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A Diversity of Moths (Lepidoptera) Trapped With Two Feeding Attractants

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ABSTRACT Feeding attractants for moths are useful as survey tools to assess moth species diversity and for monitoring of the relative abundance of certain pest species. We assessed the relative breadth of attractiveness of two such lures to moths, at sites with varied habitats during 2006. Eighty-six of the 114 species of Lepidoptera captured were in traps baited with acetic acid plus 3-methyl-1-butanol (AAMB), a moth lure that is based on the odor chemistry of fermented molasses baits. Fifty-two of the 114 species were trapped with a floral odorant lure comprised of phenylacetaldehyde, β-myrcene, methyl salicylate, and methyl-2-methoxy benzoate. Preference for one lure type was statistically supported for 10 species of moths: seven to the AAMB lure and three to the floral lure. To gain better information on lure preference, 10 pairs of traps baited with the same lures were maintained in a single habitat type (riparian) during 2008. Sixty-eight of 89 species captured were in traps baited with AAMB, and 43 were in traps baited with the floral lure. Preference for a lure type was statistically supported for 39 of the 89 species of moths trapped; 32 to the AAMB lure and seven to the floral lure. Both of these lures hold advantages for trapping different types of moths, and both lures might be used in a complementary way to sample moth biodiversity.

KEY WORDS moth, attractant, trapping, survey, biodiversity

Feeding attractants have been sought for their potential use in detecting, monitoring, and managing moths. Chemical attractants based on plant floral odorants are demonstrated for cabbage looper, *Trichoplusia ni* (Hübner) (Cantelo and Jacobson 1979, Haynes et al. 1991, Heath et al. 1992); alfalfa looper, *Autographa californica* (Speyer) (Landolt et al. 2001, 2006); *Autographa gamma* (L.) (Plepys et al. 2002); soybean looper, *Chrysodeixis* (=*Pseudoplusia*) *includens* (Walker) (Meagher 2001, 2002); tobacco budworm, *Heliothis virescens* (F.); corn earworm, *Helicoverpa zea* (Boddie) (Pair and Horvat 1997, Lopez et al. 2000); and *Helicoverpa armigera* (Hübner) (Midgley et al. 2008), among others. These lures are thought to be feeding attractants that are used by moths to locate and then feed on floral nectars.

Chemical attractants based on odorants from fermented sweet baits also are demonstrated for moths. Utrio and Eriksson (1977) trapped moths with several single chemical lures as well as an eight-component blend of compounds, based on the chemistry of fermented molasses. A subset of that blend, acetic acid with 3-methyl-1-butanol (AAMB), has been used to trap moths (Landolt 2000, Landolt and Hammond 2001, Landolt et al. 2007, Toth et al. 2010). Important pest species attracted to AAMB include the noctuids *Mamestra configurata* Walker (bertha armyworm), *Xestia c-nigrum* (L.) (spotted cutworm), *Lacanobia subjuncta* (Barnes & McDunnough), and *Mythimna* (=*Pseudaletia*) *unipuncta* (Haworth) (Landolt 2000, Landolt and Higbee 2002); the erebids *Mocis* spp. (grass loopers) (Meagher and Mislevy 2005) and *Hypena humuli* Harris (hop looper) (Landolt et al. 2011); and the stored product pyralids *Pyralis farinalis* L. (meal moth) (Landolt 2005), *Anagasta kuhniella* (Zeller), and *Plodia interpunctella* (Hübner) (Indianmeal moth) (Toth et al. 2002).

These two types of lures (floral and AAMB) are potentially attractive to numerous and diverse moth taxa. Traps in Alaska baited with a floral odorant-based lure captured 22 species of Noctuidae and 13 species of Geometridae (Landolt et al. 2007). This lure emitted phenylacetaldehyde, β-myrcene, methyl salicylate, and methyl-2-methoxy benzoate. Traps baited with the same attractant in Florida captured large numbers of nine pest species of noctuids and erebids, whereas nonpest species were not reported (Meagher and Landolt 2008). Traps baited with AAMB in Alaska captured 64 species of noctuids, four species of Erebidae, five species of Geometridae, and one species of Thyatiridae (Landolt et al. 2007). In Washington, traps baited with AAMB captured 50 species of Noctuidae, four species of Erebidae, three species of Thyatiridae, and three species of Pyralidae (Landolt and Hammond 2001). These results suggest potential for use of

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such feeding attractants in detection efforts or surveys of moth biodiversity. For our analysis, we follow the taxonomic arrangements of Lafontaine and Schmidt (2010) for Noctuoidea, Solis (2007) for Pyraloidea, and Hodges (1983) for other Lepidoptera.

Although both types of lures seem broadly attractive to moths, each of the two lures may be attractive to, or preferred by, different lepidopteran taxa. For example, in an assessment of the moths trapped with feeding attractants in Alaska (Landolt et al. 2007), all plusiine noctuids captured were in traps baited with the floral lure, whereas those in other subfamilies were captured principally in traps baited with AAMB. In Hungary, Toth et al. (2010) trapped greater numbers of the noctuid plusiines *A. gamma* and *Macdunnoughia confusa* Stephen, as well as the noctuid heliothine *H. armigera* and noctuid noctuine *Charanyca trigrammica* Hufnagel, with the floral compound phenylacetaldehyde. They trapped more of the noctuines *Agrotis exclamationis* L., *Agrotis segetum* Schiffermuller, *X. c-nigrum*, *Amphipyra pyramidea* L., *Apatele rumicis* L., *Mamestra brassicae* (L.), *Mamestra oleracea* L., and *Mamestra suasa* (Denis & Schiffermüller), with a lure that is based on fermented molasses odor and included AAMB. A comparative assessment of taxonomic patterns to these responses would be useful for determining which lure or lure type would be most appropriate to use for moth detection or monitoring applications.

