Distribution and life cycle of *Rhyacionia buoliana* (Lepidoptera: Tortricidae) in the interior of British Columbia

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ABSTRACT

The European pine shoot moth, *Rhyacionia buoliana* (Denis and Schiffermueller), is an exotic shoot-boring insect of hard pines in British Columbia. In 1999 infestations of this pest in native lodgepole pine were reported at a seed orchard in the interior of this province where large numbers of the shoot moth reduced seed production by damaging pollen and cone bearing shoots. *Rhyacionia buoliana* were recorded on about 80% of the trees in a lodgepole pine seed orchard in June 2000. Pheromone trap catches and weather observations over three years indicated that first, and peak *R. buoliana* flight occurred when approximately 1000, and 1680 degree-days, respectively had accumulated from January to August (using a threshold of –2.2 °C). We found no evidence of a serious threat to natural lodgepole pine stands from *R. buoliana* damage. Head capsule measurements confirmed the presence of six larval instars in *R. buoliana* in BC.

INTRODUCTION

The European pine shoot moth, *Rhyacionia buoliana* (Denis and Schiffermueller), is an important shoot-boring insect of hard pines in Canada (Syme *et al*. 1995). In the west, lodgepole pine *Pinus contorta* (Douglas) is the most affected native species, while it is most often found on ornamentals such as mugho pine, *Pinus mugo* (Terra). It was first discovered in North America in 1914 on Long Island, New York, on imported ornamental pines from Europe (Busck 1914; Green 1962; Martineau 1984). This moth was first recorded in British Columbia (BC), in Victoria, on imported nursery stock in 1925 (Ferris 1996). The first recorded outbreak on the mainland of BC occurred in 1938 when native lodgepole pine planted as ornamentals in Vancouver were attacked (Mathers 1938). By 1961 the moth had spread to the interior of BC (Harris and Wood 1967; Evans 1973). Presently the host range in the Pacific Northwest of North America extends from north of Kamloops, BC (50° 41' 40 N, 120° 27' W) south near Salem, Oregon (45° 31' N, 122° 41' W).

Rhyacionia buoliana has one generation per year in BC. Adult moths have light reddish orange and silver forewings, gray hind wings, and a wing span of approximately 19 mm. Adults emerge in late spring and early summer. Within 24 h of emergence they mate and begin to lay eggs (Ferris 1996). Eggs are laid on shoots during June and July, on or near the buds of the lower branches of host trees. Hatching occurs approximately two wk later;

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first- and second-instar larvae construct tunnel-like webs, coated with resin and debris, between needle bases and elongating shoots of the current year's growth (Syme *et al*. 1995). Initial feeding occurs on needles within these webs (Ferris 1996). Third-instar larvae exit these webs, migrate to new buds, and construct larger, resin-lined webs between buds. Larvae then bore into, feed upon and kill these buds before overwintering there (Martineau 1984). The following spring, larvae migrate to the upper branches and bore into and deform or kill elongating shoots. Here they complete the final three larval instars before pupating for about two wk (Martineau 1984).

Rhyacionia buoliana damage results in deformities such as forked or crooked stems, bushy growth, multiple tops (Harris and Wood 1967; Alvarez de Araya and Ramirez 1989; Ferris 1996), and, in commercially harvested species, lowered timber quality (Miller *et al.* 1961). Thus far, *R. buoliana* has not been considered an important forest pest in Canada, except for attacks on forest nursery seedlings; incidence on lodgepole pine in forestry settings is minimal.

However, in recent years significant damage has occurred in a lodgepole pine seed orchard in the Okanagan Valley of south central BC. In 1999, larvae of *R. buoliana* were detected in at least one shoot per tree in 25% of lodgepole pines at the Vernon Seed Orchard Company near Vernon, BC (50° 23' N, 119°33' W) (Tim Lee pers. comm. Vernon Seed Orchard, Vernon BC). This site includes 10,739 grafted lodgepole pine trees in three orchards, representing pines from three different areas in British Columbia: Bulkley Valley, Willow-Bowron and the Central Plateau. Due to grafting, trees vary in age from 70 to 90 y and height of 1 to 6 m. In 2000, the infestation increased to approximately 80% of the lodgepole pine trees. In response, orchard managers instituted a program of chemical and mechanical control in 2000 and 2001, and chemical control alone in 2002 (Tim Lee pers. comm. Vernon Seed Orchard, Vernon BC). Chemical control with a systemic spray was used in mid-July to target feeding larvae. Mechanical control consisted of clipping and removing infested shoots by hand, before *R. buoliana* adults had emerged.

