

Traps and Attractants for Wood-Boring Insects in Ponderosa Pine Stands in the Black Hills, South Dakota

SHERYL L. COSTELLO,^{1,2,3} JOSÉ F. NEGRÓN,² AND WILLIAM R. JACOBI¹

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ABSTRACT Recent large-scale wildfires have increased populations of wood-boring insects in the Black Hills of South Dakota. Because little is known about possible impacts of wood-boring insects in the Black Hills, land managers are interested in developing monitoring techniques such as flight trapping with semiochemical baits. Two trap designs and four semiochemical attractants were tested in a recently burned ponderosa pine, *Pinus ponderosa* Dougl. ex Laws., forest in the Black Hills. Modified panel and funnel traps were tested in combination with the attractants, which included a woodborer standard (ethanol and α -pinene), standard plus 3-carene, standard plus ipsenol, and standard plus ipsdienol. We found that funnel traps were equally efficient or more efficient in capturing wood-boring insects than modified panel traps. Trap catches of cerambycids increased when we added the *Ips* spp. pheromone components (ipsenol or ipsdienol) or the host monoterpene (3-carene) to the woodborer standard. During the summers of 2003 and 2004, 18 cerambycid, 14 buprestid, and five siricid species were collected. One species of cerambycid, *Monochamus clamator* (LeConte), composed 49 and 40% of the 2003 and 2004 trap catches, respectively. Two other cerambycids, *Acanthocinus obliquus* (LeConte) and *Acmaeops proteus* (Kirby), also were frequently collected. Flight trap data indicated that some species were present throughout the summer, whereas others were caught only at the beginning or end of the summer.

KEY WORDS Buprestidae, Cerambycidae, *Monochamus clamator*, semiochemicals, Siricidae

Longhorned beetles (Cerambycidae), metallic wood-borers (Buprestidae), and woodwasps (Siricidae) are among the most important wood-boring insects in North American forests. The larvae of these wood-boring insects feed in the phloem and xylem tissues of trees and sometimes mine deep into the heartwood. Wood-boring insects are abundant in conifer and hardwood forests; they play a vital role in forest decomposition and nutrient cycling; and they are an important nutritional resource for many insectivores, including woodpeckers (Beal 1911, Furniss and Carolin 1977, Anderson 2003). Several species create large tunnels in the heartwood that reduce the value of the wood and accelerate the process of decomposition by introducing yeasts, bacteria, and wood-rotting fungi (Linsley 1961, Ross 1966).

Wood-boring insects are attracted to pine trees that have been stressed or killed by bark beetles, drought, or fire (Gardiner 1957, Furniss and Carolin 1977). Previous studies have determined that some cerambycids are attracted to chemical compounds such as ethanol and various monoterpenes, which are released by trees under stress (Ikeda et al. 1980; Kimmerer and

Kozłowski 1982, Chénier and Philogène 1989, Kelsey and Joseph 2003, Miller 2006). These compounds may act synergistically to elicit behavioral responses. Recently, some woodborer lures also have included the *Ips* spp. (Coleoptera: Scolytidae) pheromone components, ipsenol or ipsdienol (Allison et al. 2001, 2003; de Groot and Nott 2004; Miller and Asaro 2005). Wood-boring insects are often found breeding in the same hosts as *Ips* spp., and their kairomonal response to ipsenol or ipsdienol further enhances their location of suitable trees (Allison et al. 2004). Kairomonal responses to lures, including the bark beetle pheromone components ipsenol and ipsdienol, have been demonstrated for six different species in the genus *Monochamus* (Coleoptera: Cerambycidae) (Billings and Cameron 1984, Allison et al. 2001, Pajares et al. 2004, Miller and Asaro 2005).

Prior studies have evaluated the effectiveness of several trap designs for catching wood-boring beetles. Most traps tested involved funnels or panels that intercept flying beetles that are then captured in a collection cup or pan at the base of traps (Chénier and Philogène 1989, de Groot and Nott 2001, McIntosh et al. 2001, Morewood et al. 2002). Traps with a dark silhouette were more effective in capturing *Monochamus scutellatus* (Say) (Coleoptera: Cerambycidae) than traps with a transparent cross vane (de Groot and Nott 2001). Furthermore, some studies have reported that cross-vane traps, similar to panel traps, are ap-

¹ Department of Bioagricultural Science and Pest Management, Colorado State University, Fort Collins, CO 80523-1177.

² USDA Forest Service, Rocky Mountain Research Station, 240 W. Prospect, Fort Collins, CO 80525.

³ Corresponding author: USDA Forest Service, Forest Health Protection, 740 Simms St., Denver, CO 80401 (e-mail: scostello@fs.fed.us).

Table 1. Ponderosa pine fire injury measurements and stand density characteristics (mean \pm SE) in each transect location, Rogers Shack Fire, summer 2003, Black Hills, SD

Location	Tree ht (m)	Min. char ht (%)	Max. char ht (%)	PFCR (%) ^a	dbh (cm) ^b	Basal area (m ² /ha)	Stand (density index)	Stand density (trees/ha)
1	9.2 \pm 1.2	82 \pm 10	84 \pm 9	44 \pm 5	15.2 \pm 2.4	26.7 \pm 2.0	602.5 \pm 28.1	1,729.7 \pm 420.6
2	6.6 \pm 1.3	14 \pm 4	23 \pm 7	59 \pm 3	18.3 \pm 4.4	7.2 \pm 2.4	136.5 \pm 46.1	148.3 \pm 57.1
3	4.6 \pm 0.1	92 \pm 5	96 \pm 3	46 \pm 2	8.6 \pm 0.7	23.6 \pm 3.4	555.0 \pm 77.5	2,800.5 \pm 614.3
4	9.7 \pm 1.3	100 \pm 0	100 \pm 0	34 \pm 1	19.8 \pm 2.2	22.5 \pm 0.4	416.8 \pm 8.4	560.1 \pm 57.9
5	7.0 \pm 0.4	90 \pm 1	96 \pm 6	52 \pm 4	10.9 \pm 0.8	21.7 \pm 0.3	506.1 \pm 25.5	1,812.1 \pm 336.5
6	5.6 \pm 0.5	89 \pm 3	94 \pm 2	49 \pm 1	8.9 \pm 0.6	25.1 \pm 2.7	615.4 \pm 70.9	3,080.6 \pm 688.4
7	9.2 \pm 0.3	50 \pm 15	58 \pm 12	50 \pm 6	16.5 \pm 0.5	12.1 \pm 0.8	277.7 \pm 23.8	560.1 \pm 81.3
8	7.5 \pm 0.4	65 \pm 14	76 \pm 12	55 \pm 2	14.7 \pm 0.3	22.2 \pm 3.3	292.3 \pm 65.0	741.3 \pm 148.3
9	8.5 \pm 1.5	36 \pm 10	62 \pm 14	57 \pm 4	16.4 \pm 3.1	23.5 \pm 6.1	479.3 \pm 121.5	939.0 \pm 410.8
10	9.7 \pm 0.8	100 \pm 0	100 \pm 0	38 \pm 2	17.8 \pm 1.7	28.2 \pm 3.1	549.2 \pm 69.7	922.5 \pm 196.5

^a Prefire estimate of percentage of green needles.

^b Diameter at breast height measured at 1.37 m above forest floor.

proximately 2 times more efficient at capturing wood-boring beetles than multiple funnel traps (McIntosh et al. 2001, Morewood et al. 2002).

Chemically mediated host location and trapping techniques have been examined for several species of wood-boring insects, including members of the families Buprestidae, Cerambycidae, and Siricidae in British Columbia, Canada; Nova Scotia, Canada; the southeastern United States; and Europe (Ross 1966, Cerezke 1977, Wilson 1997, Pajares et al. 2004, Sweeney et al. 2004, 2006, Miller and Asaro 2005, Miller 2006). However, little empirical data are available regarding chemical attractants for sampling wood-boring species in the central and southern Rocky Mountains of the United States. In the past several years, the Black Hills of South Dakota have experienced a number of large-scale fires, such as the Jasper Fire in 2000 that burned 33,800 ha, and the Rogers Shack/Elk Mountain Fire complex in 2001 that burned 4,814 ha. Twenty-eight to 70% of the areas in these fires were classified as moderate to high severity in which a few to all trees were killed by the fire (USDA Forest Service 2000, 2001). The large number of dead trees created an exploitable habitat for wood-boring insects. Our primary objective was to refine woodborer trapping techniques in the Black Hills by

1) testing the effectiveness of four chemical attractant combinations used in two modified commercially available traps. We also 2) identified some of the wood-boring species trapped in burned ponderosa pine, *Pinus ponderosa* Dougl. ex Laws., stands in the Black Hills and 3) observed their seasonal abundance.

