

**INFESTATION OF *ELEPHANTOPUS MOLLIS*
(ASTERACEAE) FLOWERHEADS BY *TETREUARESTA*
OBSCURIVENTRIS (DIPTERA: TEPHRITIDAE)
ON KAUAI, HAWAIIAN ISLANDS¹**

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ABSTRACT: Little information is currently available on the population dynamics of exotic insects released on the Hawaiian islands. In the present study, we surveyed present incidence of a tephritid fly of New World origin, *Tetreuaresta obscuriventris*, on the island of Kauai. This fly was introduced to the island in 1961 for the biological control of an important weed species, *Elephantopus mollis*. Between 80-90% of flowerheads collected from *E. mollis* in our survey contained immature *T. obscuriventris*. An average infested flowerhead contained approximately 5.2 fly larvae. Fly populations in the surveyed areas followed aggregated distribution, and the mean number of flies per infested flowerhead was positively correlated with the percent of infested flowerheads.

A total of 71 species of phytophagous insects were deliberately introduced to Hawaii between 1890 and 1985 in an attempt to control 21 species of weeds. Forty-three of these became permanently established on the islands (Funasaki et al. 1988). However, with few exceptions, little effort has been made to quantify population densities of introduced species after establishment. In general, populations of successfully established exotic organisms rarely reach noticeable densities in their new environment (Williamson and Fitter 1996). Little data are currently available on the long-term fate of biological control agents released on the Hawaiian islands to control weed species.

Elephantopus mollis Kunth (elephant's foot, tobacco weed) is a coarse erect herb up to 150 cm in height. It is native to tropical America, but is now pantropical in distribution. It is common in sunny, dry, disturbed areas such as plantations and pastures, and is listed as a serious weed in Hawaii (Whistler 1995; Wagner et al. 1999). In an attempt to control this plant, a tephritid fly of New World origin, *Tetreuaresta obscuriventris* (Loew.), was introduced in 1961 from Fiji to the islands of Kauai and Hawaii (Chong 1962; Hardy and Delfinado 1980). The larvae of this species reside in *E. mollis* flowerheads and feed on its seeds. The successful establishment of *T. obscuriventris* on Kauai has been confirmed by repeated captures of adult flies (Hardy and Delfinado

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1980). However, no attempt has been made to quantify the infestation of *E. mollis* flowerheads by *T. obscuriventris* in its new environment, and this was the purpose of our study.

MATERIALS AND METHODS

Survey protocol. In the present study, we surveyed the incidence of *T. obscuriventris* infesting *E. mollis* flowerheads at two sites on the island of Kauai. The first site was located along Anini Road in the Hanalei district (1-5 m elevation, 1250 mm mean annual precipitation). It was a typical disturbed roadside habitat covered by alien weedy vegetation. The second site was located at the Kauai Agricultural Research Center (KARC) (180 m elevation, 1875 mm mean annual precipitation), and was covered by unmanaged open grassland. Between 5 and 10 randomly selected flowerheads were collected from at least 5 plants growing within each site at 3-4 week intervals during the first 4 months of 1999, a time period when most of *E. mollis* flowering takes place. The exact quantity of sampled material depended on the abundance of flowering plants. Excised flowerheads were brought to the laboratory, dissected under a microscope, and the number of *T. obscuriventris* larvae and pupae infesting each of them was recorded. Flies were identified using the keys developed by Hardy and Delfinado (1980), with the identity of immatures confirmed by rearing them to adulthood as described by Duan et al. (1996). Voucher specimens of *T. obscuriventris* are stored in the Entomology Museum at the University of Hawaii at Manoa.

Statistical analysis. Effects of site and month of collection on the proportion of flowerheads infested by *T. obscuriventris* were analysed using logistic regression (PROC LOGISTIC, SAS Institute 1999). The variation in mean numbers of fly immatures dissected from different flowerheads was analysed by nested ANOVA (PROC GLM, SAS Institute 1999). Site and month of trap deployment were used as the main effects. Plants from which individual flowerheads originated were considered to be nested within the site \times month interaction (Zar 1999). Since the Wilk-Shapiro test revealed that the data were not normally distributed ($W=0.89$, $P<0.0001$) (PROC UNIVARIATE, SAS Institute 1999), data were transformed prior to ANOVA using rank transformations (Conover and Iman 1981). The relationship between the percent of infested flowerheads collected from individual plants and the mean number of flies per infested flowerhead was tested using Spearman's rank correlations (PROC CORR, SAS Institute 1999).

To determine spatial distribution patterns of flowerhead-inhabiting *T. obscuriventris*, the frequency of the numbers (including 0) of larvae and pupae dissected from each flowerhead was recorded, and data were examined for agreement with the negative binomial distribution using the chi-square goodness-of-fit test (Elliott 1983). This analysis was confirmed by calculating Lloyd's mean crowding index, m^* (Lloyd 1967), and the Morisita Index, I_δ

(Morisita 1962). All three tests were conducted separately for each sampling site.

