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Use of native range surveys to determine the potential host range of arthropod herbivores for biological control of two related weed species, *Rhamnus cathartica* and *Frangula alnus*

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Abstract

The buckthorn species, *Rhamnus cathartica* and *Frangula alnus*, are shrubs and small trees of Eurasian origin that have become invasive in North America. A program was initiated in 2001 to reassess the potential for biological control of these two species taking into consideration increasing concerns over potential non-target impacts of biological control agents. The key question was whether *R. cathartica* and *F. alnus* are distantly enough related that they would not share the same arthropod complex in Europe, and, if so, which arthropod species would be less likely to use native North American buckthorns as hosts. Some 1000 insect samples collected at 99 sites in Europe indicated that the arthropod-species richness is higher on *R. cathartica* than on *F. alnus* and includes more species that are presumed to be host-specific at the species or genus level. This discrepancy supports the hypothesis that the genus *Rhamnus* in the temperate Old World has evolved in isolation of the genus *Frangula* in the Neotropics and that taxonomic isolation has an effect on species richness of specialized herbivores. The fauna was dominated by Lepidoptera (22 species), followed by Hemiptera (8 species), Diptera (4 species), Acarina (4 species) and Coleoptera (1 species). At least 12 arthropod species were found exclusively on *Rhamnus*, some of which may be specific to *R. cathartica*. Several species usually associated with *Rhamnus* were found rarely on *F. alnus* but the field host range of these species still needs to be confirmed. Only one species was found exclusively on *F. alnus.* The findings indicate that, with one exception, there are no species or genus-specific agents available for biological control of *F. alnus* at this stage. However, additional field surveys may reveal other host-specific species.

Keywords: *Rhamnus cathartica*; *Frangula alnus*; Buckthorn; Biological control; Species richness; Food niche; Center of origin; Taxonomic isolation; Host plant phylogeny

1. Introduction

Rhamnus cathartica L. (common buckthorn) and *Frangula alnus* Miller (glossy buckthorn) (Rhamnaceae) are two shrubs and small trees of Eurasian origin which have become invasive in North America.

Rhamnus cathartica is found throughout Europe, but is absent from most parts of Scandinavia and the Iberian Peninsula, and from the extreme south (Tutin, 1968; http://linnaeus.nrm.se/flora/di/rhamna/rhamn/rhamcat.html). The species is also present in European Russia, in south-western Siberia, in the northern Caucasus as well as in the Province of Xinjiang in China (D. Jianqing, personal communication, 2001). In Europe, *R. cathartica* prefers mesic to mesic-dry, warm open or half-shaded habitats. It grows in well drained calcareous alkaline or neutral soils, but it can also be found occasionally in swampy areas (Rameau et al., 1989).

Rhamnus cathartica was introduced to North America as an ornamental shrub in the late 1800s and was originally used for hedges, farm shelter belts, and wildlife habitats

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(Gourley, 1985; Randall and Marnelli, 1996; Gale, 2001). It has spread extensively and is currently found in most Canadian provinces (Nova Scotia to Saskatchewan) and 27 states predominantly in the north central and northeastern portion of the United States (Gale, 2001; USDA/NRCS, 2001). *Rhamnus cathartica* invades mainly woodlands and savannas, although it also occurs on prairies and open fields.

Frangula alnus has a slightly wider distribution than *R. cathartica* extending from northern Scandinavia in the boreal zone up to the Iberian Peninsula and a southernmost enclave in western North Africa (Tutin, 1968; Scamoni, 1985; Medan, 1994; http://linnaeus.nrm.se/flora/di/rhamna/frang/franaln.html). *Frangula alnus* is also present in European Russia, in south-western Siberia, in the northern Caucasus as well as in the Province of Xinjiang in China (D. Jianqing, personal communication, 2001). In Europe, *F. alnus* prefers mesic to mesic-moist acid soils in open or half-shaded habitats but it can also be found occasionally in dry calcareous stands (Rameau et al., 1989).

Frangula alnus was imported to North America prior to the 1900s as horticultural stock for landscape plantings, and has become naturalized in the northeastern US and southeastern Canada (Catling and Porebski, 1994; Randall and Marnelli, 1996; Haber, 1997). Currently, *F. alnus* occurs from Nova Scotia to Manitoba, south to Minnesota, Illinois, New Jersey and Tennessee incorporating 23 states in the US (Converse, 2001; USDA/NRCS, 2001). *Frangula alnus* is most problematic in fens and other wetlands but also can invade uplands and sandy soil forests.

