The zebra caterpillar is not usually a significant pest, but local outbreaks have been recorded from eastern Canada (Beirne, 1971). The larva has a red head capsule and a black stripe running down its back. On each side of its body, a black longitudinal stripe, broken with narrow, white, vertical lines, runs between two bright yellow stripes. *M. picta* is bivoltine, with larvae present during late June and July and again in September in the Fraser Valley. Its presence on cranberries, an economically important crop in B. C., bears watching.

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Distribution of European winter moth, *Operophtera brumata* (L.)[1], and Bruce spanworm, *O. bruceata* (Hulst), in the lower Fraser Valley, British Columbia

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ABSTRACT

Sixteen pheromone traps, baited with (Z,Z,Z)-1,3,6,9-nonadecatetraene, were placed in commercial blueberry and raspberryfields, and at one woodland site in the lower Fraser Valley. Traps were monitored weekly from early November, 1990 until late January, 1991. Winter moth males were recovered from all but the eastern-most trap in Mission. Four traps in blueberry fields in Richmond caught a total of 2,928 winter moths, and 198 were caught in two traps in Delta and Surrey, whereas only 74 came to the ten traps north and east of Surrey. A total of 1,306 Bruce spanworm males were trapped. Although spanworm moths were recovered from traps in all areas, there was no correlation between trap location and number of spanworms caught. Thirteen males with characters intermediate between the two species were trapped in Richmond and Surrey. Males of both species were more numerous in raspberries than in nearby blueberry fields. Spanworm males came to the traps later in the fall than winter moths. East of Richmond, most spanworm males were trapped during November whereas, in Richmond, very few were attracted until the first week of December.

INTRODUCTION

The polyphagous European winter moth, *Operophtera brumata* (L.), was first detected in British Columbia in the mid-1970's (Gillespie *et al.*, 1978) and has become a serious pest of highbush blueberries, *Vaccinium corymbosum* L., in Richmond, B.C. (Sheppard *et al.*, 1990). In 1988, the B.C. Blueberry Co-operative Association was forced to cancel over 1.36 million kg in sales (Whaley, 1989) because larval damage to blossoms prevented entire plantings from producing fruit.

Fruit growers in the lower Fraser Valley east of Richmond are concerned that winter moths will spread undetected into their area and damage their crops. Although the female moths are flightless, larvae may be carried by the wind (Edland, 1971) and eggs and larvae can be inadvertently transported on nursery stock. To provide growers east of Richmond with an early warning system, we used pheromone traps to map the distribution of the winter moth in the lower Fraser Valley. We were able to detect the Bruce spanworm as well as the winter moth, because the pheromone isolated from winter moth females (Roelofs *et al.*, 1982) has also been isolated from spanworm females (Underhill *et al.*, 1987) and attracts males of both species (Roelofs *et al.*, 1982; Underhill *et al.*, 1987). Here we report the numbers of males of both species attracted to pheromone traps during November, 1990, to January, 1991, in blueberry-and raspberry-growing areas of the lower Fraser Valley.

METHODS AND MATERIALS

Pheromone trapping

Sixteen double-cone orifice traps (Hara traps; Hara Products Ltd., Swift Current, Sask.) were baited with rubber septa impregnated with 100 µg of (Z,Z,Z)-1,3,6,9-nonadecatetraene, the winter moth pheromone, and placed at field sites on October 31, 1990. Aninsecticide-containing strip (S.W.A.T. Insect Strip; Green Cross, Ltd.) was placed in each trap and the trap cones were covered with fine screening to keep birds from eating dead moths. Single traps were placed in four commercial blueberry fields in the municipality of Richmond (Fig. 1: 1-4), eight commercial blueberry fields from Delta to the eastern-most site in the municipality of Mission (Fig. 1: 5-9, 14-16) and in three commercial raspberry fields from Langley to Matsqui (Fig. 1: 11-13). One trap was placed in a mixed coniferous/deciduous forest at least 1 km away from cultivated land in Langley (Fig. 1: 10). Traps were emptied weekly from November 6 to December 18, 1990, and then on January 23 and 30, 1991. Very bad weather prevented us from reaching some of the sites between late December and mid-January.

Moth identification

Several authors have described external characters (Brown, 1962; Cuming, 1961; Pivnick, 1988) and genitalic characters (Eidt *et al.*, 1966; Ferguson, 1978; Wolff, 1964) of the two moths. To identify specimens accurately, we found it necessary to use a synthesis of these characters plus some previously unreported ones, and to quantify the dimensions of genitalic characters (Table 1).

Data analysis

Where appropriate, the data were analyzed by Spearman rank correlation or t-test.

Table 1

Characters used to separate males of the Bruce spanworm, *Operophtera bruceata* (Hulst), from males of the European winter moth, *Operophtera brumata* (L.)