Materials and Methods

Study Location. The study was conducted in the Black Hills National Forest, South Dakota, \approx 5 km south of Jewel Cave National Park (study site center location at 43° 40' 25" N, 103° 50' 42" W). The study site experienced a wildfire in 2001 (Rogers Shack Fire) that burned 4,814 ha from 30 July to 6 August 2001. *P. ponderosa* is the predominant tree species in the Black Hills and *Juniperus scopulorum* (Sargent) Rydberg is interspersed within the Rogers Shack Fire area. In the Black Hills, the most common age of stands is between 81 and 90 yr old and diameter class is between 18 and 43 cm (DeBlander 2002).

Ten sampling locations were randomly selected (\approx 1 km apart). Trapping transects were established within each location in burned areas where all trees were fire-killed with 100% crown scorch, but no needle consumption. Trees in other conditions, such as

Table 2. Semiochemicals tested for wood-boring insect attraction, Rogers Shack Fire, summers 2003 and 2004, Black Hills, SD

Chemical ^a	Source ^b	Release rate ^c (mg/d)	Chemical purity (%)	Enantiomeric composition (\pm)	Plastic sleeve
Ethanol	Pherotech/Biota Control Inc. ^d	400	95%	Not chiral	Plastic sleeve pouch
α -Pinene	Pherotech International Inc.	2000	97	5/95	Plastic sleeve pouch
Ipsenol	IPM Tech, Inc.	0.15	95	50/50	400- μ l microcentrifuge tube
Ipsdienol	IPM Tech, Inc.	0.15	95	50/50	400- μ l microcentrifuge tube
3-Carene	IPM Tech, Inc.	120	90	100/0	15-ml polyethylene bulb

^a International Union of Pure and Applied Chemistry names: α -pinene, 2,6,6-trimethylbicyclo[3.1.1]hept-2-ene; ipsenol, 2-methyl-6-methylene-7-octen-4-ol; ipsdienol, 2-methyl-6-methylene-2,7-octadien-4-ol; and 3-carene, 3,7,7-trimethylbicyclo[4.1.0]hept-3-ene.

^b Biota Control Inc., Box 50049, South Slope RPO, Burnaby, BC, V5J 5G3, Canada; Pherotech International Inc., 7572 Progress Way, Delta, BC, V4G 1E9, Canada; and IPM Tech, Inc., 4134 N. Vancouver Ave. #105, Portland, OR 97217.

^c Release rates for ethanol were determined at 20°C at the Rocky Mountain Research Station, 240 W Prospect, Fort Collins, CO 80526. Release rates for α -pinene were determined at 20°C by Pherotech International Inc. Release rates for ipsenol, ipsdienol, and 3-carene were determined at 21 to 22°C by IPM Tech, Inc.

^d Pherotech International Inc. supplied ethanol in black plastic sleeve pouches in 2003. Biota Control supplied ethanol in clear plastic sleeve pouches in 2004. Release rates were the same.

Table 3. Funnel and panel trap catches of wood-boring insects by year, Rogers Shack Fire, summers 2003 and 2004, Black Hills, SD

Yr	2003	2004 ^a	2004 ^b	Yr	2003	2004 ^a	2004 ^b
Cerambycidae:	9,913	5,719	474	Buprestidae:	980	530	50
<i>Monochamus clamator</i> (LeConte)	5,404	2,596	249	<i>Chalcophora virginiensis</i> (Drury)	292	140	20
<i>Acanthocinus obliquus</i> (LeConte)	2,657	1,287	19	<i>Phaenops gentilis</i> (LeConte)	195	165	0
<i>Acmaeops proteus</i> (Kirby)	1,121	1,246	167	<i>Chrysobothris dentipes</i> (Germar)	215	34	5
<i>Acanthocinus spectabilis</i> (LeConte)	346	133	0	<i>Buprestis consularis</i> Gory	100	105	11
<i>Pogonocherus pictus</i> Fall	89	108	21	<i>Chrysobothris breviloba</i> Fall	73	27	6
<i>Rhagium inquisitor</i> (L.)	93	70	6	<i>Chrysobothris rotundicollis</i> Gory & Laporte	34	22	0
<i>Arhopalus productus</i> (LeConte)	49	84	1	<i>Chrysobothris trinervia</i> (Kirby)	26	8	2
<i>Asemum striatum</i> (L.)	53	73	0	<i>Buprestis maculativentris</i> Say	27	15	4
<i>Stictoleptura canadensis</i> (LeConte)	58	26	3	<i>Dicerca tenebrosa</i> (Kirby)	10	2	0
<i>Neoclytus muricatus</i> (Kirby)	13	46	1	<i>Melanophila acuminata</i> (De Geer)	1	7	0
<i>Xylotrechus longitarsis</i> Casey	11	21	0	<i>Phaenops intrusa</i> (Horn)	4	0	0
<i>Spondylis upiformis</i> Mannerheim	14	5	1	<i>Phaenops aeneola</i> (Melsh.)	0	2	1
<i>Cosmosalia chrysocoma</i> (Kirby)	1	7	5	<i>Buprestis subornata</i> (LeConte)	3	1	0
<i>Tetropium cinnamopterum</i> Kirby	2	9	0	<i>Anthaxia</i> spp.	0	2	1
<i>Pygoleptura nigrella</i> (Say)	0	4	0	Siricidae:	123	200	4
<i>Tragosoma deparisii</i> (L.)	1	2	0	<i>Sirex juvencus</i> (L.)	84	105	3
<i>Arhopalus asperatus</i> (LeConte)	1	1	0	<i>Sirex cyanus</i> F.	31	55	0
<i>Anastrangalia sanguinea</i> (LeConte)	0	1	1	<i>Urocerus gigas</i> (F.)	4	32	0
				<i>Urocerus cressoni</i> Norton	1	1	0
				<i>Xeris morrisoni</i> (Cresson)	3	7	1
				Total of all woodborer species	11,016	6,449	528

^a To keep sample size equal for both years ($n = 10$), catches with ethanol alone and ipsdienol alone in 2004 are not included.

^b Catches from traps baited with ethanol alone and ipsdienol alone in 2004.

those with green needles or trees with no needles after fire consumption were at least 30 m away from the trap transects. Traps were suspended from tree branches ≈ 25 m apart along a linear transect and placed ≈ 1 m from the tree bole, with the trap bottom ≈ 1.8 m off the ground.

To characterize stand conditions of the study area, fixed radius plots (1/50 ha) were established at the beginning, midpoint, and end of each transect. At the time of measurement (summer 2003), trees were standing dead and sound. Tree height, minimum height of char on tree bole (expressed as percentage of total height), maximum height of char on tree bole (expressed as percentage of total height), visual estimate of prefire crown ratio by using the crown outline, percentage of circumference of tree base burned, and diameter at breast height (dbh) were measured on all *P. ponderosa* trees over 2.5 cm dbh. Stand density index was calculated by adding the stand density contribution of each individual tree (Long and Daniel 1990). In our study locations, stocking levels for trees over 2.5 cm dbh ranged from 7–28 m²/ha and 148–3,097 trees per ha, with transects 2 and 7 exhibiting lower basal areas and fewer trees (Table 1). Mean diameters ranged from 9 to 20 cm, and heights ranged from 4.6 to 9.7 m. Smaller trees were in transects three and six. Percentage of the circumference of tree base burned (not presented in Table 1), was 99–100% in all transect locations and char height ranged from 14% to 100% of the tree height being blackened, with the least amount of char in transect 2.

Trapping Methods. Two commercially available traps, the 12-unit Lindgren multiple funnel trap (Pherotech International Inc., Delta, BC, Canada) (hereafter funnel trap) and the Intercept panel trap (IPM Technologies, Portland, OR) (hereafter panel

trap), were tested 2 and 3 yr after the fire during summers 2003 and 2004. Panel traps consisted of two vertically oriented black panels bisecting one another at right angles. Funnel traps were composed of several vertically aligned, overlapping, black funnels (Lindgren 1983). Trapping surfaces of both traps were modified to 65 cm in height and 20 cm in width to provide a more comparable landing area to wood-boring insects. Panel traps were modified by removing 5 cm on each side of the panels; funnel traps were modified by removing three funnels resulting in a 9-unit funnel trap. Because the shape of the funnels is progressively narrower toward the bottom of each funnel, the surface of the funnel trap was smaller (960 cm²) than the panel trap (1,300 cm²). Collection cups were filled with soapy water (1,000 ml of soapy water in the panel trap and 500 ml in the funnel trap).

