of *Staphylococcus* attractive to laboratory strain *Anastrepha ludens* (Diptera:Tephritidae). Ann. Entomol. Soc. America 84: 555-559.
ROBACKER, D. C., W. C. WARFIELD, AND R. F. ALBACH. 1993. Partial characterization and HPLC isolation of bacteria produced attractants for the Mexican fruit fly, *Anastrepha ludens*. J. Chem. Ecol. 19:543-548.
SAS INSTITUTE. 1988. SAS/STAT users guide, release 6.03 ed. SAS Institute, Gary, N.C.
STEINER, L. F. 1952. Fruit fly control in Hawaii with poison-bait sprays containing protein hydrolysates. J. Econ. Entomol. 45:838-843.
TSIROPOULOS, G. J. 1976. Bacteria associated with the walnut huskfly, *Rhagoletis completa*. Environ. Entomol. 5: 83-86.

ANALYSIS OF CARIBBEAN FRUIT FLY (DIPTERA: TEPHRITIDAE) TRAPPING DATA, DADE COUNTY, FLORIDA, 1987-1991

MICHAEL K. HENNESSEY
Agricultural Research Service, USDA,
Subtropical Horticulture Research Station
13601 Old Cutler Road
Miami, FL 33158

ABSTRACT

Records of Caribbean fruit flies, *Anastrepha suspensa* (Loew), captured in McPhail traps were analyzed from 48 trapping locations in Dade County (Port of Miami and Homestead) from 1987-1991. Greatest numbers were trapped over all locations in May, June, and July 1987 and 1989-1991, and in November 1988. Thirteen species of Caribbean fruit fly host trees were represented among the 48 trap locations. Numbers of flies trapped weekly in all traps or just those in conspecific host trees were not linearly correlated with weekly mean temperatures or weekly precipitation. Weekly trap catches were not correlated among conspecific host tree sites or between the Port of Miami and Homestead areas.

Key Words: *Anastrepha suspensa*, populations, sampling, host.

RESUMEN

Se analizaron los registros de las trampas tipo "McPhail" de la mosca de la fruta del Caribe *Anastrepha suspensa* (Loew), en 48 sitios diferentes en el condado Dade (Puerto de Miami y Homestead) de 1987 a 1991. El aumento máximo en el número de moscas atrapadas ocurrió en todos los lugares en mayo, junio y julio de 1987 y 1989-1991, y en noviembre de 1988. Trece especies de árboles hospederos de la mosca de la fruta del caribe fueron representados en los 48 sitios donde se encontraron las trampas. El número de moscas atrapadas semanalmente en todas las trampas o en aquellas localizadas en hospederos de la misma especie, no estuvieron relacionadas linealmente con el promedio semanal de la temperatura y la precipitación. El promedio semanal de moscas atrapadas no estuvo relacionado ni entre los sitios con árboles hospederos de la misma especie ni entre las áreas del Puerto de Miami y Homestead.

McPhail trapping with hydrolyzed torula yeast and borax bait pellets to detect exotic tephritids at ports of entry has been carried out by the Florida Department of Agriculture and Consumer Services since the 1970s in Dade County, Florida, (Anonymous 1989). From these trapping data, the numbers of Caribbean fruit fly [*Anastrepha suspensa* (Loew)] adults, an introduced and established quarantine pest, have been recorded.

The effects of temperature, precipitation, wind, humidity, and host availability on trapping of adults of several species of fruit flies (not Caribbean fruit fly) have been investigated outside of Florida. In general, catches of fruit flies increased with increasing host availability and the occurrence of temperature and rainfall favorable to host and fly development (Baker & Chan 1991, Drew & Hooper 1983, Harris & Lee 1986, Harris & Lee 1987, Jiron & Hedstrom 1991, Wong et al. 1985). Fehn (1982) found a negative correlation between rainfall and numbers of flies (*Anastrepha* spp.) captured in peach groves in Brazil but no correlation between numbers of flies captured and temperature, wind, or humidity. Herrera A. & Vinas V. (1977) determined that numbers of flies [*Anastrepha* spp. and *Ceratitis capitata* (Wiedemann)] captured were positively correlated with temperature but negatively correlated with humidity in mango groves in Peru. Inayatullah et al. (1991) determined a predictive model for density of *Bactrocera cucurbitae* Coquillett, in Pakistan based on a positive correlation between trap catches and temperature. Studies on species other than the Caribbean fruit fly which have associated high numbers of trapped adults with increased host availability include those of Fletcher (1974), Houston (1981), Harris & Olalquiaga (1991), and Vargas et al. (1983a, b). The effects of temperature and precipitation on trap catches of Caribbean fruit fly adults have not been reported.

