

## CONTROL OF THE STABLE FLY, *STOMOXYS CALCITRANS* (DIPTERA: MUSCIDAE), ON ST. CROIX, U.S. VIRGIN ISLANDS, USING INTEGRATED PEST MANAGEMENT MEASURES

### III. Field techniques and population control<sup>1</sup>

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**Abstract.** In July 1974 a 3-year feasibility study was initiated on St. Croix, U.S. Virgin Islands, on the use of the sterile-male technique as a replacement or adjunct to insecticidal or physical measures to control or eliminate the stable fly, *Stomoxys calcitrans*. Sterile male insects, ca.  $1 \times 10^9$ /day (5 days/wk), were released over the 218 km<sup>2</sup> island for 18 months in 1976-1977. Because of the large wild stable fly population, some of the major breeding sites were larvicided at intervals throughout the test. For the last 6 months of the study, better than 99.9% of the wild flies were eliminated; however, a few fertile flies were found throughout the study. These fertile flies either came from isolated breeding sites, had immigrated from other islands, or had been introduced with imported livestock and/or pets.

A series of small field tests was conducted by LaBrecque et al. (1972a, 1975b) to determine the feasibility of using sterile male releases to control the stable fly, *Stomoxys calcitrans* (L.). The flies were sterilized as pupae by dipping in a 5% metepa or methiotepa solution for 60 min or irradiated at 2 kR as pupae or as young adults. All sterilized flies were sufficiently competitive in the wild to cause a significant increase in sterility in the wild population followed by a population suppression. There was no long term control effect but this was attributed to stable flies immigrating from adjoining farms, since it has been shown (Rogers 1971) that stable flies are capable of migrations of up to 117 km.

The development of economical methods for the mass rearing of stable flies (Bailey et al. 1975), and the success of these field studies led to a large scale program to demonstrate the practicality of this control technique on St. Croix, U.S. Virgin Islands. LaBrecque et al. (1981), in the companion paper, explain the feasibility of the sterile male

technique to control stable flies on this island. The other companion paper by Williams et al. (1981) explains the mass rearing, sterilization and releasing of the flies. However, for practical reasons, the actual program was developed and executed as a pest management scheme. Thus the release of sterile males was integrated with insecticidal and/or physical measures to control or eliminate the flies from a large area. This paper deals with the development of field techniques used in this program and the results of population control.

#### MATERIALS AND METHODS

##### *Test site*

St. Croix was selected because of its size (ca. 218 km<sup>2</sup>), its isolation, the size of its natural population of stable flies, and its diversity of topography, including a dry desert area, a fertile central plain and a mountainous rain forest. The island is ca. 65 km from the nearest island that produces large numbers of stable flies. Preliminary surveys of the area indicated that the indigenous fly population averaged ca.  $1 \times 10^5$  to  $1.2 \times 10^6$  in 1974. In 1975 the dairymen and ranchers on St. Croix adopted a sorghum silage program to supplement the feed of their cattle, especially during the dry season. As the sorghum silage program expanded in 1976 and 1977, the stable fly population increased proportionately (sorghum silage alone or mixed with animal wastes provides an excellent growth medium for the immature flies). As a result the fly breeding situations on St. Croix became similar to those found in northwest Florida, where the flies were serious cattle pests and detrimental to tourism (Brown 1974).

The sites on St. Croix that supported extensive fly breeding were associated primarily with the supplemental silage feed program. Moreover, there were numerous (ca. 500-1000) small breeding sites, mostly in agricultural, suburban, and urban areas, where small numbers of domestic animals were maintained for limited periods. These

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locations usually produced few flies, but they acted as foci of flies throughout the study.

Preliminary surveys of fly densities and potential breeding sites were initiated 6 months prior to the formal start of the pilot study. A 2nd survey was maintained for 6 months following the termination of releases so we could determine the rate of recovery of the fly population.

The 1st 18 months of the formal study were devoted to establishing the St. Croix stable fly colony, developing efficient rearing, sterilizing, marking, releasing and evaluation techniques as given by Williams et al. (1981), developing physical and chemical control techniques and studying the biology and ecology of the wild fly population.

