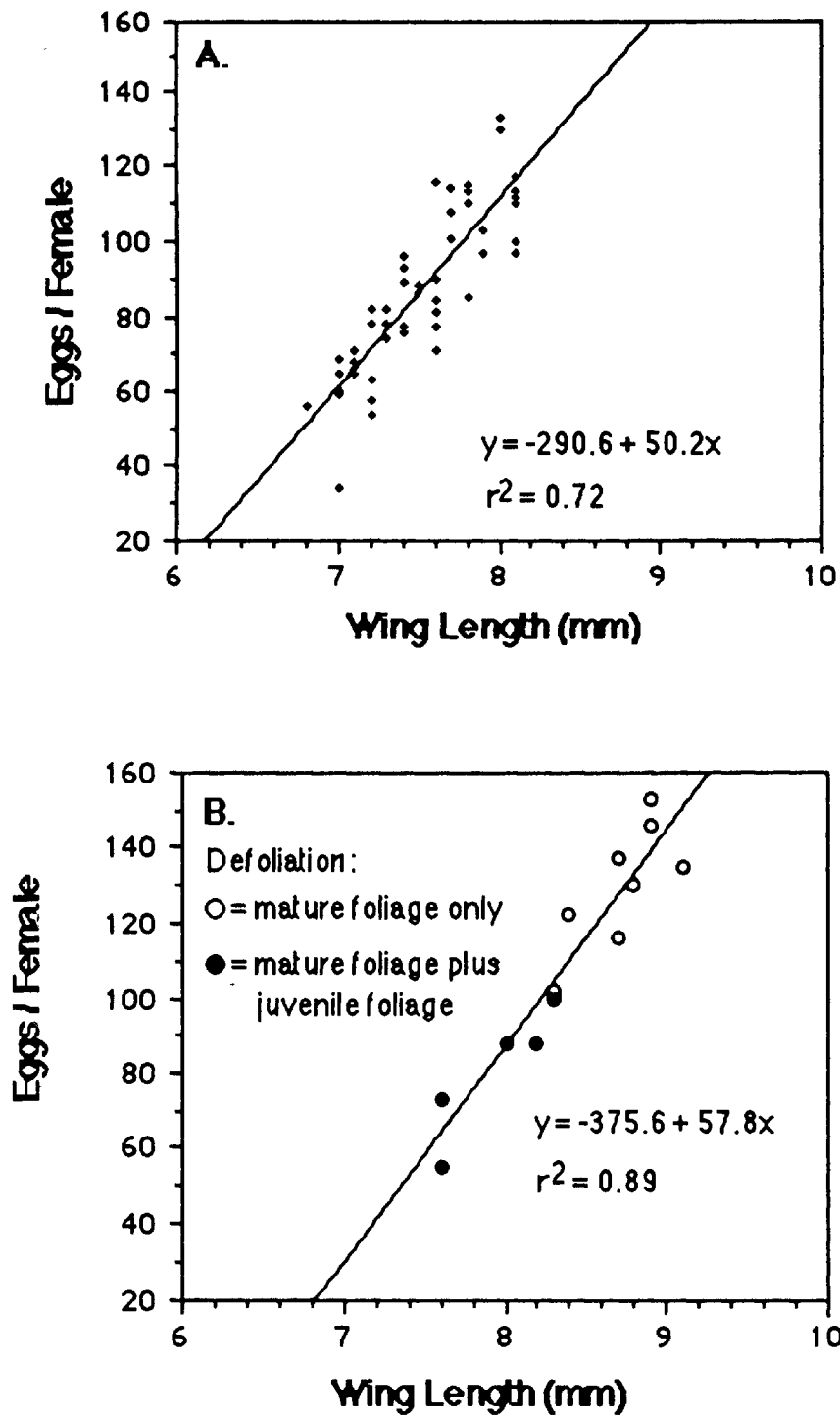


Fig. 1. Regression of fecundity with forewing length in ♀ *N. merkei*. A. 50 ♀♀ from laboratory-rearing of large, feeding larvae collected in Taylor Co., 1965. B. 13 ♀♀ from cocoons collected in the field in Glades Co., 1966. Hollow circles indicate "light" defoliation; solid circles indicate "heavy" defoliation (see text).

in a group which had sustained relatively "light" defoliation (only 50-75% of mature needles eaten per tree); the other half in a group which had sustained relatively "heavy" defoliation (100% of mature foliage plus 12.5-25% of juvenile foliage eaten per tree). A total of 13 ♀ *N. merkei* emerged from the cocoons during July-Sept. 1966; data on wing length and fecundity were analyzed as in 1965 and related to the age of foliage fed upon (Fig. 1, B).

A positive correlation was found between ♀ size (forewing length) and fecundity in *N. merkei* (Fig. 1, A); a similar relationship was reported for *Neodiprion excitans* Rohwer from Florida and Belize, C. A. (Wilkinson & Drooz 1979). Feeding on mature foliage only (light defoliation) was associated with greater size and fecundity of ♀ *N. merkei* than when larvae had fed both on mature and juvenile foliage (heavy defoliation) (Fig. 1, B). The implied negative relation between the amount of feeding damage caused to the host pine and ensuing fecundity may be explained by assuming that a feeding deterrent is produced in juvenile slash pine foliage. This deterrent may protect slash pine from complete defoliation and might also reduce the probability of an outbreak occurring or continuing by reducing ♀ fecundity. Hard & Torgerson (1975), who worked extensively with *Neodiprion tsugae* Middleton in Alaska, found that ♀ fecundity was one of several parameters that could be used collectively to determine trends in sawfly population density. Further research is needed to determine whether fecundity can be related to changes in *N. merkei* populations.

We thank H. C. Coppel, W. N. Dixon and J. L. Foltz for review. This is Florida Agric. Exp. Sta. Journal Series No. 9518.

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PARASITIZATION OF *DIATRAEA LINEOLATA* PUPAE AND DIAPAUSING LARVAE BY SEVERAL EXOTIC PARASITES

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The neotropical cornstalk borer (NCB), *Diatraea lineolata* (Walker), is a widely distributed species of the economically important genus *Diatraea* (Lepidoptera: Pyralidae) (Rodriguez-del-Bosque et al. 1988). A recent study on the parasitization of NCB in the corn agroecosystem of northern Tamaulipas, Mexico, revealed a minimal impact of native parasites. No pupal parasites were detected, and only three larval parasites appeared sporadically causing negligible levels of parasitization. The braconid larval parasite *Cotesia flavipes* (Cameron) was introduced into the corn agroecosystem of northern Tamaulipas in 1985, and rapidly became the most important parasite of both NCB and the sugarcane borer, *D. saccharalis* (F.) (Rodriguez-del-Bosque 1988). However, the impact of this exotic parasite was greatest on *D. saccharalis*, dictating the need for introduction of additional natural enemies against NCB. The successful establishment of potential parasites in this area could be limited by their ability to develop on diapausing NCB larvae, which are present during both summer and winter. Diapause of NCB is characterized by a change from a spotted to an immaculate morph, triggered by host plant maturation (Rodriguez-del-Bosque 1988). We investigated the suitability of NCB pupae and diapausing larvae to several exotic parasites. This report serves as a precursor for further detailed investigations and as a guide for selecting the best parasites for trial colonization.

