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Author(s): Peter J. Landolt, Alberto Pantoja, Aaron Hagerty, Lars Crabo, and Daryl Green
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Moths trapped in Alaska with feeding attractant lures and the seasonal flight patterns of potential agricultural pests

Peter J. Landolt[1]

USDA, ARS, Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Road, Wapato, Washington 98951, United States of America

Alberto Pantoja, Aaron Hagerty

USDA, ARS, Subarctic Agricultural Research Unit, Fairbanks, Alaska 99775, United States of America

Lars Crabo

724 18th Street, Bellingham, Washington 98225, United States of America

Daryl Green

USDA, ARS, Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Road, Wapato, Washington 98951, United States of America

Abstract—Traps baited with two types of chemical feeding attractants yielded 97 species of macrolepidoptera at three areas in Alaska (Fairbanks, Delta Junction, and Palmer). These were 16 geometrid, 1 thyatirid, and 76 noctuid moth species and 4 species of nymphalid butterflies. Potential crop pests trapped included *Apamea devastator* (Brace) (glassy cutworm), *Xestia c-nigrum* L. (spotted cutworm), *Xestia smithii* (Snellen) (Smith's dart), *Euxoa ochrogaster* (Guenée) (redbacked cutworm), and *Discestra trifolii* (Hufnagel) (clover cutworm). The clover cutworm was captured early in the season (May into June), while Smith's dart, glassy cutworm, spotted cutworm, and redbacked cutworm were captured in traps in mid to late summer. Many more species and greater numbers of moths were captured in traps baited with acetic acid and 3-methyl-1-butanol than in traps baited with a multicomponent floral lure (phenylacetaldehyde, methyl salicylate, methyl-2-methoxy benzoate, and β-myrcene). However, most of the geometrid moths captured (12 of 16 species) were in floral lure traps, while one species of Hadeninae (Noctuidae) and both species of Plusiinae (Noctuidae) were trapped exclusively in floral lure traps. The one thyatirid, both Catocalinae noctuid species, and most Amphipyrinae, Cuculliinae, Hadeninae, and Noctuinae noctuid species were captured in traps baited with acetic acid and 3-methyl-1-butanol. In addition, large numbers of bumblebees were captured in traps baited with the floral lure, while large numbers of yellowjackets were captured in traps baited with acetic acid and 3-methyl-1-butanol.

Résumé—Des pièges appâtés avec des attractifs alimentaires chimiques ont capturé 97 espèces de macrolépidoptères dans trois régions d'Alaska (Fairbanks, Delta Junction et Palmer). Parmi les papillons de nuit, il y a 16 espèces de géométridés, 1 de thyatiridés et 76 de noctuidés; les papillons de jour comptent 4 espèces de nymphalidés. Les ravageurs de culture potentiels pièges comprennent *Apamea devastator* (Brace) (ver-gris vitreux), *Xestia c-nigrum* L. (ver-gris tacheté), *Xestia smithii* (Snellen), *Euxoa ochrogaster* (Guénée) (ver-gris à dos rouge) et *Discestra trifolii* (Hufnagel) (ver-gris du trèfle). Le ver-gris du trèfle fût capturé tôt dans la saison (mai à juin), alors que *Xestia smithii*, le ver-gris vitreux, le ver-gris tacheté et le ver-gris à dos rouge sont récoltés dans les pièges du milieu à la fin de l'été. Plusieurs autres espèces et des nombres plus importants de papillons de nuit sont pris dans des pièges munis d'acide acétique et de 3-méthyl-1-butanol que dans les pièges appâtés d'un leurre à base florale et à composition complexe (phénylacétaldéhyde, salicycate de méthyle, 2-méthoxy-benzoate de méthyle et β-myrcène). Cependant, la plupart des papillons géométridés (12 de 14 espèces) ont été capturés

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[1]Corresponding author (e-mail: landolt@yarl.ars.usda.gov).

dans les pièges à appât floral; une espèce d'hadéninés (noctuidés) et les deux espèces de plusiinés (noctuidés) ont été récoltées exclusivement dans les pièges à appât floral. La seule espèce de thyatiridés, les deux espèces de noctuidés catocalinés et la plupart des noctuidés amphipyrinés, cuculliinés, hadéninés et noctuinés ont été récoltés dans des pièges munis d'acide acétique et de 3-méthyl-1-butanol. De plus, de grands nombres de bourdons ont été recueillis dans les pièges à appât floral, alors que de nombreuses guêpes ont été retrouvées dans les pièges munis d'acide acétique et de 3-méthyl-1-butanol.

[Traduit par la Rédaction]

Introduction

Published information on the moth fauna of Alaska is quite limited. Some distributional data are available in papers on Lepidoptera for Canada or North America. For example, Danks and Downes (1997), in their compilation of the Lepidoptera of Yukon, Canada, present some Alaska distribution records, but without specific locality data. Alaskan records for geometrid moths are indicated on maps presented in McGuffin's *Guide to the Geometridae of Canada* (1967–1987). Distributions for some specific genera or other taxonomic units are found scattered throughout the literature on Lepidoptera. These publications provide a limited and scattered treatment of what moths are present in Alaska.

In general, little is reported about moths of possible agricultural significance in Alaska. A diversity of crops is grown in the state, including vegetables, pasture grasses, hay, and ornamental flowers. In 2002, farm gate values were $3 million for hay and forage crops and $4 million for vegetable crops such as crucifers, carrots, lettuce, peas, and potatoes (Anonymous 2004). However, there is little documentation of which macrolepidoptera (*e.g.*, cutworms, armyworms, and loopers) might attack these crops in Alaska.

