Status of Three Pestiferous Fruit Fly (Diptera: Tephritidae) Populations on Kauai Following Hurricane Iwa[1]

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ABSTRACT

The eye of Hurricane Iwa surrounded by cyclonic winds of 144 km/h and gusts up to 176 km/h passed within 32 km of Niihau and Kauai on Nov. 23, 1982. Upper story vegetation was heavily damaged over large portions of Kauai with pronounced impact on some fauna. Fruit fly surveys had been conducted over a period of nearly 5 years prior to the hurricane to establish distribution and seasonality of the oriental fruit fly, *Dacus dorsalis* Hendel, the melon fly, *D. cucurbitae* Coquillett, and the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). This baseline information provided the impetus for assessing the ecological implications the hurricane may have had on numbers of adults present up to the fifth week following the hurricane. Both the oriental fruit fly and melon fly occupied dense vegetation sites that provided protection to habitat and host plants. Also, populations were sufficiently distributed and abundant to sustain the highest percentage reduction in numbers. Medfly, in contrast, was not captured in the island peripheral habitats and storm damage appeared to have impacted most on this species. While oriental fruit fly was trapped at the rate of hundreds/trap/day and melon fly in tens, no medflies were captured using both Jackson and McPhail traps in a concerted effort. Medfly likely was reduced to a low remnant population in isolated pockets of inland host material such as feral coffee and guava that were protected from strongest winds.

Allee et al. (1949) explained why the forward speed added to the circular wind speed makes that portion of a hurricane to the right of its general track the most devastating. It was that portion of Hurricane Iwa which initially struck the southwestern shores of Niihau and Kauai on the evening of Nov. 23, 1982. Over land, the opposite or left side becomes more damaging due to the rapid reversal of wind direction. The entire island of Kauai showed signs of high wind damage to upper story vegetation and exposed builidngs. The extent of damage to Niihau was not reported, but both islands were outside the center or eye of the storm where strongest winds occurred.

In the biological sciences, cyclonic winds are often studied from the standpoint of lift, transport, and dispersal of organisms. The inner cyclonic winds of hurricanes angle sharply upward and such updrafts may continue thousands of meters into the air. Clarke (1954) discussed several examples of insects as well as small animals, such as snakes and rodents, lifted and dispersed by cyclonic force winds. On the other hand, such phenomena also have a wide-ranging impact on existing organisms and habitats where the hurricanes occur. Steiner et al. (1965), for example, reported success in eradicating an abnormally low population of the oriental fruit fly, *Dacus dorsalis* Hendel, on Guam following the occurrence of two typhoons. The severity of these winds in destroying host material and habitat twice in a span of ca. 6 months had a pronounced effect in lowering the population size. In contrast, Iwahashi (1979) showed that captures of *D. dorsalis* on the island of Chichijima 5 days before and immediately following passage of a powerful typhoon gave no evidence of adult flies being blown away. Topography of the land mass, vegetation patterns, and wind force contribute to such variable effects. Forest bird populations are often dramati-

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cally affected for similar reasons of physical displacement as well as damage to nesting and feeding areas exposed to hurricane force winds. Insect and small animal habitat sites are generally more protected from strong winds. Allee et al. (1979) suggested that the wind intensity to which most insects are exposed would be 10% or less of the air velocity measured by the meteorologist.

Measurement of population trends for the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), the oriental fruit fly, and the melon fly, *D. cucurbitae* Coquillett, have been conducted during the past 5 years throughout Kauai. The present investigation employed this background knowledge in conducting a fifth week, post-Hurricane Iwa survey. We report the results and ecological implications of a natural catastrophe of only a few hours duration which impacted differently on populations of these three insect species.

Observations on the fruit fly habitats

A week after the hurricane, its path could still be clearly delineated because of the destroyed structures, uprooted trees, and broken trunks and branches. The track of the hurricane was also traceable by the "wind-burnt" leaves and defoliated vegetation. By standing on high vantage points it was possible to see fruit fly habitats swept over by the storm.

From our previous studies it is known that the major habitats of *D. dorsalis* and *D. cucurbitae* are along the coastal areas and up to elevations of approximately 610 meters. It was evident that the storm swept through the major habitats of these flies. The effect of the storm on the habitat of *C. capitata* was less clearly discernible since access to the deep southwest canyons of the island would have required special equipment. It was evident, however, that the storm swept into the canyons for many miles as evidenced by defoliated vegetation and "wind-burnt" leaves on the plants.