Small-scale laboratory tests were conducted from January to May 1988 to determine the host suitability of NCB to several exotic larval and pupal parasites, cultured at the Biological Control Facility, Department of Entomology, Texas A&M University, as part of a biological control program aimed at graminaceous stalkborers in Texas. Diapausing NCB larvae used in the tests were field collected from maturing cornstalks in Rio Bravo, Tamaulipas, Mexico, placed in 20-ml cups with artificial diet (Martinez et al. 1988), and transported to College Station, Texas. Pupae (1-2 days old) were obtained from a NCB colony maintained in College Station (Rodriguez-del-Bosque 1988). Larval parasites tested included the braconids *Digonogastra kimballi* (Kirkland) and *Alloporhoga pyralophagus* Marsh from Mexico, *C. flavipes* and *Rhacanotus roslinensis* Lal from Pakistan, *Apanteles minator* Muesebeck from Bolivia, and the bethylid *Goniozus natalensis* Gordh from South Africa. The braconids all developed successfully on non-diapausing (spotted) NCB larvae in preliminary trials. *Goniozus natalensis* was not tested against nondiapausing NCB larvae. Pupal parasites were the eulophids *Trichospilus diatraeae* Cherian & Margabandhu from India (founder culture obtained from Florida, U.S.A.) and *Pediobius furvus* Gahan from Kenya, and the ichneumonid *Xanthopimpla stemmator* Thunberg from Asia (founder culture obtained from Mauritius). Although *T. diatraeae* has previously been reared from NCB pupae (Bennett & Pschorn-Walker 1970), information on parasitization, emergence, progeny, and developmental time was not reported.

Twenty hosts (pupae or diapausing larvae) were used to determine NCB suitability and developmental time (host exposure to adult parasite emergence) for each parasite, except *X. stemmator*, in which 81 pupae were used. Host larvae and pupae were held at constant $26 \pm 0.5^\circ\text{C}$ and 14:10 (L:D) photoperiod during and after exposure to parasites. Host larvae were exposed for 24 h to >20 parasite females held in Plexiglas cages

(30 X 30 X 30 cm), except for *G. natalensis* which was placed individually in cups containing artificial diet and a host larvae. Host larvae were exposed freely in the cages to *C. flavipes* and *A. minator*, in petri dishes (in folds of corrugated cardboard covered with filter paper taped to the petri dishes) to *R. roslinensis* and *A. pyralophagus*, and in plastic grids (Kirkland 1982) to *D. kimballi*. Host larvae exposed to *C. flavipes* and *A. minator* were subsequently placed individually in cups with artificial diet. Host pupae were exposed freely for 24 h to >20 parasite females of *T. diatraeae* and *P. furvus* in glass vials (36 ml) in groups of 10 pupae per vial, and in paper straw sections holding five pupae each for *X. stemmator* in a plexiglas cage. Pupae were subsequently placed individually in plastic vials (14 ml) plugged with cotton for parasite emergence.

Digonogastra kimballi, *R. roslinensis*, and *C. flavipes* produced cocoons in 60, 50, and 40% of the diapausing larvae, respectively (Table 1). *Goniozus natalensis* was unsuccessful in parasitizing diapausing larvae, whereas *A. pyralophagus* and *A. minator* produced cocoons in only 10% of the hosts. Ninety percent of the diapausing larvae were paralyzed by *A. pyralophagus*, indicating that either oviposition did not occur after paralysis or parasite development was unsuccessful.

All pupal parasites developed successfully from NCB (Table 2). Adult parasite emergence was obtained from 90, 70, and 56% of the NCB pupae for *T. diatraeae*, *P. furvus*, and *X. stemmator*, respectively. *Trichospilus diatraeae* was very aggressive and prolific causing 100% parasitization, and producing 280-450 progeny per host with >99% females. The mean progeny for *P. furvus* was 134 parasites per host, whereas *X. stemmator*, a large solitary parasite, was consistent with its previously reported biology (one progeny per host).

TABLE 1. SUITABILITY OF *DIATRAEA LINEOLATA* DIAPAUSING LARVAE TO EXOTIC PARASITES CULTURED IN THE LABORATORY (N = 20).

Parasite	% paralyzed	% forming cocoons	\bar{X} progeny per host	% females	Developmental time (range)
<i>Digonogastra kimballi</i>	100	60	3.0	61	18-20
<i>Rhacanotus roslinensis</i>	80	50	7.4	65	19-20
<i>Cotesia flavipes</i>	—	40	24.5	85	17-18
<i>Allorhogas pyralophagus</i>	90	10	1.0	100	22
<i>Apanteles minator</i>	—	10	10.0	20	24
<i>Goniozus natalensis</i>	0	0	—	—	—

TABLE 2. SUITABILITY OF *DIATRAEA LINEOLATA* PUPAE TO EXOTIC PARASITES CULTURED IN THE LABORATORY (N = 20, EXCEPT *X. TEMMATOR* N = 81).

Parasite	% parasitized	% parasite emergence	\bar{X} progeny per host (range)	% females	Developmental time (range)
<i>Trichospilus diatraeae</i>	100	90	385 (280-450)	>99	15-17
<i>Pediobius furvus</i>	70	70	134 (35-223)	50	23
<i>Xanthopimpla stemmator</i>	59	56	1 (1)	84	17-23

The results suggest that *D. kimballi*, *R. roslinensis*, and all pupal parasites are good candidates for colonization against NCB. Although *T. diatraeae* has been reported to develop on tachinid puparia in laboratory tests, it usually functions as a primary pupal parasite of Lepidoptera in the field (Bennett et al. 1987).

ACKNOWLEDGMENT

We thank F. D. Bennett and Jorge L. Leyva for their comments on earlier drafts. Approved by the Texas Agricultural Experiment Station as TA 24371. Research supported by H-6796 and the Rio Grande Valley Sugar Growers, Inc.

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AN IMPROVED ARTIFICIAL NEST FOR
LABORATORY REARING OF THE IMPORTED FIRE ANT,
SOLENOPSIS INVICTA (HYMENOPTERA: FORMICIDAE)

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Present research with the imported fire ant, *Solenopsis invicta* Buren, has necessitated the maintenance of large numbers of laboratory colonies of these insects. Because of the moisture requirements for proper development and growth of laboratory colonies, we continue to make improvements in our laboratory rearing methods and materials (Williams et al. 1980 and Banks et al. 1981). Two types of laboratory nests used by our fire ant laboratories in Gainesville, Florida, and Gulfport, Mississippi, were described by Bishop et al. (1980). One of these nests, the Williams nest, has been in continuous use since 1980. I report here some modifications which have increased its usefulness.

The results suggest that *D. kimballi*, *R. roslinensis*, and all pupal parasites are good candidates for colonization against NCB. Although *T. diatraeae* has been reported to develop on tachinid puparia in laboratory tests, it usually functions as a primary pupal parasite of Lepidoptera in the field (Bennett et al. 1987).

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The original nest consisted of a small plastic petri dish (100 X 10 mm) centered on the inner bottom of a larger plastic petri dish (150 X 25 mm). The smaller petri dish contained a piece of synthetic sponge that snugly fitted the inside and was saturated with water. Small holes (ca. 3 mm) were made in the top of the small dish, the top was replaced, and the dish placed inside the larger petri dish. Then dental labstone mixed with water was poured into the larger petri dish to completely cover the smaller dish. After the labstone mixture dried, it formed a smooth arena for the ants to maintain their colony.

Recharging the water reservoir was difficult with this design. Since the sponge was sealed, it could only be recharged by drilling a hole through the bottom of the nest into the small dish and then injecting water with a hypodermic syringe and needle. Care had to be taken to avoid being stung, damaging the queen or disrupting the colony. Recharging a large number of nests (500 or more) required an excessive amount of time and dictated the need for modifications.