#### *Colonization, rearing, sterilization, and release*

The colony was established in 1974 from local flies; production was maintained at ca. 250,000 flies/day during the last 2 years of the study. Williams et al. (1981) cover the mass-rearing and sterilization techniques that were developed for this project. Many of the techniques described by Bailey et al. (1975) had to be modified for St. Croix conditions. Strict security was maintained throughout the study, since rearing was performed within the test area and any escape of laboratory-reared flies could have been detrimental to our goal of total population suppression.

Flies were initially irradiated as pupae at 2 kR. However, in the mating studies we conducted in the laboratory and in field cages prior to the releases, adults were only  $\frac{1}{3}$  to  $\frac{1}{2}$  as competitive as normal flies based on Fried's (1971) calculations of competitiveness. They did produce 60% sterility in the wild population, but survival in the field was poor, necessitating a high sterile:normal release ratio. Therefore, the procedure was adjusted to incorporate the findings by Whitfield et al. (1978) that adult flies 24–48 h old given a blood meal prior to irradiation were the most competitive in nature. Upon eclosion both male and female adult flies were held, to ensure a uniform age (24–48 h old) for irradiation (Williams et al. 1981). In laboratory and field cage studies, these insects were as competitive as normal flies. Subsequent studies by Williams et al. (1977a) on St. Croix indicated that fly competitiveness and daily loss rate (DLR) were reduced by only 5% following an exposure to 2 kR of gamma radiation from a cobalt source (Gamma cell 220®).

Flies were packaged in release kraft bags (ca. 4000 flies/bag) following irradiation. Distribution

in the field was accomplished by the method described by Skov et al. (1978). All flies that were sterilized and released on St. Croix were marked with fluorescent dusts. The dust increased the DLR of the flies by ca. 10% (Williams et al. 1977a), but we felt that marking was essential since we could rapidly derive the field ratio of sterile to normal males, assay only wild females (unmarked) for sterility and monitor the irradiated females for fertility. The ratio of sterilized to normal flies in the total population could also be calculated based on the ratio found in the animal-baited traps located throughout the island. Based on Williams' calculation from laboratory and field cage studies, the marked sterile flies were ca. 15% less competitive than normal flies. In the field the sterilized flies exhibited less competitiveness than in the field cages. This reduced level of competitiveness was probably caused by the long distance that flies had to travel after release to get a blood meal or to mix with the wild fly population, rather than by any physical damage to the flies.

Thus, with some exceptions, the sterilized flies were released daily (Monday–Friday) at 2-km intervals along the roadways throughout the island (Fig. 1). They were not released in densely populated areas such as towns, villages, housing and employment districts, nor in parts of the rain forest or a salt marsh on the uninhabited eastern end of the island because these areas were inaccessible. Sterile flies were released in lots of 4000 along the roadways at 2-km intervals and in lots of 12,000 at 7 large farms. During the last 6 months of the program the releases at the farms were terminated and only those along the roadways were continued. We found that the sterile flies had a tendency to orient toward any large animals near the release point and did not disperse evenly throughout the island. Therefore, aerial releases (Patterson et al., unpubl. data) would have given a better distribution of the sterile flies over the entire island, particularly in the areas inaccessible by land vehicles.

#### *Determination of stable fly densities*

Densities of the native populations of stable flies were monitored routinely for 4 years on St. Croix starting with the preliminary survey in 1974 (LaBrecque et al. 1981). Four methods were used. The 1st was as described by LaBrecque et al. (1975a), a procedure used regularly throughout the 4 years. The number of stable flies feeding on 10 animals selected at random in a herd was counted for 1 min. Binoculars were used so that stable

