INVASIVE BARK AND WOOD-BORING BEETLES IN BRITISH COLUMBIA, CANADA

Leland M. Humble, Natural Resources Canada, Canadian Forest Service, 506 West Burnside Road, Victoria, British Columbia, Canada V8Z 1M5
Tel: 250-363-0644, FAX: 250-363-0775, Email: lhumble@pfc.forestry.ca

ABSTRACT

Ongoing studies of the introduction and establishment of invasive bark and wood-boring insects around the major Canadian port of Vancouver, British Columbia, have shown that five previously unrecognized non-indigenous species of Scolytidae, *Trypodendron domesticum* (L.), *Xyleborus pfeili* (Ratzeburg), *Xyleborinus alni* (Niisima), *Xylosandrus germanus* (Blandford) and *Xyloterinus politus* (Say), and one non-indigenous Cerambycidae, *Phymatodes testaceus* (L.), have established in the urban forests. Within urban forest sites, the recently discovered scolytid fauna, along with other previously introduced species, now comprise the largest component of survey trap captures at some locations. Only one of the recently introduced Scolytidae was restricted to a single location across the study area. Of the remainder, one exotic scolytid and one cerambycid were restricted to forest habitats within the urban landscape. However, three of the recent introductions have successfully invaded both urban forest habitats and adjacent managed forest lands. The biological and ecological impacts resulting from the establishment of these ambrosia beetles and woodborers remains to be determined. These introduced species are now a major component of the scolytid diversity in some forest systems and may impact the diversity of native plant and animal species. Studies are currently underway to determine the extent to which these species have invaded both managed and natural forest ecosystems.

Keywords: ambrosia beetles, invasive, non-indigenous, Scolytidae

INTRODUCTION

The introduction of non-indigenous species into forest ecosystems is an ongoing consequence of international trade. Such introductions are acknowledged as serious threats to the integrity of forest ecosystems and biological diversity. In North America, past introductions have modified the functioning of forest ecosystems by eliminating native tree species as significant components of forest diversity on both continental (e.g. chestnut blight, white pine blister rust) and regional scales (e.g. balsam woolly adelgid) (Liebhold et al. 1995) and have affected the timber, recreational and wildlife values of forest resources (Humble and Allen in press). Increasing awareness of the threats posed by non-indigenous introductions and the discovery of recent introductions such as the pine shoot beetle, *Tomicus piniperda* (L.) (Haack and Kucera 1993), the Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Haack et al. 1996, 1997; Poland et al. 1999)) and the brown spruce longhorn beetle, *Tetropium fuscum* (Fabricius) (Smith and Humble 2001) in North America has resulted in increased efforts to prevent further introductions through increased surveillance for adventive bark- and woodborers associated with trade.

Between 1990 and 1994 an increase in the number of non-indigenous Scolytidae being detected around the world was noted by Bright and Skidmore (1997). In the past decade, numerous non-indigenous Scolytidae have been discovered in the forests of North America (Atkinson et al. 1990; Hoebeke 1991, 1994; Haack and Kucera 1993; Bright and Rabaglia 1999; Vandenberg et al. 2000). Considerable effort has been made to determine the geographic distributions of those introductions deemed to be of quarantine significance (e.g. *T. piniperda*) as a consequence of their impacts or potential impacts on resource values or trade. Such surveys have often demonstrated that the species in question was already widely distributed when first discovered or have led to the discovery of significant range extensions for other non-indigenous introductions (Hoebeke 1994; Rabaglia and Cavey 1994). However, for most non-indigenous species, information other than the initial record of occurrence is lacking. Knowledge of the abundance of the invasive and native species in forest habitats and the extent to which their population levels are changing over time is needed before the impacts of the non-indigenous introductions on native diversity can be evaluated.

I present an overview of the results of surveys evaluating the distribution and abundance of the native and introduced Scolytidae and Cerambycidae in forest habitats in and around the port of Vancouver, British Columbia, Canada. The results of these surveys are intended to form a baseline for the evaluation of temporal and spatial change in the diversity of native and introduced bark and wood-boring beetles.

MATERIALS AND METHODS

Between 1995 and 1999, forest habitats around import facilities, and in parks, reserves and industrial forest lands at 55 locations in southwestern British Columbia (Fig. 1) were surveyed for the presence of non-indigenous introductions by the Canadian Food Inspection Agency, Canada's quarantine agency, and the Canadian Forest Service (CFS). One 8-unit funnel trap (Lindgren 1983) baited with ethanol was used alone at 11 locations in 1995. All other locations trapped between 1995 and 1999 (n=44) employed a minimum of three funnel traps baited with the commercially available attractants, ethanol, α-pinene and an attractant for *Ips typographus* (L.) (exotic bark beetle lure in Table 1).