Both species are very adaptable, forming dense thickets that shade and inhibit the growth of native forbs, shrubs, and tree seedlings (Heidorn, 1991; Randall and Marnelli, 1996). Both species are alternate hosts for the fungus, *Puccinia coronata* Corda, which causes oat rust disease (Harder and Chong, 1983; Leonard, 2003). *Rhamnus cathartica* and *F. alnus* are also overwintering hosts for the Asian soybean aphid, *Aphis glycines* Matsumura, a pest of soybean, *Glycine max* (L.) Merrill, which was first recorded in North America in 2000 (Voegtlin et al., 2005). American robins (*Turdus migratorius* L.) nesting in *R. cathartica* experience higher rates of predation than conspecifics nesting in native shrubs (Schmidt and Whelan, 1999).

The systematics of buckthorns has a long history of complexity and uncertainty. Linnaeus described *Rhamnus cathartica* and *Rhamnus frangula* in 1753 (Linnaeus, 1753). In 1754, Miller described the genus *Frangula*, and in 1768, transferred glossy buckthorn to this genus under the name *Frangula alnus* (Miller, 1754/1768). The generic recognition of *Frangula* has been disputed and for many years *F. alnus* has gone under the name *R. frangula* L. A recent molecular study by Bolmgren and Oxelman (2004) supports the generic recognition of *Frangula*. The global sample of *Frangula* used in their study represents a well-supported monophyletic sister clade to the rest of *Rhamnus* in its widest sense. Given the lack of resolution in the *Frangula* clade, *R. cathartica* may be considered more distantly related to the American *Rhamnus* native community than *F. alnus* is to the American native *Frangula* community.

It is difficult to obtain an accurate count of *Rhamnus* and *Frangula* species, in particular in the Old World tropics and eastern Palearctic. Grubov (1949) suggested that *Rhamnus* s.l. consists of almost 200 species but this number was reduced to 125 by Johnston and Johnston (1978). Work by the same authors on Neotropical *Rhamnus* s.l. suggests that *Frangula* has an area of diversification in the mountainous areas of the Neotropics with its southern limit in Northern Argentina. Of the 21 species recognized by Johnston and Johnston (1978) in the Neotropics, 20 belong to *Frangula* and one, *Rhamnus serrata* Humb. and Bonpl. ex J.A. Schultes, to the genus *Rhamnus*. In Europe, the genus *Rhamnus* includes 23 taxa and the genus *Frangula* includes only four taxa (Tutin, 1968; Hampe et al., 2003). In the United States, *Frangula* and *Rhamnus* include five and seven native taxa, respectively, but another two *Rhamnus* subspecies and 10 *Frangula* subspecies have been recorded (USDA/NRCS, 2001). Thus, it appears that *Rhamnus* and *Frangula* are predominant in the Old World and New World, respectively. In North America, the geographical distribution of the two invasive buckthorn species overlaps most with the native species *Rhamnus alnifolia* L'Hér., *Rhamnus lanceolata* Pursh and *Frangula caroliniana* (Walt.) Gray, making these key-species in host range studies of potential biological control agents.

Research to develop biological control for buckthorns was initiated in 1964. Surveys for potential arthropod biological control agents were carried out mostly in Eastern Austria in summer 1964 and 1965 and preliminary screening tests in 1966–1967 (Malicky et al., 1970). A new program was initiated in 2001 to reassess the potential of biological control of buckthorns with regard to the work carried out by Malicky et al. (1970). In recent years there have been ever-increasing concerns over potential non-target impacts of biological control agents and greater demands for high levels of specificity (e.g. Louda et al., 1997; Pemberton, 2000). The key question was whether *R. cathartica* and *F. alnus* are sufficiently distantly related that they would not share the same arthropod complex in Europe and, consequently which arthropod species could be selected for further host range studies, and possibly later on be used for biological control without damaging native North American buckthorns.