Trapping is a useful method for sampling and assessing the biodiversity of Lepidoptera. Methods include the use of blacklight traps for sampling night-flying moths (*e.g.*, Butler *et al.* 2001) and fermented sweet baits for luring and trapping various species of butterflies and moths (Holland 1903; Norris 1936; Yamazaki 1998). Chemical lures are also useful in attracting and sampling lepidopteran diversity. Attractive sex pheromones are known for many species of moths (Mayer and McLaughlin 1991). Chemical feeding attractants from fermented sweet baits (Utrio and Eriksson 1977; Landolt 2000) are attractive to many species of moths (Landolt and Hammond 2001). Additionally, several feeding attractants for moths have been isolated from moth-visited flowers such as bladder flower, *Araujia sericofera* Brot. (Asclepiadaceae) (Cantelo and Jacobson 1979), glossy abelia, *Abelia* × *grandiflora* (André) Rehd. (Caprifoliaceae) (Haynes *et al.* 1991), Oregongrape, *Berberis aquifolium* Pursh (Berberidaceae) (Landolt and Smithhisler 2003), night-blooming jessamine, *Cestrum nocturnum* L. (Solanaceae) (Heath *et al.* 1992), scented gaura, *Gaura drummondii* (Spach) Torr. & Gray (Onagraceae) (Teranishi *et al.* 1991), and Japanese honeysuckle, *Lonicera japonica* Thunb. (Caprifoliaceae) (Pair and Horvat 1997).

We report here the results of three seasons of trapping Lepidoptera at agricultural locations in Alaska, using chemical feeding attractants as lures. The objectives of the study were to compare moths responding to the two types of chemical feeding attractants, to compile a preliminary list of species of macrolepidoptera present, and to determine the presence and seasonality of moths that are likely agricultural pests.

Materials and methods

Trapping methods

Universal moth traps (UniTrap®, AgriSense Ltd., England, United Kingdom) with a white bucket, yellow cone, and green lid were used in all experiments. Traps had a 6.45 cm^2 piece of VAPORTAPE® (Hercon Environmental, Emigsville, Pennsylvania) in the bucket to kill captured insects. Lures were 15 mL polypropylene bottles (2118-9050, Nalge Nunc International, Rochester, New York), each loaded with 10 mL of chemical attractant on cotton balls wedged into the bottom of the bottle. A 3 mm diameter hole in the center of each screw-on cap provided for release of the volatile chemical attractant. This dispenser was suspended by a wire, upright, near the bottom of the bucket of the trap. Traps were hung from shrubs or trees or on a fence at a height of 1 to 1.5 m. Lures were replaced every 2 weeks and VAPORTAPE was replaced every 4 weeks. Moths were removed from traps weekly, placed in labeled plastic Ziploc® bags, and frozen until sorted in a laboratory.

Two types of lures were used in traps, each releasing a different chemical attractant. One attractant consisted of acetic acid and 3-methyl-1-butanol (AAMB) (Landolt 2000; Landolt and Alfaro 2001). Dispensers were loaded with a 50:50 by weight mixture of glacial acetic acid (Baker Chemical, Phillipsburg, New Jersey) and 3-methyl-1-butanol (Aldrich, Milwaukee, Wisconsin). These compounds occur in fermented molasses solution (Utrio and Eriksson 1977) and are attractive to many species of moths (Landolt 2000; Landolt and Hammond 2001). The second attractant consisted of a combination of floral odor chemicals emitted by moth-visited plants such as bladder flower, glossy abelia, night-blooming jessamine, and Oregongrape that are attractive to moths (Cantelo and Jacobson 1979; Haynes *et al.* 1991; Heath *et al.* 1992; Pair and Horvat 1997; Lopez *et al.* 2000; Landolt *et al.* 2001, 2006; Meagher 2001, 2002; Landolt and Smithhisler 2003). These floral chemicals were phenylacetaldehyde, β-myrcene, methyl salicylate, and methyl-2-methoxy benzoate. These four chemicals were purchased from Aldrich Chemical Co. (Milwaukee, Wisconsin). Bottle dispensers were loaded with a mixture of equal amounts by weight of each chemical.

Three field locations were used, referred to as the Fairbanks, Delta Junction, and Palmer locations. The Fairbanks location was in Fairbanks Northstar Borough, on the University of Alaska Fairbanks campus (64°51′04″N, 147°51′04″W and 64°51′22″N, 147°51′20″W), in an area of horticultural and vegetable gardens but near pasture and forest. The Delta Junction location (63°55′22″N, 145°23′15″W) in Southeast Fairbanks Borough was at the University of Alaska Agricultural and Forestry Station at Delta Junction. This location was in field plots of vegetable and forage crops, and near forest. The Palmer location (61°31′95″N, 149°04′84″W) in Matanuska-Susitna Borough was on a commercial organic farm with a variety of vegetable and nursery plants. It was also, however, near both pasture and forest.

Trapping experiments

In 2003, three traps were set up >30 m apart at the Fairbanks location. All three traps were baited with dispensers releasing AAMB. These traps were maintained from 17 July until 8 September 2003.

In 2004, both types of attractants were used to trap moths: the AAMB lure, as in 2003, and the floral lure. Traps with these lures were used to sample moths at all three locations: Fairbanks, Delta Junction, and Palmer. At the Fairbanks location, 5 AAMB traps and 5 floral traps were set up on 1 May and maintained until 20 September. At the Delta Junction location, 5 AAMB traps were maintained from 4 May until 14 September. At the Palmer location, 5 AAMB traps were maintained from 6 May until 6 October, while 5 floral lure traps were maintained from 14 June until 24 August.