In summer 2003, one of four attractant lure combinations was attached to each trap type. Attractant combinations consisted of 1) ethanol and α -pinene (hereafter standard); 2) standard plus 3-carene; 3) standard plus ipsdienol; and 4) standard plus ipsdienol (Table 2). Control traps (no chemical attractants) for each trap type also were tested, resulting in 10 treatment combinations per site. Each of these 10 treatment combinations were placed within the 10 randomly located sites for a total of 100 traps. Attractants were replaced every 8 wk.

In 2004, two additional attractant/trap combinations were used (funnel traps with either ipsdienol or ethanol alone). Due to logistical constraints, only funnel traps were used for these two treatments, for a total of 12 treatments and 120 traps in 2004. In 2004, the ethanol release device was changed from black plastic sleeves used in 2003 to clear plastic sleeves; both delivered the same release rate (Table 2).

Table 4. Funnel and panel trap catches of wood-boring insects by attractants, Rogers Shack Fire, summers 2003 and 2004, Black Hills, SD^{a,b}

Species	Yr	Attractant				
		Control	α -Pinene ethanol	α -Pinene ethanol 3-carene	α -Pinene ethanol ipsenol	α -Pinene ethanol ipsdienol
All wood-boring insect species ^c	2003	595d	2,171c	2,524bc	2,574b	3,152a
	2004	332d	1,244c	1,462b	1,731a	1,680ab
Cerambycidae	2003	473d	1,938c	2,252bc	2,320b	2,930a
	2004	275c	1,086b	1,242b	1,568a	1,548a
<i>Acanthocinus obliquus</i> (LeConte)	2003	56d	475c	516c	680b	930a
	2004	6e	129d	255c	510a	387b
<i>Acanthocinus spectabilis</i> (LeConte)	2003	4c	55b	79b	65b	143a
	2004	0 ^d	12b	27ab	37a	57a
<i>Acmaeops proteus</i> (Kirby)	2003	123c	229b	200b	220b	349a
	2004	90b	292a	211a	312a	341a
<i>Monochamus clamator</i> (LeConte)	2003	243c	1,086b	1,378a	1,272ab	1,425a
	2004	140c	529b	647a	601ab	679a
<i>M. clamator</i> Male	2004	79c	329b	433a	391ab	432a
<i>M. clamator</i> Female	2004	61b	200a	214a	210a	247a
Buprestidae	2003	114b	215a	237a	222a	192a
	2004	56c	114ab	145a	118ab	97b
<i>Buprestis consularis</i> Gory	2003	22a	24a	19a	19a	16a
	2004	19a	20a	23a	21a	22a
<i>Chalcophora virginiensis</i> (Drury)	2003	35b	60ab	79a	69a	49ab
	2004	21b	22b	48a	29b	20b
<i>Chrysobothris breviloba</i> Fall	2003	13a	15a	11a	17a	17a
<i>Chrysobothris dentipes</i> (Germar)	2003	13b	40a	66a	45a	51a
<i>Phaenops gentilis</i> (LeConte)	2003	16b	43a	43a	46a	47a
	2004	1b	38a	44a	45a	37a
Siricidae	2003	8c	18abc	35ab	32a	30ab
	2004	2c	44ab	74a	44ab	36b
<i>Sirex juvencus</i> (L.)	2003	7c	11bc	22ab	22ab	22a
	2004	1c	19b	41a	25ab	19ab

^a Two treatments (ethanol alone and ipsdienol alone) are not included in the 2004 data entries.

^b Only species and years with large enough trap catches to be analyzed statistically are presented.

^c Within a row, totals with the same letter are not significantly different ($P < 0.005$).

^d Zero insects captured and not analyzable statistically by using logistic regression because the model does not converge with a zero count.

Collection cups were emptied and treatment positions re-randomized within site weekly from 30 May to 26 September 2003 and 2 June to 22 September 2004. All wood-boring insects were sorted to species, and *Monochamus clamator* (LeConte) were sorted by sex in 2004. Voucher specimens were deposited in the C. P. Gillette Museum of Arthropod Diversity at Colorado State University, Fort Collins, CO, and the USDA Forest Service, Rocky Mountain Research Station Collection in Fort Collins, CO.

Data Analysis. Counts were analyzed for all wood-boring insect species combined, each family, and individual species frequently collected. The counts were highly skewed and, based on the goodness-of-fit statistics were adequately described by the negative binomial distribution for most analyses. Therefore, a negative binomial regression was used to make comparisons among factors (White and Bennetts 1996). This is an analysis of variance that assumes data are distributed according to a negative binomial distribution instead of a normal distribution. Analysis factors included trap type, attractant, transect location, and collection week. A repeated measures structure was included to account for correlation among traps within the same transect location. Interactions of trap type by transect location and attractant by transect location also were tested.

In situations where too few insects were collected to be analyzed by using counts, logistic regression was used

to analyze presence/absence of insects by trap (Hosmer and Lemeshow 1989). The repeated measures structure was omitted for species with sparse collections, and in this situation Fisher exact test was used to assess variability among trap types and attractants of pooled data across trap locations. We attempted to model all individual species, but some had too many zero counts for the model to converge and in these cases treatment comparisons were not made.

Bonferroni adjustments were made to the threshold alpha value (0.05) for declaring individual pairwise comparisons as significant. Hence, the resulting threshold α value remained at 0.05 for instances where trap types were compared. The α values were adjusted to 0.005 and 0.0024 for instances where either 10 or 12 attractants were compared, respectively. All analyses were performed by using Proc GENMOD (SAS Institute 2004). Stand variables from fixed radius plots were averaged for each transect.

Results

Species Collected. During summers 2003 and 2004, 18 cerambycid, 14 buprestid, and five siricid species were collected (Table 3). The number of species caught in the treatments that included the standard, standard plus 3-carene, standard plus ipsenol, standard plus ipsdienol, and the control was similar, ranging

Table 5. Funnel trap catches of wood-boring insects by attractants (including ethanol alone and ipsdienol alone) for summer 2004, Rogers Shack Fire, Black Hills, SD^a

Species	Control	α -Pinene ethanol	α -Pinene ethanol 3-carene	α -Pinene ethanol ipsenol	α -Pinene ethanol ipsdienol	Ethanol	Ipsdienol
All wood-boring insect species ^b	163d	704b	833ab	957a	991a	253c	273c
Cerambycidae	141d	616b	732ab	891a	937a	224c	249c
<i>Acanthocinus obliquus</i> (LeConte)	5d	73c	159b	301a	221b	3 ^c	16d
<i>Acanthocinus spectabilis</i> (LeConte)	0 ^c	8b	15ab	21a	31a	0 ^c	0 ^c
<i>Acmaeops proteus</i> (Kirby)	65c	175ab	133ab	210a	259a	100bc	67c
<i>Monochamus clamator</i> (LeConte) Male	36c	201b	267a	214ab	265ab	56c	73c
<i>M. clamator</i> Female	19d	102ab	109ab	110ab	123a	51c	69bc
Buprestidae	23b	67a	72a	47ab	44ab	29b	21b
<i>Phaenops gentilis</i> (LeConte)	1b	24a	17a	16ab	12ab	0 ^c	0 ^c
Siricidae	0 ^c	21ab	30a	19ab	11ab	1b	3b

^a Only species and years with large enough trap catches to be analyzed statistically are presented.

^b Within a row, totals caught with the same letter are not significantly different ($P < 0.0024$).

^c Zero insects captured or zero insects during weeks analyzed were not analyzable statistically by using logistic regression because model does not converge with a zero count.

between 27 and 33 species caught throughout both summers (data not shown). Total trap catches were 11,016 in 2003 and 6,449 in 2004, not including the two additional treatments of ethanol and ipsdienol alone in funnel traps in 2004. Cerambycids composed the largest proportion of trap catches (90% in 2003 and 89% in 2004), followed by buprestids (9% in 2003 and 8% in 2004) and siricids (1% in 2003 and 3% in 2004). One cerambycid species, *M. clamator*, composed 49 and 40% of the 2003 and 2004 trap catches, respectively. Two other cerambycids, *Acanthocinus obliquus* (LeConte) and *Acmaeops proteus* (Kirby), together composed at least 30% of trap catches in each summer. In 2004, the two additional treatments, ethanol and ipsdienol alone in funnel traps, caught a total of 528 wood-boring insects.

