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SCIENTIFIC NOTE

Flight of the Mountain Pine Beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Curculionidae: Scolytinae), in Suburban Cheyenne, Wyoming, USA during Summer 2011

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The mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins (Coleoptera: Curculionidae: Scolytinae), is a major tree-killing bark beetle that attacks primarily ponderosa pine, *Pinus ponderosa* Lawson & C. Lawson, and lodgepole pine, *Pinus contorta* Douglas ex Loudon (Pinaceae), among other pines, across the western coniferous forests of North America (Negrón and Fettig 2014). A continental-scale outbreak of MPB occurred from the late 1990s through the mid- to late 2010s, ranging from the southern Rockies north to British Columbia (Jarvis and Kulakowski 2015; Negrón and Fettig 2014). In northern Colorado and southern Wyoming, most of the mortality occurred among lodgepole pine but mortality also occurred among ponderosa pine, whitebark pine, *Pinus albicaulis* Engelm., and limber pine, *Pinus flexilis* James. Elevated populations of mountain pine beetles across Wyoming reached their highest levels from 2007–2010. Peak mortality in 2009 affected approximately 500,000 ha. A decade later, populations had markedly declined, with tree mortality occurring on < 200 ha by 2017 (DeSantis 2017).

Throughout most of its range, MPB produces one generation per year (Bentz *et al.* 2014), though two-year life cycles occur at high elevations and latitudes (Amman 1973). Emergence and dispersal of MPBs occur primarily during late July through mid-August from trees killed the prior year. Females select new trees for attack using visual, olfactory, and gustatory cues along with random landings (Campbell and Borden 2006; Hynum and Berryman 1980; Pureswaran and Borden 2005; Raffa *et al.* 2005; Raffa and Berryman 1982). Chemical communication among MPBs utilizing insect-produced compounds and tree volatiles aggregates hundreds of beetles for attacking a single tree and overcoming its defenses. When a tree is fully colonized, an anti-aggregation pheromone arrests further attacks on that tree, causing MPBs to disperse to adjacent trees (see Progar *et al.* 2014 for a review). Females construct an elongated egg gallery in affected trees under the bark and in the phloem where eggs are deposited. Larvae emerge in approximately 10 days and begin feeding in the cambium. The insect overwinters in the larval stage under the bark, pupates in the spring, and the cycle begins again. In the process, MPB introduces various species of ophiostomatoid fungi (Ophiostomatales) that can be pathogenic to the tree but also facilitate MPB development (see Mercado *et al.* 2014 for a review).

Mountain pine beetle affects native pine species in both urban and suburban environments, as well as introduced ornamental species. For example, in Fort Collins, CO, which is about 70 km south of Cheyenne, WY, 232 trees were killed by MPB from 2008 to 2013; the majority of these trees were Scots pines, *Pinus sylvestris* L. (R. Zentz, personal communication). In Wyoming, tree mortality occurred as far east as Torrington, where beetles killed Scots pine, introduced Austrian pine, *Pinus nigra* Arnold, and native ponderosa pine (M. Hughes and R. DeSantis, *in litt.*).

In Cheyenne, WY, substantial tree mortality, approximately 450 ponderosa pines and numerous limber pines, occurred at the US Department of Agriculture, Agricultural Research Service, High Plains Grasslands Research Station. Most of the trees located at the Station were planted from 1929 through the early 1930s, including ponderosa pines

from various locations. Ponderosa pine stands cover about 5 ha with mean diameter at breast height of 37.0 ± 0.3 cm (SEM). The Station is located 8 km northwest of Cheyenne at an elevation of 1,907 m and comprises 1,163 ha. It is home to the High Plains Arboretum. Mean annual air temperature at the site is 7.3 °C, with a mean annual precipitation of 381 mm with most of it falling in May.

During 2011, we deployed five 12-funnel Lindgren funnel traps with a MPB attractant composed of exo-brevicomin, terpinolene, and trans-verbenol (Synergy Semiochemicals Corporation, Burnaby, British Columbia) to monitor the flight pattern of MPB at the research station. Traps were distributed across the station's ponderosa pine stands. Traps were hung from 3-m-long metal conduit sections anchored with rebar and the collection cups were about 1.7 m from the ground. Traps were deployed 6 June 2011 and visited weekly beginning 13 June 2011 through 3 October 2011 (except 26 September). The first MPBs were recorded on the 20 June sampling date with some collected every sampling date thereafter (Fig. 1). The majority of MPBs were caught during the trapping periods ending 26 July and 8 August.

The observed flight pattern of MPB was consistent with those observed in forested environments within their geographical range. From a study in Idaho, Bentz (2006) indicated that peak number of MPBs collected from emergence cages may not coincide with peak flight activity. However, in the current study, peak flight occurred within the same periods of MPB emergence from various studies in forested environments. A five-year study in the