The new nest design is similar to the old one except for the sponge reservoir (Fig. 1). The piece of synthetic sponge was cut in the shape of an "H" to fit into the bottom of the smaller petri dish and two holes (1.7 cm in diameter and 1.5 cm apart) made in the lid of the small petri dish with a hot soldering iron. Then the ends of a piece of 5.5 cm long Tygon tubing were inserted into the two holes. The tubing was of the type S-50-HL, 1.27 cm o.d. X 0.95 cm i.d. X 0.16 cm thick wall, Norton Performance Plastics, P.O. Box 3660, Akron, OH 44309. Four smaller holes (each ca. 3 mm) were made in the lid of the small petri dish (Fig. 1c) so that when it was covered with the labstone mixture, some of the mixture would flow into the holes and act as a wick to keep the labstone moist. The sponge was moistened, the lid was replaced, and the small dish was



Fig. 1. Components of artificial nest for rearing ants: (a) piece of Tygon tubing; (b) synthetic sponge in the shape of an "H"; (c) small plastic petri dish (100X10mm); (d) large plastic petri dish (150X25mm) containing smaller petri dish, sponge, and Tygon tubing taped in position; (e) lid of large petri dish with hole in center; (f) completed nest with hardened dental labstone and top of Tygon tubing exposed.

taped to the center of the large petri dish. Dental labstone (244 g) thoroughly mixed with tapwater (76 cc) was then slowly poured into the larger petri dish completely covering the small dish but leaving the top of the Tygon tubing exposed. After the labstone hardened (20-30 min), four exit/entrance grooves for the ants were melted through the side of the large petri dish using a soldering iron. The grooves were 90 degrees apart and extended to the level of the labstone. Another hole (ca. 1.7 cm in dia) was melted through the center of the lid of the large dish directly over the Tygon tubing. Replacement of the lid on the large petri dish made the nest ready for use. The water supply can be recharged by inserting the needle (18 ga) of a hypodermic syringe filled with water into the Tygon tubing through the hole in the lid of the large petri dish and injecting 30 cc of the water. The nest usually needs recharging every 3-4 weeks at $30 \pm 2^\circ\text{C}$ and $65 + \% \text{ RH}$. Higher temperatures and low humidity, or both, may require more frequent recharging.

Nests can be reused numerous times even though some microbial growth may occur on the surface of the labstone. The nest can be cleaned for reuse by washing with soap and water using a household sponge, rinsing thoroughly with clean water, and allowing to dry before recharging and putting into use. Worker ants will occasionally cut a hole in the Tygon tubing, especially if the tubing is thin-walled, and then the entire colony, especially the queen and most of the brood, will be moved into the sponge area of the nest. Pieces of the sponge will be removed, eventually making the nest unfit for reuse. When this happens, the ants can be forced to move out of the nest by not recharging with water and removal of the top of the nest. This technique also can be used to drive ants (colony) from old nests into a new one.

In 1988, the cost of each nest was \$1.37 US, exclusive of labor. The nest can last for a year or more until ants do cut through the tubing and enter the sponge area. The tropical fire ant, *Solenopsis geminata* (Fabricius), tends to cut through the Tygon tubing quickly. Therefore, either extra thick-walled tubing or the old type of Williams nest (Bishop et al. 1980) should be used to rear this ant species.

Colonies of the following ant species have been maintained in excellent condition in these nests in our laboratory: *S. invicta*, *S. richteri* Forel, *Camponotus socius* Roger, *C. pennsylvanicus* (DeGeer), *C. abdominalis floridanus* (Buckley), *Pheidole dentata* Mayr, *P. morrissi* Forel, *Iridomyrmex pruinosus* (Roger), *Pogonomyrmex badius* (Latreille), *Conomyrma bureni* Trager, *Monomorium minimum* (Buckley), *Paratrechina longicornis* (Latreille), *Trachymyrmex septentrionalis* (McCook), *Aphaenogaster floridana* M. R. Smith, *A. flemingi* M. R. Smith, and *Formica pallidefulva* Latreille.

We have maintained over 800 colonies of *S. invicta* in addition to numerous colonies of the other ant species in these nests. The nests require minimal maintenance, are less expensive, and enable us to rear ants more efficiently.

The author wishes to thank Gregory Knue and Bradford Lingo for their help and technical assistance.

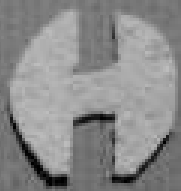
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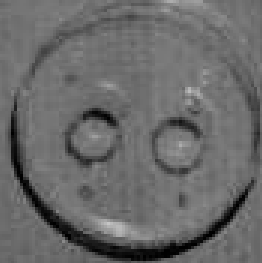
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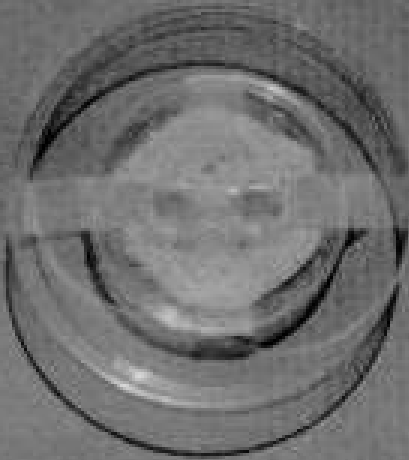
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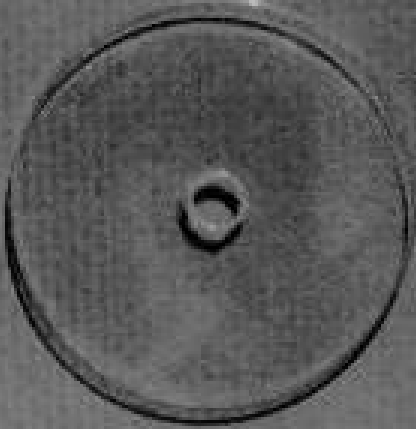
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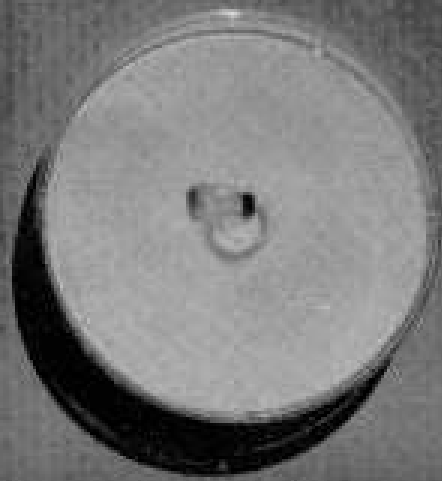
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METHOD TO RANK HOST PLANTS INFESTED WITH
MEDITERRANEAN FRUIT FLY, *CERATITIS CAPITATA*
IN MULTIPLE HOST SITUATION IN GUATEMALA

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In the years 1980 to 1983 about 1200 fruit samples were taken from 45 plots in Guatemala (Eskafi & Cunningham 1987) in order to investigate the infestation pattern of *Ceratitidis capitata* (Wied.). The plots were distributed at 21-2250 m elevations, with a total of 60 different fruit species harvested.

Samples of mature fruits were taken from all plots at biweekly intervals throughout the study period. Due to seasonal specificity of crops the number of fruit species harvested varied from one to several species at each test plot, where number of available host plants for *C. capitata* ranged from 1-14.

The infestation rate in the established host fruits of *C. capitata* varied from 95.1 to 0.04 pupae/kg fruit harvested, so it is reasonable to assume some kind of preference of *C. capitata* for the infestation of fruits.

