A Comparison of Nontarget Captures in BioLure and Liquid Protein Food Lures in Hawaii

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Abstract. MultiLure traps baited with three different food attractants for tephritid fruit flies (3-component BioLure, solulys and torula yeast) captured a broad diversity of nontarget insects, dominated by the Drosophilidae, Cecidomyiidae, Ceratopogonidae, Chloropidae, Neriidae, Calliphoridae, Sarcophagidae, Muscidae, and Corylophidae, in endemic and nonnative forests as well as in farmland, on Hawaii Island. Overall nontarget captures were highest for BioLure, followed by solulys and torula yeast, but differed among taxonomic groups. Attraction to torula yeast was, however, probably inhibited by the addition of propylene glycol to traps. Endemic nontargets, mainly Drosophilidae and Calliphoridae (Dyscritomyia spp) were trapped in large numbers in native forest, but seldom captured in nonnative forest or agricultural habitats.

Key words: torula yeast, Solulys, Tephritidae, Drosophilidae, native insects, fruit fly control

Protein-based food lures are commonly used to attract and trap fruit flies (Tephritidae), for monitoring or control purposes. Initial liquid formulations, almost exclusively used in association with glass McPhail traps, quickly fermented, decreasing fruit fly attraction and drawing large numbers of nontarget flies (Hardy 1952). To retard protein decomposition, sodium borate (borax) was added to the liquid lure (Lopez-D. and Hernandez Becerril 1967). An improved formulation marketed as dry pellets of hydrolyzed torula yeast and borax (Lopez-D. et al. 1971), soon became widely used. Corn protein hydrolysate, in various forms such as NuLure, mazoferm or solulys (Vargas and Prokopy 2006), is also commonly used in the United States for fruit fly monitoring. Solulys is a purified protein processed from drying mazoferm, and is the protein base for the current organic formulation of GF-120 NF Naturalyte Fruit Fly Bait (DowElanco 1994, Mangan and Moreno 2007). Taking advantage of the strong fruit fly attraction to ammonia derivatives, a synthetic dry food lure formulation (BioLure) consisting of three chemicals (ammonium acetate, trimethylamine hydrochloride and putrescine) was developed for use against Ceratitis capitata (Wiedemann) (Heath et al. 1995). Solulys and torula yeast, diluted in water or a propylene glycol solution to prevent desiccation in dry farmland environments (R.V. unpublished), were commonly used in traps to monitor populations of Bactrocera flies, while BioLure was used to monitor and for mass trapping Ceratitis capitata (Wiedemann) during the Area-Wide Fruit Fly Management Program in Hawaii (AWPM) (McQuate et al. 2005, Vargas et al. 2008).

Food lures are well known to attract numerous nontarget arthropods, in addition to pest fruit flies (Hardy 1952, Steyskal 1977, Neuenschwander et al. 1981, Asquith and Messing 1992, Katsoyannos et al. 1999, Thomas 2003, Conway and Forrester 2007, Martinez et al. 2007, Leblanc et al. 2010a-b). The accumulation of nontargets increases sample processing and sorting time, and the unfortunate attraction of beneficial and endemic arthropods, especially the Hawaiian Drosophilidae, was reported in the studies cited above. The use of
food lures must therefore be carefully considered in Hawaii, where 559 described endemic drosophilid species occur (O’Grady et al. 2010), including 12 endangered species (U.S. Fish and Wildlife Service 2007).

This publication reports on captures of endemic and introduced nontargets in traps baited with BioLure, solulys and torula yeast and placed in endemic and introduced forests and in farmland areas on Hawaii Island.

**Materials and Methods**

**Traps and lures.** MultiLure® traps (Better World Manufacturing Inc, Fresno, CA) were used for this study. Similar to the glass McPhail trap (Steyskal 1977), the plastic MultiLure trap (photo in Thomas 2003) consists of a transparent cover that interlocks with an opaque yellow base, with a circular bottom opening for insect entry. Three different food lure treatments were used. The first was BioLure® (Suterra LLC, Bend, OR) fruit fly food lure, with the three components formulated as sticky packets, with slow-release membranes, attached to the inner surface of the trap cover. Insects that entered the trap were killed and retained in 200 ml of an aqueous solution of 20% propylene glycol (PPG) (Sierra Antifreeze®, Old World Industries, Northbrook, IL) in the bottom of the trap. In the second treatment, 20 ml of solulys AST (Roquette America, Keokuk, IA) and 8 ml of borax powder (Dial Corporation, Scottsdale, AZ) were dissolved in 180 ml of a 20% PPG solution. The third lure treatment consisted of dissolving two 5 g torula yeast pellets (2.25 g of torula yeast and 2.75 g of borax) (ERA International, Freeport, NY), in 200 ml of 20% PPG. Traps were hung on trees, 1.5-2 m above the ground, using 15-gauge aluminum tie wire, and at least 10 meters apart to avoid interference among traps.