RESULTS AND DISCUSSION

Overall, 83.3% (SE=3.5) of all flowerheads collected at Anini Road and 89.7% (SE=2.9) of all flowerheads collected at KARC contained at least one *T. obscuriventris* larva. Percent infestation decreased as the season progressed (Fig. 1). A logistic model provided a good description of the recorded data (Score test, $df=3$, $\chi^2=20.71$, $P=0.0001$), and indicated a significant effect of both site ($df=1$, $\chi^2=5.64$, $P=0.0176$) and month ($df=1$, $\chi^2=10.22$, $P=0.0014$) of sampling on the proportion of infested flowerheads. The observed differences could be probably attributed to the environmental variation between the two sites and among the months of the study. The site \times month interaction was not statistically significant ($df=1$, $\chi^2=3.09$, $P=0.0789$).

An average infested flowerhead contained approximately 5.2 fly larvae (SE=0.2). This was not unexpected, because gregarious larvae are fairly common in the tephritid tribe Tephritini (which includes *T. obscuriventris*), with the maximum number of larvae that can occupy a single flowerhead being a function of head size (Straw 1989a). In our study, sampling site did not have any effect on fly density within infested flowerheads (ANOVA, $df=1$, 52, $F=0.03$, $P=0.8592$). The difference among the months of collection (ANOVA, $df=3$, 52, $F=2.64$, $P=0.0590$), as well as the site \times month interaction (ANOVA, $df=3$, 52, $F=2.65$, $P=0.0582$) was not significant.

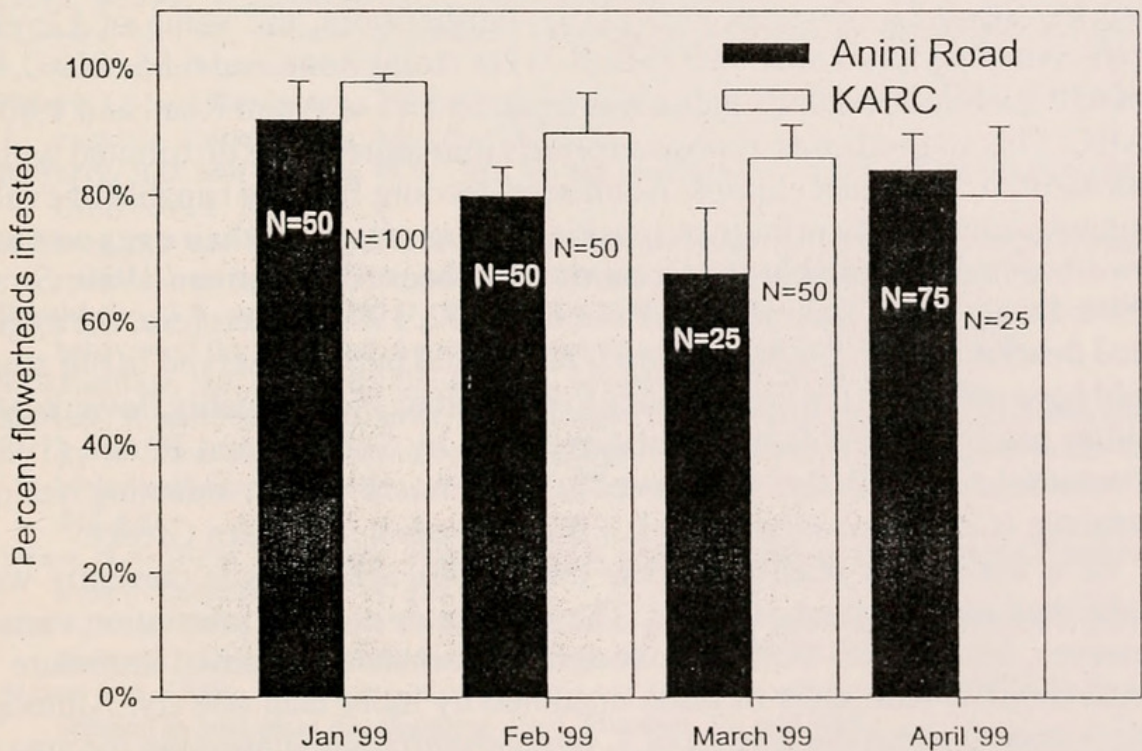


Fig. 1. Percent of *Elephantopus mollis* flowerheads infested by *Tetreuaresta obscurivetris* at two sites on the island of Kauai. N denotes a total number of flowerheads dissected.

The mean number of flies per infested flowerhead was positively correlated with the percent of infested flowerheads (Spearman's rank correlation, $\rho=0.66$, $P<0.0001$). Little is known about the oviposition behavior of *T. obscuriventris*. Nonetheless, a number of tephritid species are known to mark flowerheads where they deposit their eggs with an oviposition-detering pheromone. In those species, conspecific females usually avoid laying eggs into the marked flowerheads, thus reducing intraspecific larval competition (Straw 1989b; Pittara and Katsoyanos 1990; Lalonde and Roitberg 1992). However, when fly populations are high and uninfested hosts are rare, rejecting previously attacked hosts substantially elevates the search time costs for gravid females (Lalonde and Roitberg 1994). Therefore, flies may compensate for such an increase by either increasing clutch size when an uninfested host is located, or by allocating eggs to previously attacked flowerheads (Lalonde and Roitberg 1994). Both behaviors result in a positive correlation between fly density per infested flowerhead and the percent of flowerheads infested, comparable to the positive correlation observed in the present study. Similar compensatory mechanisms appear to be common among other insect species in which survivorship of the offspring is largely determined by the ovipositional choices of adults (Roitberg and Prokopy 1983; Charnov and Skinner 1985; Roitberg and Mangel 1988; Rosenheim and Rosen 1992).