Attractant Effectiveness. In 2003 and 2004, more wood-boring insects were caught in traps with attract-

ant combinations than in control traps ($P < 0.001$) (Table 4). In general, trap catches increased by adding ipsenol or ipsdienol in 2003 and 3-carene, ipsenol, or ipsdienol in 2004 to the woodborer standard (ethanol and α -pinene). Specifically, during both summers more wood-boring insects were caught by using the standard plus ipsenol or ipsdienol compared with the standard alone ($P < 0.001$). In 2003, the most wood-boring insects were caught in traps with the standard plus ipsdienol ($P < 0.001$). In 2004, there was no difference between traps containing the standard plus ipsenol or ipsdienol, and more wood-boring insects were caught in the standard plus 3-carene compared with the standard alone ($P < 0.001$). Additionally, in 2004 the standard plus 3-carene was not different from the standard plus ipsdienol.

Cerambycids preferred the same attractant combinations as all wood-boring insect species with two

Table 6. Wood-boring insect trap catch results by trap type, Rogers Shack Fire, summers 2003 and 2004, Black Hills, SD^a

Species ^{b,c}	2003		2004	
	Panel	Funnel	Panel	Funnel
All woodborer species	5,044b	5,972a	2,799b	3,650a
Cerambycidae	4,557b	5,356a	2,401b	3,318a
<i>Acanthocinus obliquus</i> (LeConte)	1,324a	1,333a	528b	759a
<i>Acanthocinus spectabilis</i> (LeConte)	149a	197a	58a	75a
<i>Acmaeops proteus</i> (Kirby)	430b	691a	404b	842a
<i>Arhopalus productus</i> (LeConte)	31a	18a	45a	39a
<i>Aseum striatum</i> (L.)	26a	27a	50a	23a
<i>Monochamus clamator</i> (LeConte)	2,452b	2,952a	1,150b	1,446a
<i>M. clamator</i> male			681b	983a
<i>M. clamator</i> female			469a	463a
<i>Pogonocherus pictus</i> Fall	49a	40a	56a	52a
<i>Rhagium inquisitor</i> (L.)	34a	59a	34a	36a
Buprestidae	417b	563a	277a	253a
<i>Buprestis consularis</i> Gory	45a	55a	68a	37b
<i>Chalcophora virginienis</i> (Drury)	130a	162a	79a	61a
<i>Chrysobothris breviloba</i> Fall	26b	47a		
<i>Chrysobothris dentipes</i> (Germar)	73b	142a		
<i>Phaenops gentilis</i> (LeConte)	107a	88a	95a	70b
Siricidae	70a	53a	119a	81a
<i>Sirex juvencus</i> (L.)	43a	41a	61a	44a

^a Ethanol alone and ipsdienol alone in 2004 are not included to keep sample size equal across years ($n = 10$).

^b Within year and species, totals caught with the same letter are not significantly different ($P < 0.05$).

^c Species without analysis: 1) *M. clamator* were not sorted by sex in 2003 and 2) data was too sparse to analyze *Chrysobothris* spp. in 2004.

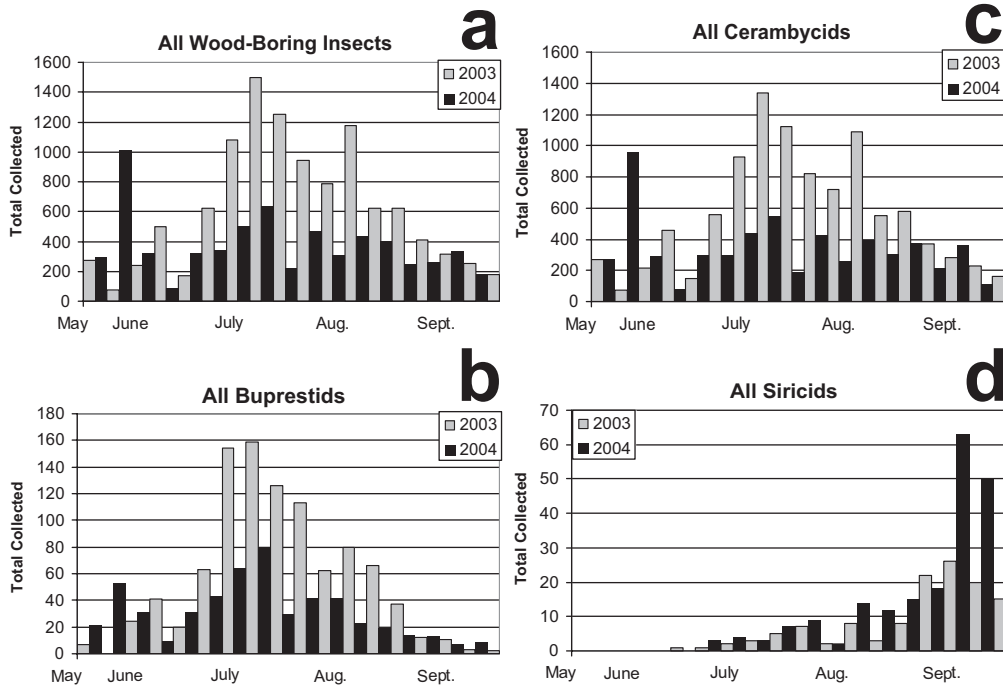


Fig. 1. Total trap catches per week after the Rogers Shack Fire, Black Hills, SD, during summers 2003 and 2004 for all wood-boring insect species and families caught in funnel and panel traps baited with the standard (ethanol and α -pinene) plus ipsenol, ipsdienol, and 3-carene and a control (no attractants). Species groups with $n \geq 223$ are presented. (a) All wood-boring insects. (b) All Buprestidae. (c) All Cerambycidae. (d) All Siricidae.

exceptions in 2004. First, whereas there was no preference between the standard plus ipsdienol and the standard plus 3-carene for all wood-boring species, cerambycids preferred traps with the standard plus ipsdienol over the standard plus 3-carene (Table 4). Second, in 2004 there was no difference between cerambycid trap catches with the standard plus 3-carene compared with trap catches with the standard alone.

In 2003 and 2004, significantly more *M. clamator* were caught in all traps with attractants than in control traps ($P < 0.001$), and more *M. clamator* were caught in traps with the standard plus ipsdienol or 3-carene compared with the standard ($P = 0.0043$) (Table 4). Additionally, catches of *M. clamator* in traps baited with the standard plus ipsenol were not significantly different than catches in traps baited with the standard attractant. During 2004, significantly more male *M. clamator* (1,664) were caught than females (932) ($P < 0.001$). In addition to *M. clamator*, in 2003 three other cerambycid species [*Acmaeops proteus* (Kirby), *Acanthocinus obliquus* (LeConte), and *Acanthocinus spectabilis* (LeConte)] demonstrated a preference for the standard plus ipsdienol over all other attractant combinations and the control. However, in 2004 *A. obliquus* demonstrated a preference for the standard plus ipsenol, unlike 2003 when it preferred the standard plus ipsdienol.

In 2003, more buprestids were caught in traps with attractants than controls ($P < 0.001$), but unlike cerambycids, there were no differences among treatments containing attractants. More specifically, *Chrysobothris dentipes* (Germar) and *Phaenops gentilis* (LeConte) preferred all traps with the standard and all combinations with the standard over control traps (Table 4). However, there were no significant differences between traps with attractants and control traps for *Buprestis consularis* Gory and *Chrysobothris breviloba* Fall. In 2004, the response patterns of all buprestids were similar, except that traps with the standard plus 3-carene caught more buprestids than traps with the standard plus ipsdienol ($P = 0.0023$). In 2004, *Chalcophora virginianensis* (Drury) preferred traps with the standard plus 3-carene over all other attractants and control traps.

In 2003, significantly more siricids and *Sirex juvencus* (L.) were caught in traps containing the standard plus 3-carene, standard plus ipsenol, or the standard plus ipsdienol than control traps ($P \leq 0.001$) (Table 4). In 2004, traps containing the standard attracted more siricids and *S. juvencus* than control traps ($P \leq 0.001$).