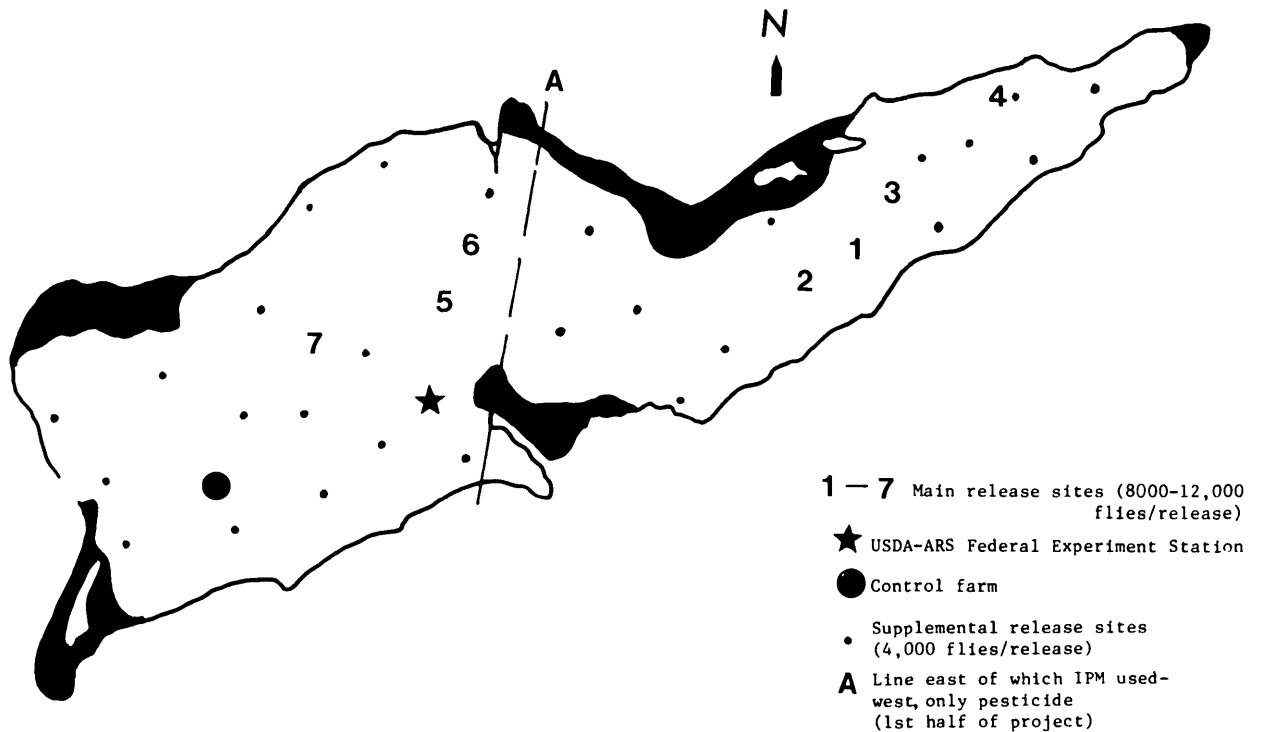


FIG. 1. Release sites of sterile flies on St. Croix and dividing line of the study (A), east of which sterile flies were released in an Integrated Pest Management (IPM) program and west of which pesticides alone were used.

flies and other flies such as house flies or horn flies could be differentiated. Each fly observed was then taken to represent another 50-60 flies resting in the area after having completed a blood meal. These data were verified by Williams and co-workers (pers. commun.) for St. Croix conditions, on Mauritius by Singh and co-workers (pers. commun.) and by both large field cage studies and the release of marked insects.

The 2nd method used routinely during the 4 years was the "Williams" trap (Williams 1973). These traps were set out for 24 h. This trap is an excellent means of monitoring fly populations, especially in and around beef cattle herds or semi-wild animals that are difficult to approach to observe flies. The traps are also useful in areas where the fly population is sparse, since stable flies in the vicinity are attracted to them.

Fly population trends were also monitored by larval counts, in which samples of breeding material 15 × 15 × 2 cm deep were taken at the major farms and the number of 3rd-instar larvae and pupae counted. The number of immatures at the location could be calculated once the size of the breeding area was determined. The number of adults eclosing could be estimated and, based on

the average DLR for stable flies in a region, the total adult fly population could be calculated for a given farm or area, providing the rates of immigration or emigration of flies were not excessive. Larval counts were taken for 1 year and a comparison run against the animal count data for estimating population size and trends. The 2 systems are compared in Table 1. The use of larval counts was discontinued because the time and effort expended was excessive. The animal count technique, however, was very simple and fast.