We first sought to improve our knowledge of the breadth of attractiveness of these two lures to moth taxa with an observational study of moths trapped in a variety of habitats. We then focused on a single habitat type to better test the hypothesis that moth species will respond preferentially to the floral lure or to the AAMB lure. We also experimentally confirmed observations of previous studies that noctuid plusiines are preferentially attracted to a floral lure, whereas noctuids in the Noctuinae generally are preferentially attracted to the AAMB lure. Results of this work confirm a potential for use of these feeding attractant lures for the trapping of several pest moth species.

Materials and Methods

Traps were UniTraps (AgriSense, PontyPridd, United Kingdom), with a 2.5- by 2.5-cm piece of Vaportape (Hercon Environmental Inc., Emigsville, PA), which was used as a killing agent, stapled to the inside wall of the trap bucket. The style of trap used was a white bucket topped with a yellow cone and a green lid above the cone. The AAMB lure was a 15-ml polypropylene vial (Nalge Nunc International, Rochester, NY) with a 6-mm-diameter hole drilled into the cap, with 10 ml of a 50:50 by volume mixture of acetic acid (Mallinckrodt Baker Chemical Co., Phillipsburg, NJ) and 3-methyl-1-butanol (Aldrich Chemical, Milwaukee, WI,) on cotton balls in the bottom of the vial (Landolt and Alfaro 2001). The floral lure was a 15-ml polypropylene vial with a 6-mm-diameter hole in the cap, with 10 ml of a mixture of equal portions by weight of phenylacetaldehyde (PAA), β-myrcene (BM), methyl salicylate (MS), and methyl-2-methoxy benzoate (M2MB) (Aldrich Chemical, Milwaukee, WI) on cotton balls in the bottom of the vial. Lures were suspended within the bucket by a length of wire folded over the bucket lip so that they remained upright but above the floor of the bucket. Traps were hung on shrubs, trees, and fencing at a height of 1.0–1.5 m and with a distance of 10 m between traps. Traps were checked weekly, lures were replaced every two weeks, and Vaportape pieces were replaced every 4 wk. Captured insects were placed in prelabeled (experiment, site, date, and lure) Ziplock plastic bags and stored in a freezer until insects were sorted and identified.

2006 Study of Diversity of Moths Trapped. Pairs of traps (a trap with an AAMB lure and a trap with a floral lure), were maintained in the Yakima Valley, Yakima Co., WA (five pairs), and in Wasco Co. of north central Oregon (10 pairs). The five Yakima Valley trap locations were 1) a forested riparian zone bordering lawn and pasture along Ahtanum Creek 3 km SE of Ahtanum; 2) a forested riparian zone bordering pasture along Cowiche Creek near Cowiche; 3) at the edge of a Yakima River flood plain forest of black cottonwood, *Populus trichocarpum* Fernald, adjacent to an irrigated apple (*Malus* spp.) orchard; 4) within an irrigated apple orchard near Parker; and 5) on Rattlesnake Ridge in sagebrush steppe habitat that was largely burned by a wildfire on 13 August 2006. Traps were maintained from 3 March until 27 October 2006. The 10 trap locations in Wasco County were 1) in a stand of mixed ponderosa pine, *Pinus ponderosa* Laws., and garry oak, *Quercus garryanna* Douglas ex Hook, surrounded by dryland wheat (*Triticum aestivum* L.) fields 5 km SW of the town of Dufur; 2) roadside adjacent to dryland wheat and rolling grassland fields 4 km SE of Dufur; 3) dryland wheat, 200 m W of Hwy 197 ≈5 km NE of Dufur; 4) 8 km W of Dufur in a transition zone from grassland to ponderosa pine and garry oak mixed forest; 5) rolling grassland hills 5 km NW of Dufur; 6) a riparian zone on Eight Mile Creek adjacent to dryland wheat, 5 km W of the town of The Dalles; 7) dryland wheat fields 5 km southeast of The Dalles; 8) east end of The Dalles with black locust trees, *Robinia pseudoacaci* L., and grasslands; 9) southeast side of The Dalles on a rocky ridge with grass; and 10) a grove of garry oak 6 km SW of The Dalles. These traps were maintained from 18 May to 30 August 2006. Traps, lures, and trap maintenance were as described above.

2008 Study of Lure Preference. Ten pairs of traps were set up in early April and were maintained until mid-October to determine whether different species are attracted (trapped) to one lure more than the other lure. Trap treatments were the AAMB and floral lures as described above. All were in riparian habitat in Yakima Co., WA. Trap sites were dominated by black poplar and willows (*Salix* spp.), with an abundant understory of shrubs, forbs, and grasses.

Statistical Analysis. For each lepidopteran species, numbers of moths in traps baited with AAMB were compared with numbers in traps baited with the floral lure by using a paired *t*-test, following square-root transformation of the data (Sokal and Rohlf 1981). For these statistical analyses, data for each trap were summed through the season, providing five and 10 replicates for the Yakima and Wasco Co. studies, respectively, in 2006 and 10 replicates for the Yakima study conducted in 2008.

Results

2006 Study of Diversity of Moths Trapped, Yakima Valley, WA. Ninety nine species of moths (1,144 individuals) were trapped at the Yakima Valley sites. These were Geometridae (four species), Erebidae (six species), Noctuidae (77 spp.), Thyatiridae (two species), Crambidae (five species), and Pyralidae (five species) (Table 1). Nearly twice as many species of moths were trapped with the AAMB lure (80 spp.) compared with the floral lure (41 spp.).