We tabulated the fruit samples per harvest with their infestation coefficient (pupae/kg fruit), except for situations in which only one fruit was available or where there was no infestation, i.e.

Testplot	Date	Host	Pupae/kg
Liberia	7-22-80	Orange	0
		Coffee	2.214
Las Minas	3-26-82	Grapefruit	7.097
		Sour Orange	3.538
		Orange	0

In many instances where more than one fruit species was harvested only some were infested, although all species were known hosts for *C. capitata*. We counted for each sample size (number of fruit species harvested together) the number of fruit species infested and applied a chi square test for goodness of fit, assuming a uniform distribution of infested fruit species. All distributions were skewed to an infestation in one or two host species only (Table 1). It was apparent that *C. capitata* showed a preference for oviposition in certain hosts, independent of the number of potential mature host fruits present at the same location.

In order to quantify the host preference we counted the number of times a host showed more pupae/kg than the others in the same harvest. In our above example in one case coffee is preferred over orange, and in another case grapefruit is preferred over sour orange and orange, and sour orange is preferred over orange. The total

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TABLE 1. FRUIT SPECIES HARVESTED TOGETHER AND INFESTED BY *C. CAPITATA* IN THE SAME PLOTS (FREQUENCIES), GUATEMALA 1980-83.

Number of species harvested together	Number of species						Goodness of fit		
	1	2	3	4	5	6	chi 2	df	p
2	32	13 ¹					8.02	1	<.01
3	18	10	3				10.9	2	<.01
4	12	3	3	0			18.0	3	<.01
5	5	0	1	0	0		²		
6	5	0	1	1	0	0	²		

¹The numbers refer to frequencies: Out of 45 cases, where two fruit species were harvested together, in 32 cases just one species was infested, and in 13 cases both species were infested.

²Not tested due to an insufficient number of observations.

TABLE 2. PREFERENCE OF *C. CAPITATA* TO INFEST HOST PLANTS IN MULTIPLE HOST FIELD PLOTS.

Rank	No. times preferred for oviposition	Grown with n differ. species	Fruit	Mean pupae/Kg fruit
1	106	18	Coffee <i>Coffea arabica</i> L.	8.411
2	29	17	Loquat <i>Eriobotrya japonica</i> Thunb. Lind.	.994
3	25	18	Orange <i>Citrus sinensis</i> (L.) Osbeck	.288
4	24	16	Sour Orange <i>C. aurantium</i> L.	2.768
5	23	19	Navel Orange <i>C. sinensis</i> (Navel)	.836
6	16	14	Tangerine <i>C. reshni</i> Hort. ex Tan.	1.088
7	14	7	Grapefruit <i>C. x paradisi</i> Macfady.	2.144
8	14	8	Guava <i>Psidium guajava</i> L.	2.265
9	8	10	Limon Persa <i>C. aurantifolia</i> (Persa)	.308
	8	7	Valencia Orange <i>C. sinensis</i> (Valencia)	.349
10	7	8	Durazno (Peach) <i>P. persica</i> L.	8.651
	7	3	Pear (Catman) <i>Pyrus communis</i> (Catman)	.485
11	6	9	Plum <i>P. domestica</i> L.	.215
	6	8	Lima Limon <i>C. limetta</i> Risso	.069

TABLE 2. (Continued)

Rank	No. times preferred for oviposition	Grown with n differ. species	Fruit	Mean pupae/Kg fruit
12	4	7	Apple <i>Malus pumila</i> Mill.	.201
	4	6	Injerto <i>Pouteria viridis</i> (Pittier) Cronquist	1.698
13	3	3	Matasano <i>Casimiroa edulis</i> Llave & Lex.	8.375
14	2	4	Cashew apple <i>Anacardium</i> <i>occidentalis</i> L.	.116
	2	2	Cuajilote <i>Paramentiera edulis</i> D.C.	.040
	3	6	Pome Granate <i>Punica granatum</i> L.	.683
	2	3	Papaya <i>Carica papaya</i> L.	.786
	1	1	Pear <i>Pyrus communis</i> L.	6.081
	1	2	Purple Mombin <i>Spondias purpurea</i> L.	.196
15	1	1	Caspirol <i>Inga ruiziana</i> G. Don.	95.701
	1	6	Strawberry Guava <i>P. littorale</i> Radd.	25.442
16	0	7	Avocado <i>Persea americana</i> Mill.	.259
	0	7	Lima <i>C. limetta</i> Risso	.096
	0	5	Melocoton (Peach) <i>P. persica</i> (L.) Batsch	.882
	0	5	Mango <i>Mangifera indica</i> L.	.070
	0	6	Nance <i>Byronima crassifolia</i> (L.) HBK	.478
	0	1	Pummelo <i>C. maxima</i> (Burm.) Merrill	.040
	0	1	Pear (Keifer) <i>Pyrus communis</i> (L.) (Keifer)	1.456

number of times a fruit is preferred over others is summarized in Table 2. Coffee was the favorite host plant of *C. capitata*, followed by loquat and citrus.

The preferences for oviposition were not correlated with the global infestation rates (pupae/kg fruit). Loquat, for instance, had a somewhat moderate infestation rate, but ranked second in preference for oviposition. Caspirol and strawberry guava had the

highest number of pupae per kg fruit harvested, but ranked low in preference for oviposition, which means, where a more preferred host was not available, large numbers of maggots were present in these fruits.

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IMMATURE STAGE OF THE AQUATIC MOTH *PETROPHILA DRUMALIS* (LEPIDOPTERA: PYRALIDAE, NYMPHULINAE)
FROM *PISTIA STRATIOTES* (WATERLETTUCE)

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A survey of the macroinvertebrates associated with the floating aquatic weed *Pistia stratiotes* L. (waterlettuce) in Florida yielded larval specimens of three pyralid moth species (Dray et al. 1988). We identified two of these species as *Samea multiplicalis* Guenée and *Synclita oblitalis* Walker, but the third proved to be unknown. Subsequently, larvae of this unknown species were collected and allowed to complete their development on waterlettuce roots in the laboratory. Dr. Eugene Munroe determined that the moths which emerged were *Petrophila drumalis* (Dyar) (pers. comm.).

Munroe (1972) and Brigham & Herlong (1982) noted that immature stages have not been associated with the adults for several species of *Petrophila* (formerly included in the genus *Parargyractis*), including *P. drumalis*. Our observations on the habits of the immature stages of this moth indicate its biology is distinct from those previously described for the genus. These stages are, however, remarkably similar to those described by Forno (1983) for *Argyractis subornata* Hampson on waterhyacinth (*Eichhornia crassipes* (Martius) Solms-Laubach) in Brazil.

Most *Petrophila* larvae live under silken webs on the surface of rocks in well-oxygenated, fast-flowing streams (Munroe 1972, Brigham & Herlong 1982). In contrast, *P. drumalis* larvae construct shelters (Figure 1) on the main (adventitious) roots of waterlettuce plants in canals, lakes, and slow-flowing streams. These shelters are 0.5-2 mm wide, 5-10 mm long, and consist of lateral roots loosely woven together, and to the main roots, by silken threads (Figure 1). They serve both as refugia from which the larvae emerge to feed and as pupation chambers.

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Fig. 1. *Petrophila drumalis* shelter with young larva inside.

Larval *Petrophila* purportedly feed on periphyton scraped from rocks near their silken retreats (Munroe 1972, Brigham & Herlong 1982). Larval *P. drumalis*, however, ingest the lateral roots from waterlettuce plants rather than scrape rocks. The larva clips a lateral root at its base on the adventitious root, cuts the lateral root into small segments, and crushes these segments between its mandibles as they pass into the buccal cavity. This habit produces "shaven" areas along the main *P. stratiotes* roots, an appearance which we found characterized the waterlettuce mats harboring *P. drumalis*.