Effects of host availability on Caribbean fruit fly trapping or larval density in Florida have been investigated. Burditt (1982) found no differences in numbers of flies trapped concurrently in loquat, guava, and tamarind trees and concluded that population fluctuations were probably synchronous in all areas of Dade County, irrespective of location of trap or availability of host. Mason & Baranowski (1989) speculated that high trap catches corresponded to suitable environmental factors, host availability, or mass synchronous adult eclosion in guava groves in Dade County. Von Windeguth et al. (1973) observed that high larval populations were maintained for most of the year in tropical almond, common guava, calamondin, and sapodilla. They also observed that loquat and Suriname cherry supported very high populations of larvae during their short fruiting seasons, and that movement of populations among hosts was imperceptible due to overlapping of fruiting seasons. Swanson & Baranowski (1972) determined monthly larval density for 6 hosts of the Caribbean fruit fly in Dade County and observed that loquat, rose apple, and Suriname cherry were among the few fruits available during winter and early spring which supported high populations during that period leading to an annual adult peak in late spring. In comparing citrus-growing areas with tropical fruit-growing areas in Indian River County, Nguyen et al. (1992) found that Caribbean fruit flies reproduced in different hosts as they became available over the year but did not heavily colonize citrus groves because citrus was not a preferred host. They captured greatest numbers of flies in McPhail traps during summer months in their 4 year study.

The objectives of the present research were to determine, through McPhail trap sampling, the time of year when the Caribbean fruit fly was captured in greatest numbers in Dade County, Florida, and any correlations between (1) trap catches and temperature and rainfall, (2) catches among traps in conspecific host trees in different areas, and (3) between traps from mixed hosts in 2 widely separated areas, Miami and Homestead.

MATERIALS AND METHODS

During 1987-1991, McPhail traps at 50 trapping locations, 25 in each of the Port of Miami and Homestead areas, were monitored by Florida Department of Agriculture and Consumer Services personnel. All but 2 traps were maintained in their original positions during the 5-year period. Data from the 2 traps which were moved were excluded, leaving 48 traps (24 in each area) for analysis. There were 252 weekly sampling dates between January 1987 and December 1991.

Traps in the Port of Miami (PM) were all located within 0.2 km of either Biscayne Bay or the Atlantic Ocean (Fig. 1). Four traps were located in Miami Beach, 6 in Miami, 4 on Dodge Island, 2 each on Watson and Palm Islands, and 1 each on Belle Isle, San Marco, Dilido, Rivo Alto, Hibiscus, and Star Islands. One trap was located in each tree. Host tree species names and numbers of each were: *Citrus paradisi* MacF., grapefruit (5); *Coccoloba diversifolia* Jacq., pigeon plum (1); *Coccoloba uvifera* (L.) L., sea grape (8); *Eriobotrya japonica* (Thunb.) Lindl., loquat (1); *Mangifera indica* L., mango (3); *Manilkara zapota* van Royen, sapodilla (2); *Psidium guajava* L., common guava (2); *Syzygium jambos* Alston, rose apple (1); and *Tamarindus indica* L., tamarind (1). All of the above plants, excepting tamarind and pigeon plum, are hosts of the Caribbean fruit fly (Norrbom & Kim 1988). Distances between traps ranged from 0.1 km to 6.0 km. The area was highly urbanized, with numerous dooryard hosts near trap sites, far from agricultural areas and forests containing feral common guava, and located at a major seaport for agricultural produce.

Traps in the Homestead Air Force Base (HAFB) area were all located about 36 km SW of the PM traps and 4-9 km inland from Biscayne Bay (Fig. 1). Sixteen traps were located on HAFB and 8 to the NE in adjacent Leisure City and Princeton. Host tree species names and numbers of each were: *Callistemon* sp., bottlebrush (1); *Citrus aurantium* L., sour orange (1); sea grape (4); *Dovyalis hebecarpa* Warb., Ceylon gooseberry (1); loquat (7); *Ficus* sp., fig (1); mango (3); sapodilla (1); *Persea americana* Mill., avocado (1); *Pouteria campechiana* Baehni, egg fruit (1); rose apple (1); *Terminalia catappa* L., tropical almond (1); and X *Citrofortunella mitis* Ingram & Moore, calamondin (1). All plants, except for bottlebrush and probably fig (species unidentified) are hosts of Caribbean fruit fly (Norrbom & Kim 1988). The distance between traps ranged from 0.2 km to 6.0 km. The area was rural, with relatively low density of dooryard hosts (compared with PM), and located near agricultural areas and forests containing feral common guava.