In 2005, only AAMB lures were used to trap moths at the Fairbanks, Palmer, and Delta Junction locations. Three traps were set up at each site on 10 May. These traps were maintained until 4 October at Delta Junction, 11 October at Fairbanks, and 26 October at Palmer.

Voucher specimens are at the USDA, ARS Yakima Agricultural Research Laboratory, Wapato, Washington, with partial collections also deposited at the USDA, ARS Subarctic Research Unit, University of Alaska, Fairbanks, Alaska, and the M.T. James Entomological Collection, Department of Entomology, Washington State University, Pullman, Washington. Taxonomic assignments generally follow those of Hodges *et al.* (1983).

Results

In 2003, 567 noctuid moths were captured in AAMB traps at the University of Alaska Fairbanks, along with 2 nymphalid butterflies (Table 1). No geometrid moths were captured in these traps. Moths trapped in the greatest numbers were *Apamea cogitata* (Small), *Xestia smithii* (Snellen), *Euxoa ochrogaster* (Guenée), *Apamea devastator* (Brace), *Enargia infumata* (Grote), *Graphiphora augur* (Fabricius), and *Lithomoia germana* (Morrison). Less than 5% of specimens were not identifiable owing to loss of scales.

In 2004, 2290 moths and butterflies were trapped in AAMB traps: 7 geometrid, 2258

Table 1. Species, numbers, and percentages of females and males for moths captured in three Unitraps baited with acetic acid + 3-methyl-1-butanol lures on the campus of the University of Alaska, Fairbanks, 2003.

Moth species	Total no.	Sex ratio (♀,♂)
Noctuidae		
Amphipyrinae		
Apamea cogitata	138	57,43
Apamea devastator	51	43,57
Apamea sora	1	0,100
Enargia infumata	44	77,23
Eremobina claudens	1	100,0
Parastichtis suspecta	4	75,25
Catocalinae		
Scoliopteryx libatrix	2	100,0
Cuculliinae		
Anathix puta	3	67,33
Brachylomia algens	5	20,80
Hillia maida	2	50,50
*Litholomia napae*a	1	100,0
Lithomoia germana	26	42,88
Lithophane pexata	6	100,0
Sunira verberata	5	60,40
Xylena cineritia	1	100,0
Hadeninae		
Discestra trifolii	2	100,0
Lacinipolia olivacea	3	0,100
Leucania yukonensis	1	100,0
Herminiinae		
Idia sp.	1	100,0
Noctuinae		
Abagrotis placida	1	100,0
Agrotis ruta	1	0,100
Eurois occulta	3	33,67
Euxoa declarata	2	0,100
Euxoa ochrogaster	104	68,32
Euxoa ridingsiana	3	33,67
Graphiphora augur	33	67,33
Xestia c-nigrum	11	64,36
Xestia smithii	109	39,61
Xestia speciosa	3	0,100
Nymphalidae		
Nymphalus vau-album	2	50,50

noctuid, and 9 thyatirid specimens as well as 16 nymphalid butterfly specimens (Table 2). This included 2 geometrid species, 51 species of Noctuidae (2 Acronictinae, 14 Amphipyrinae, 1 Catocalinae, 10 Cuculliinae, 8 Hadeninae, 2 Hypeninae, and 14 Noctuinae), 4 species of Nymphalidae, and 1 species of Thyatiridae. Two hundred and eighty-five moths were also captured in 2004 in traps baited with the floral lure (Table 3). These were 116 Geometridae (13 species) and 169 Noctuidae (22 species). In 2004, most geometrid moths captured were in floral traps (116 out of a total of 123 specimens; 11.6 per floral trap versus 0.47 per AAMB trap), while most noctuids (2258/2427; 150.5 per AAMB trap versus 16.9 per floral trap) and all nymphalids and thyatirids were in AAMB traps. The noctuids captured in AAMB-baited traps included species in most major subfamilies expected to be present (Acronictinae, Amphipyrinae, Catocalinae, Cuculliinae, Hadeninae, Hypeninae, Noctuinae), except for the subfamily Plusiinae. Relatively large numbers of several species of moths were captured in AAMB traps: 607 *A. cogitata*, 790 *G. augur*, 217 *A. devastator*, and 82 *X. smithii*, for example. Of the moths captured with the floral lure, the most abundant species were the spear-marked black moth, *Rheumaptera hastata* (L.) (76), *A. devastator* (44), and *A. cogitata* (38).

In 2005, 2575 moths and butterflies were trapped: 8 geometrid, 2534 noctuid, and 28 thyatirid moths and 13 nymphalid butterflies (Table 2). This included 5 species of Geometridae (1 Ennomiinae and 4 Larentiinae), 57 species of Noctuidae (2 Acronictinae, 15 Amphipyrinae, 2 Catocalinae, 13 Cuculliinae, 9 Hadeninae, 1 Hypeninae, and 15 Noctuinae), 1 species of Thyatiridae, and 2 species of Nymphalidae.

In all 3 years, for both types of lure, and for most moth species, both males and females were trapped. However, the sex ratio of moths in traps varied widely from species to species.

The seasonality of captures in 2003, 2004, and 2005 is presented for five pest species of noctuid moths (Figs. 1, 2): spotted cutworm (*Xestia c-nigrum* L.), Smith's dart (*X. smithii*), glassy cutworm (*A. devastator*), redbacked cutworm (*E. ochrogaster*), and clover cutworm (*Discestra trifolii* (Hufnagel)). Only one generation per year is indicated for each of these species, with a single flight period evident by the pattern of captures in traps. However, flight periods varied somewhat among species, with the clover cutworm flying in May and June, the spotted cutworm flying in June and July, and the remaining pest species flying primarily from early July into early August.