The aim of this study was to use both a literature review and field surveys to identify the specialized herbivorous arthropods on *R. cathartica* and *F. alnus* and to determine their host use patterns and preferences in the field. We report results of surveys carried out in Europe in 2002–2005 and review previous studies on the biological control of buckthorns for North America.

2. Materials and methods

Between 2002 and 2005, extensive surveys for presumed-specialized insect species (defined here as a species

restricted to one plant genus) on *Rhamnus* and *Frangula* spp. were carried out in Switzerland, Germany, Italy, the Czech Republic, Austria, Serbia and Montenegro. More intensive surveys were concentrated in the areas which had been sampled in previous years by Malicky et al. (1970), i.e. eastern Austria, Germany and Switzerland. In Serbia and Montenegro, selective surveys were carried out for a few specific insect species that had not been found in the other surveys. With the exception of the Czech Republic and Italy, most sites were sampled twice per season or more, or at different periods of the year for more than 1 year. Fruits were sampled in 2004–05 only. Leaves, stems and fruits were carefully examined for herbivory and symptoms of herbivory. Immature and mature phytophagous arthropods were handpicked or aspirated from young and mature buckthorn plants. In total, we surveyed *R. cathartica* and *F. alnus* at a total of 99 sites and 1000 samples were examined separately. In addition, *Rhamnus alpina* L. and *Rhamnus saxatilis* Jacq. were opportunistically surveyed at two and four sites, respectively, as they can co-occur with *R. cathartica* in the surveyed areas. Juvenile insects were reared on their field host plants in ventilated plastic containers in a shade house. Unhealthy fruits, shoot tips or small branches were collected for dissection or emergence of specific insects. Pheromone traps using a commercial lure developed for *Synanthedon myopaeformis* (Borkh.) by Plant Research International, Wageningen UR, The Netherlands, were used to detect the presence of the root-boring moth *Synanthedon stomoxiformis* Hb. The frequency of occurrence of each arthropod collected was calculated for each buckthorn species surveyed. The sampling unit was the whole habitat/site.

3. Results

In total, 39 specialized arthopods were recorded from *R. cathartica* and *F. alnus* in Europe (Table 1). Lepidoptera (22 species) largely dominated, followed by Hemiptera (8 species), Diptera (4 species), and Acarina (4 species). There was only one specialized beetle species, *Oberea pedemontana* Chevrolat, recorded on these two buckthorn species in Europe. The feeding guild on *R. cathartica* and *F. alnus* was dominated by leaf feeders (18 species), followed by sap-suckers (9 species) and flower or fruit feeders (6 species) of which four species were gall midges reported to induce galls either in the flowers or fruits of buckthorn. In addition to the gall midges, the larvae of *Hysterosia sodaliana* Haw. developed within the fruits of buckthorn and those of *Sorhagenia rhamniella* Zeller lived gregariously between spun blossoms of *R. cathartica*. There were only three shoot/root borers. The larvae of *Sorhagenia janiszewskae* Riedl developed in the shoot-tips and those of *O. pedemontana* in the branches. The larvae of *S. stomoxiformis* mined the roots of buckthorn. Of the leaf feeding phytophages, five species (i.e. *Bucculatrix frangutella* Goeze, *Bucculatrix rhamniella* Zeller, *Calybites quadrisignella* Zeller, *Stigmella catharticella* Stainton and *Stigmella rhamnella* H.-S.) mined in the leaves of buckthorn partially or during their entire life cycle. Finally, there were three leaf gall forming species, *Trichochermes walkeri* Foerster, *Trioza rhamni* Schrank and *Phyllocoptes annulatus* (Nal.). Comparatively, Brändle and Brandl (2001) found 29 specialists for a total of 91 herbivores on *Frangula* and *Rhamnus* in a study on herbivore species richness on 25 native trees in Germany.

The number of specialized arthropods was much larger on *R. cathartica* than on *F. alnus*. Twenty-two species were mostly associated with *R. cathartica* and other species in the genus *Rhamnus* (Tables 1 and 2). Of these 22 species, only eight species have also been occasionally recorded on *F. alnus* and among those, five consist of literature records, i.e. *S. rhamniella*, *Triphosa sabaudiata* Dup., *C. quadrisignella*, *S. rhamnella* and *H. sodaliana*, which were not confirmed during surveys for biological control. However, host affiliations can vary geographically (Fox and Morrow, 1981). For example, *S. rhamniella* is known from *F. alnus* in England (Emmet, 1969), an area that was not surveyed for biological control agents. Another eleven species have been found occurring on both *R. cathartica* and *F. alnus*. Of those, three species, *Ancylis apicella* Den. and Schiff., *Gonopteryx rhamni* L. and *S. janiszewskae* were found more often on *F. alnus* than on *R. cathartica* (Table 2).