Type of Character	Spanworm	Winter moth
External		
Wings	distinct lines and bands on dorsal surfaces	lines on dorsal forewing are obscure; often no lines on dorsal hindwing
Forewing	pale yellow-orange ventral costal margin[1]	yellow-orange colour faint to absent
Hindwing*	dark dorsal discal dot	dot absent
Abdomen*	golden brown[2]	brown
Genitalic[3]		
Uncus	narrow (< 0.12 mm); nearly parallel-sided; not spatulate	wider (*ca.* 0.14 mm); slightly spatulate
Juxta	shallow medial notch at base; dorsal process wide (*ca.* 0.25 mm) at base	divided at base by a medial cleft; dorsal process narrowed (ca. 0.16 mm) at base
Saccus	long (*ca.* 0.63 mm); as long as or longer than width at base of valva	short (*ca.* 0.40 mm); shorter than width at base of valva

* Previously unreported characters
1, 2 True only of Bruce spanworms in B.C.
3 Genitalic characters are illustrated in Eidt *et al.* (1966).

RESULTS

A total of 3,200 winter moths, 1,306 spanworms and 13 moths with characters intermediate between the two species were trapped during the 13-week period. Most (2,928) of the winter moths were recovered from the four blueberry fields in Richmond (Fig. 1: 1-4; Spearman rank correlation coefficient = 0.8294, $p < 0.001$, $n = 16$). A total of 198 winter moths were captured in Delta and Surrey (Fig. 1: 5 and 6), and 74 came to the ten traps north and east of Surrey (Fig. 1: 7-16). More winter moths were trapped in the three raspberry fields (Fig. 1: 11-13; $\bar{X} \pm S.D. = 10.0 \pm 11.27$ per trap) than in three nearby blueberry fields (Fig. 1: 9, 14 and 15; $\bar{X} \pm S.D. = 3.33 \pm 4.04$ per trap; $t = 2.95$, $p = 0.042$). No winter moths were recovered from the trap in Mission (Fig. 1: 16).

Spanworms were recovered from all sites, but there was no correlation between trap location and number of spanworms caught (Spearman rank correlation coefficient = -0.0106, $p \geq 0.05$, $n = 16$). More spanworms were found in the three raspberry fields (Fig. 1: 11-13; $\bar{X} \pm S.D. = 90.33 \pm 101.5$ per trap) than in three nearby blueberry fields (Fig. 1: 9, 14 and 15; $\bar{X} \pm S.D. = 42 \pm 45.18$ per trap; $t = 6.912$, $p = 0.0023$).

Eleven of the 13 moths with characters intermediate between the two species were trapped in Richmond (Fig. 1: 1-4); two were trapped in Surrey (Fig. 1: 5).