Elevations (0-5 m), soils (mostly loamy on level terrain, well-drained, shallow, over Miami oolite), temperatures, and rainfall were considered to be very similar at all trapping sites. Monthly rainfall and maximum and minimum temperatures for the eastern Dade County region were averaged (Fig. 2) from 6 National Oceanic and Atmospheric Administrations (National Climatic Data Center 1987-1991) weather stations (Miami Beach, Hialeah, Miami International Airport, Royal Palm Ranger Station, University of Florida TREC [Homestead Airport after May 1990], and USDA Miami [Perrine after May 1989].

Fruiting periods of the 13 species of host trees in which traps were located were delineated by Morton (1987) and confirmed by personal observation in the field (Fig. 3).

Trapping data were transformed to $(x + 0.5)^{1/2}$ and analyzed by PROC CORR (Pearson correlation) and PROC GLM (ANOVA, LSD) programs for personal computer (SAS Institute 1990).

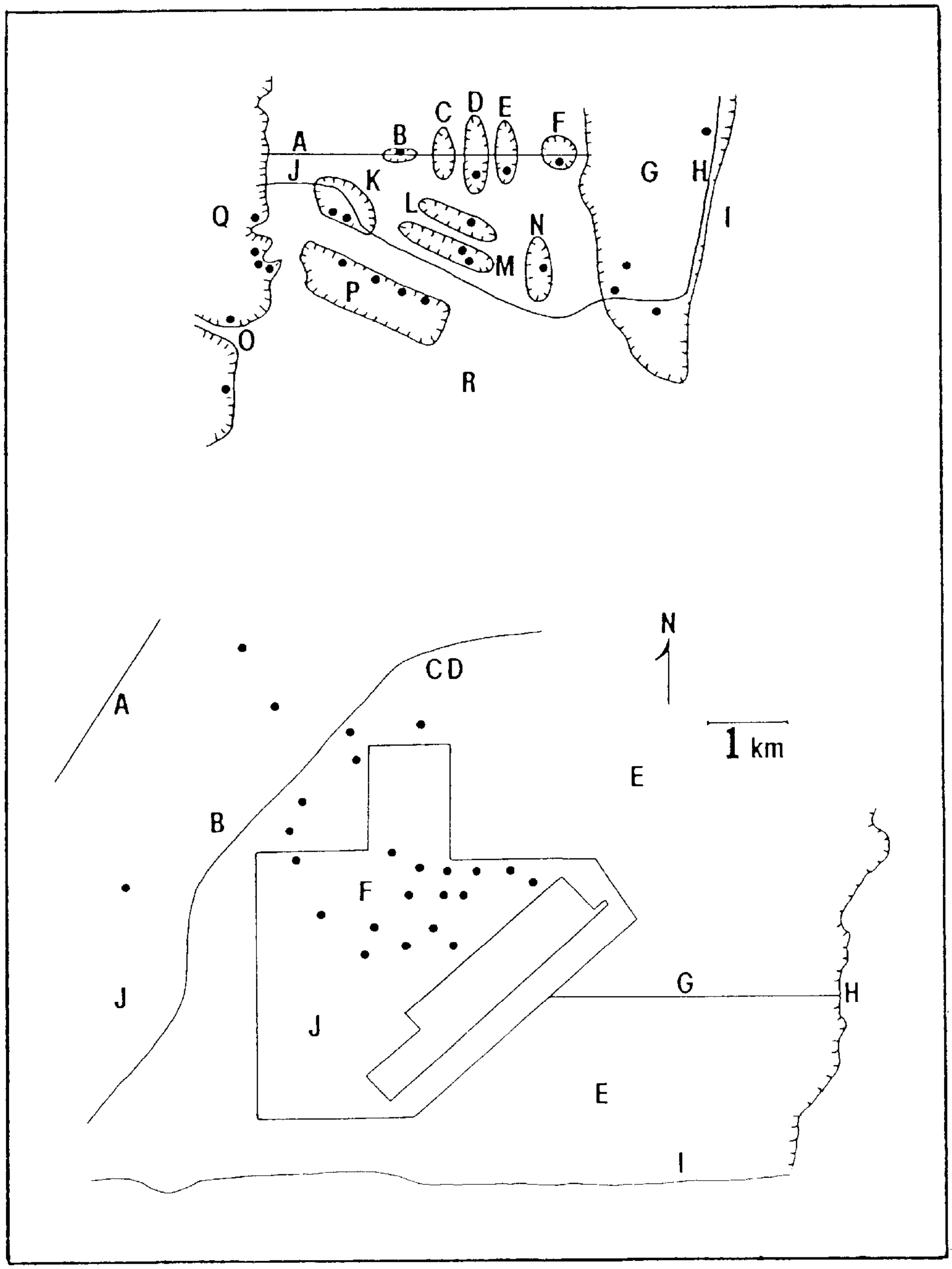

Fig. 1. Map of McPhail trap sampling locations, Dade County Florida, 1987-1991, black circles are trap locations. Upper map is Port of Miami: A, Venetian Causeway; B - F, San Marco, San Marino, Dilido, Rivo Alto, Belle Isle Islands; G, Miami Beach; H, route A1A; I, Atlantic Ocean; J, MacArthur Causeway; K - N, Watson, Hibiscus, Palm, Star Islands; O, Miami River; P, Dodge Island, Port of Miami; Q, Miami; R, Biscayne Bay. Lower map is Homestead Air Force Base: A, route US1; B, Leisure City; C, Florida Turnpike; D, Princeton; E, agricultural and forest area; F, Homestead Air Force Base; G, Military Canal; H, Biscayne Bay; I, Mowry Canal; J, residential area. Scale applies to both maps.