Throughout the major habitat of *D. dorsalis* there are many host plants. The guava, *Psidium guajava* L., is a major host which generally survived extensive storm damage because it is a well rooted, understory shrub. In many areas ripe and mature green fruits were on the ground under the defoliated plants. On the northern and northeastern coastal areas, the kamani, *Calophyllus inophyllum* L., and the false kamani, *Terminalia catappa* L., trees that bear numerous nut-like fruits, are important hosts of *D. dorsalis*. Defoliated trees with broken trunks were seen everywhere along the coast where dense forests of these trees were present. Mango, *Mangifera indica* L., is an important host which was not in fruiting during the storm. In many areas, large limbs were broken off and the leaves remaining on the trees were severely "wind-burnt." There are many other host plants of minor importance which were similarly damaged.

The host plants of *D. cucurbitae* were also damaged. Its host plants were mainly in the coastal commercial farm areas and in small backyard gardens. In the southwestern part of the island all crops which are hosts of this fly were completely destroyed. The wild host, *Momordica balsamina* L., growing along the side of the roads were completely destroyed. Commercially grown crops, such as tomatoes, cucumbers, squash, and papayas were also destroyed.

Besides host plants, the hurricane destroyed other resources necessary for the existence of fruit flies. These flies need roosting and sheltering sites in the adult stage. For example, castor bean, *Ricinus communis* L., and corn, *Zea mays* L., on which *D. dorsalis* and *D. cucurbitae* roost, were completely destroyed in the southwest areas of the island. Many other plants, which provided favorable micro-habitats, were destroyed. There is no doubt that Hurricane Iwa also had adverse effects on the food resources of the adults. The destruction of the vegetation removed food source of extra-floral secretions, nectar, and pollen. In addition, the destruction of the vegetation destroyed many species of insects that produce honeydew, an important food of adult fruit flies.

Although the hurricane swept over the island, the destructive wind energy was not distributed uniformly throughout the landscape. It was clear that there were localized areas which were not affected. These "wind-shadow" areas were apparently not affected due to rugged topographic features of the island. The shape of the island is roughly circular with high mountains in the central areas. Valleys radiate in all directions from the central mountains down to the coast. Valleys facing southwest and south were subjected to strongest wind currents because they paralleled the hurricane's path. On the other hand, valleys radiating northward were protected by the high central mountains.

Typical wind-shadow areas were observed in the Waimea and Hanapepe canyons located on the southwestern part of the island. The unaffected vegetation along the western wall was green from recent rains; whereas, that along the eastern wall facing southwest were either defoliated or wind-burnt. Wind-shadow areas were evident in the fruit fly habitats in the northern coastal areas of Haena and Wainiha. Here the narrow belt of the strand vegetation consisting mainly of kamani and false kamani was heavily damaged. However, the vegetation in the sheltered nearby valleys and hillsides was not affected by the storm.

MATERIALS AND METHODS

Traps for the three pestiferous species of tephritids (generally referred to by the pseudonym 'tri-fly" since Hawaii is the only known cohabitation of all three species) had been operated on the island of Kauai since 1978. Two of the authors (E.J. Harris, unpublished data, and Vargas et al. 1983) will report on the seasonal abundance and distribution of *D. dorsalis* and *C. capitata*. Four years of monthly catches and ecological observation from 105 trap stations have been computerized to aid the study of host/habitat relationships of these species. Adult males respond to their respective lures with only occasional females or cross-species attractancy occurring. Searches were also conducted for natural host material as well as presence of suitable, man-made, biological bridges around garbage landfills. Traps were inspected twice per day for 3 consecutive days of comparable climatic conditions favorable to fruit fly activity (20–27°C; 62–78% RH daytime range). Post-hurricane observations were made during the second, fourth and fifth weeks following the hurricane.