**Sites.** Twenty trapping sites were selected on Hawaii Island, along two transects and among farmlands (for site maps, see Figs. 1-2 in Leblanc et al. 2009). The first transect was setup along a 20-km segment of Stainback Highway and contained nine sites, from mixed introduced forest at the Panaewa Rainforest Zoo, near Hilo (138 m above sea level), to endemic forest up to 1,045 m elevation. Habitats covered native wet montane ohia-dominated (*Metrosideros polymorpha* Gaudich.) forest (four sites), invasive strawberry guava (*Psidium cattleianum* Sabine) dominated forest (three sites), and a citrus orchard and a mixed fruit orchard. The second transect was implemented in the North Kohala Forest Reserve (Hawaii Island) and had six sites along the upper Hamakua Ditch Trail, from the far end of the flume (1,019 m) to the entrance of the reserve (906 m). Five sites were in mixed native wet montane ohia forest, and one site, at the forest entrance, was in the strawberry guava belt. The last five sites were distributed in the agricultural community of Waimea (744-872 m), 4 km southwest of the North Kohala Reserve, with two sites in mixed backyard orchards, one in a commercial citrus orchard, one in a large feral stand of common guava (*Psidium guajava* L.), and the last site at the foot of the North Kohala Forest Range, in a forest dominated by invasive tropical ash (*Fraxinus uhdei* (Wenzig) Lingelsh). For analysis purposes, the Waimea sites and the five lower sites along Stainback Highway (sites 5 to 9 on Fig. 1 in Leblanc et al. 2009) were treated as nonnative forest and farmland sites, while the four upper sites in Stainback (sites 1 to 4 on Fig. 1 in Leblanc et al. 2009) and all Kohala sites were treated as endemic habitats.

**Design and trapping frequency.** Each site had four traps, with the first three baited as described above, and the last as an unbaited control, with 200 ml of PPG solution. Traps were maintained from June to August 2005, for 10 wk in Stainback, 7 wk in Kohala, and 9 wk in Waimea. Trapping was continuous, with traps emptied weekly, in all nonnative sites, and intermittent, with traps deployed for 1 wk straight every other week, in the endemic forest sites. The solulys and torula yeast solutions were replaced weekly after each col-
lection, and the same BioLure membranes were used for the whole duration. Positions of traps were re-randomized every 3 wk for continuously serviced sites, and every 2 wk for intermittently serviced sites.

Data analysis. All insects were counted and identified to species level. Very large numbers of adult *Drosophila sulfurigaster bilimbata* Bezzi were estimated by counting flies in a 2 ml subsample (631 ± 133 SEM, n = 38). Counts were converted to number of insects per trap per day, subjected to the log(n+1) transformation to stabilize variance, and analyzed using analysis of variance (ANOVA), with the minimum variance unbiased quadratic estimation (MIVQUE0). The MIVQUE0 provides reliable estimates of parameters for data with a non-normal distribution, large numbers of zero values, and unequal variances (PROC MIXED MIVQUE0, SAS Institute 2004). Lure effect was analyzed in a mixed model, with lure, habitat (endemic forest or nonnative habitats) and their interaction treated as fixed variables and trapping site as random variables. Capture data from the separate collections of each trap were used as replicate data for individual traps in the statistical analyses. Data were analyzed by family for all nontarget families represented by at least 200 specimens and in more detail, by species or group of related species, for the Drosophilidae. For each taxonomic group analyzed, we used only data from sites where at least one specimen was collected, to avoid including data from sites where the nontarget group may be absent. Because the interactions between lure and habitat were significant only for the endemic Drosophilidae, Cecidomyiidae, Chloropidae, and the Calliphoridae, and none of these families were collected in sufficient numbers in both habitats to display meaningful information on the interactions, the lure and habitat effects are presented on separate graphs in the paper. Habitat effect was analyzed by comparing capture data of the three attractants in all the endemic and nonnative sites for each family of insect. Least square means estimates for each lure treatment or habitat were compared using Tukey’s Honest Significant Difference test (SAS Institute 2004). Means and standard errors are presented in their original, untransformed, form. Pinned voucher specimens of all species were deposited at the University of Hawaii Insect Museum (Honolulu) and at the Bernice P. Bishop Museum (Honolulu).