When tested alone ethanol or ipsdienol elicited few different responses from wood-boring insects when compared with the control or attractant-baited traps (Table 5). Traps with ethanol or ipsdienol alone at-

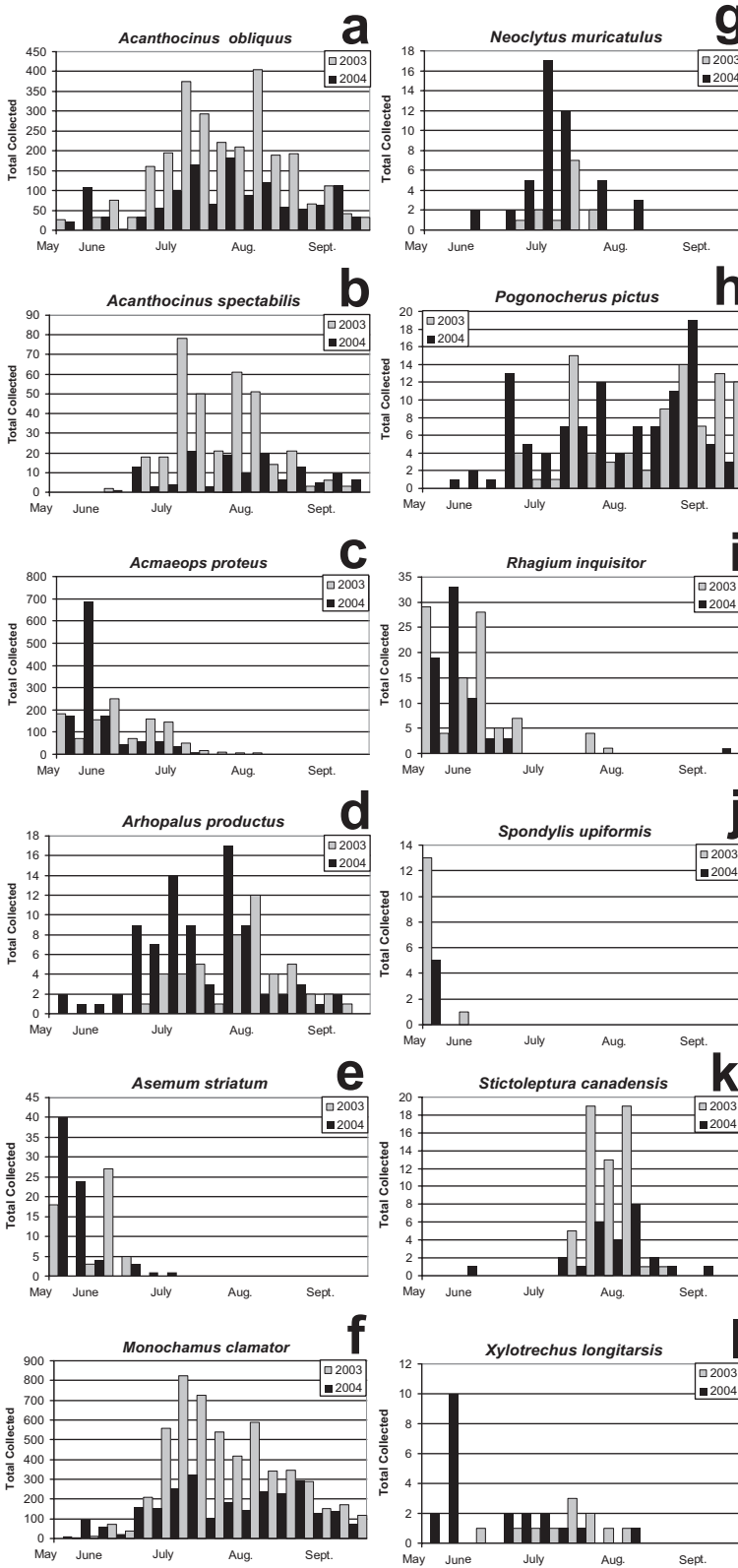


Fig. 2. Total trap catches per week after the Rogers Shack Fire, Black Hills, SD, during summers 2003 and 2004 for cerambycid species caught in funnel and panel traps baited with the standard (ethanol and α -pinene) plus ipsenol, ipsdienol, and 3-carene and a control (no attractants). Species with $n \geq 19$ are presented. (a) *Acanthocinus obliquus*. (b) *Acanthocinus spectabilis*. (c) *Acmaeops proteus*. (d) *Arhopalus productus*. (e) *Asemum striatum*. (f) *Monochamus clamator*. (g) *Neoclytus muricatus*. (h) *Pogonocherus pictus*. (i) *Rhagium inquisitor*. (j) *Spondylis upiformis*. (k) *Stictoleptura canadensis*. (l) *Xylotrechus longitarsis*.

tracted significantly more cerambycids than control traps, but fewer cerambycids than traps with attractant combinations. A smaller number of buprestids were captured in traps baited with ethanol or ipsdienol alone than in traps baited with the standard or the standard plus 3-carene. Male *M. clamator* response to traps with ethanol and ipsdienol alone was less than to traps with the woodborer standard ($P < 0.001$). However, female response to ipsdienol alone was similar to traps with the standard, the standard plus 3-carene or the standard plus ipsenol. In general, trap catches for *A. obliquus*, *A. spectabilis*, *A. proteus*, and *P. gentilis* with ipsdienol or ethanol alone were not different from control traps.

Trap Effectiveness. Funnel traps caught significantly more wood-boring insects than panel traps for all wood-boring insects combined during both years; for Cerambycidae during both years; for Buprestidae during 2003; for *A. obliquus* during 2004; for *A. proteus* during both years; for *M. clamator* during both years; for *C. breviloba* during 2003; and for *C. dentipes* during 2003 ($P < 0.05$). Two species, *B. consularis* and *P. gentilis*, were caught more often in panel than funnel traps in 2004 ($P < 0.05$). There were no significant differences between traps for other species analyzed (Table 6).

Seasonal Abundance. Peak trap catches for all wood-boring insects occurred between 9 July and 16 July 2003 and between 2 June and 8 June 2004 (Fig. 1a). Buprestidae and Cerambycidae were caught throughout the entire summer (Fig. 1b and c), whereas Siricidae were caught later in the summer (Fig. 1d). *Acanthocinus obliquus*, *A. spectabilis*, *Arhopalus productus* (LeConte), *M. clamator*, and *Pogonocherus pictus* Fall were captured June through September (Fig. 2a, b, d, f, and h). *Acmaeops proteus*, *Asemum striatum* (L.), *Rhagium inquisitor* (L.), and *Spondylis upiformis* Mannerheim were all caught primarily in early summer (Fig. 2c, e, i, and j). *Neoclytus muricatus* (Kirby) and *Stictolepura canadensis* (LeConte) were caught midsummer (Fig. 2g and k). *Xylotrechus longitarsis* Casey was caught from June through August (Fig. 2l).

Both *Buprestis* spp. were caught after 18 June and trap catches peaked late July to mid-August (Fig. 3a and b). All *Chrysobothris* spp. and *P. gentilis* were caught throughout the summer, with peak catches occurring in July (Fig. 3d–h). Peak catches for *Cha. virginensis* occurred in June and July, and the species was not caught in September (Fig. 3c). Trap catches of *Sirex cyaneus* F. and *S. juvencus* peaked in September (Fig. 4a and b). However, because *S. cyaneus* and *S. juvencus* were actively flying at the end of our sampling period, it is possible that peak trap catch of these species could have occurred later. Comparatively, peak trap catches of *Urocera gigas* (F.) were earlier in late-July in 2004 (Fig. 4c).

Discussion

Wood-boring and bark beetle larvae frequently occur within the tree at the same time (Coulson et al.

1976). Bark beetles (Coleoptera: Scolytidae) weaken or kill the tree, making it suitable for woodborer attack, and wood-boring larvae may improve their fitness by feeding on bark beetle larvae (Hellrigl 1971, Dodds et al. 2001). Thus, it would be beneficial for wood-boring insects to use bark beetle pheromones when selecting a suitable host location. The bark beetles *Ips pini* (Say), *I. calligraphus* (Germer), *I. grandicollis* (Eichhoff), *I. knausi* Swaine, and most likely *Orthotomicus latidens* (LeConte) (= *I. latidens*) all occur in the Black Hills (Wood 1982; Lanier 1987; Lanier et al. 1991; S. J. Seybold, personal communication). Ipsdienol is an aggregation pheromone component for *I. pini*, *I. calligraphus*, and *I. knausi*, whereas ipsenol is an aggregation pheromone component for *I. grandicollis* and *O. latidens* (Vité and Renwick 1971, Vité et al. 1972, Miller et al. 1991, Borden 1995). Consistent with previous findings, we observed kairomonal responses to either ipsenol or ipsdienol for some cerambycids (Billings and Cameron 1984; Allison et al. 2001, 2003, 2004).