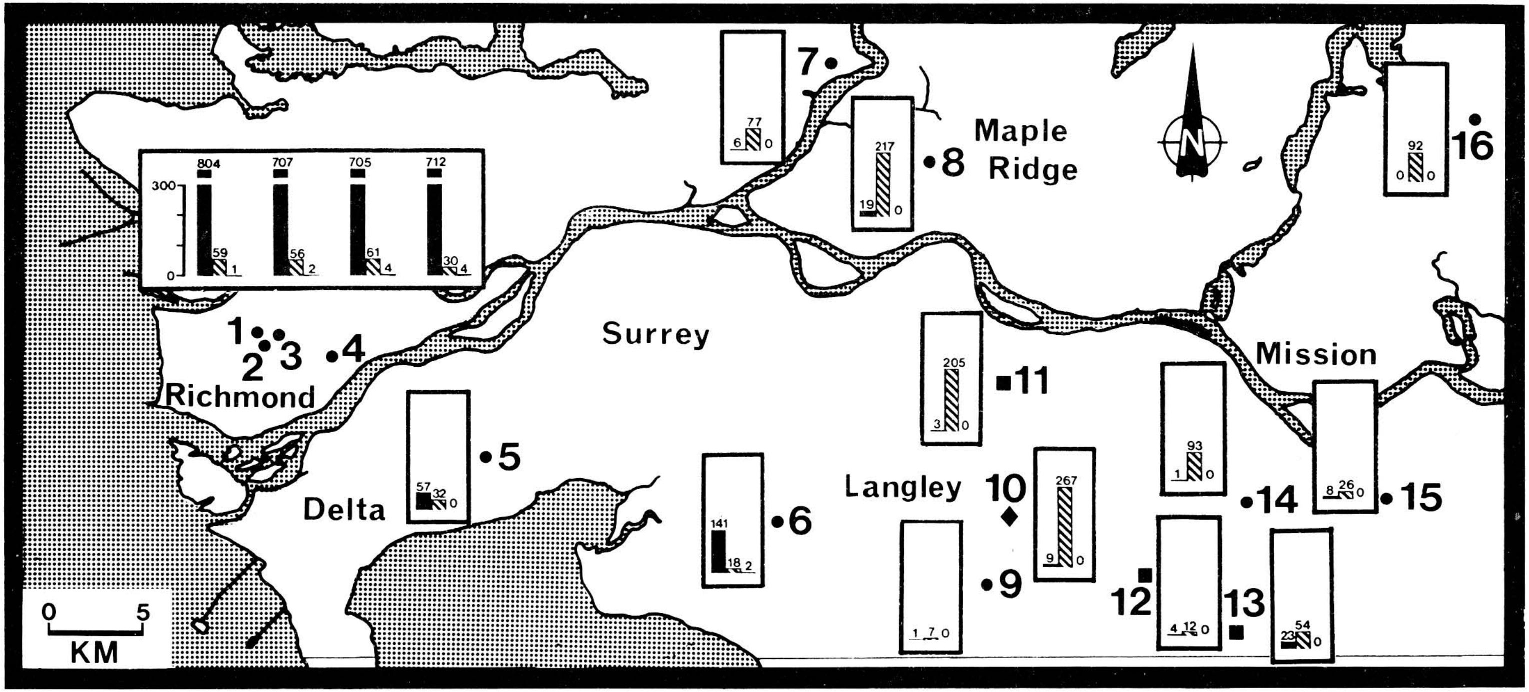

Figure 1. The lower Fraser Valley of British Columbia showing the location of pheromone traps for the European winter moth, *Operophtera brumata* (L.), and Bruce spanworm, *O. bruceata* (Hulst). Traps in blueberry fields are represented by circles, those in raspberry fields by squares, and the one in coniferous/deciduous woodland by a diamond. Traps 13, 14 and 15 lie within the municipality of Matsqui. Total numbers of winter moths (first column, solid bars), spanworms (second column, hatched bars) and moths with characters intermediate between the two species (third column) are indicated near each trap site.

Table 2

Numbers (#) and cumulative percentages (%) of Bruce spanworm, *Operophtera bruceata* (Hulst), males collected from four pheromone traps in Richmond and 12 traps east of Richmond during November, 1990, to January, 1991.

Date	Richmond (4 traps) #	%	East of Richmond (12 traps) #	%
Nov. 6	0	0	13	1.2
Nov. 13	3	1.5	151	15.0
Nov. 20	2	2.5	135	27.2
Nov. 28	15	9.7	328	57.0
Dec. 3	57	47.1	251	79.8
Dec. 11	46	69.4	162	94.5
Dec. 18	52	94.7	55	99.6
Jan. 23	11	100	5	100

Most winter moths were trapped earlier in the fall than most spanworms (Fig. 2). By the fourth week of November, 86% of the total number of winter moths had been recovered from the traps, whereas only 50% of the spanworm males had been caught. The mothswith intermediate characters were trapped during the first, second and third weeks of November, and the second week of December.

In Richmond, very few spanworms (< 10% of the total number caught) were trapped until the first week of December but, further east, most (57%) had come to the traps by the last week of November (Table 2).

DISCUSSION

The European winter moth is well established on blueberries in Richmond, and is present in blueberry and raspberry plantings as far east as Matsqui (Fig. 1). We found winter moths at one coniferous/deciduous site east of Richmond and suspect that they may be established at other wooded sites in the Valley. We recommend that growers east of Richmond, especially those in Delta and Surrey, monitor their plants closely in late March and early April when winter moth eggs hatch.

The Bruce spanworm is also present throughout the lower Fraser Valley (Fig. 1), but there is no correlation between location and number of spanworms trapped. Although spanworms were numerous in Maple Ridge and Langley (Fig. 1: 8, 11), there is no history of economic damage to fruit crops in these areas.

Both species were more numerous on raspberries than on nearby blueberries, suggesting that they may prefer, or have a higher fitness on, raspberries. A more extensive survey and developmental studies are needed to test this hypothesis.

Spanworm adults generally emerge later in the fall than winter moths (Hale, 1989), so the pheromone trap counts (Fig. 2) probably reflect the flight periods of the two species except, perhaps, in Richmond, where spanworms were trapped even later than at sites further east (Table 1). We suspect that spanworm males emerging in Richmond in November may have been attracted to calling winter moth females rather than to pheromone traps. Several facts support this hypothesis. The pheromone (Z,Z,Z)-1,3,6,9-nonadecatetraene has been isolated from winter moth (Roelofs *et al.* 1982) and spanworm (Underhill *et al.* 1987). Spanworm males can mate successfully with winter moth females, but pairings between winter moth males and spanworm females rarely succeed (Hale, 1989). We recovered several possible hybrids from traps in Richmond and Surrey,