Our objectives were to study *R. buoliana* in the south central interior of BC and determine: a) its current distribution using pheromone-baited traps, b) male flight activity in relation to degree-day accumulation, and c) larval development period.

MATERIALS AND METHODS

Rhyacionia buoliana distribution and flight period. Pherocon II Diamond Traps© (Pherocon Ltd, Adair , Oklahoma) containing a Pherotech© (Pherotech Ltd, Richmond, BC Canada) flex pheromone lure with 20 μg of 97:3 E-9-dodecenyl : E-9-dodecenol (Gray *et al*. 1984) were placed in areas of high lodgepole pine density in the south central interior of BC (Fig. 1) in the summers of 2001 and 2002. In 2001, 86 of the 134 traps were hung in lodgepole pine at the Vernon Seed Orchard Company, thought to be the center of the infestation. The average orchard size is 119 by 237 m. Traps were placed in 60 x 54 m spacing at a height of 1 to 2 m, close to the stem, on the northeast side for protection against the direct sun. The remaining 48 traps were placed on ornamental and native pines, primarily mugho, lodgepole and ponderosa pines, in urban and rural settings around Kelowna and Vernon. In urban areas traps were placed on mugho pine, in outlying rural areas on ponderosa pine and at higher elevations and the Vernon seed orchard, lodgepole pine. Traps were placed in trees in early May before moth flight had begun, and removed after moth counts remained zero for more than two wk. Traps were checked and cleaned twice a week; pheromone flex lures did not require changing during the study period. In 2002, the trapping program was expanded south to Osoyoos and north to Kamloops and Salmon Arm (Fig. 1). Traps were placed on accessible pine trees.

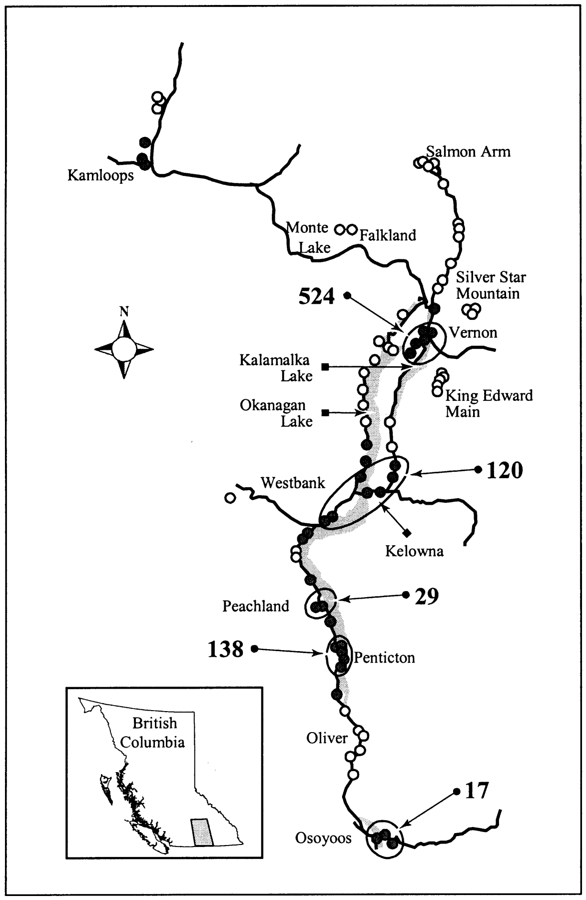

Figure 1. Location of pheromone traps used to monitor the distribution of *Rhyacionia buoliana* in the south central interior of British Columbia in 2002. Numbers with arrows attached to circles indicate number of moths caught in a group of traps. The dark gray circles indicate trap captures of more than five moths.