In addition to moths and butterflies, other insects were captured in these traps. Of some

Table 2. Species, numbers, and percentages of females and males for moths captured at three sites (FB, Fairbanks; DJ, Delta Junction; PR, Palmer) in Unitraps baited with lures releasing acetic acid and 3-methyl-1-butanol, 2004 and 2005.

	2004					2005				
Moth species	FB	DJ	PR	Total no.	Sex ratio (♀,♂)	FB	DJ	PR	Total no.	Sex ratio (♀,♂)
Geometridae										
Ennomiinae										
Campaea perlata	0	1	4	5	100,0	1	0	1	2	100,0
Larentiinae										
Ecliptoptera silaceata	0	0	0	0		0	0	1	1	100,0
Eulithus propulsata	0	0	0	0		1	0	0	1	100,0
Operopthera bruceata	0	0	0	0		1	1	0	2	50,50
Rheumaptera hastata	0	1	1	2	100,0	1	1	0	2	100,0
Noctuidae										
Acronictinae										
Acronicta impressa	0	4	0	4	67,33	0	3	35	38	53,47
Acronicta vulpina	0	2	0	2	100,0	0	2	1	3	67,33
Amphipyrinae										
Andropolia contacta	1	10	5	16	25,75	0	2	0	2	0,100
Apamea alia	1	2	2	5	60,40	0	0	7	7	43,57
Apamea cinefacta	0	0	1	1	0,100	0	0	0	0	
Apamea cogitata	11	7	589	607	25,75	401	0	227	628	31,69
Apamea commoda	0	0	12	12	17,83	5	0	0	5	20,80
Apamea devastator	12	22	183	217	52,48	41	7	98	146	33,67
Apamea inficita	0	0	17	17	53,47	4	0	0	4	50,50
Apamea remissa	0	3	3	6	83,17	1	0	0	1	100,0
Apamea scoparia	0	4	0	4	50,50	0	0	14	14	36,64
Apamea sordens	0	0	3	3	33,67	0	0	3	3	33,67
Apamea vultuosa	0	0	0	0		0	0	1	1	100,0
Enargia infumata	50	1	0	51	75,25	0	0	0	0	
Hyppa brunneicrista	0	0	2	2	100,0	1	0	0	1	0,100
Hyppa contrasta	0	1	0	1	100,0	2	2	22	26	39,61
Luperina innota	0	0	0	0		0	1	0	1	100,0
Parastichtis suspecta	2	2	0	4	75,25	12	0	0	12	50,50

Table 2 (*continued*).

Moth species	2004 FB	2004 DJ	2004 PR	2004 Total no.	2004 Sex ratio (♀,♂)	2005 FB	2005 DJ	2005 PR	2005 Total no.	2005 Sex ratio (♀,♂)
Platyperigea montana	0	0	0	0		1	0	0	1	100,0
Catocalinae										
Caenurgina crassiuscula	0	0	0	0		0	0	1	1	100,0
Scoliopteryx libatrix	10	55	6	71	52,48	144	59	21	224	55,45
Cuculliinae										
Anathix puta	13	4	2	19	74,26	22	11	40	73	41,59
Brachylomia algens	41	20	6	67	66,34	34	5	0	39	74,26
Hillia maida	0	0	0	0		0	1	0	1	100,0
Litholomia napaea	0	1	1	2	50,50	0	1	0	1	0,100
Lithomoia germana	26	5	1	32	59,41	0	1	7	8	75,25
Lithophane georgii	1	1	0	2	0,100	0	0	13	13	77,23
Lithophane pexata	0	0	0	0		1	0	1	2	0,100
Lithophane thaxteri	0	1	0	1	100,0	0	0	0	0	
Mniotype ducta	0	0	2	2	100,0	4	0	0	4	75,25
Mniotype tenera	0	3	2	5	60,40	2	0	1	3	100,0
Sunira bicolorago	0	0	0	0		0	1	0	1	0,100
Sunira verberata	1	0	59	60	18,82	2	0	26	28	55,45
Xylena cineritia	0	0	2	2	100,0	0	0	0	0	
Xylena nupera	0	0	0	0		0	0	1	1	0,100
Xylena thoracica	0	0	0	0		0	1	0	1	100,0
Hadeninae										
Discestra trifolii	0	2	1	3	0,100	2	27	1	30	37,63
Lacanobia nevadae	0	0	6	6	50,50	1	0	0	1	0,100
Lacanobia radix	0	0	0	0		0	1	0	1	0,100
Lacinipolia anguina	0	1	0	1	100,0	0	0	0	0	
Lacinipolia olivacea	0	0	0	0		1	0	0	1	100,0
Leucania insueta	0	4	5	9	55,45	0	1	9	10	50,50
Leucania yukonensis	0	0	20	20	45,55	25	2	0	27	37,63
Melanchra pulverulenta	0	1	1	2	0,100	1	0	3	4	50,50
Orthosia hibisci	0	0	3	3	67,33	0	0	0	0	
Polia purpurissata	0	2	0	2	0,100	0	0	2	2	50,50