The leaf-hopper *Zygina suavis* Rey was the only species found on *F. alnus* but not on *R. cathartica*, although the literature record list *R. cathartica* as a host of *Z. suavis* (Ossiannilsson, 1981). In addition to *Z. suavis*, literature records indicated another five arthropod species known from *F. alnus*, i.e. *Contarinia rhamni* Ruebs., *Dasyneura frangulae* Ruebs., *Lygocoris rhamnicolla* Reuter, *Aristotelia pancaliella* Stgr. and *Eriophyes rhamni* (Pgst.).

Records of presence or absence of most arthropods associated with *R. cathartica* and *F. alnus* in the areas surveyed in Europe in 2002–2005 matched well with those from Malicky et al. (1970) (Table 2). In contrast, the frequency of occurrence of several species differed considerably reflecting a non-random sampling method focussing on pre-selected specialized species in our surveys. *Trichochermes walkeri*, *T. rhamni* and to a slightly lesser extent *Phileremo vetulata* Den. and Schiff. and *Triphosa dubitata* L., best represented the specific arthropod community associated with *R. cathartica* in Europe.

Frangula alnus was best represented by *Z. suavis*, *G. rhamni* and *A. apicella* while *B. frangutella* and *O. pedemontana* were recorded equally on both buckthorn species. *Sorhagenia janiszewskae* has been recorded on *F. alnus* and *R. cathartica* in Austria only. The occurrence of this species has not been confirmed on *R. cathartica* in Switzerland and Germany. The frequency of occurrence of most of the other species collected was too low to draw conclusions about host specificity, but our observation matched those of Malicky et al. (1970), indicating that most of the additional species are not associated with *F. alnus* in the areas surveyed.

Table 1
Specialized arthropods associated with *Rhamnus cathartica* and *Frangula alnus* in Europe (*field records from our surveys; **Malicky et al., 1970; remaining records from literature as indicated)