Results and Discussion

Over 233 species of nontarget arthropods, in 113 recognized genera, 64 families, and 14 orders were collected during the study. Captures were dominated by the saprophagous fly families Drosophilidae (85.7% of all nontarget captures, with 83.5% as 16 introduced species and 2.2% as 35 endemic species) and Chloropidae (9.7%, 9 introduced species). Species in the most commonly captured families are scavengers (Drosophilidae, Chloropidae, Ceratopogonidae, Lonchaeidae, Calliphoridae, Sarcophagidae, and Muscidae) or fungal spore feeders (Corylophidae) in the larval stage. These findings are consistent with other published records of scavenger attraction to food lures (Steyskal 1977, Asquith and Messing 1992, Thomas 2003, Leblanc et al. 2010a,b), and decaying fruit flies in male lure traps (Uchida et al. 2007, Leblanc et al. 2009).

Captures of nontargets (all species combined) were greatest in BioLure (145.4 ± 41.6 per trap per day), followed by solulys (14.5 ± 1.6), torula yeast (9.4 ± 1.6), and the controls (0.9 ± 0.1), but response to the attractants varied widely depending on individual families (Figures 1-2). BioLure traps captured significantly larger numbers of Drosophilidae, Neriidae and calyptrate flies (Calliphoridae, Muscidae and Sarcophagidae) than either of the protein lures. For drosophilids, solulys was second and torula yeast captured the fewest flies. Both protein attractants captured small but similar numbers of Neriidae and calyptrate flies. All three lures collected equal numbers of Ceratopogonidae, Chloropidae and Corylophidae (Coleoptera), the only non-Diptera attracted in sizeable numbers. Solulys was equally
Captures (in logarithmic scale) (mean ± SEM per trap per day) of the most abundant non-target Dipteran species in traps baited with three-component BioLure, solulys, or torula yeast, and unbaited traps. All traps contained propylene glycol as a drowning agent. Values in each family with the same letter are not significantly different at the $P = 0.05$ level, ANOVA, PROC MIXED mivque0 (SAS Institute, 2004). $F$ values, degrees of freedom and $P$ values are presented for lure (lur), habitat (hab), and their interaction (int) in that order for each family. $P < 0.0001$ for all analyzes, except when otherwise specified. Drosophilidae (endemic): $F = 138.91, 66.38, 114.28$; df = 3,374 (lur, int), 1,374 (hab); Drosophilidae (introduced): $F = 162.34, 0.55, 2.01$; df = 3,516 (lur, int), 1,516 (int); Drosophilidae: $F = 4.597$ (hab), 0.1122 (int); Cecidomyiidae: $F = 3.42, 0.62, 2.82$; df = 3,399 (lur, int), 1,399 (int); $P = 0.0347$ (lur), 0.4298 (hab), 0.0387 (int); Ceratopogonidae: $F = 9.10, 1.15, 0.31$; df = 3,497 (lur, int), 1,497 (int); $P = 0.2849$ (hab), 0.8205 (int); Chloropidae: $F = 5.45, 1.55, 3.17$; df = 3,371 (lur, int), 1,371 (hab); $P = 0.011$ (lur), 0.2140 (hab), 0.0245 (int).

Food lures are strongly attractive to endemic Drosophilidae and Calliphoridae (Dyscrito-
Figure 2. Captures (in logarithmic scale) (mean ± SEM per trap per day) of less abundant non-target Dipteran and Coleopteran species in traps baited with three-component BioLure, solulys, or torula yeast, and unbaited traps. All traps contained propylene glycol as a drowning agent.

Values in each family with the same letter are not significantly different at the $P = 0.05$ level, ANOVA, PROC MIXED mivque0 (SAS Institute, 2004). $F$ values, degrees of freedom and $P$ values are presented for lure (lur), habitat (hab), and their interaction (int) in that order for each family. $P < 0.0001$ for all analyzes, except when otherwise specified. Neriiidae [(Telostylinus lineolatus (Wiedemann)]: $F = 9.17, 0.02, 0.18; df = 3,206$ (lur, int), $1,206$ (hab); $P = 0.8803$ (hab), $0.9068$ (int); Calliphoridae (Dyscritomyia lucilioides Grimshaw): $F = 7.31, 2.58, 7.49; df = 3,191$ (lur, int), $1,191$ (hab); $P = 0.0001$ (lur), $0.1097$ (hab); Muscidae: $F = 13.99, 0.89, 2.59; df = 3,433$ (lur, int); $P = 0.3466$ (hab), $0.525$ (int); Sarcophagidae: $F = 3.83, 0.34, 1.72; df = 3,333$ (lur, int), $1,333$ (hab); $P = 0.0102$ (lur), $0.5588$ (int), $0.1630$ (int); Corylophidae [Corylophodes suturalis (Sharp)]: $F = 3.73, 1.65, 1.62; df = 3,401$ (lur, int), $1,401$ (hab); $P = 0.0115$ (lur), $0.1992$ (hab), $0.1836$ (int).