Statistically significant differences between the two trap lure treatments were seen for one erebid, four noctuid, and one pyralid species (Table 2). Five of these six species were captured in greater numbers in traps baited with AAMB compared with traps baited with the floral lure, whereas one species, alfalfa looper, was more abundant in traps baited with the floral lure. Pest species that were trapped were glassy cutworm, *Apamea devastator* (Brace); forage looper, *Caenurgina erechtea* (Cramer); *Anarta trifolii* (Hufnagel); bertha armyworm; spotted cutworm; and meal moths trapped with AAMB and the alfalfa looper moth trapped with the floral lure.

2006 Study of Diversity of Moths Trapped, Wasco Co., OR. Thirty-two species of Lepidoptera (187 individuals) were captured in traps in Wasco Co., OR (Table 1). These were Geometridae (six species), Erebidae (three species), Noctuidae (22 spp.), and Crambidae (one species). Statistically significant differences between the two lure treatments were seen for five of the 34 species of moths captured (Table 2). One species, an erebid, was trapped in greater numbers with the AAMB lure, whereas three noctuids and a crambid were trapped in significantly greater numbers with the floral lure. Pest species that were captured were clover loopers (AAMB) and alfalfa loopers (floral lure). Of interest was the capture in floral lure traps of the Palearctic species *Hecatera dysodea* (Denis & Schiffermüller), which is recently introduced and now widely present in northern Oregon and southern Washington (Landolt et al. 2010).

2008 Study of Lure Preference. Eighty-nine species of Lepidoptera (3,804 individuals) were trapped. The majority of species (64) were noctuids, whereas others were five erebids, 10 geometrids, three crambids, five pyralids, one sphingid, and one thyatirid (Table 1). Sixty-eight species were captured in AAMB traps and 43 species in floral traps. For 37 species, numbers captured were significantly different between trap lure treatments (Table 2), indicating a lure preference. Species that showed a preference for the floral lure were one noctuine noctuid, three plusiine noctuids, and two pyralids. Three erebids, and 25 noctuine noctuids were trapped in greater numbers with AAMB than with the floral lure. In addition, three species of Pyralidae preferred the AAMB lure.

Pest species of note were glassy cutworm, *L. subjuncta,* bertha armyworm, *Pseudaletia unipuncta* (Haworth) (armyworm), hop looper, spotted cutworm, and meal moth, all trapped with AAMB, and the celery looper [*Anagrapha falcifera* (Kirby)], alfalfa looper, cabbage looper, and *Udea profundalis* (Packard) (false celery leaftier) trapped with the floral lure. The underwing *Noctua pronuba* L., introduced from Eurasia and now widespread in North America (Lafontaine and Schmidt 2010), was trapped exclusively with the AAMB lure.

Combined observations from the three trapping studies show a preponderance of noctuids trapped compared with other families, both with the AAMB lure and with the floral lure (Fig. 1A). Combining the results of the three studies to examine the numbers of species showing a preference reveals a much larger number of species attracted to the AAMB lure, primarily Noctuidae (Fig. 1B).

Discussion

Numerous species of moths were captured in traps baited with AAMB, an attractant derived from fermented molasses baits (Utrio and Eriksson 1977, Landolt 2000). These species were primarily Noctuidae, with a few species of Erebidae, Geometridae, Crambidae, and Pyralidae; two Thyatiridae; and one Sphingidae. This taxonomic makeup of species trapped is similar to that reported previously for this type of lure in central Washington (Landolt and Hammond 2001) and in Alaska (Landolt et al. 2007). The composition of noctuids captured was also similar to that reported by Landolt et al. (2007), considering the recent reorganization of the higher categories of the Noctuoidea (Lafontaine and Schmidt 2010), with most species trapped being in the noctuid subfamily Noctuinae, and primarily representing the tribes Apameini, Xylinini, Hadenini, Eriopygini, and Noctuini. This taxonomic pattern might be due in part to the makeup of species and species abundance at the trapping sites, as well as the relative responsiveness of moth species within various higher taxa to this lure.

Fewer species of moths were captured in traps baited with the feeding attractant comprised of four chemicals (phenylacetaldehyde, β-myrcene, methyl salicylate, and methyl-2-methoxy benzoate) emitted by certain moth-visited flowers (Lopez et al. 2000, Pair and Horvat 1997, Landolt and Smithhisler 2003), compared with AAMB. These moths again were mostly Noctuidae, but also small numbers of Geometridae, Erebidae, Crambidae, and Pyralidae. The noctuids trapped with the floral lure were in several subfamilies, but 87% were Plusiinae. The preponderance of plusiines in traps baited with the floral lure is not surprising given that the floral compounds used in this lure were derived from studies of pest species of Plusiinae (Haynes et al. 1991, Heath et al. 1992, Lopez et al. 2000, Landolt and Smithhisler 2003). The taxonomic

Table 1. Species and numbers (mean ± SE) of moths captured in five Unitraps baited with AAMB lures and five Unitraps baited with floral attractant lures, in the Yakima Valley, Yakima Co., WA, and in The Dalles, Wasco Co., OR, 2006