Species	Host plants	Specificity[a]	Food niche	References
Coleoptera				
Cerambycidae				
Oberea pedemontana Chevrolat	*R. cathartica**, *F. alnus**, *R. alpina*, *Lonicera*?	O?	Stem, woodboring	Horion (1974); Lekic and Mihajlovic (1976); Contarini and Garagnani (1980); Baronio et al. (1988); Demelt and Franz (1990); Frisch (1992)
Diptera				
Cecidomyiidae				
Contarinia rhamni Ruebs.	*F. alnus*	M	Gall forming (flowers)	Houard (1909); Barnes (1951); Buhr (1965); Zerova et al. (1991)
Dasyneura frangulae Ruebs.	*F. alnus*	M	Gall forming (flowers)	Barnes (1951); Buhr (1965)
Lasioptera kozarzewskella Mar.	*R. cathartica*	M	Gall forming (fruits)	Stelter (1975); Zerova et al. (1991)
Wachtliella krumbholzi Stelter	*R. cathartica**	M	Gall forming (fruits)	Stelter (1975)
Heteroptera				
Miridae				
Heterocordylus erythrophtalmus Hb	*R. cathartica***, *F. alnus***	O	Sap sucking	Gollner-Scheiding (1972)
Lygocoris rhamnicola Reuter	*F. alnus*	M	Sap sucking	Coulianos (1998)
Homoptera				
Aphididae				
Aphis commensalis Stroyan	*R. cathartica*	M	Gall forming? (leaves)	Buhr (1965); Heie (1986)
Aphis mammulata Gimingh. & HRL	*R. cathartica*	M	Sap sucking, free living	Heie (1986); Blackman and Eastop (1994)
Cicadellidae				
Zygina suavis Rey	*F. alnus**/*R. cathartica*	O	Sap sucking, free living	Ossiannilsson (1981)
Psyllidae				
Cacopsylla rhamnicola (Scott)	*R. cathartica**/**/*F. alnus***	O	Sap sucking, free living	Ossiannilsson (1992)
Triozidae				
Trichochermes walkeri Foerster	*R. cathartica**/**	M	Gall forming (leaves)	Buhr (1965); Okopnyi and Poddubnyi (1983); Meyer (1987); Zerova et al. (1991); Ossiannilsson (1992); McLean (1993)
Trioza rhamni Schrank	*R. cathartica**/**/*F. alnus***	O	Gall forming (leaves)	Buhr (1965); Ossiannilsson (1992)
Lepidoptera				
Bucculatricidae				
Bucculatrix frangutella Goeze	*R. cathartica**/**/*F. alnus**/**/*R. alpina**/**	O	Leaf miner/leaf chewer	Hering (1957); Heath and Emmet (1985)
Bucculatrix rhamniella H.-S.	*R. cathartica*	M	Leaf miner/leaf chewer	Hering (1957); Buszko (1992)
Cosmopterigidae				
Sorhagenia lophyrella Douglas	*R. cathartica***/*R. saxatilis***	O	Leaf roller	Baran (1997); Malicky et al. (1970)
Sorhagenia janiszewskae Riedl	*R. cathartica**/**/*R. alpina***/*F. alnus**/**/	O	Shoot miner	Malicky et al. (1970)
Sorhagenia rhamniella Zeller	*R. cathartica***/*F. alnus*	M?	Flower feeder	Malicky et al. (1970); Emmet (1969)
Gelechiidae				
Aristotelia pancaliella Stgr.	*F. alnus*	M	Leaf chewer	Ivinskis et al. (1982)
Geometridae				
Odontognophos dumetata Treitschke	*R. cathartica*	M	Leaf chewer	Forster and Wohlfahrt (1981)
Philereme transversata Hufnagel	*R. cathartica**/**/*R. saxatilis***/*R. orbiculata***/*F. alnus***	O		(Skinner, 1984)
Philereme vetulata Den. and Schiff.	*R. cathartica*,*/**/*R. alpina***	O	Leaf chewer	Forster and Wohlfahrt (1981); Skinner (1984)

Table 1 (*continued*)

Species	Host plants	Specificity[a]	Food niche	References
Triphosa dubitata L.	*R. cathartica**/**/*R. alpina**/**/*F. alnus**/**/*Prunus* ?/ *Fraxinus* ?/ *Crataegus* ?	O?	Leaf chewer	Blaschke (1914); Forster and Wohlfahrt (1981); Skinner (1984); Jacobi and Menne (1991)
Triphosa sabaudiata Dup.	*R. cathartica***/*R. saxatilis***/*R. orbiculata***/*F. alnus*/*R. alpina*	O	Leaf chewer	Blaschke (1914); Forster and Wohlfahrt (1981)
Gracillariidae				
Calybites quadrisignella Zeller	*R. cathartica**/**/*F. alnus*	M?	Leaf miner/leaf chewer	Hering (1957)
Nepticulidae				
Stigmella catharticella Stainton	*R. cathartica**/**/*R. alaternus*	M?	Leaf miner	Hering (1957); Heath (1976); Speight and Cogan (1979); Puplyasis (1984); Puplesis (1994); Michalska (1996)
Stigmella rhamnella H.-S.	*R. cathartica**/**/*R. alpina**/*F. alnus*	O	Leaf miner	Hering (1957); Puplesis (1994); Michalska (1996)
Pieridae				
Gonopteryx rhamni L.	*R. cathartica**/**/*R. orbiculata**/*F. alnus**/**	O	Leaf chewer	Frohawk (1940); Bergmann (1952); Pollard and Hall (1980); de Freina (1983); Bibby (1983); Rippey (1984); Heath and Emmet (1989); McKay (1991); Gutierrez and Thomas (2000)
Pyralidae				
Acrobasis romanella Mill.	*R. cathartica**/*R. alaternus***	O	Lchewer	Malicky et al. (1970)
Trachycera legatea Haw.	*R. cathartica***/*R. saxatilis***	O	Leaf chewer	Mihajlovic (1978)
Sesiidae				
Synanthedon stomoxiformis Hb.	*R. cathartica**/*F. alnus**/*Sorbus aria*?/*Coryllus avelana* ?	O?	Root miner	Doczkal and Rennwald (1992); Stadie (1995); Bittermann (1997); de Freina (1997); Spatenka et al. (1999)
Tortricidae				
Ancylis apicella Den. & Schiff.	*R. cathartica**/**/*F. alnus**/**/*R. alpina***/*Ligustrum* ?/ *Cornus* ?/ *Prunus* ?	O?	Leaf chewer	Razowski (2003)
Ancylis derasana Hb. (=*unculana* Haw.)	*R. cathartica**/**/*F. alnus**/*Corylus* ?/*Rubus* ?/*Populus* ?	O?	Leaf chewer	Razowski (2003)
Ancylis obtusana Haw.	*R. cathartica*/*F. alnus*	O	Leaf chewer	Razowski (2003)
Hysterosia sodaliana Haw.	*R. cathartica***/*F. alnus*	O	Fruit feeder	Hannemann (1964); Razowski (1970)
Acari				
Eriophyidae				
Aceria rhamni Roiv.	*R. cathartica*	M	Sap sucker, free living	Amrine and Stasny (1994)
Eriophyes rhamni (Pgst)	*F. alnus*	M	Leaf erineum ?	Amrine and Stasny (1994)
Phyllocoptes annulatus (Nal.)	*R. cathartica**	M	Leaf erineum	Amrine and Stasny (1994)
Tetra rhamni Roiv.	*R. cathartica*	M	Sap sucker, free living	Amrine and Stasny (1994); Petanovic, personal communication (2005)