Based on the chi-square goodness-of-fit test, the spatial pattern of *T. obscuriventris* followed the negative binomial distribution both at the Anini Road site ($k=1.10$, $SE=0.10$, $\chi^2=15.85$, $P=0.1039$), as well as at the KARC site ($k=2.16$, $SE=0.22$, $\chi^2=15.0$, $P=0.1319$). Furthermore, the value of Lloyd's mean-crowding index was 8.03 ($SE=0.71$) at Anini Road and 6.86 ($SE=0.44$) at KARC, while Morisita's index was equal to 1.81 at Anini Road and 1.46 at KARC. This suggests that *T. obscuriventris* immatures were distributed within both habitats in distinct clumps. Adult seed-feeding flies are capable of evaluating substrate quality prior to oviposition, and prefer to lay their eggs on those flowerheads most suitable for larval development (Zimmerman 1980; Straw 1989c; Brody 1992; Lalonde and Roitberg 1992, 1994). Therefore, the aggregated distribution of *T. obscuriventris* larvae and pupae observed in our study could have resulted from the tendency to oviposit on higher quality flowerheads. Similar patchy distribution was also reported by Sobhian and Pittara (1988) for another tephritid fly, *Chaetorellia hexachaeta* Loew, infesting yellow starthistle (*Centaurea solstitialis* L.) flowerheads in Northern Greece.

As a whole, our results indicate that *T. obscuriventris* is currently well established on the island of Kauai. The exact rates of plant infestation varied. However, between 80-90% of collected flowerheads contained immature *T. obscuriventris*, with most of them inhabited by more than one fly. Although little is known about the density of *T. obscuriventris* populations in the area of its original distribution, preventing us from evaluating the effects of intentionally moving this fly beyond its native range, it appears that the Hawaiian envi-

ronment proved to be generally favorable for this species.

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SOCIETY MEETING OF APRIL 24, 2002

Jane Earle

Bureau of Watershed Conservation

Pennsylvania Department of Environmental Protection

Stoneflies of Pennsylvania

Ms. Earle's presentation covered the full range of biological and habitat diversity among the Plecoptera of Pennsylvania. Her talk included slides of the larvae and adults of most of the major groups. Stoneflies are good indicators of stream water quality and good for determining progress of restoration; however, little known about life history, habitats, tolerances. More adults need to be collected for species identification, but adults hard to find and collect. Winter adults are easy to see but not often collected. Collections by citizens, fishermen and members of watershed associations could add to knowledge of their watersheds and the Pennsylvania fauna. Challenges for species records are limitations on stream sampling, finding representative aquatic communities, sampling all ecoregions / major drainage basins and all types habitats, both good sites and impaired sites, including springs. Seeps and tiny intermittent and perennial streams are often ignored but can harbor unusual or rarely collected species.

The best stonefly habitats for highest diversity are cold, forested high gradient streams (brook trout streams). Warm water creeks and rivers can have a high diversity; however, some stonefly families are absent or limited in species. Springs and seeps and first order runs are good and acidic streams provide an interesting fauna. Limestone streams have a low diversity. Threats to stoneflies include removal of riparian vegetation, warming of water, nutrient enrichment, sewage & industrial discharges, alteration of substrate or stream habitat, siltation, acid mine drainage, and metals. Stoneflies are generally not affected by acidity as badly as some other insect orders. Stoneflies are very sensitive to warm water and nutrient enrichment and generally only species with large gills or summer diapause can thrive under these conditions.

Goals of the Ms. Earle's PA Stonefly Project are to document Pennsylvania diversity, identify places of high species diversity for protection, determine those species expected after remediation, identify species habitat preferences, pollution tolerances and life history, emergence/ flight periods. The official Pennsylvania record is for 136 species in the state compared with the North American total of 630. Some species should be deleted from the list and at least 10 additional species could be added. Old collections/records need to be checked and problems of taxonomic differences integrated. Ms Earle also mentioned that New Jersey's stoneflies are very poorly known and few species are included on the official fauna list. Research is needed throughout the state.

In notes of entomological interest, effects of the warm winter and spring continue to show up: Paul Goddard witnessed an emergence of Green Drake (*Ephemera guttulata*) mayfly adults on the West Branch of the Delaware River last weekend, about a month earlier than normal. Dale Schweitzer reported that *Shistocerca americana* survived through the winter to late March/early April in Cumberland Co. NJ. Several attendees reported early sightings of swallowtail butterflies around the area.

William J. Cromartie
Corresponding Secretary



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