Trap Types

Past surveys had shown *D. dorsalis* to be readily captured in Harris traps baited with methyl eugenol lure/naled mixture (Steiner et al. 1965). We duplicated the catching methods used previously on Kauai for this species and, where possible, hung the traps on the same tree limb used prior to the hurricane. For *C. capitata* and *D. cucurbitae* sticky, cardboard traps (Anonymous 1975) and glass traps (Steyskal 1977) known as Jackson and McPhail traps, respectively, were used. McPhail traps, roughly one-half size of the standard glass trap, were baited with PIB–7® proteinaceous lure plus a single drop (ca. 0.05 cc) of each of the three species' respective male lure dispersed over the liquid surface. Tanglefoot was used to capture flies in the cardboard traps by coating the interior surface. Catches were replicated as to catch/trap/day for the period of Dec. 28–30, 1982, inclusive.

Trap Sites

Two criteria were used to select trapping sites. First, only those locations where the highest numbers of all three species had been captured during the previous years of surveying were chosen. Second, such sites were selected in moderately to heavily wind-damaged areas as evidenced by destruction to surrounding vegetation. Five sites were selected on the southern perimeter of the island from Kekaha eastward to Wailua Valley using these criteria (Fig. 1 lower right). Site 1, at Kekaha, was bounded by residential dwellings and a cemetery on one side. This vacant plot was covered predominantly by koa-haole, *Leucaena glauca* (L.) Benth., and kiawe trees, *Prosopis pallida* HBK. Site 2 was located within the mouth of Waimea Canyon at Waimea. Traps were placed on mango, mock orange, *Murraya paniculata* (L.), and *Citrus* spp. hosts. These two sites represented the dry, leeward side of Kauai and were the locations of highest pre-hurricane *C. capitata* captures. Site 3 was near Puhi in a damaged Java plum, *Eugenia cuminii* (L.), and koa-haole admixture overstory. Site 4 was in Lihue beside the State Plant Quarantine Station and less than a kilometer from the Lihue sanitary landfill. Christmas berry tree, *Schinus terebinthifolius* Raddi, breadfruit tree, *Artocarpus communis* Forst., and hau, *Hibiscus tiliaceus* L., were host plants used for placing traps at the fourth site. Site 5 was at Wailua Falls, an inland site where evidence of less severe damage to vegetation was observed. At this site, dense strawberry guava, *P. cattleianum* Sabine, and common guava, in mixture with Java plum, provided a more wind-sheltered habitat in the lower few meters of canopy. An inventory of *D. dorsalis* at other sites in Haena, Anahola, and Hanalei Valley was accomplished by employing a timed response to methyl eugenol lure (Steiner 1952) and trapping for 30-min intervals.

RESULTS AND DISCUSSION

Generally, *C. capitata, D. cucurbitae,* and *D. dorsalis* male fly captures in response to their specific lures and computed as catch/trap/day on Kauai are measurable in units, tens and hundreds, respectively. The average catch/trap/day for the month of December for the years 1978 through 1981 for these specific sites were used for comparison. Numbers of male flies captured during different years in the 4-year period varied widely for the month of December at these sites, but the total yearly catches for the entire island were fairly comparable during this period. Weather was very stable during the post-hurricane survey and probably contributed to the small variation among daily captures. Numerically, then, *D. dorsalis* predominates throughout the island followed by the melon fly and Mediterranean fruit fly.

D. dorsalis

The duplicated trapping system for oriental fruit fly was the most accurate comparison of the three of pre- and post-hurricane population status. *D. dorsalis* populations were higher in the wetter habitats which contained a greater abundance of suitable hosts; i.e., the more windward sites 3, 4, and 5 (Fig. 2). On the leeward side of the island, in contrast, habitats and concomitant fly populations were more sparse and thus more susceptible to the heavy wind damage. At sites 1 and 2, only 7–8% of the pre-hurricane mean number of males were captured, whereas at site 5, 68% of the pre-hurricane population was present — an average of 433.7 males/trap/day. Even in heavily wind-damaged site 3, almost 150 males were captured daily. The plant quarantine facility at site 4 was damged and temporarily out of service. In the past, due perhaps to the volume of host commodities handled through the station, large numbers of both *D. dorsalis* and *D. cucurbitae* male flies were