[a] M, monophagous, restricted to *R. cathartica* or *F. alnus*; O, oligophagous, restricted to species in the genus *Rhamnus* and/or *Frangula*.

In Serbia and Montenegro, *O. pedemontana* and *S. stomoxiformis* were recorded on *R. cathartica* and *F. alnus*, and *Wachtiella krumbholzi* Stelter reared from the fruits of the former species (Gassmann et al., 2006). According to M. Skuhrava (personal communication, 2005), *W. krumbholzi*, which was known from Northern Germany and the Czech Republic only, cannot be considered to be cecidogenous, but it is rather a seed feeder.

Rhamnus cathartica and *F. alnus* were observed growing sympatrically in 20 sites. Host plant records for 18 arthropod taxa associated with *R. cathartica* and *F. alnus* were similar in allopatric and sympatric sites (Table 3). None of the species known exclusively from *R. cathartica* in allo-

Table 2
Frequency of occurrence of specialized buckthorn arthropods in 2002–05 in Italy, Austria, Switzerland, Germany and the Czech Rep. (records from Malicky et al. (1970) are presented on shaded columns)

	Rhamnus cathartica		*Frangula alnus*	
Total # of sites sampled :	52	214	47	83
Number of sites with (%):				
LEPIDOPTERA :				
Bucculatricidae :				
Bucculatrix frangutella [4]	7 (13.5)	44 (20.6)	6 (12.8)	11 (13.3)
Cosmopterigidae :				
Sorhagenia janiszewskae [4]	13 (25.0)	9 (4.2)	14 (29.8)	14 (16.9)
Sorhagenia rhamniella	-	14 (6.5)	-	-
Sorhagenia lophyrella [3]	-	27 (12.6)	-	-
Gracillariidae :				
Calybites quadrisignella	3 (5.8)	10 (4.7)	-	-
Nepticulidae:				
Stigmella catharticella	2 (3.8)	25 (11.7)	-	-
Stigmella rhamnella [4]	1 (1.9)	2 (0.9)	-	-
Pyralidae :				
Acrobasis romanella [1]	1 (1.9)	--		-
Trachycera legatea [3]	-	3 (1.4)	-	-
Pieridae :				
Gonopteryx rhamni [2] [4] [5]	7 (13.5)	18 (8.4)	21 (44.7)	22 (26.5)
Geometridae :				
Philereme vetulata [4]	14 (26.9)	68 (31.8)	-	-
Philereme transversata [2] [3]	8 (15.4)	38 (17.8)	-	1 (1.2)
Triphosa dubitata [2] [4]	22 (42.3)	42 (19.6)	-	3 (3.6)
Triphosa sabaudiata [3]	-	2 (0.9)	-	-
Tortricidae :				
Ancylis apicella [1] [3] [4]	5 (9.6)	2 (0.9)	7 (14.9)	2 (2.4)
Ancylis derasana	6 (11.5)	9 (4.2)	3 (6.4)	-
Cochylidae:				
Hysterosia sodaliana	-	14 (6.5)	-	-
HOMOPTERA				
Psyllidae :				
Cacopsylla rhamnicola	5 (9.6)	6 (2.8)	-	1 (1.2)
Triozidae :				
Trichochermes walkeri	43 (82.7)	67 (16.8)	-	-
Trioza rhamni [4]	36 (69.2)	36 (16.8)	-	1 (1.2)
Cicadellidae :				
Zygina suavis	-	-5	(10.6)	-
HETEROPTERA				
Miridae:				
Heterocordylus erythrophtalmus	-	6 (2.8)	-	1 (1.2)
COLEOPTERA				
Cerambycidae:				
Oberea pedemontana	2 (3.8)	-2	(4.3)	-
ACARI				
Eriophyidae				
Phyllocoptes annulatus	9 (17.3)	--		-