The 2001 and 2002 catches and flight duration at the Vernon Seed Orchard Company were compared to catch data in 2000 (data provided by CropHealth Advising and Research, Kelowna BC). Multiple years were compared to determine the repeatability of adult male captures in pheromone traps in relation to degree-days.

Degree-day accumulation. Daily minimum and maximum temperature data from Environment Canada were used to calculate degree-day accumulation from 1 January to 31 August, 2000 to 2002 using data from the Vernon/Coldstream weather station, located approximately 6 km east of the seed orchard. Regan *et al.* (1991) concluded that the most reliable degree-day calculations for development of *R. buoliana* larvae in Oregon, USA, were obtained using a minimum threshold temperature of –2.2 °C. Therefore we used this temperature and the sine method outlined by Raworth (1994) for degree-day calculations. Based on trap catches we calculated the degree-day accumulation to initial and peak flight and to various percent levels of trapped males. For 2000, pheromone trap data collected by CropHealth Advising and Research were used.

Larval development. The number and moult timing of *R. buoliana* instars were determined through larval head capsule measurements. From 27 April through 12 June 2002 fifty infested pine shoots were collected at two-wk intervals from the Vernon area and dissected to extract and measure *R. buoliana* larvae. On 12 August 2002, samples of shoots were collected in order to obtain third-instar larvae. Larvae were preserved in glass jars with 70% ethanol. Subsequently, larval head capsule widths were measured using SigmaPro Scan© software to an accuracy of ±0.01 mm. Voucher specimens of larvae and adult moths were deposited in the Insectary at the Pacific Forestry Centre, Victoria BC (PFCI).

RESULTS

Rhyacionia buoliana distribution. *Rhyacionia buoliana* was detected in the western portion of the Vernon Forest District, and concentrated in the urban centers of Penticton, Kelowna, and Vernon areas (Fig. 1). Low populations were found in the Kamloops, Salmon Arm and Oliver urban areas. Higher elevation, natural lodgepole pine stands, such as the Rob Roy Forest Service road and King Edward main locations, yielded no evidence of *R. buoliana.* Moth populations were found to be higher in urban than in suburban areas, perhaps due to higher concentrations of ornamental pines which offer a more readily available source of food for larvae. The absence of trapped adults in high-elevation pine forests may be due to the fact that the natural stands sampled are older than the urban trees or orchard trees, and therefore, have shoots of different foliage quality. In addition, it is possible that the absence of populations in natural lodgepole stands may be due to the fact that these stands occur at high elevations, where winter temperatures often fall below the *R. buoliana* survival threshold of –22 °C (Green 1962). In 2001, two adult males were caught in two traps in outlying rural areas of Kelowna and Vernon where no exotic ornamental pines appear to occur within less than five km. This suggests the presence of *R. buoliana* in wild lodgepole pine stands. However, a comprehensive trapping in wild lodgepole pine is necessary to confirm this point.

Degree-day accumulation and flight period. Flight period of adult male *R. buoliana* in the Okanagan Valley and neighbouring areas began in mid-June and ended in the third week of July. In all study years moths began to appear in traps between Julian dates 157 and 165, or after the accumulation of approximately 1000 degree-days. Table 1 indicates degree-day accumulations required to obtain various percent levels of male captures in the south central interior of BC. Fifty percent of the total catch occurred after accumulation of 1958, 1545, and 1507 degree-days in 2000, 2001, and 2002 respectively (mean value = 1670) (Table 1). These results are comparable to values obtained by Regan *et al.* (1991) in Oregon. A quadratic curve fitted to the moth catch data for 2000, 2001, 2002 (Fig. 2) estimated that, the beginning of moth captures and peak flight occur when approximately 1000 and 1680 degree-days above –2.2 ^{o}C, respectively, have accumulated from 1 January.

Table 1.