It is unclear whether the larvae derive their nutrition directly from ingested root segments. Forno (1983) thought that waterhyacinth root segments ingested in a similar manner by *A. subornata* provide little direct nutrition. *Neargyractis slossonalis* Dyar (belonging to a closely related genus), lives primarily among tree roots where the larvae consume the young tender rootlets (Habeck 1988). The microflora or microfauna adhering to roots may be the source of nutrition for these species, but this remains to be investigated.

Petrophila larvae, including *P. drumalis* (Figure 2), have unbranched gills filled with hemolymph, but these reportedly have little respiratory function (Brigham & Herlong 1982). Larval *P. drumalis* are unique in having numerous cone-shaped tubercles on the ventral surface of the abdomen (Figure 2). Such structures are of uncertain function and have not been observed on other known *Petrophila* larvae.

Munroe (1972) reported this moth throughout peninsular Florida from Weekiwachee Springs (Hernando Co.) to Fort Lauderdale (Broward Co.). We've collected *P. drumalis* larvae throughout southern Florida including sites in Broward, Collier, Glades, Okeechobee, Palm Beach, and St. Lucie Counties. Preliminary investigations at a canal in Moore Haven (February 1986-April 1987), a canal at the Loxahatchee National Wild-



Fig. 2. Larval *Petrophila drumalis* on waterlettuce root from which the larva has clipped the rootlets. Note the cone-like tubercles on the venter.

life Refuge (September 1986-March 1987), and a borrow pit on Torry Island in Lake Okeechobee (May 1986-April 1987) indicate this is a multivoltine species with asynchronous emergences. Abundances vary from site to site, but generally are highest during the fall and lowest in summer. Population levels during our studies were greatest at Loxahatchee National Wildlife Refuge where we estimate larval abundance reached 219,000/ha (average of 10 0.25 m² samples) in November 1986.

Mike Bouhadana, Jim Grocki, Donna Niehaus, Willey Durden, Sandy Vardaman, Tessa Schaefer, and Lisa Juliano assisted with portions of this research. The study is published as the Florida Agricultural Experiment Stations Journal Series No. 9134, and was conducted through Specific Cooperative Agreement No. 58-7B30-3-586 between the United States Department of Agriculture, Agriculture Research Service, South Atlantic Region and the University of Florida, Institute of Food and Agriculture Services. It was funded, in part, by the U.S. Army Engineers (USAE) District, Jacksonville, and the office, Chief of Engineers U.S. Army, Washington, D.C., through the Aquatic Plant Control Research Program at the U.S. Army Waterways Experiment Station. Director Burkett Neeley arranged permission for us to conduct research at the Aurther R. Marshall Loxahatchee National Wildlife Refuge, U.S. Fish and Wildlife Service.

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NEW INSECT RECORDS ON BRAZILIAN PEPPERTREE,
SCHINUS TEREBINTHIFOLIUS (ANACARDIACEAE),
IN SOUTH FLORIDA

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Brazilian peppertree (*Schinus terebinthifolius* Raddi; Anacardiaceae) is a woody shrub that has been widely introduced and is naturalized in over 20 countries (Ewel et al. 1982). *Schinus terebinthifolius* has attained weed status in many areas outside its native range of Argentina, Paraguay and Brazil. In south Florida, *S. terebinthifolius* is an aggressive invader in a variety of habitats, especially those that have been disturbed by burning, clearcutting or natural disruptions such as hurricanes (Alexander & Crook 1973).

Schinus terebinthifolius is presently under investigation to determine the potential for biological control in Florida with insects or other arthropod control agents (Bennett et al. in press). Previous surveys of the arthropod fauna on *S. terebinthifolius* in Florida have resulted in a relatively low proportion (40%) of foliage consuming arthropods (Ewel et al. 1982, Cassani 1986). Many of these were collected as adults and represent only incidental associations.

Periodic surveys of the arthropod fauna on *S. terebinthifolius* in south Florida during the period 1986-1988 have resulted in several new insect records on *S. terebinthifolius*. These records represent the first association of foliage consuming Lepidoptera on *S. terebinthifolius* in Florida. A list of Lepidoptera species collected on *S. terebinthifolius* and related phenological information is presented in Table 1. *Schinus terebinthifolius* represents a new host record for all species involved and is apparently the only host record for *Paectes obrotunda* (Gn.) and *Protambulyx carteri* (R & J).





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TABLE 1. FIELD AND LABORATORY DATA PERTAINING TO LEPIDOPTERA COLLECTED ON *SCHINUS TEREBINTHIFOLIUS* IN SOUTH FLORIDA.

Taxa	Date(s) Collected	Stage	Association	Date(s) Pupating	Date(s) Emerged
Blastobasidae					
<i>Blastobasis eriobotryae</i> Busck	04-III-87	larvae	dead leaves	15-III-87 — —	30-III-87 06-IV-87 29-IV-87
<i>Holcocera</i> sp.	28-X-87	pupa	?	—	02-XI-87
Limacodidae					
<i>Sibine stimulea</i> (Clem.)	09-X-85	eggs	leaves	14-X-85 ^a	—
Noctuidae					
<i>Paectes abrostoloides</i> (Gn.)	16-IX-87 18-IX-87 " 23-IX-87 24-IX-87 18-X-87	larva " " " " "	leaves " " " " "	23-IX-87 21-IX-87 28-IX-87 05-X-87 05-X-87 parasitized	06-X-87 ♀ 05-X-87 ♂ 09-X-87 ♀ 18-X-87 ♀ 26-X-87 ♀
<i>Paectes obrotunda</i> (Gn.)	18-VIII-86 "	larva "	leaves "	05-IX-86 08-IX-86	22-IX-86 ♂ 25-IX-86 ♀
Pyralidae					
<i>Tallula atrifascialis</i> (Hulst)	12-IX-88	larva	leaves	19-IX-88	29-IX-88
Sphingidae					
<i>Protambulyx carteri</i> R.&J.	18-VIII-86	larva	leaves	31-VIII-86	29-IX-86 ♂
<i>Protambulyx strigilis</i> L.	01-XII-85	larva	leaves	06-XII-85	31-XII-85
Tortricidae					
<i>Episimus augmentus</i> (Zeller)	04-III-87 " "	larva " "	seeds/leaves " "	23-III-87 15-III-87 17-III-87	03-IV-87 26-III-87 28-III-87
<i>Platynota rostrana</i> (Wlk.)	12-IX-88	larva	?	23-IX-88	03-X-88

^aEgg eclosion, larvae preserved in 4th instar.

Paectes abrostoloides (Gn.) was the most common species encountered. It is more frequently found associated with sweetgum (*Liquidambar styraciflua*) (Kimball 1965), and is occasionally a significant pest of sweetgum in Louisiana (Solomon and Cook 1978). Larvae of *P. obrotunda* and *P. abrostoloides* feed on the tender apical leaves but cause little damage because of their generally low overall density. One larva of *P. abrostoloides* was parasitized by the tachinid fly *Chetogena* sp. A previously unidentified Lepidoptera larva was found to be parasitized by the braconid *Macrocentrus delicatus* Cresson and adult emergence was prevented by the parasite. However, an identical larva was reared on *S. terebinthifolius* and identified at a later date from an adult specimen as *Tallula atrifascialis* (Hulst) (Table 1).