Heifer trap counts recorded the number of flies captured over a 4-h interval in a heifer-baited trap (Williams et al. 1977c). These traps were used to derive population ratios of sterile:normal flies in the field and to collect wild females to determine

TABLE 1. Estimates of wild stable fly populations (×1000) on 7 dairy farms on St. Croix, based on 2 methods of sampling.

GENERATION	LARVAL COUNT	ANIMAL COUNT
1-3	20	53
4-6	11	39
7-9	44	26
10-12	6	64
13-15	394	347

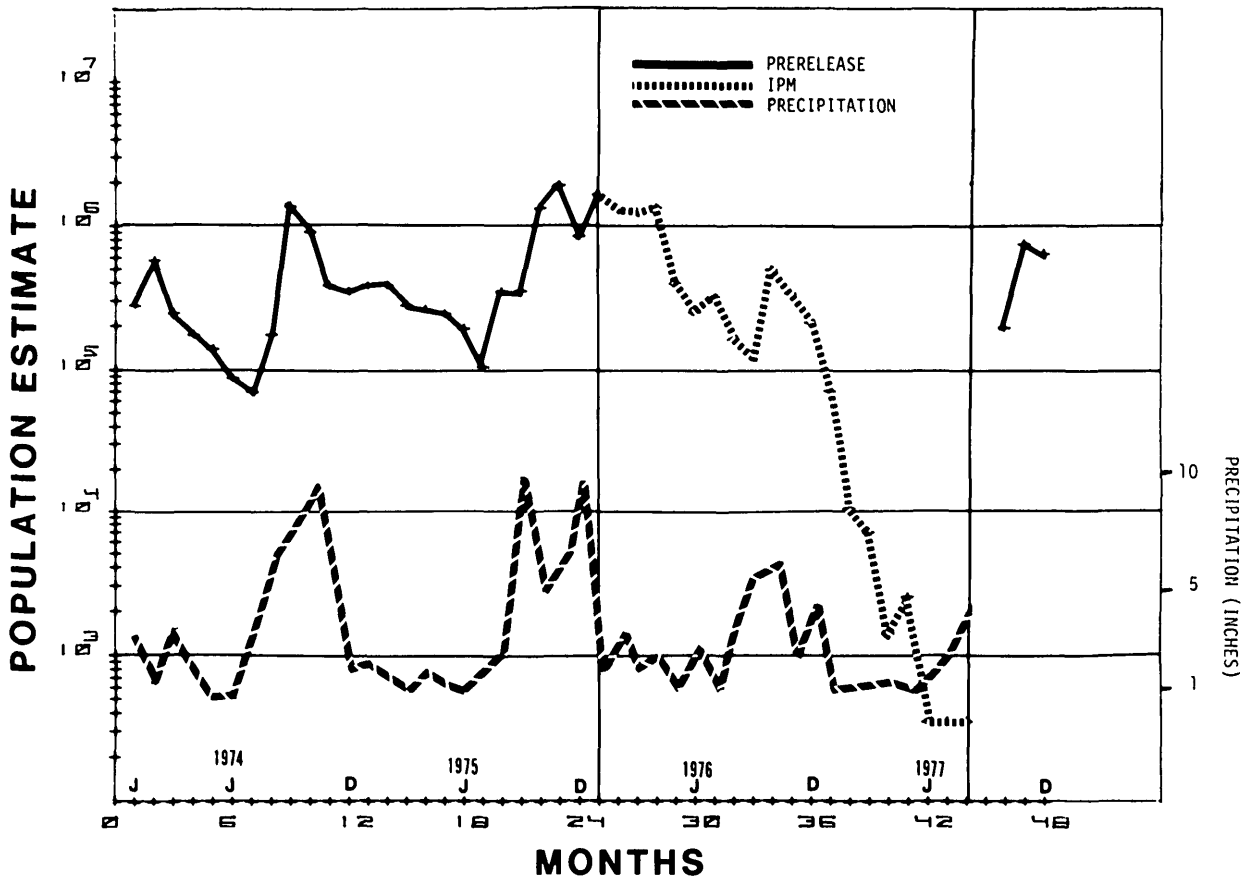


FIG. 2. Estimation of the size of the stable fly population in relation to precipitation and the effect of the Integrated Pest Management (IPM) program on the population.

the degree of sterility induced into the indigenous stable fly population on St. Croix.