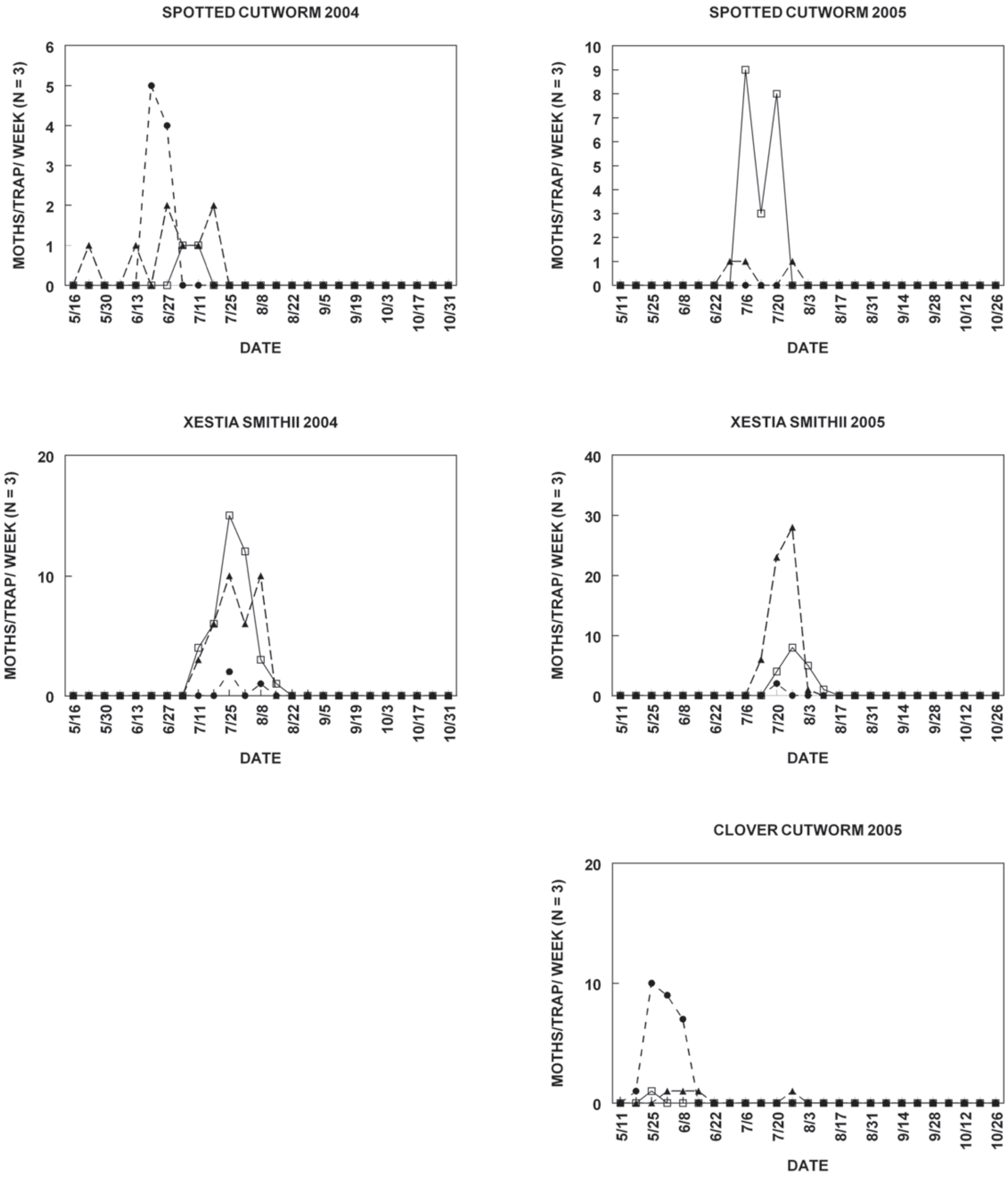
Table 2 (*concluded*).

	2004					2005				
Moth species	FB	DJ	PR	Total no.	Sex ratio (♀,♂)	FB	DJ	PR	Total no.	Sex ratio (♀,♂)
Polia rogenhoferi	0	0	0	0		0	1	0	1	0,100
Hypeninae										
Hypena californica	0	0	7	7	86,14	0	1	0	1	100,0
Hypena sp.	0	0	2	2	100,0	0	0	0	0	
Noctuinae										
Abagrotis placida	3	4	0	7	43,57	0	0	0	0	
Agrotis vetusta	0	0	0	0		2	0	0	2	100,0
Diarsia dislocata	1	1	0	2	0,100	1	0	0	1	0,100
Diarsia esurialis	0	1	25	26	35,65	90	0	1	91	3,97
Diarsia rosaria	0	0	8	8	75,25	8	0	0	8	50,50
Eurois astricta	1	0	5	6	83,17	0	0	0	0	
Eurois occulta	1	0	5	6	50,50	46	4	87	137	64,36
Euxoa aequalis	0	0	0	0		0	1	0	1	100,0
Euxoa comosa	0	0	0	0		1	0	0	1	100,0
Euxoa cursoria	0	0	0	0		0	1	0	1	100,0
Euxoa ochrogaster	1	2	32	35	57,43	31	1	24	56	64,36
Euxoa ridingsiana	1	0	1	2	50,50	2	0	0	2	0,100
Euxoa tessellata	1	0	1	2	100,0	6	0	0	6	50,50
Graphiphora augur	50	721	19	790	59,41	182	126	398	706	51,49
Protolampra rufipectus	1	5	2	8	63,37	0	1	0	1	100,0
Spaelotis clandestina	0	1	1	2	100,0	0	0	0	0	
Xestia c-nigrum	1	9	2	12	50,50	54	2	43	99	47,53
Xestia smithii	44	3	35	82	71,29	30	2	18	50	46,54
Nymphalidae										
Basilarchia anthemis	0	8	0	8	100,0	0	0	1	1	0,100
Nymphalus antiopa	0	3	0	3	100,0	0	0	0	0	
Nymphalus vau-album	3	0	1	4	100,0	0	0	12	12	100,0
Polygonia faunus	1	0	0	1	100,0	0	0	0	0	
Thyatiridae										
Habrosyne scripta	0	0	9	9	67,33	28	0	0	28	71,29

Table 3. Species, numbers, and percentages of females and males for moths captured at two sites in Unitraps baited with lures releasing a blend of floral attractants, 2004.