During 1999, the scolytid and cerambycid fauna of 5 forested habitats along a transect extending inland 120 km from the mouth of the Fraser River and 5 locations within the University of British Columbia's Malcolm Knapp Research Forest (MKRF) were evaluated with baited funnel traps. Nine baited and one unbaited trap were placed at each location. Baits employed at all locations in 1999 are given in Table 1. In all instances, traps were separated from each other by a minimum of 25 m and order of the lures was randomized. The collection bucket of each trap was filled with about 100 ml of a propylene glycol: water mixture (50:50) with a few drops of Kodak Photo-Flo 200 (Eastman Kodak Co., Rochester, NY) added as a surfactant to ensure the retention of captured beetles. Traps were operated continuously between 16 March and 19 September, 1999. Trap captures were collected on a monthly basis and all Scolytidae and Cerambycidae were counted and identified to species.

With the exception of the site located in the Mission Municipal Forest, locations included in the transect along the Fraser River (sites 1-5) were established in undisturbed forested habitats protected as wildlife habitat, parks or private land. The forest at site 1, the Alaksen National Wildlife Area (NWA), consisted of hedgerow growing on dikes surrounding agricultural fields. The remainder of the sites had continuous forest cover. Sites 1-4 were situated within the heavily urbanized portion of the Fraser River valley while Ruby Creek (Site 5) is well removed from the urban industrial environs of greater Vancouver. The forests of the Malcolm Knapp Research Forest and Mission Municipal Forest were being managed for timber production and had harvesting activity across their landscapes.

RESULTS

Between 1995 and 1999, more than 115 000 individuals of 47 species of Scolytidae were recovered from 55 locations (Fig. 1). Twelve species of non-indigenous Scolytidae and one non-indigenous species of Cerambycidae were captured across all years of trapping. Three of the scolytid species, *Cyrtogenius brevior* (Eggers), *Euwallacea validus* (Eichhoff) and *Xylosandrus crassiusculus* (Motschulsky), were recovered in association with solid wood packaging at warehouses and are not known to be established in British Columbia. An additional four of the non-indigenous Scolytidae, *Hylastinus obscurus* (Marsham), *Scolytus rugulosus* (Müller), *Xyleborinus saxeseni* (Ratzeburg) and *Xyleborus dispar* (Fabricius), were known to occur in BC prior to the initiation of these studies (McNamara 1991). The remaining 5 non-indigenous scolytids, *Trypodendron domesticum* (L.), *Xyleborus pfeili* (Ratzeburg), *Xyleborinus alni* (Niisima), *Xylosandrus germanus* (Blandford) and *Xyloterinus politus* (Say), as well as the cerambycid, *Phymatodes testaceus* (L.) were discovered during these studies. One or more of the established non-indigenous scolytids was present at 48 of the 55 locations surveyed (87%) while the single non-indigenous cerambycid was found at only two sites. At least one and up to four of the historically introduced species were present at all locations positive for non-indigenous taxa, while, recently introduced taxa were recovered from only 47% of the 55 sites sampled (Table 2).

More than 104, 000 individuals of 25 species of Scolytidae were recovered across all lures in 1999 (Table 3). The number of beetles captured per site varied more than 70-fold, with fewer than 500 adults caught at Alaksen NWA and more than 35 000 caught at Mission. Similarly, the proportional representation of native and non-indigenous Scolytidae in the captures, both as numbers of individuals and species, ranged widely between locations. The lowest representation of native taxa occurred at the Port Mann site, where only 37% of the individuals and 50% of the species captured were indigenous. Four recently introduced and three historically introduced species were present at Port Mann and accounted for 62.9% and 0.4% respectively of the individuals captured at that site. The location with the next highest incidence of non-indigenous taxa was Alaksen NWA, where 4.3% and 1% respectively of the individuals were recently or historically introduced taxa. At the remainder of the locations surveyed, native species accounted for 95% or more of the individuals captured. Surprisingly, captures of recently introduced taxa at the most easterly location, Ruby Creek, and at A-Road in MKRF were above 2%, surpassing the proportions of historically introduced taxa at those locations. Recently introduced species were absent from only three of the locations surveyed while historically introduced taxa were recovered at all locations.