[1] Also recorded on *Rhamnus alaternus* (Malicky et al. 1970)
[2] Also recorded on *R. orbiculata* (Malicky et al. 1970)
[3] Also recorded on *R. saxatilis* (Malicky et al. 1970)
[4] Also recorded on *R. alpina* (Malicky et al. 1970; personal observations)
[5] Also recorded on *Frangula rupestris* (Malicky et al. 1970)

patric sites have been recorded on *F. alnus* in sympatric sites, i.e. when given a proximate choice. In sympatric sites, *S. janiszewskae* and *G. rhamni* were the only species that were recorded more often on *F. alnus* than on *R. cathartica.*

Preliminary screening tests with *P. vetulata*, *T. dubitata* and *T. walkeri*, confirmed host plant use observed in the field and the unsuitability of *F. alnus* for insect species associated with *Rhamnus* in their native range (unpublished data). In contrast, both *Rhamnus* and *Frangula* species were suitable hosts for the larvae of *A. apicella* and *S. stomoxiformis*, two species which were recorded on both buckthorns in Europe.

4. Discussion

Assessing the risk to non-target species by a biological control agent has been a fundamental part of classical biological weed control for many decades. When developing biological control for *R. cathartica* and *F. alnus*, minimizing the risk of potential non-target effects might require the selection of agents which are specific to either *R. cathartica* or *F. alnus*. Several of the European arthropod species commonly found in areas that were surveyed during this study are considered monophagous on *R. cathartica*, or oligophagous on species in the genus *Rhamnus*.

Among the leaf chewing species associated with the genus *Rhamnus*, a geometrid, *P. vetulata*, appears to be the most specialised. Among the gall formers and sap-suckers that have been studied so far, the leaf margin gall psyllid *T. walkeri* seems to be monospecific on *R. cathartica*. There is considerable interest in this species because it attacks *R. cathartica* later in the season than *P. vetulata*. In North America, the high rate of seed production is an important element contributing to the invasiveness of *R. cathartica* (Knight et al., 2007). The seed-feeding midge, *W. krumbholzi* is considered a key candidate biocontrol agent because it could significantly reduce the seed production of common buckthorn in North America. The psyllids *C. rhamnicolla* and *T. rhamni*, the leaf miners *S. catharticella*, *C. quadrisignella* and *B. rhamniella*, the leaf chewers *T. dubitata* and *P. transversata*, and the mites *A. rhamni* and *T. rhamni* are probably specific to *R. cathartica* or to a few species in the genus *Rhamnus* and should be considered in a future phase of the project. With the possible exception of *S. janizewskae*, the few shoot borers and root borers associated with buckthorns in Europe lack host specificity at the genus level.

There are few genus-specific arthropods on *F. alnus*. Besides the leaf-hopper, *Z. suavis*, which was the most host-specific species found in this study, literature records indicate the existence of another five arthropod species known from *F. alnus* only. None of these were encountered during this study and additional surveys are needed to confirm their host ranges in the field in Europe. Current indications are that finding species-specific or genus-specific agents for biological control of *F. alnus* will be difficult.