Since the addition of ipsdienol to the standard in 2003 attracted significantly more wood-boring insects than the addition of ipsenol, we hypothesized that ipsdienol alone would attract more wood-boring insects than control traps and might elicit a similar response as the woodborer standard. Miller and Asaro (2005) found that compared with unbaited control traps, ipsenol and ipsdienol alone increased trap catches of *Monochamus titillator* (F.) in Florida, Louisiana, and Georgia, and *Acanthocinus obsoletus* (Oliver) in Florida and North Carolina. We found that only in one circumstance, female *M. clamator*, were trap catches with ipsdienol alone greater than control traps and similar to traps with the woodborer standard. Although woodborer lures using only an *Ips* spp. pheromone would be easier to use (a small microcentrifuge tube compared with a larger pouch) and more cost-effective (one *Ips* component was less than half the cost of the α -pinene and ethanol components), our findings in the Black Hills indicate that attractants with the woodborer standard are more appropriate for trapping wood-boring insects than traps with one *Ips* spp. pheromone component.

Compared with the standard woodborer lure, adding the host monoterpene 3-carene to the standard increased trap catches significantly for all wood-boring insect species combined in 2004 (but not 2003) and for a few individual wood-boring species including: *A. obliquus* in 2004, *C. virginensis* in 2004, *M. clamator* in 2003 and 2004, *M. clamator* males in 2004 and *S. juvencus* in 2004. This finding agrees with findings that some woodborers can respond to multiple monoterpenes being emitted from a tree (Chénier and Philogène 1989). A combination of 3-carene with ethanol was not examined and our results could be a specific response to 3-carene or a synergistic effect of 3-carene and ethanol similar to that of α -pinene with ethanol in the standard. Additionally, for all wood-boring insects combined, 3-carene added to the woodborer standard resulted in no difference in trap catches compared with the addition of ipsenol in 2003 or ipsdienol in

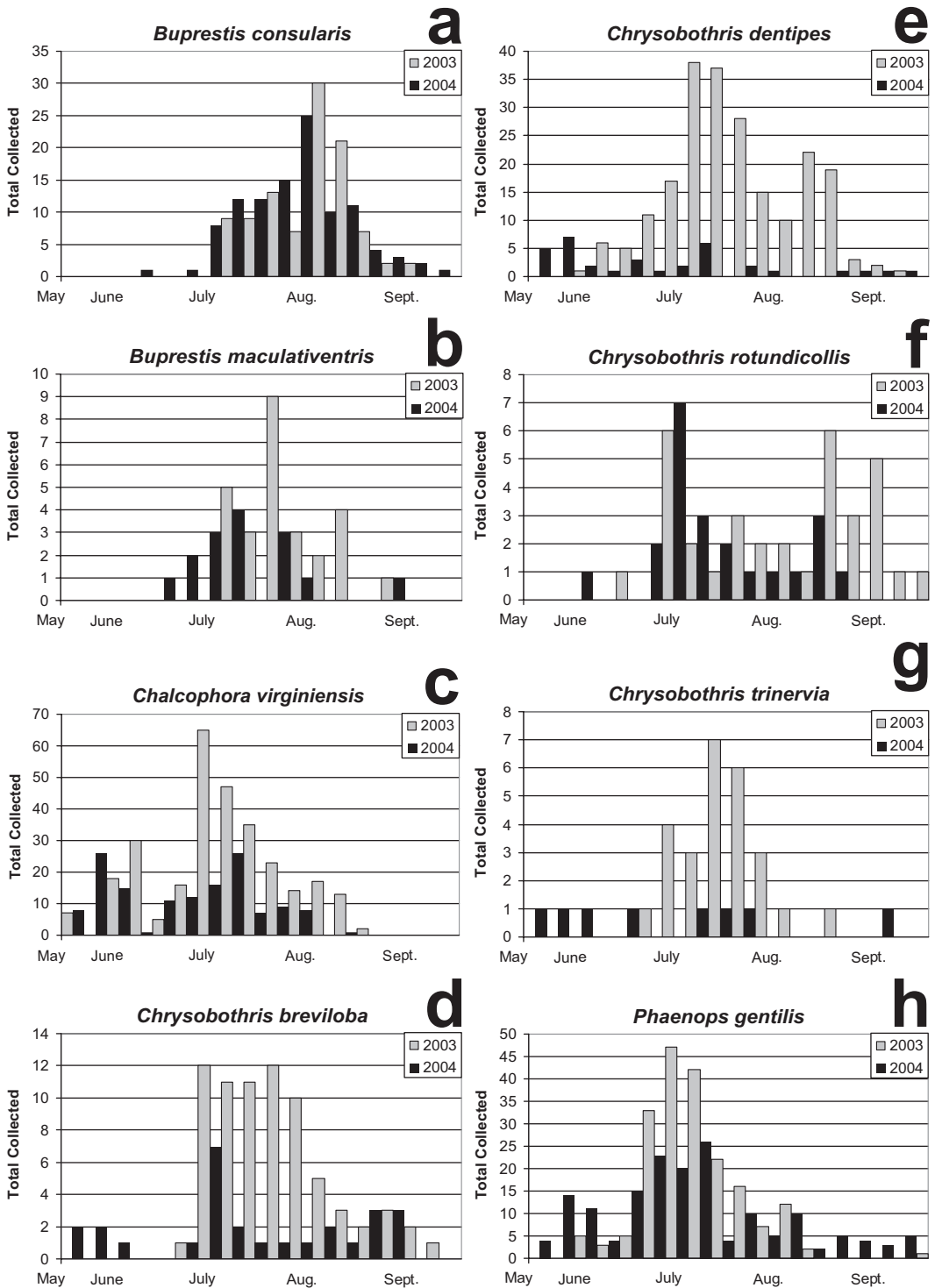


Fig. 3. Total trap catches per week after the Rogers Shack Fire, Black Hills, SD, during summers 2003 and 2004 for buprestid species caught in funnel and panel traps baited with the standard (ethanol and α -pinene) plus ipsenol, ipsdienol, 3-carene, and a control (no attractants). Species with $n \geq 42$ are presented. (a) *Buprestis consularis*. (b) *Buprestis maculativentris*. (c) *Chalchophora virginiensis*. (d) *Chrysobothris breviloba*. (e) *Chrysobothris dentipes*. (f) *Chrysobothris rotundicollis*. (g) *Chrysobothris trinervia*. (h) *Phaenops gentiles*.

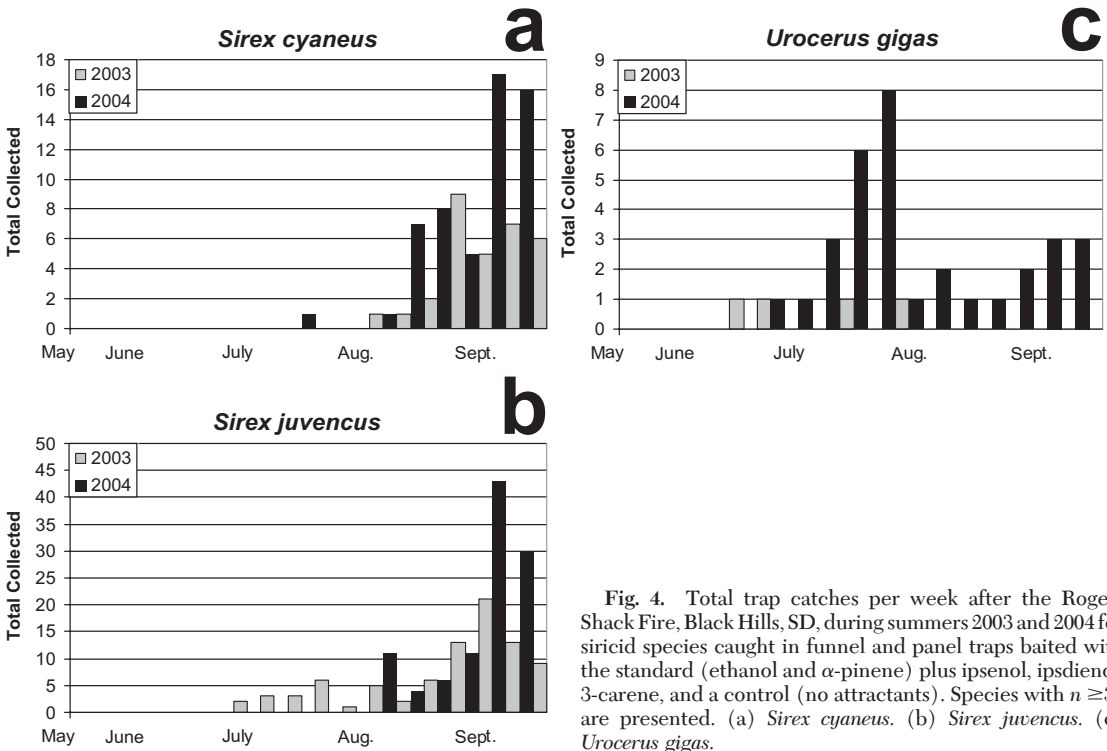


Fig. 4. Total trap catches per week after the Rogers Shack Fire, Black Hills, SD, during summers 2003 and 2004 for siricid species caught in funnel and panel traps baited with the standard (ethanol and α -pinene) plus ipsenol, ipsdienol, 3-carene, and a control (no attractants). Species with $n \geq 36$ are presented. (a) *Sirex cyaneus*. (b) *Sirex juvenens*. (c) *Urocerus gigas*.