Trap captures varied widely between lures in the 1999 study (Table 4). More than 98% of all Scolytidae were recovered from lineatin or sulcatol baited traps. Captures with these two lures were dominated by two native species, *Trypodendron lineatum* (Olivier) and *Gnathotrichus sulcatus* (LeConte), respectively. At all locations except Port Mann, one native species, *T. lineatum*, was the predominant species captured, accounting for from almost 66% to more than 96% of captures pooled across all lures. However, at Port Mann, one of the recently introduced species, *T. domesticum* was dominant. It comprised 66% of all individuals captured with the lineatin lure and 60% of the captures across all lures while *T. lineatum* accounted for only 34% of the captures with lineatin and 30% of the captures across all lures at that location.

Trap captures pooled across only the attractants (see Table 1) and control are presented in Table 5. A total of 1,926 individuals of 21 species of Scolytidae were captured across all locations in 1999. These represent less than 2% of the individuals but 84 % of the species recovered with all lures (Table 3). Ethanol was the most effective of all attractants (Table 4), capturing 17 of the 25 species recovered across all lures. All of the established introduced species of Scolytidae were represented in the pooled captures of the attractants and control, and all but *H. obscurus* were represented in the ethanol lure captures. The proportion of native species in catches made with the pooled attractants ranged from a low of 4.3% at Port Mann to a maximum of 87% in MKRF and averaged 55% across all locations. The abundance of introduced ambrosia beetles captured with attractants exceeded that of all native Scolytidae at four locations. Additionally, at four locations individuals of recently introduced species equaled or exceeded those of the historically introduced taxa (Table 5). They comprised more than 84% of the captures with attractants at Port Mann and were significant components of captures at Ruby Creek (41.8%), Alaksen NWA (22%), and MKRF-A Road (21.7%). Historically introduced species of Scolytidae were represented in captures from all locations and ranged in relative abundance from a low of 7.8% at MKRF-G to a maximum of 52% at Alaksen NWA.

DISCUSSION

Ten non-indigenous Scolytidae are now known to be established in British Columbia. Half of these introduced taxa have been discovered since detection surveys were initiated in 1995. With the exception of three of the historically introduced taxa, two phloeophagous species, *Scolytus multistriatus* (Marsham) and *S. rugulosus*, and a borer in the roots of clover, *H. obscurus*, the introduced Scolytidae are ambrosia beetles, feeding on symbiotic fungi introduced into the galleries by the parental beetles (Wood 1982). Introductions of the latter seven xylomycetophagous species are assumed to have resulted from their inadvertent transport in untreated solid wood packaging. The interception of two additional non-indigenous ambrosia beetles, *E. validus* and *X. crassiusculus*, at warehouses during these studies indicates that the inadvertent transport of xylomycetophagous Scolytidae is continuing.

The distribution of each of the non-indigenous species across the landscape surveyed was variable, however, at least one non-indigenous scolytid was present at 87% of all locations examined between 1995 and 1999 (Table 2). As the intensity of survey efforts varied among years and locations (both in numbers of lures and traps), data presented in Table 2 likely underestimates the total number of non-indigenous Scolytidae present across all locations.

The intensive trapping program conducted in 1999 provides evidence for the invasive nature of the recently introduced Scolytidae. One or more of the species were present at 7 of the 10 locations surveyed including the most easterly location examined. At two of these locations, Port Mann and MKRF-G Road, species of recently introduced ambrosia beetles outnumbered those non-indigenous species present historically, while at 4 locations, Alaksen NWA, MKRF – A, E and K Roads and Ruby Creek, the number of species of Scolytidae in the two categories were equal. The maximum number of recently introduced species present at any one location was four at Port Mann. Surprisingly, three of the recently introduced species were also present in the Malcolm Knapp Research Forest, more than 30 km east of the nearest port facility.