Number of degree-days accumulated above a threshold of –2.2 ^{o}C from 1 January for different percentages of *Rhyacionia buoliana* adult males caught at the Vernon Seed Orchard Company, Vernon BC

	10%		20%		50%		90%	
Year	Julian Date	Degree Day	Julian Date	Degree Day	Julian Date	Degree Day	Julian Date	Degree Day
2000	174	1515.99	181	1680.99	195	1957.79	195	1957.79
2001	157	1166.34	172	1418.84	179	1544.54	193	1877.66
2002	168	1330.85	170	1366.20	176	1507.27	183	1649.67
Mean	**166**	**1337.73**	**174**	**1488.68**	**183**	**1669.87**	**190**	**1828.37**

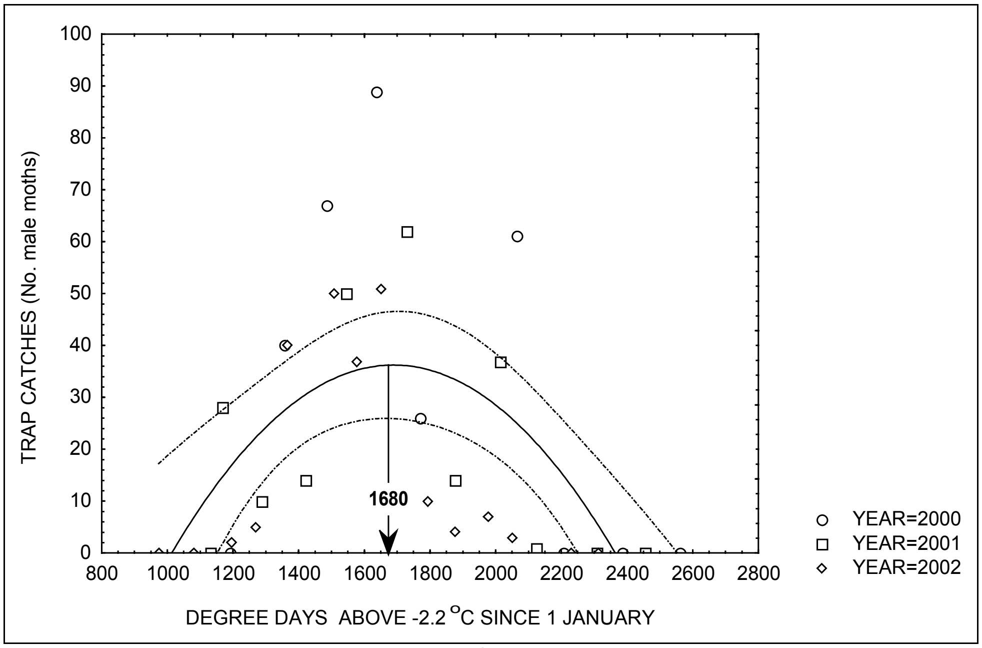

Figure 2. Degree-day accumulation (–2.2 °C threshold, 1 Jan start date) at the Vernon Seed Orchard Company for adult *Rhyacionia buoliana* catches in pheromone traps for three years (2000 – 2002). Solid curve represents fitted quadratic regression; dotted lines are the 95% confidence limits for the curve. Arrow indicates degree-days to peak emergence ($y = -7.94 \bullet 10^{-5}x^2 + 0.268x - 190$, $F = 8.91$, df = 2, 31, $R^2 = 0.365$ and $P < 0.0008$)

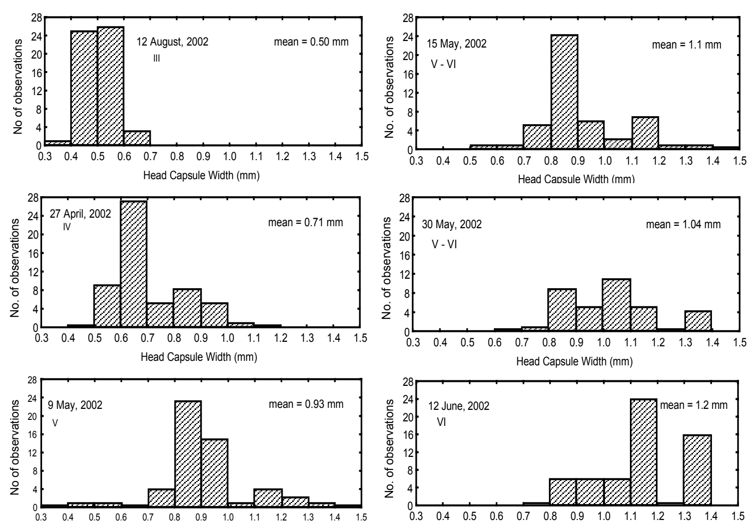

Figure 3. *Rhyacionia buoliana* head capsule widths and instar stages (Vernon BC area, 2002). Graphs arranged according to head capsule width sizes, rather than in chronological order, to depict clearly the different instar head capsule sizes. A bar represents the sum of all points in the interval. Mean head capsule widths (mm) for each instar according to Pointing (1963) are I = 0.28, II = 0.37, III = 0.55, IV = 0.64, V = 0.90, VI = 1.23.