2004. This suggests that adding 3-carene may be as efficacious for trapping woodborers as adding *Ips* spp. pheromones to the standard.

The proportion of monoterpenes in *P. ponderosa* pine varies across its geographical distribution (Smith 2000). In southern Arizona, *P. ponderosa* had a greater percentage of α -pinene than 3-carene, whereas 3-carene was found in higher concentrations than α -pinene in ponderosa pine stands in the Rocky Mountain Region. Because monoterpene concentrations in pine phloem and xylem tissues vary across regions, the response of woodborers to such kairomones also may vary regionally. With bark beetles, different regional responses have been reported to pheromones (e.g., *I. pini*, Miller et al. 1997), but not to kairomones [e.g., *Dendroctonus valens* LeConte, Erbilgin et al. 2007]. It would be interesting to explore whether there are local adaptations by wood-boring insects to the most abundant monoterpene in the eco-region. To test this hypothesis, experiments comparing various monoterpenes in different geographical regions should be performed.

Previous studies found that crossvane traps (similar to panel traps) captured more *Arhopalus asperatus* (LeConte), *Xylotrechus longitarsis* Casey, *M. scutellatus*, and *Asemum striatum* (L.) females than funnel traps with wet cups, indicating that the panel trap design could be more appropriate for trapping woodborers (McIntosh et al. 2001, Morewood et al. 2002). However, another study found no significant differences between the 12-unit Lindgren multiple funnel

trap and Intercept panel trap for *M. scutellatus*, *M. mutator* LeConte, *Buprestis maculativentris* Say, *Dicerca tenebrosa* (Kirby), and *Chalcophora virginiensis* (de Groot and Nott 2003). In our study, with the exception of two buprestid species, the modified funnel trap was more effective or not different from the modified panel trap in capturing adult wood-boring insects, suggesting that either trap is appropriate for capturing wood-boring insects in the Black Hills.

Lower capture rates in panel traps than funnel traps for some species could be due to modifications made before deployment. Panel trap width was reduced resulting in a narrower trap than previously tested. Furthermore, to obtain similar height and width for both traps, three funnels were removed from the 12-unit funnel traps. It has been suggested that the narrow, irregular silhouette of a funnel trap could contribute to lower trap catches (Morewood et al. 2002). Although the surface area of the traps was still larger in the panel traps, we found that with the modifications, the funnel trap performed as well or better than the panel trap. The trapping modifications made in this study suggest the possible importance of trap size.

Similar to other results in northern Arizona ponderosa pine forests, wood-boring insects were captured throughout the trapping period, but peak flights varied by groups and species (Gaylord et al. 2006). This is consistent with other studies that present different peak flights for different species (Ross 1966, McIntosh et al. 2001, Smith and Schiff 2002). These

findings suggest that specific taxa of woodborers might be targeted by deploying traps only during the period of peak flight for the taxa.

Our results demonstrated that more wood-boring insects were caught in 2003 compared with 2004. The decrease in all wood-boring insect trap catches in 2004 may have been due to a decrease in suitable host material over time as fire-killed trees become less suitable for wood-boring species that infest recently dead trees. Another possible factor may have been environmental conditions. For example, although we do not completely understand the relationship between woodborer flight and temperatures, cooler temperatures were observed in 2004. For example, during summer 2003, there were 57 d $\geq 27^{\circ}\text{C}$ compared with only 37 d in 2004 (National Climate Data Center 2005). However, the number of siricids caught nearly doubled from 123 caught in 2003 to 204 in 2004. The increase in siricids could be due to a longer life cycle and delayed emergence relative to the other woodborers. Hansen (1939) reported that the life cycle of both *Sirex gigas* (L.) [= *Urocerus gigas* (F.)] and *S. cyaneus* extended over a period of 3 yr and could be longer. Stillwell (1966) found that *S. juvencus* completed development in 2–3 yr.

In summary, results demonstrated that the funnel trap was equally effective or more effective as the panel trap. By using flight periodicity information combined with responses to different attractants found in this study, land managers and forest health specialists can implement monitoring programs for wood-boring insects in the Black Hills.

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References Cited

- Allison, J. D., J. H. Borden, R. L. McIntosh, P. de Groot, and R. Gries. 2001. Kairomonal responses by four *Monochamus* species (Coleoptera: Cerambycidae) to bark beetle pheromones. *J. Chem. Ecol.* 27: 633–646.
- Allison, J. D., W. D. Morewood, J. H. Borden, K. E. Hein, and I. M. Wilson. 2003. Differential bio-activity of *Ips* and *Dendroctonus* (Coleoptera: Scolytidae) pheromone components for *Monochamus clamator* and *M. scutellatus* (Coleoptera: Cerambycidae). *Environ. Entomol.* 32: 23–30.
- Allison, J. D., J. H. Borden, and S. J. Seybold. 2004. A review of the chemical ecology of the Cerambycidae (Coleoptera). *Chemoecology* 14: 123–150.
- Anderson, T. 2003. Conservation assessment for the woodpeckers in the Black Hills National Forest South Dakota and Wyoming. U.S. Dep. Agric., Forest Service, Black Hills National Forest. Custer, SD.
- Beal, F.E.L. 1911. Food of the woodpeckers of the United States. U.S. Dep. Agric. Biol. Surv. Bull. 37.
- Billings, R. F., and R. S. Cameron. 1984. Kairomonal responses of Coleoptera, *Monochamus titillator* (Cerambycidae), *Thanasimus dubis* (Cleridae), and *Temnochila virescens* (Trogositidae), to behavioral chemicals of southern pine bark beetles (Coleoptera: Scolytidae). *Environ. Entomol.* 13: 1542–1548.
- Borden, J. H. 1995. Development and use of semiochemicals against bark and timber beetles, pp. 431–449. In J. A. Armstrong and W.G.H. Ives [eds.], *Forest insect pests in Canada*. Canadian Forest Service, Ottawa, ON, Canada.
- Cerezke, H. F. 1977. Characteristics of damage in tree-length white spruce logs caused by the white-spotted sawyer, *Monochamus scutellatus*. *Can. J. For. Res.* 7: 232–240.
- Chénier, J.V.R., and B.J.R. Philogène. 1989. Field responses of certain forest Coleoptera to conifer monoterpenes and ethanol. *J. Chem. Ecol.* 15: 1729–1746.
- Coulson, R. N., A. M. Mayyasi, J. L. Foltz, and F. P. Hain. 1976. Interspecific competition between *Monochamus titillator* and *Dendroctonus frontalis*. *Environ. Entomol.* 5: 235–247.
- DeBlander, L. T. 2002. Forest resources of the Black Hills National Forest. U.S. Dep. Agric., Forest Service, Rocky Mountain Research Station, Ogden, UT.
- de Groot, P., and R. Nott. 2001. Evaluation of traps of six different designs to capture pine sawyer beetles (Coleoptera: Cerambycidae). *Agric. For. Entomol.* 3: 107–111.
- de Groot, P., and R. W. Nott. 2003. Response of *Monochamus* (Col., Cerambycidae) and some Buprestidae to flight intercept traps. *J. Appl. Entomol.* 127: 548–552.
- de Groot, P., and R. W. Nott. 2004. Response of the white-spotted sawyer beetle, *Monochamus s. scutellatus*, and associated woodborers to pheromones of some *Ips* and *Dendroctonus* bark beetles. *J. Appl. Entomol.* 128: 483–487.
- Dodds, K. J., C. Graber, and F. M. Stephen. 2001. Facultative interguild predation by larval Cerambycidae (Coleoptera) on bark beetle larvae (Coleoptera: Scolytidae). *Environ. Entomol.* 30: 17–22.
- Erbilgin, N., S. R. Mori, J. H. Sun, J. D. Stein, D. R. Owen, L. D. Merrill, R. Campos Bolaños, K. F. Raffa, T. Méndez Montiel, D. L. Wood, and N. E. Gillette. 2007. Response to host volatiles by native and introduced populations of *Dendroctonus valens* (Coleoptera: Curculionidae, Scolytinae) in North America and China. *J. Chem. Ecol.* 33: 131–146.
- Furniss, R. L., and V. M. Carolin. 1977. *Western forest insects*. U.S. Dep. Agric., Forest Service Misc. Publ. No. 1339. Washington, DC.
- Gardiner, L. M. 1957. Collecting wood-boring beetle adults by turpentine and smoke. *Can. For. Serv. Bi-mo. Res. Notes* 13: 2.
- Gaylord, M. L., T. E. Kolb, K. F. Wallin, and M. R. Wagner. 2006. Seasonality and lure preference of bark beetles (Curculionidae: Scolytinae) and associates in a northern