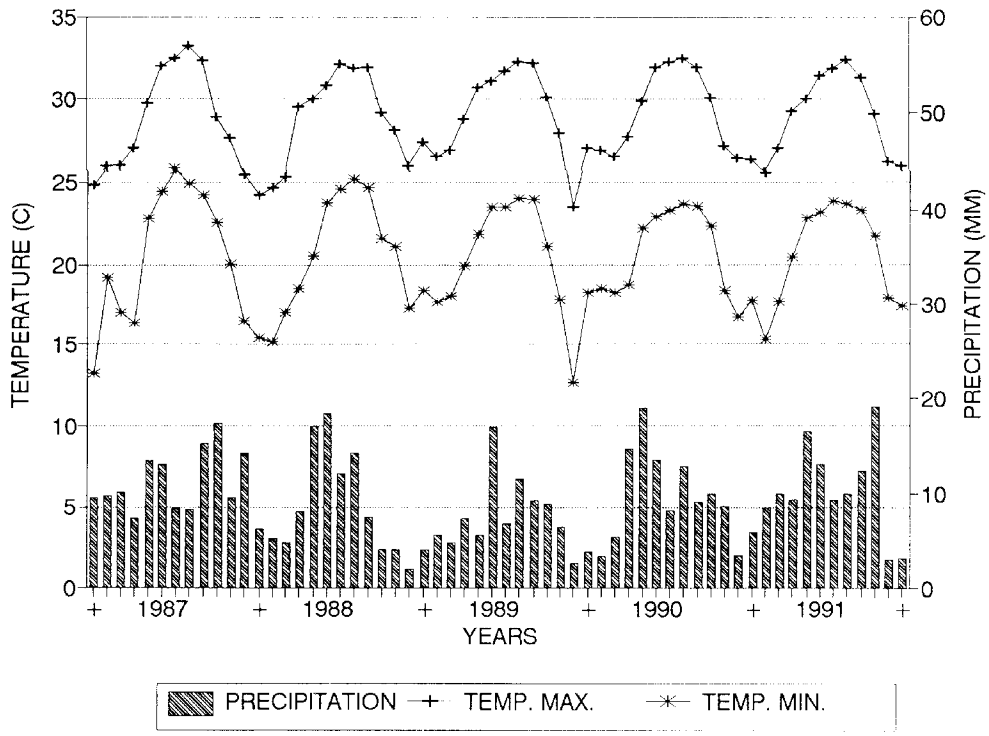

Fig. 2. Monthly average maximum and minimum temperatures and precipitation for eastern Dade County, Florida, 1987-1991.

Results and Discussion

Analysis of Fig. 3 indicated that 6-9 of the 13 host species were fruiting in each month in the trapping areas. Fruiting periods for the various hosts overlapped and oviposition and development sites were available year-round in various fruits. Individual trees probably varied from year to year in the amount of fruit produced depending on available water, fertilization, pesticide applications, and other management practices, which were not documented.

Monthly average temperatures ranged from 13 °C to 33 °C over the 5 years (Fig. 2). Temperatures dipped below freezing for 2 nights during week 52 of 1989, but flies were trapped the week after the freeze (Fig. 4). Sixty-eight percent of the flies captured that week were located in a trap in a tropical almond tree at HAFB. Flies were also trapped that week in grapefruit, guava, loquat, and rose apple trees.

The mean number (± SEM) of Caribbean fruit flies captured per week and per trap over 5 years in each species of tree was: tropical almond (13.1 ± 4.4); calamondin (10.0 ± 2.0); grapefruit (8.0 ± 0.9), rose apple (7.0 ± 1.5); guava (6.6 ± 0.9); loquat (4.7 ± 0.8); egg fruit (3.2 ± 0.7); mango (1.9 ± 0.3); and sea grape (0.9 ± 0.2). Fewer than 0.9 flies per week per trap were caught in avocado, Ceylon gooseberry, pigeon plum, sapodilla, sour orange, and tamarind.