Larval development. Comparing our head capsule measurement data to established head capsule size classes (Pointing 1963), we confirmed the presence of four of the six larval instars (III to VI) in the south central interior of BC (Fig. 3) as identified for *R. buoliana* in Ontario (Pointing 1963). The sampling period utilized in our study did not allow us to identify instars I and II. Head capsule measurements of larval samples collected on 12 August indicated a mean width of 0.50 mm, which according to Pointing (1963) corresponds to instar III (Fig. 3). Between May and June there were three instars, IV, V, and VI. The head capsule widths for instar III show a clearly defined single peak (Fig. 3). However, the frequency distribution for samples collected at all other dates exhibited a greater range of variability than instar III. This increased range in head capsule size may be attributable to larval females being larger than males; larval females may outnumber males three to one (Pointing 1963), which may result in wider head capsule distributions. Earlier instars would not have such a distribution because male and female larvae are similar in morphology.

In summary, our observations indicate that in south central BC, moth flight occurs between mid-June (Julian date 166, Table 1) and mid-July (Julian date 190, Table 1). Instars I to III occur between late July to mid-August (Fig 3). Following overwintering, instar IV can be observed in late April and instars V and VI occur between early May and mid-June. Also observations conducted in 2000 to 2002 indicate that pupation begins at the end of May and continues until early July.

DISCUSSION

Economic losses attributable to *R. buoliana* in seed orchards have not been documented in the literature, but we believe that prolonged infestations can result in economic loss due to reduced seed production and increased costs of chemical and mechanical control in order to manage this pest. Moth distribution within the western portion of the Vernon Forest District indicates the potential for an increase in shoot moth population in the Okanagan Valley. However, the winter temperatures at high elevations may limit the range at which the shoot moth can survive (Green 1962). This may account for the absence of trap catches in natural lodgepole stands, that largely occur at high elevations, such as up the Rob Roy Forest Service road, west of Falkland (Fig. 1). Since *R. buoliana* is likely to continue to damage lodegpole pine trees at the Vernon Seed Orchard Company and may affect other sites, we recommend that surveys be conducted on other lodgepole pine seed orchards in the area, as well as in neighbouring natural and planted pine plantations, including Christmas tree plantations.

The information on lifecycle, periods of larval activity, and degree-day accumulation presented here can be incorporated into a management plan for effective monitoring and control of *R. buoliana* populations. Pheromone traps should be in place prior to the accumulation of 1000 degree-days above $-2.2\ ^{o}C$ (i.e. before first flight). Chemical control using systemic insecticides, if needed, should target sixth-instar larvae in late May to early June (accumulation of 973 degree-days). First-instar larvae migrating to new buds about two weeks after peak adult flight period (1680 degree-days) may also be vulnerable to systemic chemical control.

The *R. buoliana* infestation at the Vernon Seed Orchard Company might be attributed to superior tree stock, grown under optimal conditions, providing well-developed needles and buds, which make the trees more susceptible to attack. This abundant supply of susceptible food may have been a factor in the shoot moth host shift from ornamentals to this lodgepole pine seed orchard.

When *R. buoliana* was first discovered on nursery stock in BC, the likelihood of its spread to native pine plantations was considered by both the Canadian and US Forest

Service's (Harris and Wood 1967, Howard 1963). After noting that attacks concentrated mostly on ornamentals and did not pose a threat to native pine plantations, interest in this insect decreased. However, with increased planting of genetically improved, fast-growing lodgepole pine, the increased reliance on site amelioration, and the potential for climate change to create a favorable environment, the ability of this exotic insect to increase its range and cause serious economic damage in forestry settings must be considered.

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