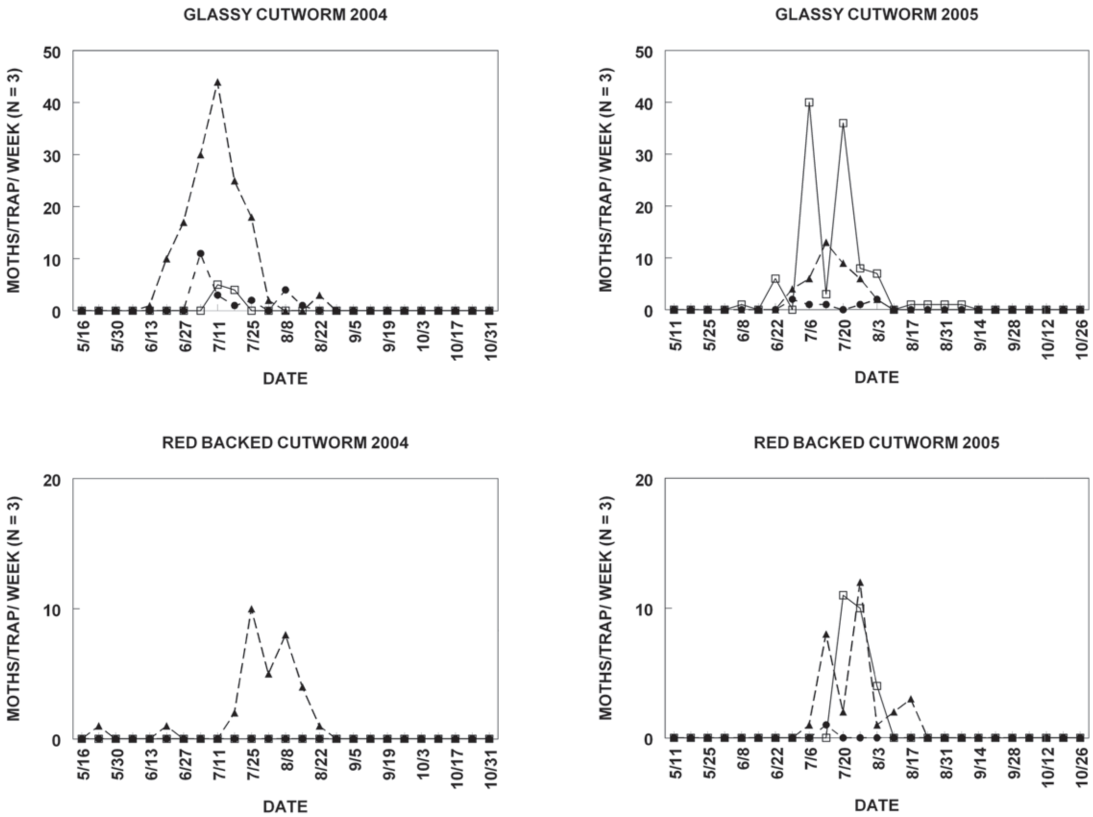
Moth species	Fairbanks	Palmer	Total no.	Sex ratio (♀,♂)
Geometridae				
Ennomiinae				
Sicya macularia	0	1	1	100,0
Cabera borealis	0	4	4	50,50
Larentiinae				
Epirrhoe alternata	1	0	1	100,0
Eulithus propulsata	0	3	3	33,67
Eulithus xylini	2	0	2	100,0
Lobophora montanata	0	9	9	78,22
Plemyria georgi	2	3	5	100,0
Rheumaptera hastata	0	76	76	89,11
Spargania luctuata	2	0	2	100,0
Trichodezia albovittata	1	6	7	86,14
Xanthorhoe baffinensis	1	0	1	100,0
Xanthorhoe defensaria	0	5	5	60,40
Sterrhinae				
Scopula junctaria	0	1	1	0,100
Noctuidae				
Amphipyrinae				
Apamea cogitata	3	35	38	55,45
Apamea devastator	3	41	44	64,36
Hyppa contrasta	0	1	1	0,100
Cuculliinae				
Lithophane thaxteri	2	0	2	50,50
Mniotype tenera	1	1	2	50,50
Xylena cineritia	3	0	3	100,0
Hadeninae				
Discestra trifolii	3	0	3	100,0
Hecatera sutrina	0	2	2	0,100
Leucania insueta	1	0	1	0,100
Leucania yukonensis	0	11	11	73,27
Parastichtus suspecta	1	3	4	25,75
Hypeninae				
Hypena californica	0	1	1	100,0
Noctuinae				
Diarsia esurialis	0	11	11	18,82
Diarsia rosaria	0	1	1	100,0
Euxoa ochrogaster	11	7	18	83,17
Euxoa ridingsiana	1	0	1	0,100
Euxoa tessellata	0	1	1	100,0
Graphiphora augur	1	1	2	100,0
Xestia c-nigrum	1	0	1	10,0
Xestia smithii	0	7	7	57,43
Plusiinae				
Autographa pseudogamma	1	7	8	75,25
Syngrapha alias	3	4	7	71,29