Weekly trap catches (Fig. 4) appeared to mirror temperature fluctuations (Fig. 2). Four of the 5 highest weekly trap catches were in May, June, or July (Fig. 4) except for 1988 when the greatest number of flies was captured in November. Weeks each year in which greatest mean numbers ($\alpha = 0.05$, LSD) of flies per trap were caught over all

HOST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AVOCADO	+	+				+	+	+	+	+	+	+
CALAMONDIN	+	+	+	+	+	+	+	+	+	+	+	+
CEYLON GOOSEBERRY			+	+	+				+	+	+	
EGGFRUIT	+	+	+								+	+
GRAPEFRUIT	+	+	+	+	+				+	+	+	+
GUAVA	+	+			+	+	+	+	+			
LOQUAT		+	+	+								
MANGO					+	+	+	+				
ROSE APPLE					+	+	+					
SAPODILLA					+	+	+	+	+			
SEA GRAPE	+	+	+	+	+	+	+	+	+	+	+	+
SOUR ORANGE	+	+	+	+	+	+						+
TROPICAL ALMOND									+	+	+	+

HOST PRESENT: +

Fig. 3. Fruiting phenologies of the 13 hosts of the Caribbean fruit fly in which McPhail traps were placed in Dade County, Florida, 1987-91.

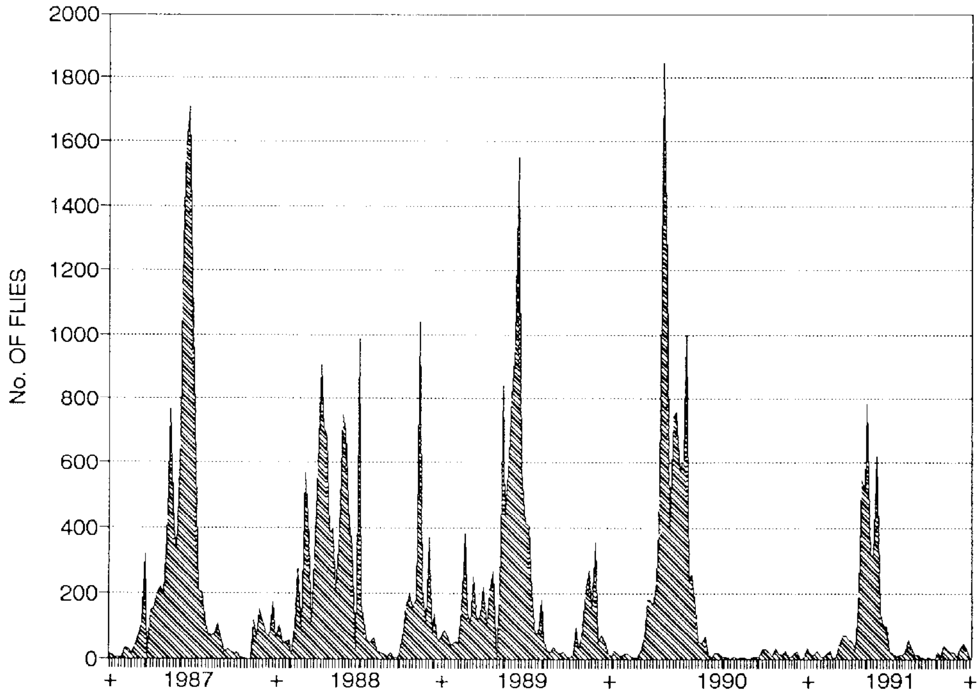

Fig. 4. Weekly Caribbean fruit fly adult captures in McPhail traps (each week represents a total of 48 traps), Dade County, Florida, 1987-1991.

locations were: 1987, week 26 (34 per trap); 1988, week 46 (21 per trap); 1989, week 25 (32 per trap); 1990, week 18 (38 per trap); 1991, week 20 (16 per trap). Smaller peaks in the winters of 1987 and 1989 reflected captures in the tropical almond trap.

Weekly fly catches from all traps together and mean temperatures for the same weeks were correlated significantly ($\alpha = 0.05$) in 1987, 1989, and 1991, but the correlations were not linear in those years, given the extremely small correlation coefficients (1987, $P = 0.0001$, $r = 0.01$; 1989, $P = 0.004$, $r = 0.003$; 1991, $P = 0.0003$, $r = 0.005$). In 1988 and 1990, correlations were not significant (1988, $P = 0.33$; 1990, $P = 0.06$). These results agreed with findings of Fehn (1982) who found no correlation between temperature and trap catches (*Anastrepha* spp.) in Brazil but were in contrast to the findings of Herrera A. & Vinas V. (1977), who found a positive correlation between temperature and trap catches (*Anastrepha* spp.) in Peru.