All 4 techniques showed general trends in population fluctuation. The data from Williams and heifer traps were influenced by trap placement in relation to the herds and fly breeding sites.

Since the fly population (Fig. 2) in 1974 and 1975 peaked in the fall in September or October and then gradually declined to a low point during the summer, there is close correlation between the size of the fly population and amount of precipitation. The intensity of fly breeding varied considerably among the dairies and ranches surveyed. For example, manure and silage allowed to accumulate on some farms resulted in extensive fly breeding. Because of the threat of ticks carrying anaplasmosis and piroplasmosis, an insecticide control program is in effect whereby all beef and dairy cattle are to be sprayed or dipped every 2 weeks with a 0.1% suspension of coumaphos. Adherence to this program ranged from strict compliance to sporadic treatments, especially in areas

relatively free of ticks. Following the dipping, reductions in the adult fly population were observed for several days. Consequently, some variation in our samples was noted. However, this was minimized by plotting the data gathered weekly on a monthly basis and averaging the counts from the 10 sampling stations.

Flies did not appear to disperse far from the principal breeding sources, since relatively few marked flies of a given color were found in adjacent areas. There was no noticeable difference in the extent of fly breeding attributable to the geographical locations of the dairies. The major factors affecting breeding were the extent of the cultural control carried on at the individual farms and precipitation.

The rate of increase based on flies/animal counts never exceeded 6.3× and was usually 1× (population static) or less. As the fly population increased during the wet season, the rate of increase was only 1.1, 1.7 and 1.5 for the next 3 generations. These data agree closely with those of previous studies