Large numbers of herbivores are known to be associated with plants with larger geographical ranges (Lawton and Schroeder, 1977; Strong et al., 1984). *Rhamnus cathartica* and *F. alnus* have similar geographical distributions in Europe (Tutin, 1968), so range should not account for differences in the arthropod richness associated with the two

Table 3
Comparison of the frequency of occurrence of specialized buckthorn arthropods on *R. cathartica* and *F. alnus* in 59 allopatric and 20 sympatric sites (2002–05, Italy, Austria, Switzerland, Germany and the Czech Rep.)

	Allopatric sites		Sympatric sites		
Total No. of sites sampled:	32	27	20		
	Rhamnus cathartica	*Frangula alnus*	*Rhamnus cathartica*	*Frangula alnus*	*R. cathartica* and *F. alnus*
	Number of sites (%) with:		Number of sites (%) with:		
Bucculatrix frangutella	4 (12.5)	4 (14.8)	1 (5.0)	—	2 (10.0)
Sorhagenia janiszewskae	12 (37.5)	8 (29.6)	—	5 (25.0)	1 (5.0)
Calybites quadrisignella	1 (3.1)	—	2 (10.0)	—	—
Stigmella catharticella	1 (3.1)	—	1 (5.0)	—	—
Stigmella rhamnella	—	—	1 (5.0)	—	—
Acrobasis romanella	—	—	1 (5.0)	—	—
Gonopteryx rhamni	1 (3.1)	14 (51.9)	2 (10.0)	3 (15.0)	4 (20.0)
Philereme vetulata	6 (18.8)	—	8 (40.0)	—	—
Philereme transversata	3 (9.4)	—	5 (25.0)	—	—
Triphosa dubitata	17 (53.1)	—	5 (25.0)	—	—
Ancylis apicella	3 (9.4)	5 (18.5)	1 (5.0)	1 (5.0)	1 (5.0)
Ancylis derasana	3 (9.4)	2 (7.4)	2 (10.0)	—	1 (5.0)
Cacopsylla rhamnicola	4 (12.5)	—	1 (5.0)	—	—
Trichochermes walkeri	26 (81.3)	—	17 (85.0)	—	—
Trioza rhamni	23 (71.9)	—	13 (65.5)	—	—
Zygina suavis	—	3 (11.1)	—	2 (10.0)	—
Oberea pedemontana	—	—	—	—	2 (10.0)
Phyllocoptes annulatus	6 (18.8)	—	3 (15.0)	—	—

species. Centers of diversification of weed tribes or genera, which in turn are reflected by the highest number of congeneric or contribal species, are known to be the richest source of suitable herbivore species on certain weeds (Wapshere et al., 1989). Several studies found that taxonomic relatedness contributed significantly, though slightly, to arthropod species richness (e.g. Lawton and Schroeder, 1977; Neuvonen and Niemelä, 1981; Kennedy and Southwood, 1984). This is because related plants are likely to have the same chemical and physical traits and so are more likely to share herbivore insect species. Thus, plants with close relatives in a region (low taxonomic isolation) should have more herbivore species than those growing in isolation. In a study on the species richness of phytophagous insects and mites associated with 25 native tree genera in Germany, Brändle and Brandl (2001) concluded however that the importance of taxonomic isolation affecting herbivore species richness remains ambivalent. Contradictory results may be the consequence of the degree of taxonomic isolation (genus vs tribe or family), or the origin of the plant species considered (native vs introduced), the level of specificity of the herbivores considered (specialist vs generalist) or whether only a subset of the arthropod community is included in the study.

The genera *Rhamnus* and *Frangula* are predominant in the Old World and New World, respectively. In Europe there are 23 *Rhamnus* taxa as compared to four *Frangula* taxa. Thus, it appears that the evolution of *Rhamnus* and *Frangula* in isolation has led to specialization of arthropods on *Rhamnus* and *Frangula* species, with only a few specialist species on *F. alnus* in its native range in Europe and few species which are equally associated with both buckthorn species. Although we did not consider other sources of variability in the species richness of the arthropod fauna, such as plant abundance, this work supports the hypothesis that the species richness of specialized herbivores on native trees is affected by the taxonomic isolation of their hosts. It also shows that the search for, and selection of, potential biological control agents for a target weed can be facilitated by studying the arthropod species associated with related host plants from different lineages in centers of diversification.

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