Fig. 1. Numbers of pest moths per week in traps baited with AAMB (acetic acid and 3-methyl-1-butanol), throughout the trapping season, at Fairbanks (□), Delta Junction (●), and Palmer, Alaska (▲). Species are *Xestia c-nigrum* (spotted cutworm), *Xestia smithii* (Smith's dart), and *Discestra trifolii* (clover cutworm).



interest, many bumblebees (*Bombus* spp.) and yellowjackets (*Vespula* and *Dolichovespula* spp.) were captured (Table 4). Large numbers of two species of *Bombus* were captured in floral lure traps in 2004, both at Fairbanks and at Palmer. However, bumblebees were not captured in AAMB traps. Large numbers of yellowjackets were captured in AAMB traps, and a few were captured in floral traps. Most yellowjackets captured were either the common yellowjacket, *Vespula vulgaris* (L.), or the baldfaced hornet, *Dolichovespula maculata* (L.). Yellowjackets captured in AAMB traps included queens, workers, and males, while

Fig. 2. Numbers of pest moths per week in traps baited with AAMB, throughout the trapping season, at Fairbanks (□), Delta Junction (●), and Palmer, Alaska (▲). Species are *Apamea devastator* (glassy cutworm) and *Euxoa ochrogaster* (redbacked cutworm).



bumblebees captured in floral traps included queens and workers but no males.

Discussion

Baited traps have been used to sample moth diversity and determine moth phenology. Yamazaki (1998) used molasses traps to sample moth communities in early spring in a forest environment in central Japan and captured 37 species of noctuids and thyatirids. Landolt and Hammond (2001) trapped 54 species of Noctuidae, 3 species of Pyralidae, and 3 species of Thyatiridae in areas in eastern Washington with AAMB lures.

This study provides a sampling of macrolepidoptera present in three agricultural areas of Alaska (Benz *et al.* 2004). Over the 3-year period of our study, 16 species of Geometridae, 76 species of Noctuidae, 4 species of Nymphalidae, and 1 species of Thyatiridae were captured in traps baited with feeding attractant lures. Although the feeding attractant lures used in this study (AAMB and floral) attract somewhat different groups of moths, they are still broadly attractive compared with moth sex pheromones, which are fairly specific. In addition, they appear to consistently attract both males and females. Thus, these feeding attractants appear to be useful as a means of general sampling.

Several species of moths were trapped that are potential pests of forage and vegetable crops in Alaska. The clover cutworm was captured at all three locations. It is widely distributed in North and Central America (Forbes 1954), including Alaska (Crumb 1956), and uses many vegetable and forage crops as larval host plants (Crumb 1956; Rings *et al.* 1992). The glassy cutworm is an underground feeder, primarily of grasses, and is widely distributed in northern North America (Crumb 1956). The redbacked cutworm is widely distributed in Asia and North America, including Alaska (Lafontaine

Table 4. Numbers of bumblebees (*Bombus* spp.) and yellowjackets (*Vespula* spp. and *Dolichovespula* spp.) captured in traps baited with the feeding attractant AAMB (acetic acid with 3-methyl-1-butanol) or a floral lure (phenylacetaldehyde, β-myrcene, methyl-2-methoxy benzoate, and methyl salicylate).

	AAMB			Floral	
Species	Fairbanks	Delta J.	Palmer	Fairbanks	Palmer
2004					
V. vulgaris					
Queens	1	1	1	1	4
Workers	173	17	26	8	4
Males	0	0	12	0	0
D. maculata					
Queens	9	4	0	1	0
Workers	37	11	0	0	0
Males	1	1	0	0	0
D. arenaria					
Queens	0	0	0	8	0
Workers	0	0	0	0	4
Bombus spp.					
Queens	0	0	0	52	8
Workers	0	0	0	697	1080
2005					
V. vulgaris					
Queens	1	1	3	—	—
Workers	620	73	11	—	—
Males	33	1	0	—	—
D. maculata					
Queens	57	22	52	—	—
Workers	20	2	0	—	—
Males	22	0	0	—	—
Bombus spp.					
Queens	0	0	0	—	—
Workers	0	0	0	—	—

1987). It can be a pest of numerous vegetable and grain crops. The spotted cutworm is Holarctic in distribution, including Alaska (Crumb 1956; Lafontaine 1998). Crumb (1956) considered it a general pest of orchard, garden, and field crops. Smith's dart has a broad host plant range, including both woody and herbaceous plants, and has been reported to be a pest of strawberry (Crumb 1956). It is widely distributed in temperate and boreal North America, including Alaska (Lafontaine 1998).

The presence of these highly polyphagous species of cutworm moths suggests that some may be pests in Alaska on vegetable or forage crops, whether in gardens or on farms. Additional study is needed to determine the pest status of these species in these areas and determine what crop plants grown there are at risk. This likely will involve collecting larvae on crop plants and rearing them for specific determination of the adults. There is the possibility that additional pest macrolepidotera species are present in Alaska but did not respond to the lures, occurred at non-detectable densities, or were not present in the areas trapped. An example is *Autographa californica* (Speyer), the alfalfa looper, which has been collected at Anchorage and Fairbanks, Alaska (Lafontaine and Poole 1991), but was not collected in our study. It responds well to the floral feeding attractant phenylacetaldehyde with β-myrcene in Washington (Landolt *et al.* 2001, 2006).