- Arizona ponderosa pine forest. *Environ. Entomol.* 35: 37–47.
- Hansen, H. S. 1939. Ecological notes on the *Sirex* wood wasps and their parasites. *Bull. Entomol. Res.* 30: 27–76.
- Hellrigl, K. G. 1971. Die Bionomie der europäischen *Monochamus*-arten (Coleopt., Cerambycid) und ihre Bedeutung für die Forst- und Holzwirtschaft. *Redia* 52.
- Hosmer, D. W., and S. Lemeshow. 1989. Applied logistic regression. Wiley, New York.
- Ikeda, T., N. Enda, A. Yamane, K. Oda, and T. Toyoda. 1980. Attractants for the Japanese pine sawyer, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae). *Appl. Entomol. Zool.* 15: 358–361.
- Kelsey, R. G., and Joseph, G. 2003. Ethanol in ponderosa pine as an indicator of physiological injury from fire and its relationship to secondary beetles. *Can. J. For. Res.* 33: 870–884.
- Kimmerer, T. W., and T. T. Kozlowski. 1982. Ethylene, ethane, acetaldehyde and ethanol production by plants under stress. *Plant Physiol.* 69: 840–847.
- Lanier, G. N. 1987. The validity of *Ips cribricollis* (Eich.) (Coleoptera: Scolytidae) as distinct from *I. grandicollis* (Eich.) and the occurrence of both species in Central America. *Can. Entomol.* 119: 179–197.
- Lanier, G. N., S. A. Teale, and J. A. Pajares. 1991. Biosystematics of the genus *Ips* (Coleoptera: Scolytidae) in North America: review of the *Ips calligraphus* group. *Can. Entomol.* 123: 1103–1124.
- Lindgren, B. S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). *Can. Entomol.* 115: 299–302.
- Linsley, E. G. 1961. The Cerambycidae of North America: Part I. Introduction. Vol. 18. University of California Press, Berkeley and Los Angeles, CA.
- Long, J. N., and T. W. Daniel. 1990. Assessment of growing stock in uneven-aged stands. *West. J. Appl. For.* 5: 93–96.
- McIntosh, R. L., P. J. Katinic, J. D. Allison, J. H. Borden, and D. L. Downey. 2001. Comparative efficacy of five types of trap for woodborers in the Cerambycidae, Buprestidae, and Siricidae. *Agric. For. Entomol.* 3: 113–120.
- Miller, D. R. 2006. Ethanol and (–)- α -pinene: attractant kairomones for some large wood-boring beetles in southeastern USA. *J. Chem. Ecol.* 32: 779–794.
- Miller, D. R., and C. Asaro. 2005. Ipsenol and ipsdienol attract *Monochamus titillator* (Coleoptera: Cerambycidae) and associated large pine woodborers in southeastern United States. *J. Econ. Entomol.* 98: 2033–2040.
- Miller, D. R., J. H. Borden, G.G.S. King, and K. N. Slessor. 1991. Ipsenol: an aggregation pheromone for *Ips latidens* (LeConte) (Coleoptera: Scolytidae). *J. Chem. Ecol.* 17: 1517–1527.
- Miller, R., K. E. Gibson, K. F. Raffa, S. J. Seybold, S. A. Teale, and D. L. Wood. 1997. Geographic variation in response of pine engraver, *Ips pini*, and associated species to pheromone, lanierone. *J. Chem. Ecol.* 23: 2013–2031.
- Morewood, W. D., K. E. Hein, P. J. Katinic, and J. H. Borden. 2002. An improved trap for large wood-boring insects, with special reference to *Monochamus scutellatus* (Coleoptera: Cerambycidae). *Can. J. For. Res.* 32: 519–525.
- National Climate Data Center. 2005. Surface data, daily—Hill City, SD (<http://lwf.ncdc.noaa.gov/oa/ncdc.html>).
- Pajares, J. A., F. Ibeas, J. J. Diez, and D. Gallego. 2004. Attractive responses by *Monochamus galloprovincialis* (Col., Cerambycidae) to host and bark beetle semiochemicals. *J. Appl. Entomol.* 128: 633–638.
- Ross, D. A. 1966. Biology of the spotted pine sawyer *Monochamus maculosus* (Haldeman) (Coleoptera: Cerambycidae). Internal Report BC-5. Forest Research Laboratory, Department of Forestry, Victoria, BC, Canada.
- SAS Institute. 2004. SAS/STAT[®] 9.1 user's guide. SAS Institute, Cary, NC.
- Smith, R. H. 2000. Xylem monoterpenes of pines: distribution, variation, genetics, function. U.S. Dep. Agric. Forest Service Gen. Tech. Rep. PSW-GTR-177. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.
- Smith, D. R., and N. M. Schiff. 2002. A review of the siricid woodwasps and their ibalid parasitoids (Hymenoptera: Siricidae, Ibalidae) in the eastern United States, with emphasis on the mid-Atlantic region. *Proc. Entomol. Soc. Wash.* 104: 174–194.
- Stillwell, M. A. 1966. Woodwasps (Siricidae) in conifers and the associated fungus, *Stereum chailletii*, in eastern Canada. *For. Sci.* 12: 121–128.
- Sweeney, J., P. de Groot, L. MacDonald, S. Smith, C. Cocquemot, M. Kenis, and J. M. Gutowski. 2004. Host volatile attractants and traps for detection of *Tetropium fuscum* (F.), *Tetropium castaneum* L., and other long-horned beetles (Coleoptera: Cerambycidae). *Environ. Entomol.* 33: 844–854.
- Sweeney, J., J. M. Gutowski, J. Price, and P. de Groot. 2006. Effect of semiochemicals release rate, killing agent, and trap design on detection of *Tetropium fuscum* (F.) and other longhorn beetles (Coleoptera: Cerambycidae). *Environ. Entomol.* 35: 645–654.
- [USDA Forest Service] U.S. Dep. Agric. Forest Service. 2000. Burned area emergency rehabilitation report (BAER): Jasper Fire, September 2000. U.S. Dep. Agric., Forest Service, Black Hills National Forest, Hell Canyon District, SD.
- [USDA Forest Service] U.S. Dep. Agric. Forest Service. 2001. Burned area emergency rehabilitation report (BAER): Rogers Shack Elk Mountain Complex Fire, August 2001. U.S. Dep. Agric., Forest Service, Black Hills National Forest, Hell Canyon District, SD.
- Vité, J. P., and J.A.A. Renwick. 1971. Population aggregating pheromone in the bark beetle, *Ips grandicollis*. *J. Insect Physiol.* 17: 1699–1704.
- Vité, J. P., A. Bakke, and J.A.A. Renwick. 1972. Pheromones in *Ips* (Coleoptera: Scolytidae): occurrence and production. *Can. Entomol.* 104: 1967–1975.
- White, G. C., and R. E. Bennetts. 1996. Analysis of frequency count data using the negative binomial distribution. *Ecology* 77: 2549–2557.
- Wilson, I. 1997. Damage assessment of wood borers in the interior of British Columbia. Phero Tech, Inc., Delta, BC, Canada.
- Wood, S. L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. *Great Basin Nat. Mem.* 6: 1–1326.

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