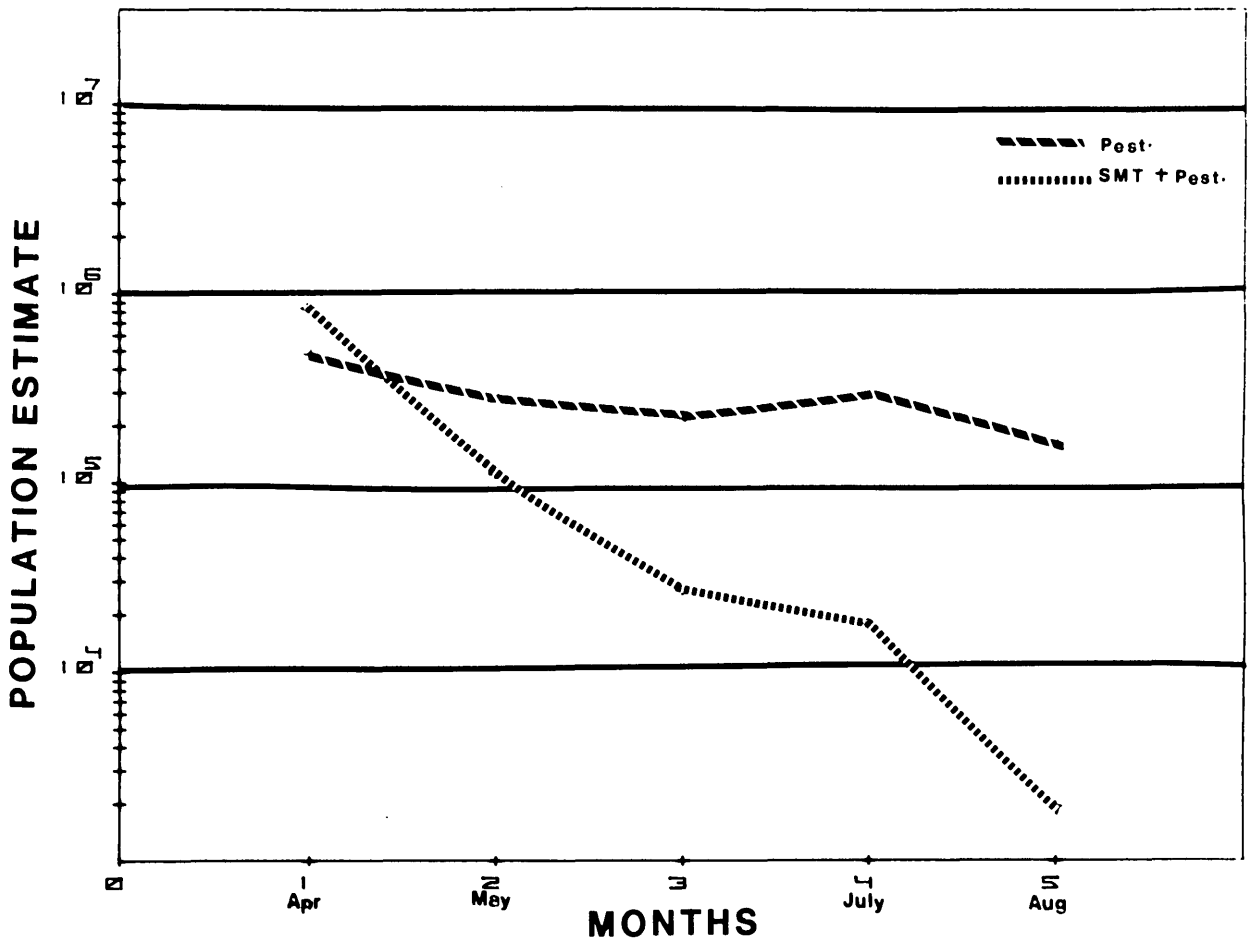


FIG. 3. Estimate of stable fly populations on St. Croix using pesticides alone vs. pesticides + sterile male technique.

(LaBrecque et al. 1972b) on several farms in central Florida, but unlike Florida there was no seasonal variation in the population density owing to temperature on St. Croix.

#### *Other control methods used in this program*

As stated previously, some of the farmers treated their cattle periodically for tick control and these treatments usually produced some stable fly control (Williams et al. 1977b). The coumaphos treatment caused an equal loss of wild and sterile flies and probably had little effect on reducing the total fly population, since most animals other than dairy cattle were not treated on a regular basis. Many animals were never treated. Wild flies were checked for coumaphos resistance and none was observed.

With the increased use of sorghum silage there was a corresponding increase in the wild stable fly population. In 1973 there were only 35 acres in

sorghum; 3 years later there were over 533 acres in sorghum production on St. Croix. All sorghum was stored and fed as silage to cattle. This sorghum silage is an excellent habitat for immature stable flies. Williams et al. (1980) found larval densities as high as 2755 per cubic foot. Production of flies for release, however, could not be increased because of limitations of staff, facilities and funds. Also, we were reluctant to increase the number of biting flies in the area because of their nuisance value. Therefore, we decided to reduce the wild population by treating the major larval habitats with methoxychlor. The 1% spray acted mainly upon newly emerging adults and ovipositing females. Larval sites were treated routinely at 7 of the dairies and 1 ranch starting in December 1975, prior to the systematic releases of sterile flies in March 1976. These treatments caused an estimated 50–60% overall reduction in the fly populations in the areas. Although methoxychlor sprays were

used at the major breeding sites throughout the island, sterile insects were released on only the eastern  $\frac{1}{2}$  (ca. 58 km<sup>2</sup>) for a 4-month period. Therefore the effects of the chemical alone vs. those of the chemical and the sterile insect releases (Fig. 3) could be compared. The data clearly indicate that the spraying checked all population growth but that other control methods, such as the release of sterile insects, were needed to produce a significant downward trend in the population.

Since the use of methoxychlor sprays or release of sterile flies was denied at some breeding sites, other control measures were used. Although cultural control is the preferred method of reducing fly populations few farmers cooperated. Some were persuaded to feed silage from troughs rather than from the ground and in one instance where a farmer forbade the use of pesticides, he accumulated all waste material at a central point at regular intervals, thereby reducing fly breeding. The parasite *Spalangia endius* Walker was also used in a caged layer operation of ca. 20,000 chickens to control house flies, *Musca domestica* L., and stable flies. We released ca.  $2.5 \times 10^5$  parasites/wk for ca. 8 months and eliminated both the house and stable fly problems. The releases were carried out in the manner described by Morgan et al. (1975).