Taxon	Yakima 2006		The Dalles 2006		Yakima 2008	
	AAMB	Floral	AAMB	Floral	AAMB	Floral
Geometridae						
Digrammia curvata (Grote)	0	0	0	0.4 ± 0.2	0	0
Digrammia denticulata (Grote)	0	0	0	0	0	0.1 ± 0.1
Digrammia irrorata (Packard)	0	0	0	0	0.2 ± 0.1	0.1 ± 0.1
Epirrhoe plebiculata (Guenée)	0	0.6 ± 0.6	0	0	0	0.3 ± 0.2
Euchlaena johnsonaria (Fitch)	0	0	0.2 ± 0.2	0.1 ± 0.1	0	0
Idaea dimidiata (Hufnagel)	0	0	0	0.1 ± 0.1	0	0
Iridopsis clivinaria (Guenée)	0	0.3 ± 0.2	0	0.1 ± 0.1	0	0.3 ± 0.2
Nematocampa limbata (Haworth)	0	0	0	0	0.1 ± 0.1	0
Orthonama obstipata (F.)	0	0	0	0	0	0.1 ± 0.1
Pero occidentalis (Hulst)	0	0	0	0	0	0.1 ± 0.1
Prochoerodes amplicineraria (Pearson)	0	0.2 ± 0.2	0	0	0	0
Sericosema juturnaria (Guenée)	0	0	0	0.1 ± 0.1	0	0
Synaxis cervinaria (Packard)	0.2 ± 0.2	0.8 ± 0.4	0	0	0	0.8 ± 0.3
Triphosa haesitata (Guenée)	0	0	0	0	0	0.1 ± 0.1
Xanthorhoe defensaria (Guenée)	0	0	0	0.1 ± 0.1	0	0
Erebidae						
Boletobiinae						
Metalectra bigallis (Smith)	2.0 ± 0.6	0	0	0	4.6 ± 1.7	0
Erebinae						
Caenurgina erechtea (Cramer)	7.0 ± 4.3	0.2 ± 0.2	2.8 ± 1.1	0.4 ± 0.2	1.6 ± 0.7	0
Drasteria ochracea (Behr)	0	0	0.1 ± 0.1	0	0	0
Melipotis jucunda (Hübner)	0.6 ± 0.2	0	0	0	0.1 ± 0.1	0
Zale lunata (Drury)	1.0 ± 0.8	0.2 ± 0.2	0.2 ± 0.2	0	0.3 ± 0.2	0
Hypeninae						
Hypena humuli (Harris)	0.4 ± 0.2	0.4 ± 0.2	0	0	1.5 ± 0.5	0.2 ± 0.1
Scoliopteryginae						
Scoliopteryx libatrix (L.)	0.2 ± 0.2	0	0	0	0	0
Noctuidae						
Plusiinae						
Anagrapha falcifera (Kirby)	0	0.4 ± 0.4	0	0	0	1.5 ± 0.6
Autographa californica (Speyer)	0	25.8 ± 9.9	0.1 ± 0.1	7.0 ± 5.0	0	55.1 ± 7.3
Plusia nichollae (Hampson)	0	0.2 ± 0.2	0	0.1 ± 0.1	0	0.2 ± 0.1
Syngrapha celsa (H. Edwards)	0	0.4 ± 0.2	0	0	0	0
Trichoplusia ni (Hübner)	0	0.6 ± 0.4	0	0	0	5.8 ± 104
Oncocnemidinae						
Behrensia conchiformis Grote	0	0	0	0	0	0.2 ± 0.1
Catabena lineolata Walker	0	0.2 ± 0.2	0	0	0	0
Heliothinae						
Heliothis phloxiphaga Grote & Robinson	0.2 ± 0.2	0.2 ± 0.2	0.1 ± 0.1	0.3 ± 0.2	0	0.1 ± 0.1
Noctuinae						
Abagrotis duanca (Smith)	0.4 ± 0.2	0	0	0	0.2 ± 0.1	0
Abagrotis erratica (Smith)	0.4 ± 0.2	0	0	0	0.7 ± 0.3	0
Abagrotis forbesi (Benjamin)	1.2 ± 0.7	0	0	0	2.3 ± 1.1	0
Abagrotis nefascia (Smith)	0.4 ± 0.4	0	0	0	0	0
Abagrotis orbis (Grote)	1.2 ± 1.0	0	0	0	1.5 ± 0.6	0
Abagrotis reedi Buckett	0.2 ± 0.2	0	0	0	4.4 ± 1.7	0
Abagrotis trigona (Smith)	0.2 ± 0.2	0	0	0	0	0
Adelphagrotis indeterminata (Walker)	1.8 ± 0.7	0	0	0	3.5 ± 1.2	0
Agrochola purpurea (Grote)	0.6 ± 0.2	0	0	0	0.3 ± 0.2	0
Agrotis vetusta (Walker)	0.8 ± 0.6	0	0	0	0.5 ± 0.2	0
Anarta crotchii (Grote)	0	0.8 ± 0.5	0	0	0	0
Anarta trifolii (Hufnagel)	45.8 ± 45.3	1.2 ± 1.2	0	0	0.1 ± 0.1	0.1 ± 0.1
Anhimella contrahens (Walker)	4.2 ± 1.6	0	0.3 ± 0.2	0	22.3 ± 4.6	0
Apamea amputatrix (Fitch)	1.2 ± 1.0	0.6 ± 0.6	0	0	0.2 ± 0.1	0
Apamea cinefacta (Grote)	0	0	1.1 ± 0.7	0.3 ± 0.2	0	0
Apamea cogitata (Smith)	8.0 ± 7.8	0.2 ± 0.2	0	0	0.6 ± 0.5	0
Apamea cuculliformis (Grote)	0.4 ± 0.2	0.8 ± 0.4	0.1 ± 0.1	0	1.8 ± 0.6	0.1 ± 0.1
Apamea devastator (Brace)	18.0 ± 14.2	0.8 ± 0.8	0.2 ± 0.1	0.1 ± 0.1	3.9 ± 1.0	0.4 ± 0.2
Apamea niveivenosa (Grote)	0.4 ± 0.2	0	0	0	0	0
Apamea occidens (Grote)	0.2 ± 0.2	0	0	0	0	0
Apamea sordens (Hufnagel)	0.4 ± 0.4	0	0	0	0	0
Apamea spaldingi (Smith)	0.2 ± 0.2	0	0.1 ± 0.1	0	0	0
Aseptis characta (Grote)	0	0	0.1 ± 0.1	0	0	0
Caradrina montana (Bremer)	0.2 ± 0.2	0	0.1 ± 0.1	0	0	0.1 ± 0.1
Caradrina morpheus (Hufnagel)	0.2 ± 0.2	0	0	0	1.2 ± 0.5	0.2 ± 0.1
Chytonix divesta (Grote)	2.0 ± 0.8	0	2.0 ± 1.2	0	0	0
Dargida procinctus (Grote)	0.6 ± 0.4	1.6 ± 1.0	0	0.6 ± 0.3	1.2 ± 0.4	4.1 ± 1.2
Dargida terrapictalis (Buckett)	0	0	0	0.5 ± 0.3	0	0
Diarsia rosaria Grote)	3.2 ± 2.1	1.6 ± 1.1	0	0	2.1 ± 0.6	0.2 ± 0.1
Diarsia rubifera (Grote)	0.4 ± 0.4	0	0	0	0.1 ± 0.1	0
Dichagyris variabilis (Grote)	1.2 ± 0.6	0	0	0	1.2 ± 0.6	0