The numerical dominance of recently introduced ambrosia beetles at Port Mann and Ruby Creek and their equivalence with the abundance of historically introduced taxa at two sites in the MKRF provides a further indication of the invasive nature of these species. However, the quantitative results of the 1999 trapping must be interpreted with caution as the response of individual species varies across lures. While variable efficacy between lures is of no consequence when only the presence/absence of species is considered, it can strongly bias quantitative data. Differences in the relative attractiveness of lures are most pronounced with pheromone-based lures. In the Scolytidae, such compounds function to aggregate conspecifics (and, in some instances, congeneric species) on suitable host material (Wood 1982). As a consequence, trap captures with pheromones are dominated by one or a few closely related native species (Table 4) and data obtained are not representative of

the relative abundance of all target taxa (e.g. Scolytidae) co-occurring in the sample area. Abundance data collected using compounds involved in primary attraction of species to susceptible host material (attractants in Table 1) are considered to provide better estimates of abundance as captures are not biased by species specific responses to pheromones. Additionally, pheromones are not known to occur in any of the more than 1600 species of *Xyleborus, Xyleborinus* or *Xylosandrus* (Wood 1982) and have not been reported for *X. politus*, thus detection of those taxa is reliant on other lures. Many Scolytidae are attracted to host produced volatiles, particularly ethanol alone or in combination with monoterpenes (Chénier and Philogène 1989; Schroeder and Lindelöw 1989; Byers 1992, 1995). Ethanol, produced by stressed, dying or dead hosts (Kimmerer and Kozlowski 1982), is a primary attractant of a wide range of bark and ambrosia beetles including species of all of the genera of ambrosia beetles captured in this study (Graham 1968; Cade et al. 1970; Moeck 1970, 1971; Nijholt and Schönherr 1976; Klimetzek et al. 1986; Schroeder and Lindelöw 1989; Byers 1992). For these reasons, quantitative results pooled across attractants are considered to be more representative of the relative abundances of Scolytidae during host location.

CONCLUSION

Multiple lure systems were used to detect the presence and determine the abundance of non-indigenous Scolytidae in forested habitats across an urban landscape and in adjacent industrial forest lands in southwestern British Columbia. This study demonstrates the invasive nature of recently established Scolytidae in urban and natural forest habitats in southwestern British Columbia. Three of the recently introduced ambrosia beetles, *X. politus, X. alni* and *X. germanus*, are widely distributed in urban forest habitats and have been detected in natural forest habitats in the study area. A fourth species, *T. domesticum*, is the predominant ambrosia beetle at one urban site and is present in nearby urban forests. The fifth, *X. pfeili*, is restricted to a single location where it has been consistently present over the duration of the study. The abundance of non-indigenous Scolytidae relative to native taxa indicates that introduced species are becoming a significant component of diversity in these forests. Their effect on these forest ecosystems is yet to be determined. The data from these studies provides a baseline for future evaluation of changes in the abundance and distribution of these species.

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Table 1. Lures, release devices (RD) and source of lure or active ingredient(s) used during surveys for Scolytidae and Cerambycidae with multiple funnel traps in 1999. Individual components are given for lures comprised of multiple components.

[1] Release devices (RD): 1 - ultra high release polyethylene pouch; 2 - 15 ml polyethylene bottle; 3 - bubble cap; 4 - flexlure; and 5 - three components combined in one high release polyethylene pouch.

[2] Source of lure: a – PheroTech, Inc.; and b – Aldrich Chemical Co., Inc.

Lure	Lure Components	RD[1]	Source[2]
ATTRACTANTS			
α-pinene	(1S)-(-)-α-pinene	1	a
Dipentene	p-mentha-1,8-diene, technical	2	b
3-C. *Tomicus piniperda*	(1S)-(-)-α-pinene	2	a
	terpinolene	2	a
	3-carene	2	a
Ethanol	ethanol, 95%	1	a
Methyl salicylate	methyl salicylate, 98%	2	b
PHEROMONES			
Exotic bark beetle	Ipsdienol	3	a
	methyl-butenol	3	a
	cis-verbenol	3	a
Lineatin	(1R)-1,3,3-trimethyl-4,6dioxatricyclo [3.3.1.0 2,7] nonane	4	a
Retusol	6-methyl-5-hepten-2-ol	3	a
Pityogenes chalcographus	Chalcogran	5	a
	2,3,2-methyl butenol		a
	methyl (E,Z)-2,4-dodecadienoate		a

Table 2. Number of locations surveyed between 1995 and 1999 at which one or more established non-indigenous species of Scolytidae were found in southwestern BC. Historical introductions are non-indigenous species recorded as occurring in BC prior to 1995; recent introductions include only those established species discovered during these studies.

	Number of Non-indigenous Species Present							
Category	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Historical introduction	7	19	21	7	1			
Recent introduction	29	12	9	4	1			
All introductions	7	14	9	9	11	2	2	1

Table 3. Numbers of individuals and species and percentages of native taxa and recent and historical introductions of pooled trap captures (all lures and control) of Scolytidae by location in southwestern BC during 1999. Recent and historic introductions are defined in the Table 2.