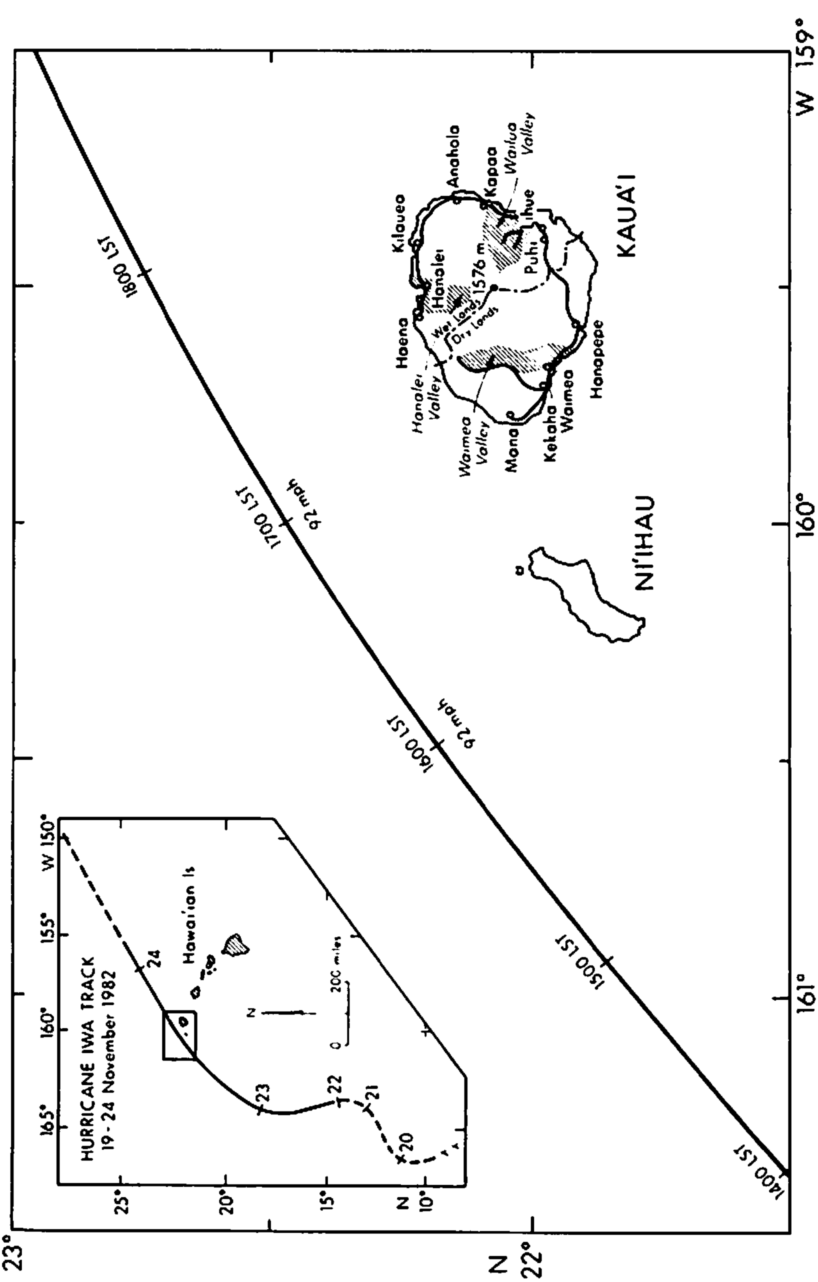

FIGURE 1. Path of Hurricane Iwa in Hawaiian Islands (upper left) with position and direction in local standard time in relation to surveyed area (lower right).