Continued on following page

Table 1. Continued

Taxon	Yakima 2006		The Dalles 2006		Yakima 2008	
	AAMB	Floral	AAMB	Floral	AAMB	Floral
Egira curialis (Grote)	0.2 ± 0.2	0	0	0	0	0
Egira rubrica (Harvey)	0	0.6 ± 0.4	0	0	0	0.8 ± 0.3
Enargia infumata (Grote)	0	0	0	0	0.1 ± 0.1	0
Epidemas cinerea Smith	0	0	0	0	0.1 ± 0.1	0
Eupsilia tristigmata (Grote)	0.2 ± 0.2	0	0	0	0	0
Eurois astricta Morrison	0.2 ± 0.2	0	0	0	0	0
Euxoa atomaris (Smith)	0	0.2 ± 0.2	0	0	0	0
Euxoa auxiliaris (Grote)	0	0	0	0	0.2 ± 0.1	0
Euxoa bicollaris (Grote)	0.2 ± 0.2	0	0	0	0	0
Euxoa declarata (Walker)	0	0	0	0	0.1 ± 0.1	0.1 ± 0.1
Euxoa infausta (Walker)	2.6 ± 1.7	0	0.2 ± 0.1	0	0.7 ± 0.3	0
Euxoa messoria (Harris)	1.6 ± 0.8	0.2 ± 0.2	0	0.1 ± 0.1	1.5 ± 0.8	0
Euxoa olivia (Morrison)	0.6 ± 0.4	0	0	0	3.3 ± 2.1	0
Euxoa rockburnei Hardwick	0.4 ± 0.4	0	0	0	0	0
Euxoa scotogrammoides McDunnough	0	0	0	0.1 ± 0.1	0	0
Euxoa septentrionalis (Walker)	6.2 ± 2.3	0.2 ± 0.2	0	0	24.5 ± 8.0	0.4 ± 0.2
Euxoa terrenus (Smith)	0.4 ± 0.2	0	0	0	0	0
Feltia jaculifera (Guenée)	0.6 ± 0.3	0.4 ± 0.4	0	0	0.1 ± 0.1	0.1 ± 0.1
Fishia discors (Grote)	0.2 ± 0.2	0	0	0	0.3 ± 0.2	0
Hecatera dysodea (Denis & Schiffermller)	0	0	0	1.5 ± 0.6	0	0
Helotropha reniformis (Grote)	0	0	0	0.1 ± 0.1	0	0
Homoglaea carbonaria (Harvey)	0	0.2 ± 0.2	0	0	0	0
Homoglaea dives Smith	0	0.8 ± 0.6	0	0	0	0.1 ± 0.1
Homorthodes communis (Dyar)	4.6 ± 3.0	0	0	0	1.6 ± 0.6	0
Lacanobia subjuncta (Grote & Robinson)	1.4 ± 0.7	0	0	0	1.5 ± 0.6	0
Lacinipolia pensilis (Grote)	4.0 ± 4.0	0	0	0	0	0
Lacinipolia stricta (Walker)	2.8 ± 1.7	0	0	0	2.8 ± 0.9	0
Leucania farcta (Grote)	4.8 ± 3.4	0.6 ± 0.6	0.5 ± 0.4	0.2 ± 0.1	2.4 ± 0.7	0.3 ± 0.2
Mamestra configurata Walker	7.2 ± 6.2	0.2 ± 0.2	0	0	1.2 ± 0.5	0.1 ± 0.1
Mesogona olivata (Harvey)	1.2 ± 1.0	0	0	0	1.2 ± 0.5	0.1 ± 0.1
Mythimna oxygala (Grote)	2.4 ± 2.2	0	0	0	0.2 ± 0.1	0
Mythimna unipuncta (Haworth)	1.0 ± 1.0	0	0	0	3.4 ± 1.0	0.8 ± 0.4
Neoligia tonsa (Grote)	0.6 ± 0.4	0	0	0	0.5 ± 0.2	0
Noctua pronuba (L.)	0.4 ± 0.2	0	0	0	4.0 ± 1.1	0
Oligia indirecta (Grote)	0.2 ± 0.2	0	0	0	0.8 ± 0.3	0
Orthodes delecta (Barnes & McDunnough)	1.6 ± 1.0	0	0	0	0.4 ± 0.2	0
Orthosia hibisci (Guenée)	0	1.2 ± 0.7	0	0	0.3 ± 0.2	0.5 ± 0.3
Parabagrotis exsertistigma (Morrison)	0.2 ± 0.2	0	0	0	0.7 ± 0.3	0
Parabagrotis formalis (Grote)	0.2 ± 0.2	0	0	0	0.8 ± 0.5	0.1 ± 0.1
Parabagrotis insularis (Grote)	0	0	0	0	1.2 ± 0.5	0
Peridroma saucia (Hübner)	1.8 ± 1.8	0	0	0	0.1 ± 0.1	0
Protorthodes curtica (Smith)	5.4 ± 2.0	0	0	0	45.3 ± 13.5	0.2 ± 0.2
Proxenus mendosa McDunnough	0	0	0	0.1 ± 0.1	0	0
Rhyacia quadrangula (Zetterstedt)	0	0	0	0	0.1 ± 0.1	0.1 ± 0.1
Spaelotis bicava Lafontaine	0.2 ± 0.2	0.2 ± 0.2	0	0	0.2 ± 0.1	0
Spaelotis clandestina (Harris)	0	0	0	0.1 ± 0.1	0.1 ± 0.1	0
Spodoptera praefica (Grote)	1.0 ± 0.8	0	0.1 ± 0.1	0	0.1 ± 0.1	0
Xestia cinerascens (Smith)	0.2 ± 0.2	0	0	0	0	0
Xestia c-nigrum (L.)	3.0 ± 1.5	0.4 ± 0.4	0	0	1.3 ± 0.6	0.1 ± 0.1
Xestia infimatis (Grote)	3.4 ± 1.7	0	0	0	1.5 ± 0.7	0
Xestia smithii (Snellen)	1.6 ± 1.0	0	0	0	0	0
Xylena cineritia (Grote)	0.2 ± 0.2	0	0	0	0	0
Xylena nupera (Lintner)	0.2 ± 0.2	0	0	0	0.1 ± 0.1	0
Crambidae						
Achyra rantalis (Guenée)	0	0	0	1.7 ± 0.9	0	0
Crambus cypridalis Hulst	0	0.4 ± 0.2	0	0	0.2 ± 0.2	0.7 ± 0.4
Evergestis pallidata (Hufnagel)	0	0.2 ± 0.2	0	0	0	0
Loxostege cereralis Zeller	0	0.4 ± 0.4	0	0	0	0.2 ± 0.2
Phlyctaenia coronata (Hufnagel)	0	0	0	0	0.1 ± 01	0
Saucrobotys futilalis (Lederer)	0	1.0 ± 0.5	0	0	0	0.5 ± 0.2
Pyralidae						
Dioryctria abietivorella (Grote)	3.6 ± 3.6	0.2 ± 0.2	0	0	0	0
Dioryctria cambiicola (Dyar)	1.2 ± 1.2	0	0	0	8.6 ± 2.6	0.6 ± 0.2
Hypsopygia costalis (F.)	9.4 ± 7.4	0	0	0	3.6 ± 1.3	0
Petrophila avernalis (Grote)	0	0	0	0	0.5 ± 0.5	122.9 ± 37.6
Pyralis farinalis L.	4.8 ± 1.7	0	0	0	2.1 ± 0.7	0
Udea profundalis (Packard)	0.6 ± 0.4	0.8 ± 0.6	0	0	0.2 ± 0.2	6.8 ± 1.8
Sphingidae						
Smerinthus cerisyi (Kirby)	0	0	0	0	0	0.1 ± 0.1
Thyatiridae						
Euthyatira semicircularis (Grote)	0.6 ± 0.4	0	0	0	0.3 ± 0.2	0
Habrosyne scripta (Gosse)	0.2 ± 0.2	0	0	0	0	0