		Percentage of Individuals			No. of spp. of Scolytidae		
		Native	Introduced spp.			Introduced	
Site	**No. of Indiv.**	**spp.**	**Recent**	**Historic**	**Native**	**Recent**	**Historic**
ANWA	440	85.9	4.3	9.8	6	2	2
Port Mann	5 296	36.6	62.9	0.4	7	4	3
Kanaka Cr.	35 714	99.8		0.2	11		2
Mission MF	9 728	99.6		0.4	7		1
Ruby Creek	3 194	94.9	2.9	2.2	6	2	2
MKRF – A	5 393	95.9	2.5	1.6	9	2	2
MKRF – K	12 129	99.4	<0.1	0.6	6	1	1
MKRF – E	7 074	99.0	<0.1	1.0	7	1	2
MKRF – G	15 470	99.7	0.2	0.1	7	3	2
MKRF – F	9 823	99.8		0.2	6		2
All	104 261	96.0	3.5	0.5	17	5	3

Table 4. See next page (landscape format)

Table 5. Numbers of individuals and species and percentages of native taxa, and recent and historic introductions for pooled trap captures of Scolytidae (all attractants and control) by location in southwestern BC during 1999. Recent and historic introductions are defined in the Table 2.

		Percentage of Individuals			No. of spp. of Scolytidae		
		Native	Introduced spp.			Introduced	
Site	**No. of Indiv.**	**spp.**	**Recent**	**Historic**	**Native**	**Recent**	**Historic**
ANWA	82	25.6	22.0	52.4	5	2	2
Port Mann	184	4.3	84.2	11.4	3	4	3
Kanaka Cr.	182	76.4		23.6	6		2
Mission MF	159	59.1		40.9	5		1
Ruby Creek	182	20.3	41.8	37.9	4	2	2
MKRF – A	414	57.0	21.7	21.3	6	1	2
MKRF – K	210	65.7	0.5	33.8	5	1	1
MKRF – E	119	42.9		57.1	5		2
MKRF – G	270	84.1	8.1	7.8	6	3	2
MKRF – F	124	87.1		12.9	6		2
All sites	1 716	55.0	18.8	26.2	13	5	3

Table 4. Percentage of the total captures recovered by lure type and location, and the relative abundance of *Trypodendron lineatum* and *Gnathotrichus sulcatus* as a percentage of total captures in southwestern BC during 1999. The number of species of Scolytidae captured across all locations is given for each lure. Percentages of total captures <0.1% are denoted by an asterisk.

		Proportion of total captures										
							Malcolm Knapp Research Forest					
LURE	**No. of spp.**	**Alaksen NWA**	**Port Mann**	**Kanaka Creek**	**Mission M.F.**	**Ruby Creek**	**A Road**	**K Road**	**E Road**	**G Road**	**F Road**	**All sites**
Lineatin	10	80.4	89.3	92.4	93.9	93.6	65.7	94.6	96.3	68.4	94.6	88.5
Sulcatol	10	0.4	6.9	5.6	5.6	0.4	25.9	3.7	1.7	2.97	4.1	9.5
Chalcogran	11	0.2	0.1	*	*	0.1	0.6	*	*	0.1	*	0.1
EBB	12	0.2	0.2	*	*	0.2	0.1	*	0.2	0.1	*	0.1
Ethanol	17	16.4	1.9	1.2	0.3	4.2	5.6	0.2	1.3	1.0	1.1	1.2
α-pinene	12	0.4	0.1	0.5	0.1	0.4	0.1	1.3	*	0.2	*	0.3
Methyl salicylate	10		1.0		*	0.4	1.3	*		0.2	*	0.2
3-C *Tomicus*	12	0.2	0.2	0.1		0.5	0.2	0.1	0.2	0.2	0.1	0.1
Dipentene	14	0.9	0.2	*	*	0.2	0.3	*	0.1	*	*	0.1
Control	10	0.7	0.1			*	0.1		*	*	*	*
SPECIES												
T. lineatum		80.2	30.1	92.9	94.0	93.9	65.6	94.6	96.3	68.4	94.7	85.6
G. sulcatus		0.5	6.4	6.5	5.8	0.5	29.8	4.7	2.5	31.1	5.0	3.1