Traps baited with AAMB or floral lures also captured other nontarget insects. Generally these were relatively small numbers of butterflies and at times large numbers of bumblebees (*Bombus* spp.) and yellowjackets (the common yellowjacket and the baldfaced hornet). Bumblebees and yellowjackets are attracted to yellow (Sharp and James 1979), and some of the response by Hymenoptera may have been due to trap color in addition to chemical lures. However, because bumblebees were primarily in floral traps and not AAMB traps, and yellowjackets were primarily in AAMB traps and less so in floral traps, it seems likely that these insects were responding largely to the chemical lures. It is not a surprise that bumblebees may have responded to our floral odorants, since they visit flowers, and Landolt *et al.* (2000) reported attraction of other species of yellowjackets to AAMB. Meagher and Mitchell (1999) trapped a diversity of Hymenoptera, primarily bees and wasps, in Florida using white traps baited with the sex pheromone of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith), or the floral odorant phenylacetaldehyde. In that case, bumblebees responded more strongly to the traps with pheromone than to the traps with phenylacetaldehyde. The trapping of numerous beneficial insects such as bumblebees is of concern when using traps to sample insect biodiversity or potential agricultural pests.

The capture of workers and males of the common yellowjacket and queens and workers of the baldfaced hornet in AAMB traps was not unexpected, although these responses had not been previously observed. Workers of the German wasp, *Vespula germanica* (Fabr.), and the western yellowjacket, *Vespula pensylvanica* (Saussure), were captured in traps baited with the same AAMB lures in Washington state (Landolt *et al.* 2000). That study, however, was not conducted in an area where the common yellowjacket or baldfaced hornet were present or at a time of the season when either foundress or fall queens or males of *V. pensylvanica* or *V. germanica* would be in flight. Workers and males of the common yellowjacket and workers and queens of the baldfaced hornet were, however, captured in traps baited with a similar chemical lure, acetic acid with isobutanol, in Alaska (Landolt *et al.* 2005).

Sampling and collecting moths in subarctic and boreal areas may be more difficult than in southern latitudes because of a potentially weaker response to blacklight traps. Moth response to trap lights is diminished by background or competing light, such as moonlight (Williams 1936; Yela and Holyoak 1997), and probably by solar twilight. However, we do not expect interference with moth responses to bait traps from lights such as moonlight (Yela and Holyoak 1997) or other light sources. In subarctic environments at high latitudes, the summer season (when moths are active) coincides with the fewest hours of darkness and a relatively long period of twilight, which may diminish moth responses to blacklight traps. Sampling with feeding attractants may be particularly advantageous in such environments, compared with sampling with blacklight traps. However, direct comparisons of the two trapping techniques have not been made.

There was great overlap in the species captured in 2003, 2004, and 2005 with AAMB lures. Generally, those species that were abundantly trapped were abundant in all 3 years and those that were trapped much less frequently were infrequent in all 3 years. However, there were some species with considerable year to year variance. For example, numbers of *Acronicta impressa* Walker went from 0 moths in 3 traps in 2003 to 4 moths in 15 traps in 2004 and 38 moths in 9 traps in 2005, while numbers of *Sunira verberata* Smith went from 5 to 60 to 28 during the same years. These observations suggest broad swings in population densities at the trapping sites from year to year for these species.

In 2004, traps baited with AAMB generally captured different species of moths than traps baited with floral lures, with exceptions. Of note, two species of Plusiinae were captured in floral traps, whereas no Plusiinae were captured in AAMB traps. This is not surprising, as the chemistry of the floral lures is based on responses of Plusiinae to odorants from moth-visited flowers at lower latitudes. Those Plusiinae include the cabbage looper, *Trichoplusia ni* (Hübner), the soybean looper, *Pseudoplusia includens* (Walker), and the alfalfa looper (Cantelo and Jacobson 1979; Haynes *et al.* 1991; Heath *et al.* 1992; Pair and Horvat 1997; Lopez *et al.* 2000; Landolt *et al.* 2001, 2006). Also, Plusiinae and Heliothinae were absent from AAMB traps in Washington (Landolt and Hammond 2001). Thus, these results in Alaska are consistent with results reported in other areas. With regard to other subfamilies of Noctuidae, most of the species captured in AAMB traps were not captured in floral traps, indicating some response specificity. There were species, however, that were trapped in large numbers with AAMB lures and much smaller numbers with floral lures, indicating a response to both lures but a much lower response to floral lures. No heliothine moths were captured in traps of either kind in this study, probably indicating a dearth of heliothines in these areas of Alaska.

Also of interest, many more individuals and species of Geometridae were captured in floral traps than in AAMB traps. There are no prior indications of strong responses by geometrids to either of these lures. Utrio and Eriksson (1977) and Utrio (1983) noted a generally poor response of Geometridae compared with Noctuidae to sugar baits and to a mixture of volatile compounds from fermented molasses. No Geometridae were captured in AAMB traps in Washington (Landolt and Hammond 2001), and responses of Geometridae to floral lures were not indicated in the field tests by Pair and Horvat (1977) and Lopez *et al.* (2000).

Differential attraction to these lures may reflect differences in food foraging strategies by moths. While plusiine species are noteworthy in visiting flowers for nectar, little information is available on food foraging by most Acronictinae, Amphipyrinae, Catocalinae, Hadeninae, and Noctuinae, with exceptions. Some moths in these subfamilies, such as species of *Catocala* (Sargent), respond to fermented sugar solutions used in the collecting technique called sugaring (Holland 1903), and in nature they may be feeding at tree sap flows, fruits, and insect honeydews (Norris 1936; Sargent 1976). Moth responses to AAMB lures, which are based on odors from fermented molasses (Utrio and Eriksson 1977; Landolt 2000), probably are a means to locate natural sugar sources by way of responses to volatile microbial fermentation by-products.

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