Table 2. Species and numbers (mean ± SE) of moths captured in paired traps baited with AAMB and floral-based lures

Taxa	AAMB	Floral	*t*	*P*	Location, year
Erebidae					
Boletobiinae					
Metalectra bigallis	2.0 ± 0.6	0	3.16	0.02	Yakima, 2006
Metalectra bigallis	4.6 ± 1.7	0	3.80	0.004	Yakima, 2008
Erebinae					
Caenurgina erechtea	2.8 ± 1.1	0.4 ± 0.2	2.57	0.02	The Dalles, 2006
Caenurgina erechtea	1.6 ± 0.7	0	3.08	0.01	Yakima, 2008
Hypeninae					
Hypena humuli	1.5 ± 0.5	0.2 ± 0.1	3.68	0.005	Yakima, 2008
Noctuidae					
Noctuinae					
Abagrotis forbesi	2.3 ± 1.1	0	2.61	0.03	Yakima, 2008
Abagrotis orbis	1.5 ± 0.6	0	2.91	0.02	Yakima, 2008
Abagrotis reedi	4.4 ± 1.7	0	3.15	0.01	Yakima, 2008
Adelphagrotis indeterminata	3.5 ± 1.2	0	3.79	0.004	Yakima, 2008
Anhimella contrahens	4.2 ± 1.6	0	2.65	0.05	Yakima, 2006
Anhimella contrahens	22.3 ± 4.6	0	6.08	<0.001	Yakima, 2008
Apamea cuculliformis	1.8 ± 0.6	0.1 ± 0.1	4.24	0.002	Yakima, 2008
Apamea devastator	3.9 ± 1.0	0.4 ± 0.2	4.99	<0.001	Yakima, 2008
Caradrina morpheus	1.2 ± 0.5	0.2 ± 0.1	2.32	0.05	Yakima, 2008
Chytonix divesta	2.0 ± 0.8	0	2.39	0.04	Yakima, 2006
Dargida procinctus	1.2 ± 0.4	4.4 ± 1.2	3.77	0.004	Yakima, 2008
Diarsia rosaria	2.1 ± 0.6	0.2 ± 0.1	4.03	0.003	Yakima, 2008
Dichagyris variabilis	1.2 ± 0.6	0	2.34	0.04	Yakima, 2008
Euxoa messoria	1.5 ± 0.8	0	2.57	0.03	Yakima, 2008
Euxoa olivia	3.3 ± 2.1	0	2.34	0.04	Yakima, 2008
Euxoa septentrionalis	6.2 ± 2.3	0.2 ± 0.2	4.12	0.01	Yakima, 2006
Euxoa septentrionalis	24.5 ± 8.0	0.4 ± 0.2	4.81	0.001	Yakima, 2008
Hecatera dysodea	0	1.5 ± 0.6	2.67	0.03	The Dalles, 2006
Homorthodes communis	1.6 ± 0.6	0	3.25	0.01	Yakima, 2008
Lacanobia subjuncta	1.5 ± 0.6	0	3.16	0.01	Yakima, 2008
Lacinipolia stricta	2.8 ± 0.9	0	3.50	0.007	Yakima, 2008
Leucania farcta	2.4 ± 0.7	0.3 ± 0.2	3.65	0.005	Yakima, 2008
Mamestra configurata	1.2 ± 0.5	0.1 ± 0.1	3.86	0.004	Yakima, 2008
Mesogona olivata	1.2 ± 0.5	0.1	2.83	0.02	Yakima, 2008
Mythimna unipuncta	3.5 ± 1.0	0.8 ± 0.4	3.08	0.01	Yakima, 2008
Noctua pronuba	4.0 ± 1.1	0	4.57	0.001	Yakima, 2008
Parabagrotis insularis	1.2 ± 0.5	0	2.86	0.02	Yakima, 2008
Protorthodes curtica	45.3 ± 13.5	0.2 ± 0.2	5.81	<0.001	Yakima, 2008
Xestia c-nigrum	1.3 ± 0.6	0.1 ± 0.1	2.84	0.02	Yakima, 2008
Xestia infimatis	1.5 ± 0.7	0	3.08	0.01	Yakima, 2008
Plusiinae					