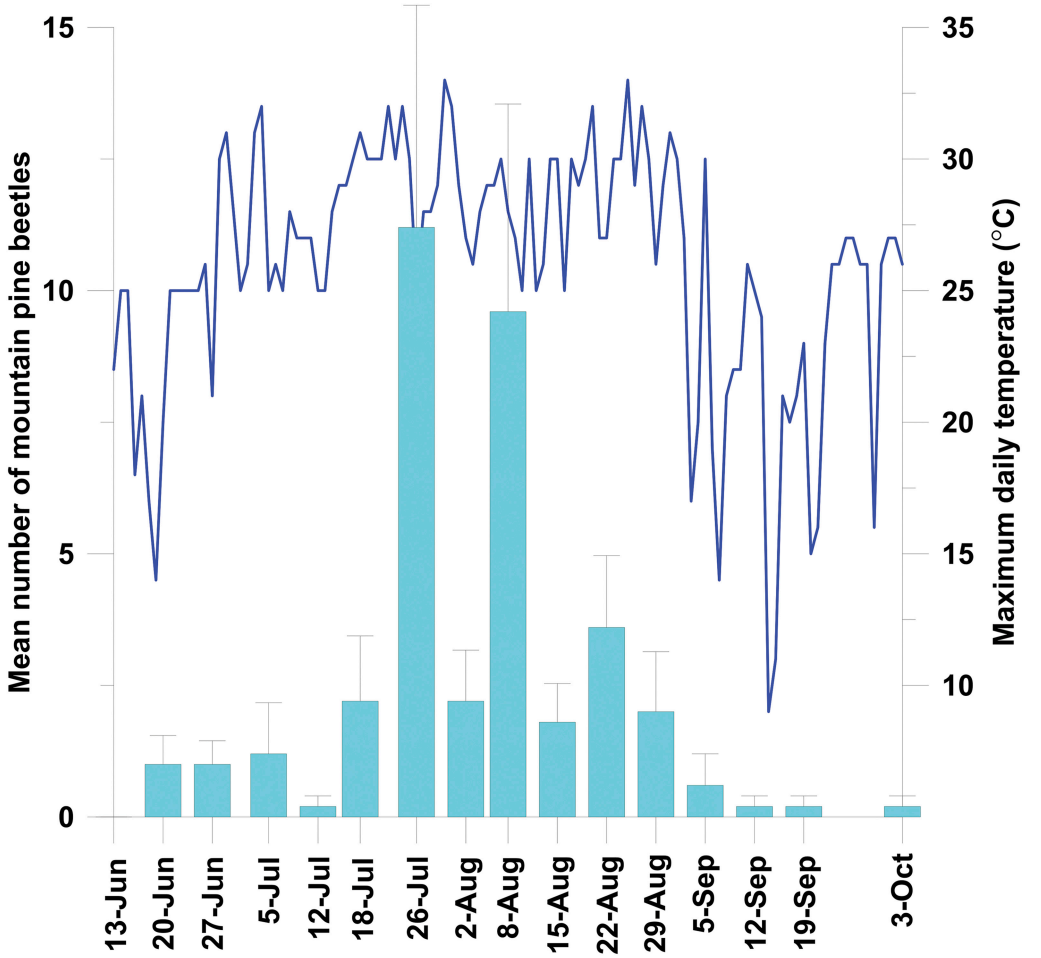

Fig. 1. Mean per-trap number of mountain pine beetles (cyan bars) caught in Lindgren funnel traps (n = 5) per collection date and maximum daily temperature (blue line) at High Plains Grasslands Research Station, Cheyenne, WY, during 2011. Error bars indicate standard errors. Temperature data were obtained from an on-site weather station.

Colorado Front Range found that MPB emergence peaked during mid-August (McCambridge 1964). Mountain pine beetles emerged from early July through early September, with peak emergence between early and mid-August across different elevations from 2,070 m to 3,018 m in Fraser, CO (Tishmack *et al.* 2005). Emergence of MPB from ponderosa and lodgepole pine trees during 2010–2011 in the Colorado Front Range peaked over a two-week period from the end of July through the beginning of August (West *et al.* 2016). Negrón (2019) studied MPB emergence from trees growing at different densities in Fraser, CO, and reported that the beetle's peak emergence occurred from late July to mid-August. Further north, in the Black Hills of South Dakota and Wyoming, MPBs emerged starting during July with peak emergence also during mid-August (Schmid 1972). In California, MPB is active during late spring, summer and early fall (June–October), with peak flight occurring in many locations during early fall (Fettig *et al.* 2004, 2005). Across British Columbia, emergence peaks between mid-July and mid-August (Carroll and Safranyik 2004).

In our study site, MPB started flying when daily maximum air temperatures were about 25 °C, with peak emergence occurring at temperatures between 25 °C and 32 °C (Fig. 1). Temperature is a critical environmental cue for MPB emergence, regulating the initiation and dispersal period (Carroll and Safranyik 2004). Flights of MPBs can occur while temperatures are as low as 15 °C to an upper limit of 41 °C (Billings and Gara 1975; Carroll and Safranyik 2004; Gray *et al.* 1972; McCambridge 1971; Reid 1962; Schmid 1972). However, beetles fly primarily while temperatures are between 22 °C and 32 °C (Carroll and Safranyik 2004).

We acknowledge limitations of this study with only a single year of flight monitoring and a small study site; nevertheless, to our knowledge, this information is novel in that it is the first MPB flight data from a suburban site in southeastern Wyoming. Our observed findings regarding MPB flight, as well as relationships to air temperatures, are consistent with MPB emergence patterns previously documented. Therefore, these data substantiate that patterns of MPB flight periodicity, peak emergence, and influence of air temperatures may be consistent in both natural landscapes of forested ecosystems and suburban settings.

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