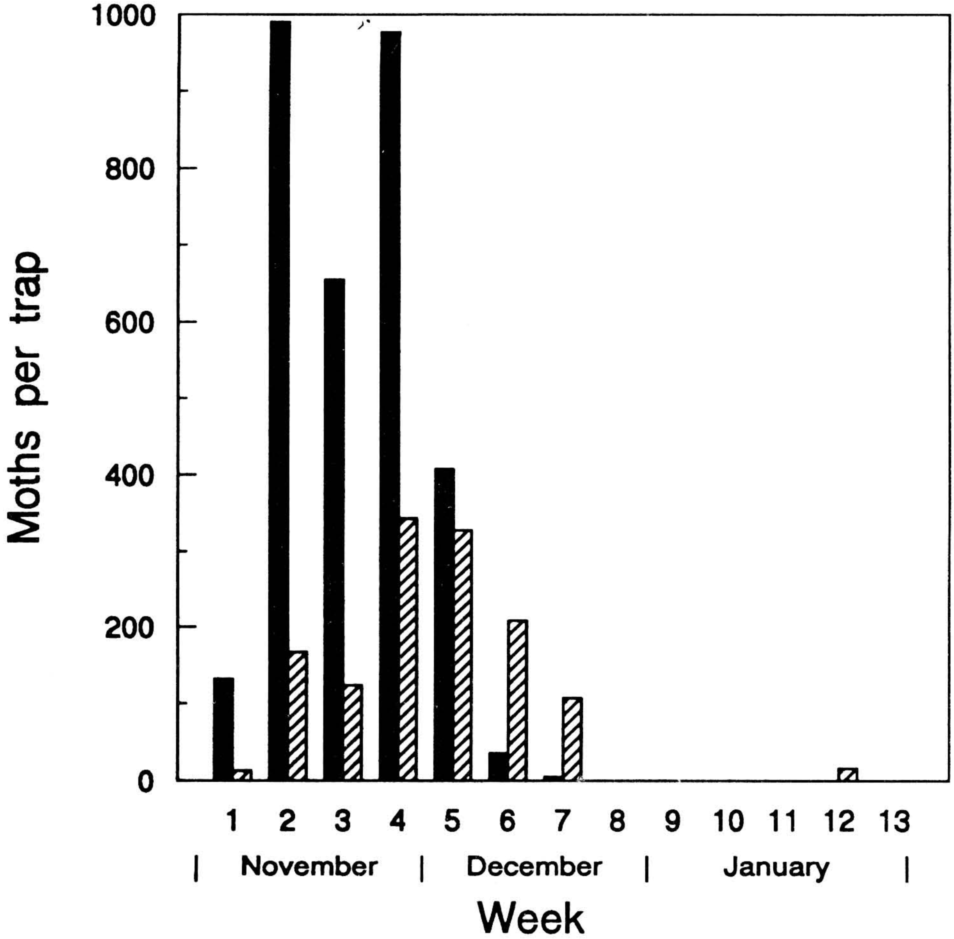

Figure 2. Total numbers of the European winter moth, *Operophtera brumata* (L.), (solid bars) and the Bruce spanworm, *O. bruceata* (Hulst), (hatched bars) caught in pheromone traps in the lower Fraser Valley during the fall and winter of 1990-91. The spanworms recovered from traps during week 12 were probably attracted during the preceding four weeks, when traps were not emptied.

suggesting that interspecific mating may be occurring in the field. An alternative explanation for the delayed spanworm catch in Richmond is that hybridization problems (Hale, 1989) may have resulted in natural selection for late-emerging spanworm.

Our results show that monitoring with pheromone traps can be used to indicate the presence of adult winter moths, and to identify regions where the risk of winter moth damage to crops is high. A pheromone-trap survey of the Okanagan Valley would provide an early warning system for this pest in that area.

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Cuticular metal hardening of mouthparts and claws of some forest insects of British Columbia.

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ABSTRACT

The presence of metals in mouthparts and claws of some forest insects associated with British Columbia conifers, particularly cone and seed pests, were detected and mapped by energy dispersive X-ray microanalysis. Zinc was concentrated in the mandibular cutting edges and claw tips of larval lepidopterans (but not in adult mouthparts), in the mandibles and claws of larval and adult coleopterans and in the mandibles of the hymenopteran, *Megastigmus spermatotrophus*. Calcium was the predominant metal in the mouth hooks of dipteran larvae, but minor peaks of zinc or manganese were present additionally in two species. Manganese occurred in the stylets of the hemipteran, *Leptoglossus occidentalis*, in the mandibles and claws of one coleopteran species, and with zinc in the mandibles of a clerid predator. The function of metal concentrations in specific areas of these structures is probably related to hardening of cuticular regions in some instances and to some other biomechanical aspect of cuticular strengthening in other cases.