myia spp) when traps are deployed in native forest, but endemic nontarget captures drop to nearly zero in nonnative habitats (Figure 4 and Leblanc et al. 2010a). The only exception is the endemic Forcipomyia hardyi Wirth and Howarth (Ceratopogonidae), which is abundant throughout the main islands of Hawaii (Wirth and Howarth 1982), hence not a concern for conservation. The other nontarget families, all represented by introduced species, were collected in the largest numbers in habitats dominated by introduced plants, and in rather small numbers in endemic forest (Figure 4). Hence the continuous use of food lures should be discouraged in, or near, endemic habitats to reduce native insect bycatch. Because nontarget attraction to food baits is relatively short-ranged, and captures of endemic species are insignificant in orchards and non-native forest (Leblanc et al. 2009, 2010a), keeping traps at a minimal safe distance of at least 300 m from endemic forest minimizes the risks of killing endemic Hawaiian insects (Leblanc et al. 2009). The study was conducted in a single year, over a comparatively short period of time, and therefore the results apply only to the summer conditions of that particular year. Results may have been different in the cooler and wetter winter and spring months, but the captures of endemic insects in the agricultural environments are likely to remain very low throughout the year.
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Figure 3. Captures (in logarithmic scale) (mean ± SEM per trap per day) of endemic (Anthonopocerus, modified tarsus, S. cryptoloba) and introduced (D. immigrans, D. sulfurigaster bilimbata, D. suzukii) Drosophilidae in traps baited with three-component BioLure, solulys or torula yeast, and unbaited control traps.

Values in each group or species with the same letter are not significantly different at the $P = 0.05$ level, ANOVA, PROC MIXED mivque0 (SAS Institute, 2004). $F$ values, degrees of freedom and $P$ values are presented for lure (lur), habitat (hab), and their interaction (int) in that order for each family. Drosophila (Antopocerus) [includes D. cognata Grimshaw and D. tanythrix (Hardy)]; $F = 77.72$ (lur); df = 3,163 (lur); Drosophila (modified tarsus) [includes mainly D. conformis Hardy, D. dasycnemia Hardy, D. incognita Hardy, D. neutralis Hardy, D. percnosoma Hardy, and D. sordidapex Grimshaw]; $F = 32.90, 14.58, 33.44$; df = 3,273 (lur, int), 1,273 (hab); $P = 0.0002$ (hab); Scaptomyza cryptoloba Hardy: $F = 12.71$ (lur); df = 3,163 (lur); D. immigrans Sturtevant: $F = 93.92, 0.29, 3.84$; df = 3,481 (lur, int), 1,481 (hab); $P = 0.5925$ (hab), 0.0098 (int); D. sulfurigaster bilimbata Bezzi: $F = 23.56, 1.61, 11.73$; df = 3,371 (lur, int), 1,371 (hab); $P = 0.2049$ (hab); D. suzukii (Matsumura): $F = 128.72, 0.25, 0.25$; df = 3,516 (lur, int), 1,516 (hab); $P = 0.6143$ (hab), 0.8603 (int). Drosophila (Antopocerus) and S. cryptoloba were collected only in endemic forest, hence no habitat or interaction.
Figure 4. Captures (in logarithmic scale) (mean ± SEM per trap per day) of nontarget flies and beetles in traps baited with three-component BioLure, solulyis and torula yeast in endemic forest and nonnative forest and farmlands. All species are introduced, except for the endemic Drosophilidae, Dyscritomyia lucilioides (Calliphoridae) and one of the two species of Ceratopogonidae (Forcipomyia hardyi Wirth and Howarth).

Values in each family are all significantly different at the $P = 0.05$ level, ANOVA, PROC MIXED mivque0 (SAS Institute, 2004). Numerator and denominator degrees of freedom are 1,404 and $P < 0.0001$ for all analyzes, except when otherwise indicated. Drosophilidae (endemic): $F = 473.48$; Drosophilidae (introduced): $F = 6.19; P = 0.0133$; Cecidomyiidae: $F = 22.3$; Ceratopogonidae: $F = 10.03; P = 0.0017$; Chloropidae: $F = 46.67$; T. lineolatus: $F = 7.96; P = 0.005$; D. lucilioides: $F = 72.41$; Muscidae: $F = 10.96; P = 0.001$; Sarcophagidae: $F = 7.81; P = 0.0055$; C. suturalis: $F = 19.66$. Only one specimen of D. lucilioides collected in nonnative habitats.

**Literature Cited**


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