Anagrapha falcifera	0	1.5 ± 0.6	3.88	0.004	Yakima, 2008
Autographa californica	0	25.8 ± 9.9	2.60	0.03	Yakima, 2006
Autographa californica	0.1 ± 0.1	7.0 ± 5.0	2.57	0.02	The Dalles, 2006
Autographa californica	0	55.1 ± 7.3	14.63	<0.001	Yakima, 2008
Trichoplusia ni	0	5.8 ± 1.4	5.81	<0.001	Yakima, 2008
Crambidae					
Achyra rantalis	0	1.7 ± 0.9	1.98	0.04	The Dalles, 2006
Pyralidae					
Dioryctria cambiicola	8.6 ± 2.6	0.6 ± 0.2	4.48	0.002	Yakima, 2008
Hypsopygia costalis	3.6 ± 1.3	0	4.21	0.002	Yakima, 2008
Petrophila avernalis	0.5 ± 0.5	122.9 ± 37.6	3.45	0.007	Yakima, 2008
Pyralis farinalis	4.8 ± 1.7	0	2.90	0.02	Yakima, 2006
Pyralis farinalis	2.1 ± 0.7	0	4.59	0.001	Yakima, 2008
Udea profundalis	0.2 ± 0.2	6.8 ± 1.8	7.71	<0.001	Yakima, 2008

Combined results for trapping in Yakima 2006, The Dalles, 2006, and Yakima 2008, limited to statistically significant data sets by paired *t*-test ($P \leq 0.05$).

makeup of moths trapped with the floral lure was similar to that seen in Alaska (Landolt et al. 2007).

Direct comparison of numbers of moths in traps baited with the two lure types reveal preferences by some moth species for AAMB and preferences by others for the floral lure. Moths showing a preference for AAMB were mostly Noctuinae in the tribes Apameini, Xylenini, Hadenini, Eryopygini, and Noctuini, and several Erebidae and Pyralidae. However, two species of Noctuinae, *Dargida procinctus* (Grote) and *H. dysodea* of the tribe Hadenini, showed a significant preference for the floral lure. Species of moths in the noctuid subfamily Plusiinae showed strong preference for the floral lure, consistent with previous reports (Landolt and Hammond 2001; Landolt et al. 2001, 2007).

For many species captured in this study, the absence of statistically significant differences between the two lures was probably due to the small numbers of moths trapped. It is not known if these low numbers

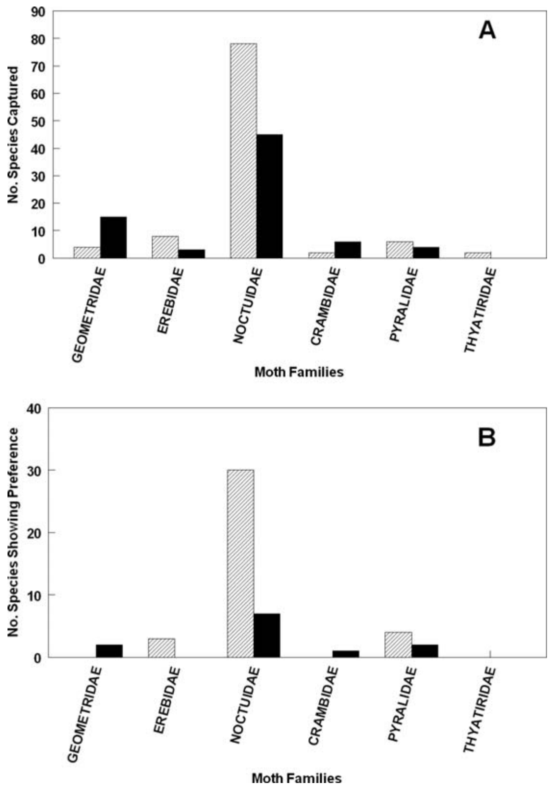

Fig. 1. (A) Combined numbers of species of moths by family captured in traps baited with the AAMB lure (slashed bars) or the floral lure (solid bars) in Yakima Co., WA, in 2006 and 2008, and Wasco Co., OR in 2006. (B) Combined numbers of species of moths by family showing statistically significant preference for either the AAMB lure (slashed bars) or the floral lure (solid bars).