None of the remaining Lepidoptera species collected on *S. terebinthifolius* were found to cause significant damage to the plant. Several species, such as *Platynota rostrana* (Wlk.), *Tallula atrifascialis* and *Sibine stimulea* (Clem.) represent somewhat incidental associations with *S. terebinthifolius* due to their polyphagous nature.

We thank the following for identifying or confirming the identity of our Lepidoptera collections and associated parasites: D. Adamski, D. C. Ferguson, J. B. Heppner, P. Marsh, R. W. Poole, and N. E. Woodley.

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LEPTAGRIA PEREXILIS AND *MYLLAENA AUDAX*
(COLEOPTERA: STAPHYLINIDAE) IN FLORIDA

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Leptagria perexilis Casey (Staphylinidae: Aleocharinae: Falagriini) is known from North America from two records: 1) south-central New York, and 2) southern Texas (Hoebeke 1985). We report here 60 specimens collected by sifting horse dung on Big Pine Key (together with specimens of the staphylinid *Aleochara notula* Erichson, a known member of the dung fauna). Probably *L. perexilis* is widely distributed across the entire eastern United States. Its habitat is poorly known, though Hoebeke (1985) recorded it from cow dung and by a pond. Collection data are: USA, Florida, Monroe Co., Big Pine Key, 15.XII.1986, J. Klimaszewski & S. B. Peck, sifting horse dung (2 males, 6 females, and 52 specimens of undetermined sex). Specimens are in the Canadian National Collection, Florida State Collection of Arthropods, and in the collections of J. Klimaszewski and J. H. Frank.

Myllaena audax Casey (Staphylinidae: Aleocharinae: Myllaenini) is known mainly from western North America, with a few records from the northeast and still fewer from the southern USA (Klimaszewski 1982, Klimaszewski & Génier 1986). Its habitat is the banks of rivers, streams and lakes. We report here the first record from Florida: USA, Florida, Putnam Co., Ordway Preserve, Mill Creek Ford, 12.X.1985, J. H. Frank, in wet leaves at stream edge, 1 female (in collection J. H. Frank).


Six other species of Staphylinidae have been added to the Florida list since Frank's (1986) checklist. *Cephaloxynnum rambouseki* Bierig was reported from Dade Co. by Newton (1988); it was known previously only from Cuba, but may have occurred in southern Florida since prehistoric times as a component of the West Indian biota of the Florida Keys and adjacent mainland. *Neohypnus coloratus* Smetana and *Oxybleptes meridionalis* Smetana were described as new (Smetana 1988) from a few specimens from north-central Florida and southeastern Florida respectively; at present they must be considered as precinctive to Florida (i.e., occurring only in Florida). *Lepitacnus pallidulus* (LeConte) was reported from Florida by Smetana (1988) and is now known in the southern tier of states west to California. *Atheta trogliphila* Klimaszewski & Peck and *Atheta lucifuga* Klimaszewski & Peck are known only from caves in the southern USA, including Florida (Klimaszewski & Peck 1986).

Field work by S. B. & J. Peck and J. Klimaszewski was supported by a grant to S. B. Peck from the Natural Sciences and Engineering Research Council of Canada. We thank M. C. Thomas and R. E. Woodruff for reviewing a manuscript draft. This is University of Florida, Institute of Food & Agricultural Sciences, journal series no. 9967.

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LACK OF SUITABILITY OF COMMERCIAL LIMES
AND LEMONS AS HOSTS OF *ANASTREPHA SUSPENS*A
(DIPTERA: TEPHRITIDAE)


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Caribbean fruit fly, *Anastrepha suspensa* (Loew), a pest of West Indies origin, was found in fruit of Surinam cherry, *Eugenia uniflora* L., in Miami Springs, Florida, on 23 April 1965. From this original infestation, *A. suspensa* spread over much of Dade county by the fall of 1966 (Weems 1966). Eighty-four species of fruit in 23 plant families were listed as hosts of *A. suspensa*. Eleven species or cultivars of citrus were found to be infested with *A. suspensa* (Swanson & Baranowski 1972).

Florida citrus fruit shipped to Japan, California, Texas, and Arizona was required to be fumigated with ethylene dibromide (EDB) before shipping to ensure an *A. suspensa* free product. The use of EDB as a post-harvest fumigant for citrus was terminated in September 1984 by the Environmental Protection Agency (EPA) (Anonymous 1984). In September 1985, an agreement was negotiated whereby Japan agreed to accept lemons, *Citrus limon* (L.) Burm. f. from Florida without post-harvest fumigation but not limes, *Citrus aurantiifolia* (Christm.) Swingle, because limes were listed as a host of *A. suspensa* (Anonymous 1988). The objective of this study was to evaluate whether or not limes and lemons produced in Florida are suitable hosts of *A. suspensa*.

The test was conducted in the laboratory by placing Persian lime, Bearss lemon, calamondin, and kumquat fruit in a screened cage (100x100x75cm). Calamondin, *Citrofortunella mitis* (Blanco) J. Ingram & H. E. Moore, and kumquat, *Fortunella japonica* (Thumb.) Swingle, were present in the cage as the control. The cage contained about 600-800 pupae of *A. suspensa* which were obtained from USDA-ARS, Miami, Florida. The percent emergence ranged from 80-90% and the sex ratio was approxi-

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mately 1:1. As soon as the flies emerged, sugar cubes and moist sponges were placed on the top of the cage to provide food and water. A moist plastic sponge was sprinkled with yeast hydrolysate and hung inside the cage to supply additional protein for the flies. Citrus was collected from the Division of Plant Industry Arboretum, Winter Haven, Florida. Fruit was washed and weighed before being placed in the cage. The number of fruit placed in each cage was determined by availability (Table 1).

One week after fly emergence, freshly collected fruit was placed in the oviposition cage. A week later, the fruit was removed and housed separately for each type of fruit in 2-gallon (8-liter) ice cream containers prepared with a 2 cm layer of white sand put in the bottom. An elevated platform made of wire screen was placed in the container upon which a fruit was placed to keep it above the sand. A piece of 60-mesh nylon organdy covered the container and was secured by a plastic lid from which the center had been removed.

The fruits were left in containers for 5 weeks to allow for larval development and pupation. Two weeks after the start of the incubation period, sand was sifted to obtain any pupae until fruit was discarded. Wet sand was replaced with dry sand to insure maximal pupal survival. Pupae were counted and placed in modified 50-dram plastic snap-cap vials with the bottoms removed and each vial was sealed with a small piece of nylon organdy to prevent emerging adults from escaping. Pupae were allowed to emerge to adult over a period of 3-4 weeks and flies were then counted to determine the percentage of emergence. Three days after fruit was removed from the oviposition cage, one-quarter of the flavedo of one fruit of each type was dissected and the numbers of eggs and larvae were recorded. This process was repeated 4 days later to the same fruit to study the development of any larvae inside the fruit; however, albedo and pulp were further examined if damage from the 2nd instar was found. The oviposition cage was housed in a greenhouse ($27 \pm 5^\circ\text{C}$) and the ice cream containers were housed in the laboratory ($27 \pm 2^\circ\text{C}$, 14L:10D) at the Division of Plant Industry in Gainesville.