During the last 6 months of the study an additional control measure was introduced. An attractant toxicant trap system as described by Meifert et al. (1978) was used at several farms to eliminate the few remaining flies. Unfortunately we did not have sufficient traps to cover all isolated and urban breeding sites where releases could not be conducted.

### Evaluation

The effectiveness of this integrated pest management program for stable fly control was evaluated by 3 methods: (1) by estimating the total population based on the number of flies observed feeding on the animals, corrected for the sterile to normal ratio observed in the field; (2) the number of wild flies captured on the Williams traps; and (3) the degree of sterility in wild female flies.

At weekly intervals, animal counts were made and heifer-baited traps and Williams traps set at 10 farms. Since all released flies were marked, the ratio of released to wild could be determined. Consequently, the number of flies observed on an animal could be amended to derive only the wild flies feeding and the total wild stable fly population estimated. At monthly intervals, an island-wide sur-

vey with 100 Williams traps was run. The panels were checked for marked and unmarked flies with a UV light at the laboratory. It was difficult to detect the marking on older flies and nearly impossible on flies coated with the adhesive. Therefore, the use of Williams trap data was discontinued in assessing fly populations and we relied on data derived from heifer trap catches.

The degree of infertility in the wild population was assayed by capturing wild females in the heifer trap over a 4-h period. To collect the flies, the heifer was removed and the cage vacuumed using a 115-V AC vacuum cleaner modified with a plastic collecting tube. Where electricity was not available, a 12-V vacuum unit using a vehicle's electrical system was used. The flies were transferred to a holding cage following collection and returned to the laboratory, chilled, counted, and separated by sex. Unmarked females were placed in individual plastic tubes for oviposition. The tubes had an open base and a screened top, and were fitted into holes in a block of wood. The open bottom of each hole was fitted with a piece of cotton covered with black cloth that served as an oviposition site. The cotton was kept moist by resting the blocks of wood in metal trays containing ca. 16 mm of water. The flies were fed daily by placing a small piece of cotton saturated with citrated bovine blood on the screened top. When oviposition occurred, the cloth was removed and placed on a small wet sponge in a petri dish and held for 74 h (most stable flies hatch within 4 h), and the eggs checked for hatch under a microscope.

### RESULTS AND DISCUSSION

The integrated control system was started on the eastern  $\frac{1}{2}$  of the island (58 km<sup>2</sup>) in March 1976. Sterility steadily increased in the wild population as shown in Fig. 4 until September. At that time the fly population was at such a low level that releases on the western  $\frac{1}{2}$  of the island (ca. 83 km<sup>2</sup>) were initiated, using only enough sterile flies on the eastern  $\frac{1}{2}$  to maintain population suppression. However, because of a change in the milling of the bran used in the larval diet there was a severe curtailment of fly production and of subsequent releases. We terminated regular releases on the western  $\frac{1}{2}$  of the island and tried to maintain releases on the eastern  $\frac{1}{2}$ . Still sterility declined to 70% in November, with a corresponding increase in the wild population as shown in Fig. 4. Once colony fly production returned to normal, sufficient numbers of flies were again available for release, and