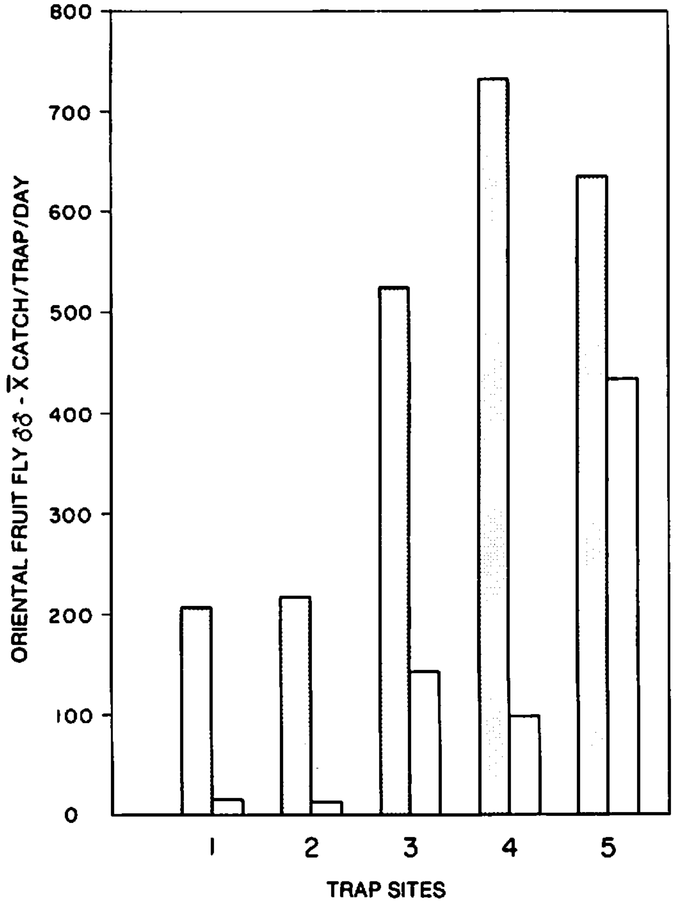

FIGURE 2. *D. dorsalis* 4-year mean December capture 1978–81 (shaded columns) and mean post-Hurricane Iwa December 1982 (unshaded columns) comparison at 1—Kekaha, 2—Waimea, 3—Puhi, 4—Lihue, and 5—Waimea Falls.

captured and, at periods of the year, *C. capitata* as well. With no fruits being processed, and vegetation wind-stripped, the drop in captures was very great as might be expected. However, at the nearby Lihue sanitary landfill in a ravine where wind damage was negligible among low dense vegetation, 1,171 *D. dorsalis* males were captured in one 12-hr period. On a separate test day at the same spot, 479 *D. dorsalis* males were captured in 2 hrs. *D. cucurbitae* also responded to and was readily captured with cue-lure. This evidence suggests movement and concentration of these species in sites where hurricane damage was least disruptive to the required habitat. At Haena and Anahola, where deep valleys afforded protection from the hurricane, *D. dorsalis* quickly responded to methyl eugenol. At Haena, 160 male flies were captured in 30 min in a single trap, the first fly entering the trap after 3 min. At Anahola, the same 30-min test produced 144 males, with the first response in the first minute. The insects were readily available near host plants in areas of lesser hurricane damage.

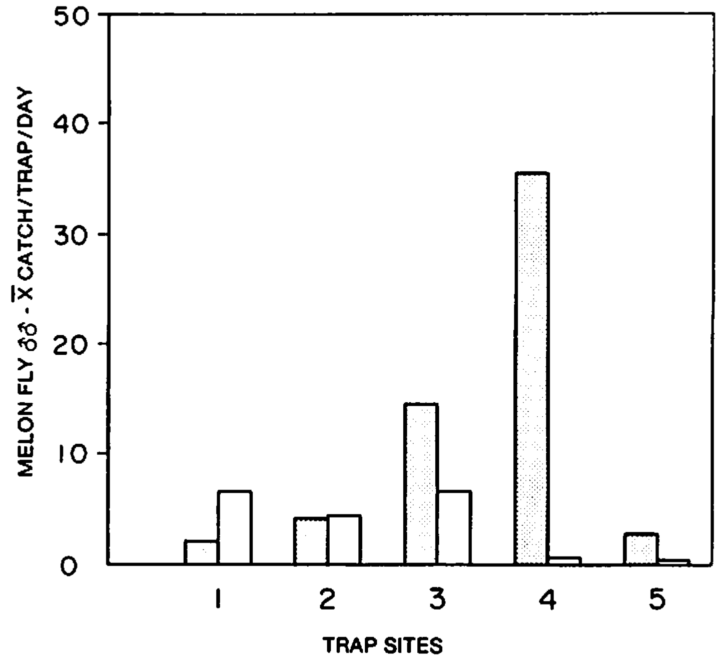

FIGURE 3. *D. cucurbitae* 4-year mean December capture 1978-81 (shaded columns) and mean post-Hurricane Iwa December 1982 (unshaded columns) comparison at 1—Kekaha, 2—Waimea, 3—Puhi, 4—Lihue, and 5—Waimea Falls.