are due to low population densities at the trap sites or to a low rate of moth response to lures. It seems likely that many additional species are indeed attracted to one or both of these lures and that greater numbers of traps or selection of habitats with greater populations of these species would provide added statistically significant data sets. For example, the documentation by Landolt and Higbee (2002), Landolt (2005), and Landolt et al. (2011) of responses of meal moth, armyworm, and hop looper to AAMB were evaluated in separate experiments in field cropping systems where the moths were known to occur in abundance.

The differential responses of some moth taxa to the two types of lures could be reflective of differences in moth feeding behavior. The AAMB lure is based on the odor chemistry of fermented solutions of molasses (Utrio and Eriksson 1977, Landolt 2000). Molasses solutions are known to be generally attractive to moths, including Noctuidae (Utrio 1983, Landolt 1995, Yamazaki 1998). Given the absence of molasses in the natural environment, it is assumed that many moths seek to feed at other fermented sugar sources after attraction to these same compounds (such as AAMB). This might include saps, fruits, and honeydews that are high in sugars and are fed on by Lepidoptera (Norris 1936). Pestiferous species of several plusiine noctuids commonly visit flowers (Cantelo and Jacobson 1979, Plepys et al. 2002, Landolt and Smithhisler 2003) at which they seem to feed, which might be the basis of their response to lures based on floral odorants.

These results confirm earlier experimental documentation of pest moth responses to these or similar lures. For Noctuidae, examples are the trapping of *L. subjuncta,* spotted cutworm, bertha armyworm, and armyworm with AAMB (Landolt 2000, Landolt and Higbee 2002) and alfalfa looper with floral lures (Landolt et al. 2001, 2006). For Pyralidae, these include the meal moth (Toth et al. 2002, Landolt 2005) and the clover hayworm, *Hypsopygia costalis* (F.) (Toth et al. 2002), trapped with AAMB. The glassy cutworm and hop looper were trapped with AAMB also by Landolt and Hammond (2001) and Landolt et al. (2011).

Fifteen species of Geometridae (42 individuals) were captured in this study. Numbers of geometrid moths trapped were insufficient for statistical analysis and comparisons of lures. However, we note that 36 of the 42 geometrid moths captured were in traps baited with the floral lure, and 223 geometrid moths in 13 species were captured with the same floral lure in Alaska (Landolt et al. 2007), suggesting the hypothesis that some species of geometrids are attracted to one or more of the compounds in that floral-based lure (PAA, MS, BM, and M2MB). We are not aware of any reports of geometrid moths commonly visiting flowers, or attracted to flower odor or odorants. Additional experiments should be conducted to test this hypothesis, using an appropriate controlled and replicated experimental design and targeting the times of activity and locations of abundant populations of pest geometrid species. The near absence of geometrid moths in our AAMB traps is consistent with earlier findings with this lure (Landolt and Hammond 2001, Landolt et al. 2007), but at odds with the capture of numerous Geometridae in traps baited with complex blends of volatile chemicals isolated from fermented molasses bait in Finland (Utrio and Eriksson 1977, Utrio 1983). The Finnish results suggest that a number of Geometridae might indeed be attracted to molasses-like sweet baits, and feed on fermented sugar sources, but we suggest that their attraction might be to chemicals other than the combination of acetic acid with 3-methyl-1-butanol.

These two chemical attractants that are based on adult moth food sources (fermented solutions of molasses and the odors of moth visited flowers), have advantages and disadvantages for use in surveys and for the monitoring of pest species. The responses of numerous taxa could make these lures useful in efforts to determine the diversity of moths at a site. For example, there are places and circumstances where light traps are not practical or effective for sampling night flying Lepidoptera, and traps baited with feeding attractants may be a useful alternative. Background lighting such as a visible moon (Bowden 1973, Yela and Holyoak 1997) or street lighting (Frank 1988) can interfere with moth response to an artificial light source in a trap. Light traps also require a power source, and feeding attractant traps may be an alternative approach where the power supply is a problem. The large diversity of species that potentially may respond to one or the other lure could be of concern when the lure is used as bait to trap a pest species. In that case, sorting and identifying the insects trapped requires added time and skill. This problem is likely to be minimal if traps are placed well within the crop, as suggested by Landolt et al. (2011) for monitoring hop looper moths in hop yards.

A concern is the potential for positive responses of Hymenoptera such as vespids and Apoidea bees to moth feeding attractants. Numerous bees and wasps were captured in traps baited with a moth pheromone or with phenylacetaldehyde in Florida (Meagher and Mitchell 1999), and large numbers of yellowjacket wasps (*Vespula* spp.) and bumble bees (*Bombus* spp.) were captured in Universal Moth Traps baited with a multicomponent floral lure in Alaska (Landolt et al. 2007). We captured numerous genera and species of Apoidea in this study, to be reported elsewhere. Certain aspects of the trap design seem to impact captures of attracted Hymenoptera (Meagher and Mitchell 1999, Clare et al. 2000) and might be useful to mitigate the capture of beneficial pollinators and predators in traps baited with moth feeding attractants or pheromones.

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