Rainfall was generally heaviest in summer or early fall months during all years (Fig. 2). While the correlations between weekly fly catches from all traps together and total rainfall from the same weeks were significant ($\alpha = 0.05$) in 1989 and 1990, they were not linear in those years (1989, $P = 0.0001$, $r = 0.008$; 1990, $P = 0.003$, $r = 0.001$). Correlations between fly catches and rainfall were not significant for the other 3 years (1987, $P = 0.66$; 1988, $P = 0.06$; 1991, $P = 0.15$). Analyses were also run for weekly fly catches and rainfall from 1, 2, and 3 weeks prior to trapping weeks to determine if there was a lagged response of fly activity to precipitation, but correlations were not higher.

Correlations of weekly fly catches from all traps together with rain and temperature together were significant ($\alpha = 0.05$) for 1987, 1989, 1990, and 1991, but were not linear for those years (1987, $P = 0.0001$, $r = 0.01$; 1989, $P = 0.0001$, $r = 0.008$; 1990, $P = 0.01$, $r = 0.004$; 1991, $P = 0.0001$, $r = 0.008$). The factors were not significantly correlated in 1988.

In general, catches in traps within each host tree species did not have a high linear correlation with rainfall and temperature. The best linear correlation of a host with rainfall and temperature together was common guava (P = 0.0001, r = 0.32). As has been suggested by Harris & Lee (1986, 1987) for other tropical fruit flies, weather probably affected the fruiting period and yields of hosts more than it affected fly trap catches. The present results support Fehn's (1982) conclusion that environmental factors and availability of hosts interact to affect trapping frequency.

Weekly mean (± SEM) numbers of flies per trap, over all locations and weeks, were 4.7 ± 0.5 (1987), 4.6 ± 0.6 (1988), 4.3 ± 0.4 (1989), 3.9 ±0.7 (1990), and 1.8 ± 0.2 (1991). More flies were trapped weekly per trap in 1988 than in other years (P = 0.05, LSD) and the fewest were trapped in 1991. Significant ($P < 0.05$) correlation coefficients between weekly mean captures over all locations and years ranged from 0.34 to 0.83. The catch patterns of 1990 and 1991 were highly correlated (P = 0.0001, r = 0.83), which may be confirmed by visual comparison of the trapping curves for both years (Fig. 4).

A mean (± SEM) of 3.6 ± 0.5 flies were taken weekly per trap in the PM and 4.1 ± 0.5 flies were taken in the HAFB over the 5 years. The difference between the means was not significant ($P > 0.05$). PM and HAFB weekly trap catch means were not significantly correlated ($P > 0.05$) for any year. Visual comparison of weekly fly catches in the PM (Fig. 5) and the HAFB (Fig. 6) confirms the disparity between catch patterns in the 2 areas.

Numbers of flies trapped weekly were compared among hosts of the same species in each year. Only 2 (from among 450 possible trap pairs) of the sea grape trap catches were highly linearly correlated (r = 0.85, P = 0.01). There were no correlations ($P >$ 0.05) between trap catches for any 2 mango, rose apple, guava, loquat, sapodilla, grapefruit, or sour orange trees within any year. Thus, a high trap catch in a tree did not