D. cucurbitae

Since we expected populations would be much lower than *D. dorsalis*, a much more intensified trapping effort was conducted. This partially accounts for the higher catches than previously obtained at sites 1 and 2 (Fig. 3). As stated, one criterion for trap location was degree of vegetative damage and, at these two sites, garden and ornamental host plants had been heavily damaged by sea water and wind. However, a well-known alternate host named bittermelon, *Momordica charantia* L., growns abundantly in and around the nearby sugarcane fields. The hurricane flattened the sugarcane over the *Momordica* and provided protection for this melon fly host during the high winds. The sugarcane was erect again within 3 weeks after the hurricane had passed. Even in the heaviest damaged sites such as site 4, a few melon fly males were captured each day, although length of time for response was often very slow, exceeding an hour in some instances at sites 4 and 5.

C. capitata

Despite the intensified trapping efforts which included coating all three sides of triangular traps with sticky compound to ensnare the flies, placing a drop of lure in PIB–7 bait inside McPhail traps and choosing highest known trap stations, not a single *C. capitata* was captured (Fig. 4). Pre-hurricane surveys indicated that of the three species, *C. capitata* occurred in the lowest numbers at this time of year and its

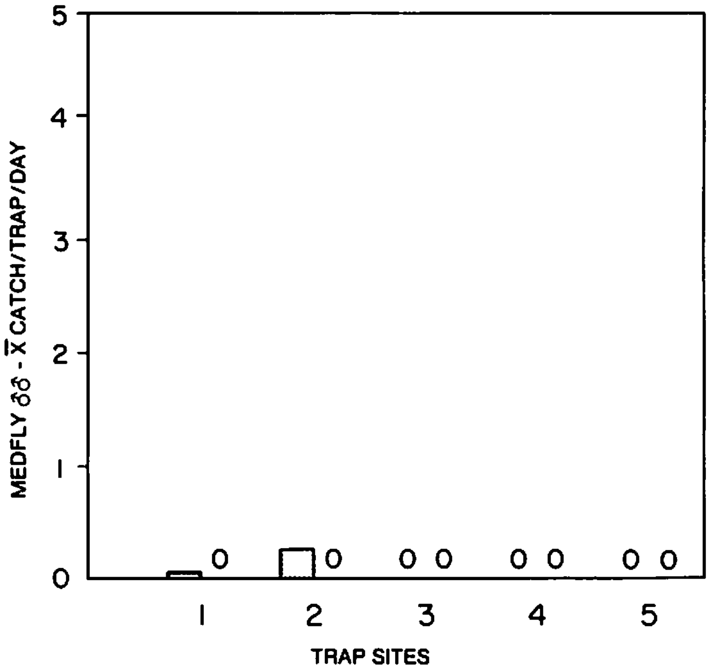

FIGURE 4. *C. capitata* 4-year mean December capture 1978–81 (shaded column) and mean post-Hurricane Iwa December 1982 (unshaded columns) comparison at 1—Kekaha, 2—Waimea, 3—Puhi, 4—Lihue, and 5—Waimea Falls.

range was largely restricted to the portion of Kauai most heavily hurricane-damaged. As a result, the habitat of this species was heavily damaged and it likely succumbed to significant reduction in numbers. Mock orange, associated with past high *C. capitata* capture in the Kekaha township, showed marked evidence of salt water damage. Yard hedges, commonly made with this plant, were wilted and brown, much leaf fall had already occurred, and the plants appeared dead. *C. capitata* that survived the hurricane effects were likely sustained inland in guava and feral coffee hosts, although even the drier valleys, most notably, Waimea Valley, were raked more heavily by the cyclonic winds than where denser vegetation existed.

Fruit fly larvae were found in citrus that had been discarded by people cleaning up after the hurricane. We observed that a biological bridge between new fruiting of wind-stripped plants was provided by the disposal of spoiled host commodities that were discarded in landfill areas, and by areas of dense vegetation missed by hurricane-force winds. With the possible exception of *C. capitata*, hurricane-caused reduction in the three pestiferous tephritid species found on Kauai is believed to be of minor consequence, which suggest that long-term ecological changes would not occur.

The resiliency of tropical vegetation to violent disruptions caused by hurricanes appears suited to the bionomics of tephritid fruit flies. In-depth studies following such catastrophes could offer important understanding of the ecology of these pestiferous species.

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