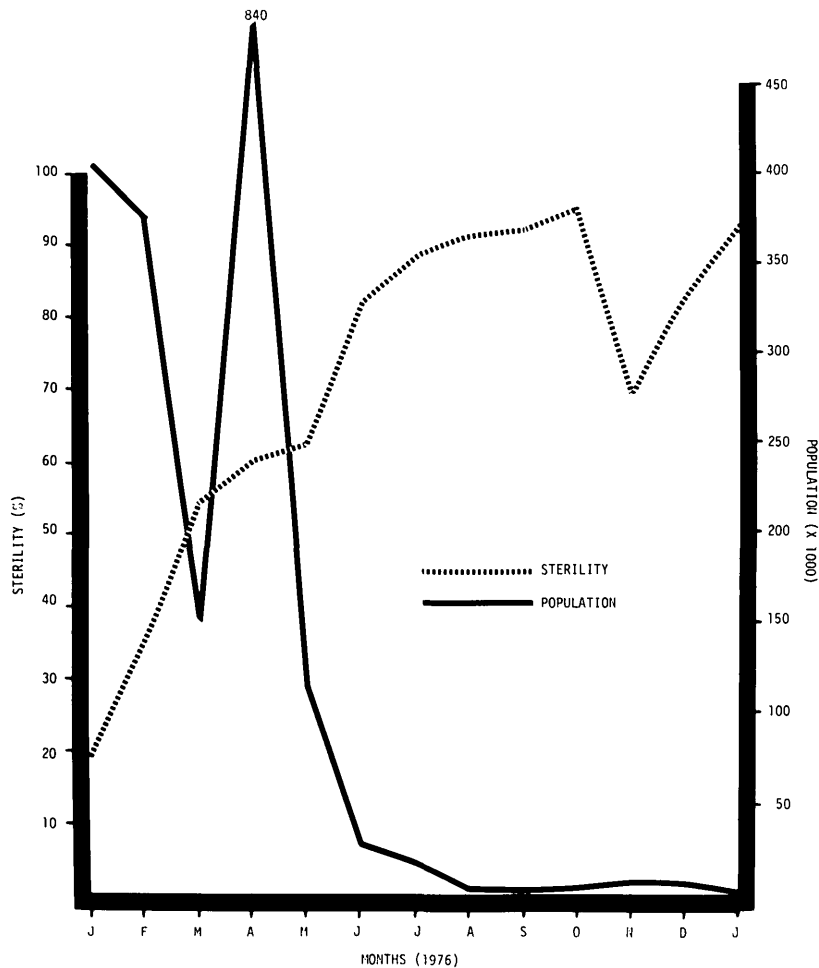


FIG. 4. Sterility and population of wild stable flies on east end of St. Croix using Integrated Pest Management (IPM) with sterile males.

sterility on the eastern side rose again to 99% followed by a steady decline in the wild population. Throughout this period sterility on the western  $\frac{1}{2}$  of the island remained low and the population did not decrease until sterile insects were again released in sufficient numbers. Larvicide treatments were used throughout this period, which helped to curtail the rapid buildup of the population.

By January 1977 all systems of the Integrated Pest Management (IPM) program were functional and, as shown in Fig. 2, the wild fly population rapidly declined to an estimated low level of only ca. 350 wild flies on the 218 km<sup>2</sup> island. Sterility also rose and maintained itself, for the most part, at ca. 99+%. However, since the wild fly population was very low, frequently weeks elapsed before a wild female could be captured for infertility assessment. If a wild female was fertile, it could not be determined whether the fly came from some

small, isolated breeding area, was indigenous to St. Croix, or was introduced with livestock imported from the other islands.

Although we tried in June, July, and August of 1977, we could not eliminate the wild stable flies. It is speculated that the flies could have been eliminated if (1) we could have established a quarantine and inspected and sprayed all planes and boats coming to St. Croix to kill any flies, and/or (2) we could have better dispersed the sterile flies or had more manpower to put out a greater number of the attractive-toxicant panels, and/or (3) closer inspection and treatment of urban areas could have been accomplished where domestic animals were quartered. Unless a strict quarantine is maintained, flies will quickly reestablish themselves on the island. The importation of flies with animals from planes and boats, plus native flies breeding at small isolated spots in towns and villages, created

foci for the rapid spread of the wild fly population once the control program was suspended. The study was terminated at the start of the rainy season when survival and rates of increase were at their maximum. During the 3-generation period following the termination of releases, the population increased from 350 to 210,000, an average of 8–9×/generation. Since 6× was the highest rate of increase recorded in either Florida or previously on St. Croix, 9× is considered high even under optimal survival conditions.

This study proves that an IPM program using sterile insects could successfully control stable flies over a large area. Although it is possible to obtain total population control by the release of sterile males alone, the use of integrated control techniques is a more practical approach. A newly instituted sorghum-feeding program increased the number of flies on the island so that the planned number of released flies was insufficient to achieve population control. Source reduction, insecticide treatments and management procedures overcame this problem, as well as actual and potential complaints about excessive numbers of released flies. The release of a pupal parasite at 1 special problem site and the use of an attractant-toxicant device demonstrated 2 additional technologies that can be incorporated into an IPM program.

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