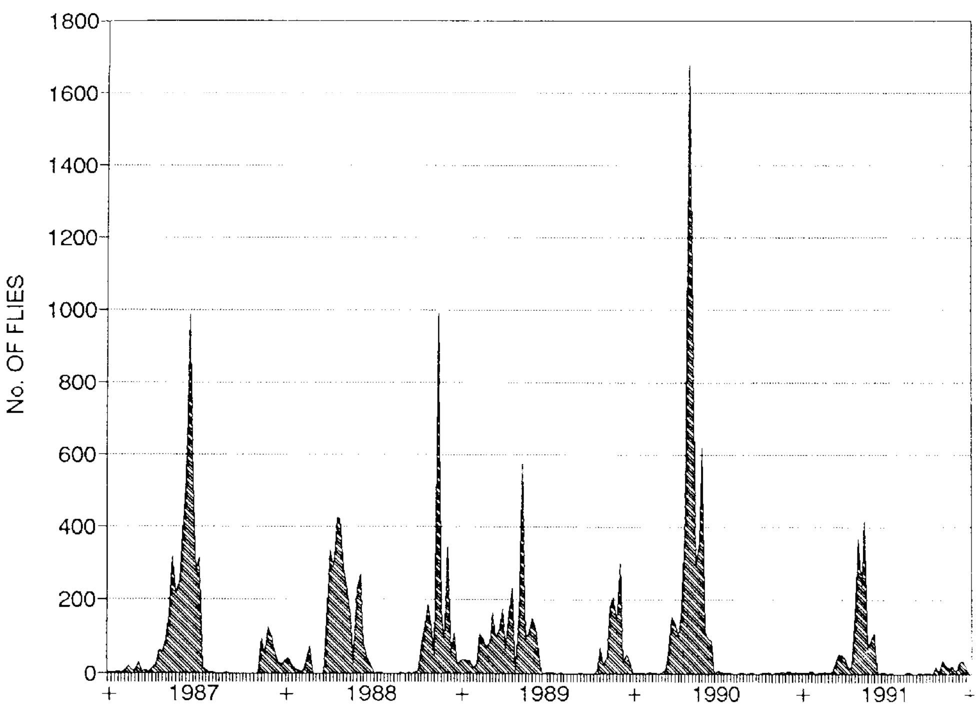

Fig. 5. Weekly Caribbean fruit fly adult captures in McPhail traps (each week represents a total of 24 traps), Port of Miami, Dade County, Florida, 1987-1991.

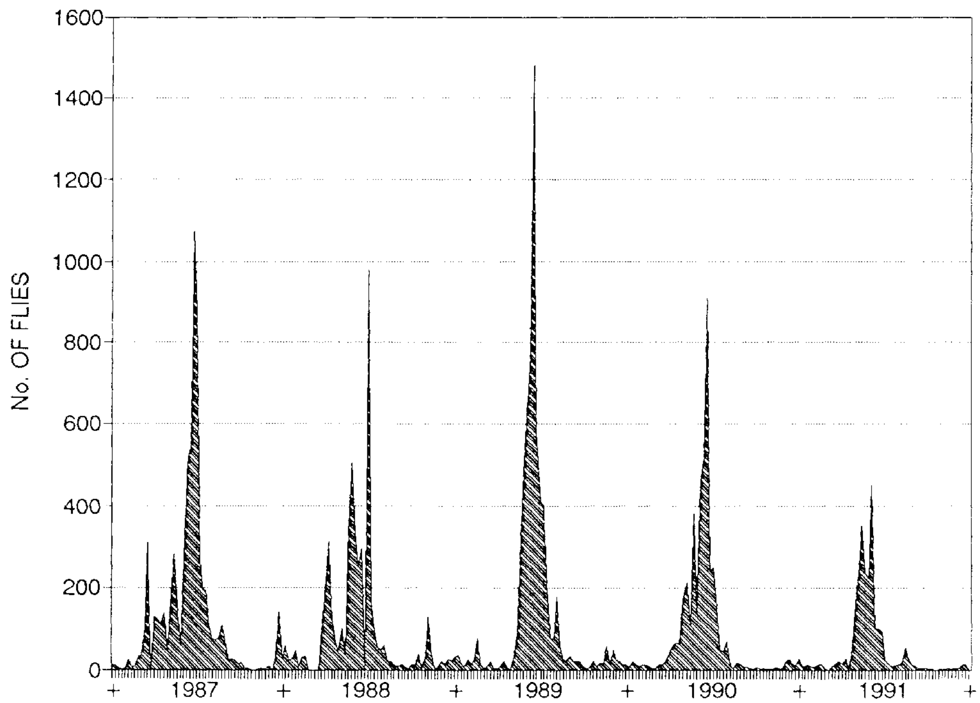

Fig. 6. Weekly Caribbean fruit fly adult captures in McPhail traps (each week represents a total of 24 traps), Homestead Air Force Base, Dade County, Florida, 1987-1991.

allow a prediction that there would be a high trap catch in another tree of the same species during the same sampling period. Individual trap catches were, therefore, essentially independent of each other in this trapping scheme. These results conflict with those of Burditt (1982) who concluded that Caribbean fruit fly activity was synchronous over an area irrespective of host in which traps were placed.

ENDNOTE

I thank R. Pantaleon (Agricultural Research Service, Miami) for tabulating the data and preparing the Spanish abstract, and D. Chalot (Florida Department of Agriculture and Consumer Services, Miami) for providing the trapping records. Mention of a proprietary product does not constitute endorsement by the USDA.

REFERENCES CITED

ANONYMOUS. 1989. Florida fruit fly detection manual. USDA - APHIS - PPQ and Florida Department of Plant Industry, Gainesville, Florida.

BAKER, P. S., AND A. S. T. CHAN. 1991. Quantification of tephritid fruit fly dispersal. Guidelines for a sterile release programme. J. Appl. Entomol. 112: 410-421.

BURDITT, A. K., JR. 1982. *Anastrepha suspensa* (Loew) (Diptera: Tephritidae) McPhail traps for survey and detection. Florida Entomol. 65: 367-373.