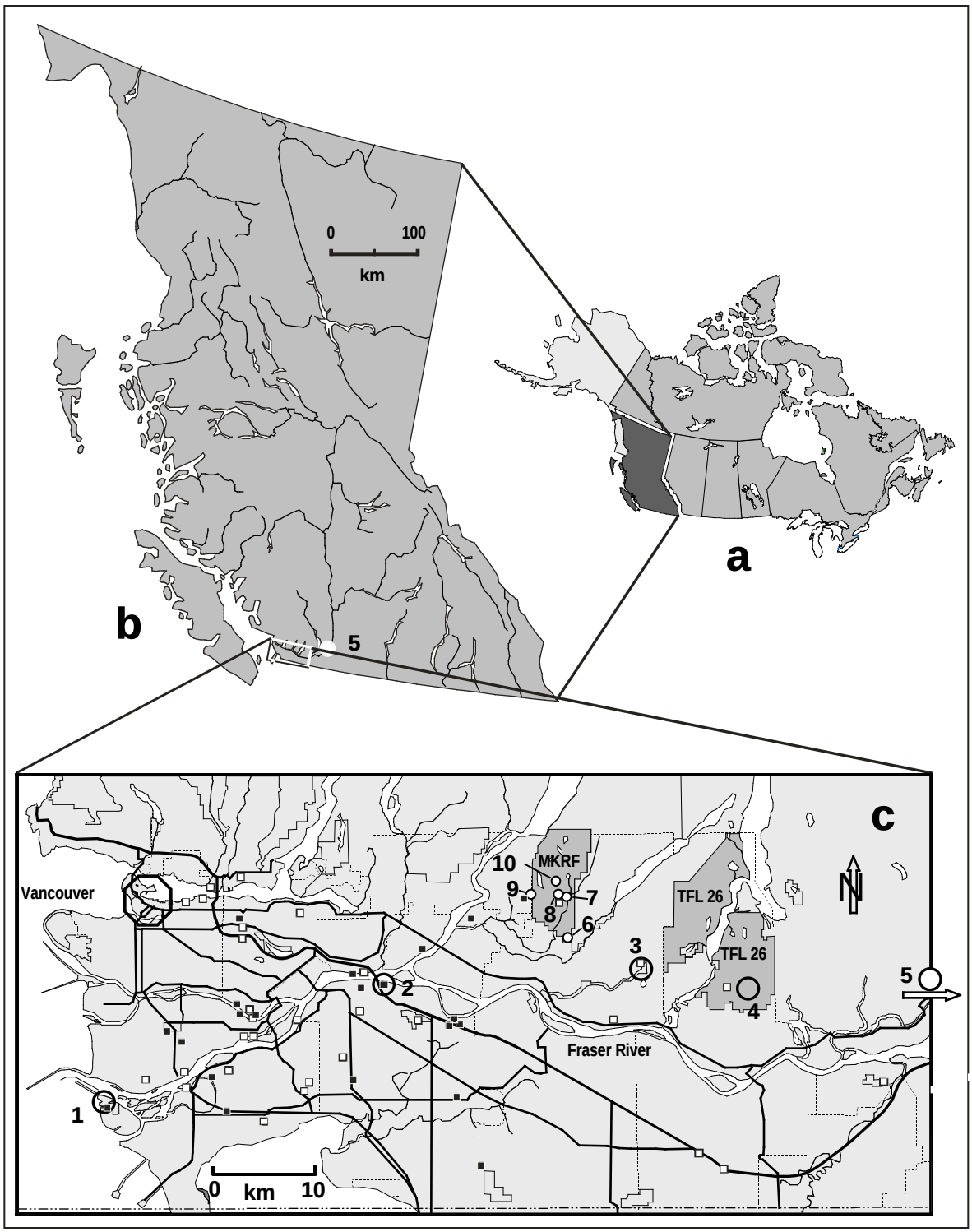

Figure 1. Location of study areas. a. British Columbia; b. location of the study area and; c. sample locations within the study area. Squares denote locations at which surveys for non-indigenous Scolytidae or Cerambycidae were conducted between 1995 and 1999: black squares – locations at which one or more non-indigenous species were discovered; white squares – no non-indigenous species present. Circles denote locations of 1999 diversity studies: 1 – Alaksen National Wildlife Area, 2 – Port Mann (abandoned landfill), 3 – Kanaka Creek Regional Park; 4 – Mission Municipal Forest (Tree Farm License 26), 5 – Ruby Creek (located 32 km east of edge of map), 6-10 – the University of British Columbia's Malcolm Knapp Research Forest (MKRF): 6 – A Road; 7 – K Road; 8 – E Road; 9 – G Road; and 10 – F Road.