Lime and lemon were acceptable for oviposition by *A. suspensa* throughout the year, regardless of the state of the fruit, whether green during August-October or starting to ripen in early December. Eggs were deposited in the oil glands or between glands. Most of the eggs hatched to first instars, then died; no mature larvae or pupae were found. Results of the experiment are shown in Table 1. Calamondin and kumquat were acceptable for oviposition and development by *A. suspensa*. Larvae developed in the pulp and emerged from the fruit for pupation. An average of 2.6 and 12.6 pupae/100g fruit were reared from calamondin and kumquat, respectively. The percent emergence from these pupae was 32% for calamondin and 35% for kumquat. Greany et al. (1983)

TABLE 1. AVERAGE NUMBER OF EGGS FOUND AND NUMBER OF PUPAE REARED FROM FRUIT PLACED IN THE OVIPOSITION CAGE AND INNOCULATED WITH *ANASTREPHA SUSPENS*A (600-800 PUPAE) IN THE LABORATORY ($\bar{x} \pm \text{SE}$).

Type of Fruit	No. of Replications	Average No. of fruit/replication	Average No. of eggs first instar larvae larvae/100 g fruit	Average No. of pupae/100 g fruit
Persian lime	51	3.19 \pm 0.95	53.40 \pm 141.90	0.00
Bearss lemon	46	3.13 \pm 0.49	19.70 \pm 23.91	0.00
Calamondin	28	14.35 \pm 4.73	269.11 \pm 249.66	4.28 \pm 3.54
Kumquat	23	15.56 \pm 3.97	246.41 \pm 243.44	13.07 \pm 11.30

found that egg hatchability was 64-74% for Eureka and Lisbon lemons, but lemons were immune to successful development by *A. suspensa*. Lime was considered as a host of *A. suspensa* because a pupa was recovered from a lime during the 3-year study by Swanson & Baranowski (Swanson 1982, personal communication).

Results from this study indicate that Persian lime and Bearss lemon should not be considered as the hosts of *A. suspensa*, and fumigation or other means of disinfestation are not necessary.

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METHOD FOR COLLECTING ARTHROPODS DISLODGED FROM SOYBEAN PLANTS

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In ground cloth sampling in soybean, arthropods are dislodged from the plants onto a cloth and counted either in the field or removed to a container and taken to the laboratory for processing (Kogan & Pitre 1980). Shepard & Carner (1976) dislodged insects onto a polyethylene sheet in order to allow the samples to slide more easily into a container than is permitted by cloth. However, transfer may require two people and often insects escape, especially when sampling high densities of predators in the field (Deighan et al. 1985). We describe a polyethylene ground cloth in the shape of a funnel that facilitates the collection of arthropods.

The "beat funnel" is constructed from four triangular pieces of 2 mil (0.0508 mm) black polyethylene film, duct tape, a one gal. (3.8 liter) paper container (Fonda, Union,



Fig. 1. Beat funnel construction. A & B, Two isosceles triangles each (a & b) were cut from polyethylene sheets and one of the tips (c & d) removed. C, The four pieces (a, b, a', and b') were taped together with duct tape, with a and b connected to form the funnel. Duct tape was used also to attach the rods and reinforce the 102.3 cm edges. D, A small binder clip was inserted in a horizontal slit at the top of a tube (e) cut from a paper container. E, The paper tube was bent to fit the opening and taped to the polyethylene. A brown paper bag was attached to the tube on the completed beat funnel to collect arthropod samples.

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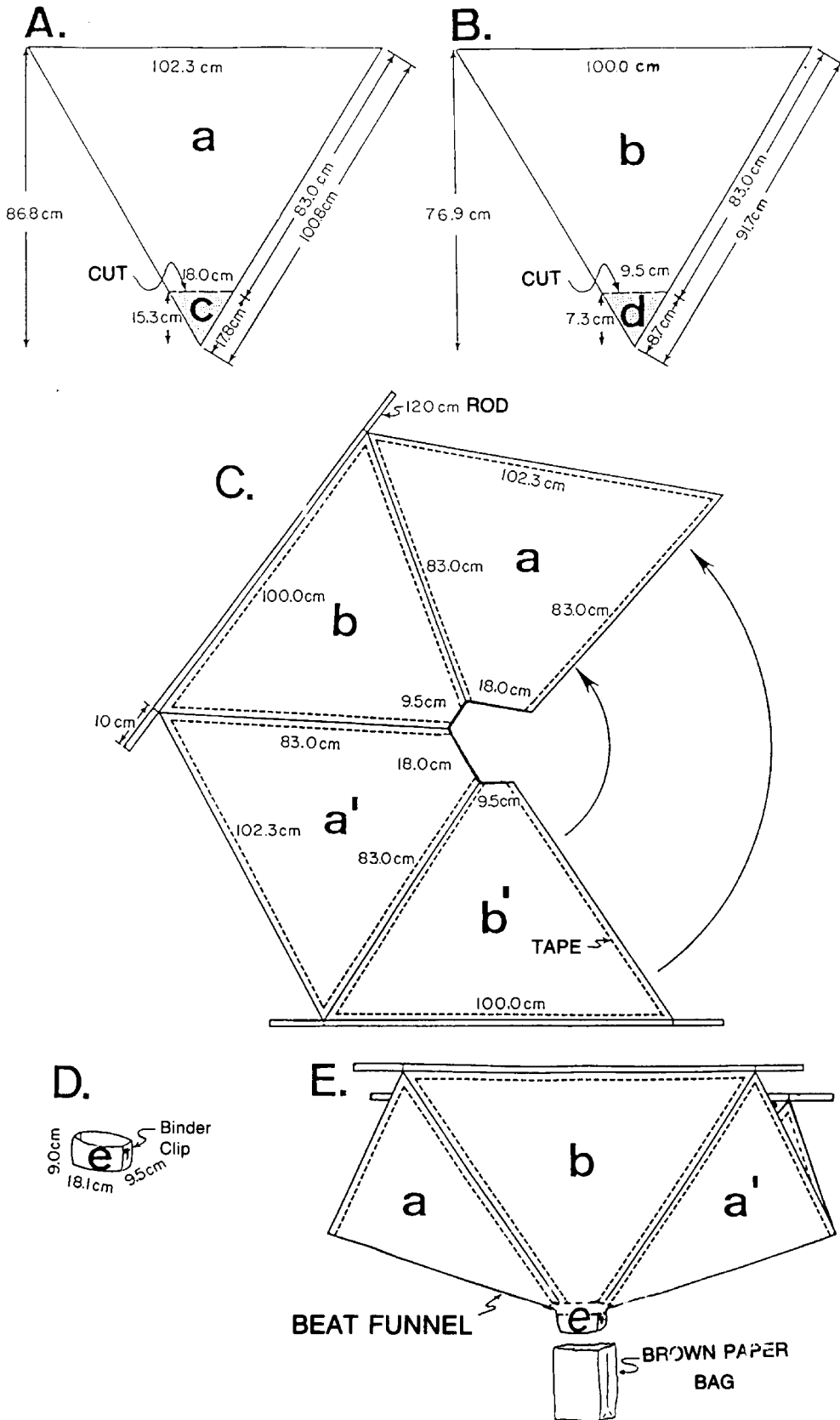
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N.J.), a small binder clip and two 1.2 m wooden rods (1.5 cm doweling) (Fig. 1A-E). The beat funnel (Fig. 1E) is 0.79 m deep and narrows from a 1.02 x 1.00 m rim down to a 18.1 x 9.5 cm paper tube (Fig. 1D). A paper bag (20.5 x 13.0 x 45.3 cm) is placed over the paper tube, the mouth of the bag folded to make a tight fit around the tube and secured by slipping the folded portion under the binder clip. The two dowel rods are attached at the rim to two edges of the funnel (b¹ and b, Fig. 1D). The beat funnel may be rolled up for transportation or storage.