DREW, R. A. I., AND G. H. S. HOOPER. 1983. Population studies of fruit flies (Diptera: Tephritidae) in south-east Queensland. Oecologia 56: 153-159.

FEHN, L. M. 1982. Influéncia dos fatores meteorológicos na flutuaçáo e dinámicade populaçáo de *Anastrepha* spp. Pesq. Agropec. Brasileira 17: 533-544.

FLETCHER, B. S. 1974. The ecology of a natural population of the Queensland fruit fly, *Dacus tryoni* VI. Seasonal changes in fruit fly numbers in the areas surrounding the orchard. Australian J. Zool. 22: 189-202.

HARRIS, E. J., AND C. Y. L. LEE. 1986. Seasonal and annual occurrence of Mediterranean fruit flies (Diptera: Tephritidae) in Makaha and Waianae Valleys, Oahu, Hawaii. Environ. Entomol. 15: 507-512.

HARRIS, E. J., AND C. Y. L. LEE. 1987. Seasonal and annual distribution of the Mediterranean fruit fly (Diptera: Tephritidae) in Honolulu and suburban areas of Oahu, Hawaii. Environ. Entomol. 16: 1273-1282.

HARRIS, E. J., AND G. OLALQUIAGA. 1991. Occurrence and distribution patterns of Mediterranean fruit fly (Diptera: Tephritidae) in desert areas in Chile and Peru. Environ. Entomol. 20: 174-178.

HERRERA A., J. M., AND L. E. VINAS V. 1977. "Moscas de la fruta" (Dipt.: Tephritidae) en mangos de Chulucanas, Piura. Rev. Peru Entomol. Agr. 20: 107-114.

HOUSTON, W. W. K. 1981. Fluctuations in numbers and the significance of the sex ratio of the Mexican fruit fly, *Anastrepha ludens* caught in McPhail traps. Entomol. Exp. Appl. 30: 140-150.

INAYATULLAH, C., L. KHAN, M. HAQ, AND A. MOHSIN. 1991. Water-based models to predict the population densities of melon fruit fly, *Dacus cucurbitae* Coq. Trop.. Pest Management 37: 211-215.

JIRÓN, L. F., AND I. HEDSTROM. 1991. Population fluctuations of economic species of *Anastrepha* (Diptera: Tephritidae) related to mango fruiting phenology in Costa Rica. Florida Entomol. 74: 98-105.

MASON, L. J., AND R. M. BARANOWSKI. 1989. Response of Caribbean fruit fly (Diptera: Tephritidae) to modified McPhail and Jackson traps: effects of trapping duration and population density. J. Econ. Entomol. 82: 139-142.

MORTON, J. F. 1987. Fruits of Warm Climates. J. F. Morton Publisher, Miami, Florida.

NATIONAL CLIMATIC DATA CENTER. 1987-1991. Climatological data, Florida, vol. 91(1)-95(12). National Climatic Data Center, Asheville, North Carolina.

NORRBOM, A. L., AND K. C. KIM. 1988. A list of the reported host plants of the species of *Anastrepha* (Diptera: Tephritidae). USDA - APHIS - PPQ Publ. 81-52.

NGUYEN, R., C. POUCHER, AND J. R. BRAZZEL. 1992. Seasonal occurence of *Anastrepha suspensa* (Diptera: Tephritidae) in Indian River County, Florida, 1984-1987. J. Econ. Entomol. 85: 813-820.

SAS INSTITUTE. 1990. SAS/STAT User Guide. SAS Institute, Cary, North Carolina.

SWANSON, R. W., AND R. M. BARANOWSKI. 1972. Host range and infestation by the Caribbean fruit fly, *Anastrepha suspensa* (Diptera: Tephritidae), in south Florida. Proc. Florida State Hortic. Soc. 85: 271-274.

VARGAS, R. I., E. J. HARRIS, AND T. NISHIDA. 1983a. Distribution and seasonal occurrence of *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) on the island of Kauai in the Hawaiian Islands. Environ. Entomol. 12: 303-310.

VARGAS, R. I., T. NISHIDA, AND J. W. BEARDSLEY. 1983b. Distribution and abundance of *Dacus dorsalis* (Diptera: Tephritidae) in native and exotic forest areas on Kauai. Environ. Entomol. 12: 1185-1189.

VON WINDEGUTH, D. L., W. H. PIERCE, AND L. F. STEINER. 1973. Infestations of *Anastrepha suspensa* in fruit on Key West, Florida and adjacent islands. Florida Entomol. 56: 127-131.

WONG, T. T. Y., D. O. MCINNIS, AND N. MOCHIZUKI. 1985. Seasonal distribution and abundance of adult male Oriental fruit flies (Diptera: Tephritidae) in Kula, Maui, Hawaii. J. Econ. Entomol. 78: 1267-1271.