The sampling procedure includes separating the rods between two rows such that the perimeter is taut, but the funnel (with bag attached) is folded underneath to lie roughly flat on the ground. One meter of each adjacent row is beaten (Turnipseed 1974) ten times over the beat funnel. Immediately, the beat funnel is lifted and closed by bringing the rods together. The darkened inside of the black polyethylene funnel may help prevent escape of arthropods. Holding the sticks in one hand, the funnel is shaken vigorously with the other hand until all arthropods and plant material fall into the collection bag. The bag is then pinched shut, removed from the paper tube, and closed. The bagged samples are placed in an insulated box with ice to prevent predation among arthropods within the sample and taken to the laboratory for processing. Samples from more than 2 m of row were taken by closing the polyethylene funnel after sampling at the first site, moving to another site, and repeating the procedure. When placing the beat funnel on the ground at additional sites, escape of arthropods is prevented because the polyethylene folds over the opening of the paper tube.

Although differences between insect sampling by shake funnel and conventional ground cloth were not directly tested, indirect comparisons were made by determining the relationships of beat funnel to sweep net captures of common pest and beneficial species and comparing these relationships with relationships of ground cloth to sweep net captures reported by Deighan et al. (1985) and Rudd & Jensen (1977). Our samples and those by Deighan et al. (1985) were made during soybean growth stages R5 and R6, and those by Rudd & Jensen (1977) from R2 to R8 (Fehr & Caviness 1977). Samples in this study were taken in six 1 ha plots of Braxton soybean (1.01 m row spacing) over four weekly intervals. A total of twenty samples were taken, each consisting of six sets of 50 sweeps across a single row (Kogan & Pitre 1980) and of five 2 m of row beat funnel samples, in order to reduce within plot variability (Rudd & Jensen 1977). Sweep data were transformed to number per 25 sweeps to compare with published data. For purposes of comparison, linear regressions through the origin were calculated for only the species recorded at similar densities to ours by Deighan et al. (1985). Power and linear models are presented for nabids, primarily *N. roseipennis* Reuter, because Deighan et al. (1985) reported a significantly nonlinear relationship indicated by a power term (c) < 1. They speculated that the nonlinear relationship resulted from nabids escaping before they could be counted from the ground cloth samples but not from the bagged sweep net samples when densities were high. Outliers were identified using studentized residuals (SAS Institute 1982) at $\alpha = 0.05$ and were removed from the analysis. Differences between slopes were compared by failure of the 95% confidence limits to overlap.

The slope (b) for adults of bean leaf beetle, *Cerotoma trifurcata* (Forster), obtained by beat funnel vs. sweep net was within the range of values reported in the literature obtained by shake cloth vs. sweep net (Table 1). Higher sampling efficiency for nabid nymphs and adults combined by the beat funnel than ground cloth was indicated by the higher slope (b) of the linear model obtained with the beat funnel than that obtained with the ground cloth (Deighan et al. 1985).

The lower efficiency of recovery of nabids by the ground cloth at high than low densities reported by Deighan et al. (1985) was not observed with the beat funnel. Regressions for nabid nymphs and adults combined and nabid adults alone, obtained with the beat funnel had 3.2- and 1.8-fold higher R² values with linear than with power

TABLE 1. REGRESSIONS OF NUMBERS OF INSECTS PER SAMPLE TAKEN BY BEAT FUNNEL VS. SWEEP NET WITH PUBLISHED REGRESSIONS OF GROUND CLOTH VS. SWEEP NET IN CONVENTIONALLY PLANTED SOYBEAN AT R5-R6 GROWTH STAGES.

Species & Stages	Study	Density		Regressions				
		beat	sweep	model ¹	n	coefficient	(x ± 95% CI)	R ²
Bean leaf beetle adults	Felland & Pitre	0-7.7	0.3-29.7	Linear	19	b	0.18 ± 0.03	0.94
	Deighan et al. 1985	0-4.3	0.1-21.1	Linear	34	b	0.19 ± 0.02	0.89
	Rudd & Jensen 1977 ²	na	na	Linear	21	b	0.22 ± 0.07	0.80
Nabid nymphs and adults	Felland & Pitre	0.1-10.0	0-7.1	Linear	17	b	1.66 ± 0.79	0.74
				Power	20	b	0.60 ± 0.60	0.15
						c		6.61 ± 2.76
	Deighan et al. 1985	0-2.6	0.2-4.8	Linear	23	b	0.34 ± 0.15	0.52
				Power	23	b	0.92 ± 0.37	0.65
						c	0.20 ± 0.42	
Nabid adults	Felland & Pitre	0-2.2	0-2.8	Linear	19	b	0.86 ± 0.20	0.83
				Power	20	b	0.70 ± 0.35	0.46
							c	1.09 ± 1.52
	Deighan et al. 1985			Not reported				

¹Linear (forced through origin), Y (no. per 1.0 row-meter) = b * X (no. per 25 sweeps); Power, Y = b * X^c

²Sample during growth stages R2-R8; Used Y = a + b * X, a reported not different from 0 (no significance given).

models. For the beat funnel a very poor fit was obtained by the power curve for nymphs and adults combined ($R^2 = 0.15$), but adults alone were better fit ($R^2 = 0.46$) and the power curve was not significantly nonlinear, indicating that the beat funnel prevented escape of the fast moving adults when densities were high. At lower densities sampling efficiency appeared similar based on visual comparisons of regression lines, which had nonsignificantly different slopes (b) for nabids nymphs and adults and nabid adults obtained by ground cloth (power model) and beat funnel (linear and power models).

The beat funnel described here is easily handled and is quickly and uniformly operated by one person. Up to thirty 4.0 m row samples were taken in 2 h by a single sampler. Processing time in the laboratory varied with number of arthropods and the amount of foliage in the samples. Beat funnel and ground cloth sampling are of comparable efficiency for sampling bean leaf beetles, a species that does not show a rapid escape response (Kogan et al. 1980). For the more mobile species the beat funnel is equally efficient at low densities, but at high densities appears to limit escapes and be more efficient than the ground cloth.

The original concept of the beat funnel method was provided by R. Lardizabal, a field assistant, who is currently residing in Tegucigalpa, Honduras, Central America. C. G. Helms (for M. Kogan), S. Ramaswamy and J. Schneider reviewed the manuscript. This work was done in partial fulfillment of a Ph.D. by the senior author. This is Publication Number J-7185 of the Mississippi Agricultural and Forestry Experiment Station, Mississippi State, MS 39762.

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224 Desota Road
West Palm Beach, FL 33405

D. M. Scott & Sons
Attn: Wayne C. Mixson
P.O.Box 2187
Apopka, FL 32704-2187

South Bay Growers
Attn: Stewart Swanson
P.O. Drawer "A"
South Bay, FL 33493

Sun Refining & Marketing Co.
Attn: Ms. N. E. H. Wright
P.O. Box 1135
Marcus Hook, PA 19061-0835

Uniroyal Chemical
Attn: Keith H. Griffith
6233 Ridgeberry Court
Orlando, FL 32819

Van Waters & Rogers
Attn: Norman R. Ehmann
2256 Junction Ave.
San Jose, CA 95131

Walt Disney World
Attn: Jerry A. Hagedorn
P.O. Box 40
Lake Buena Vista, FL 32830

A. C. "Abe" White R.P.E.
817 W. Fairbanks Avenue
Orlando, FL 32804

W.M.P.C., Inc.
Attn: Norman Goldenberg
11900 Biscayne Blvd., Suite 618
Maimi, FL 33181-2726

Wright Pest Control
Attn: M. L. Wright, Jr.
P.O. Box 2185
Winter Haven, FL 33880