Result 1- Part 2: Investigate potential insects as biological control of European Buckthorn

BI Ref: VM01730
Issued January 2008

Reassessment of the potential for Biological Control of Buckthorns (*Rhamnus cathartica* and *Frangula alnus*)

(2002-2007)

with

a summary of work done in 2007

B. Gassmann, I. Tosevski, L. Edelmann

CABI Europe - Switzerland
Rue des Grillons 1, CH-2800 Delémont, Switzerland

Tel: ++ 41 32 421 4870
Fax: ++ 41 32 421 4871
E-mail: Europe-CH@cabi.org

Sponsored by:
- Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources (LCMR);
- Minnesota Department of Natural Resources

Table of Contents

Summary

Acknowledgments
References
Annex

Summary

In total, 39 specialized arthopods were recorded from *R. cathartica* and *F. alnus* in Europe. The feeding guild on *R. cathartica* and *F. alnus* was dominated by leaf feeders (18 species), followed by sap-suckers/leaf gall formers (12 species), flower or fruit feeders (6 species), and shoot/root borers (3 species).

The reassessment of the potential for biological control of *R. cathartica* and *F. alnus* is presented by target species and by the arthropod feeding guilds. It is based on work done in Europe from 2002-2007 on 10 selected potential biological control agents.

This reassessment is based on the assumption that candidate biological control agents should be monospecific either to *R. cathartica* or to *F. alnus* or their host range should be restricted to either a few species in the genus *Rhamnus* or to a few species in the genus *Frangula*.

A summary of 10 priority species for future research on biological control of *R. cathartica* is given in Table 1, page 13.

The discovery of genus or species specific potential biological control agents for F. alnus will undoubtfully be difficult in Europe. Priority should be given to two fruit and seed feeding midges which are likely to be specific at the species or genus level according to field records in Europe.

The last part of this report gives a summary of work carried out in 2007.

PART I

Reassessment of the potential for biological control of *R. cathartica* and *F. alnus*

Introduction

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

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 (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 U.S. states predominantly in the north central and northeastern portion of the United States (Gale, 2001; USDA/NRCS, 2001).

Rhamnus cathartica is found throughout Europe, but is absent from most parts of Scandinavia and the Iberian Peninsula, and from the extreme south. It prefers mesic to mesic-dry warm open or half-shaded habitats. It grows best in calcareous alkaline or neutral soils but it can also be found occasionally in humid or swampy areas (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 USA 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 USA (Converse 2001; USDA/NRCS 2001).

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. In temperate Europe, *Frangula alnus* grows in various open to half shaded habitats. It can be found occasionally in dry calcareous stands but it is usually a widespread woody pioneer species on acid, moist soils (Rameau et al. 1989).

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 programme 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 species or genus specific to be selected for further host range studies, and possibly later on be used for biological control of either *R. cathartica* or *F. alnus* without damaging native North American buckthorns.

The reassessment of the potential for biological control of *R. cathartica* and *F. alnus* is presented by target species and by the arthropod feeding guilds. It is based on work done in Europe from 2002-2007 on 10 selected potential biological control agents (Gassmann et al. 2004; 2006; 2007).

The last part of this report gives a summary of work carried out in 2007.

The arthropod fauna on *R. cathartica* and *F. alnus* in Europe

In total, 39 specialized arthopods were recorded from *R. cathartica* and *F. alnus* in Europe (Annex 1). The feeding guild on *R. cathartica* and *F. alnus* was dominated by leaf feeders (18 species), followed by sap-suckers/leaf gall formers (12 species), flower or fruit feeders (6 species), and shoot/root borers (3 species). A paper on the arthropod fauna on *R. cathartica* and *F. alnus* in Europe by A. Gassmann, I. Tosevski and L. Skinner entitled "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*" has been accepted for publication in Biological Control (2008).

Reassessment of the potential for biological control of *R. cathartica* (2002-2007)

This reassessment is based on the assumption that candidate biological control agents should be monospecific to *R. cathartica* or their host range should be restricted to a few species in the genus *Rhamnus*. In the United States, *Frangula* and *Rhamnus* include 5 and 7 native taxa respectively, but another two *Rhamnus* subspecies and ten Frangula subspecies have been recorded (USDA/NRCS, 2001). The following buckthorn species have been included in host range studies:

R. cathartica	(Europe)
R. alpina	(Europe)
R. alnifolia	(native in North America with a wide geographical distribution, largely overlapping the distribution of *R. cathartica*)
F. alnus	(Europe)
F. caroliniana	(native in North America, with a wide geographical distribution, partially overlapping the distribution of *R. cathartica*)

Internal borers

***Oberea pedemontana* (Col., Cerambycidae)**

Status: *Oberea pedemontana* has a restricted geographical distribution, mainly around the Adriatic Sea. The beetle has been recorded in Northern Italy and former Yugoslavia, and less frequently in southern Austria and southern Hungary, western

Bulgaria and Rumania and perhaps in Turkey (Baronio et al. 1988). During our surveys, *O. pedemontana* was found on *R. cathartica* and *F. alnus* in Northern Italy and Serbia. The beetle has also been reported from *R. alpina* (Sama 1988) and from *Lonicera* species (Horion 1974; Demelt and Franz 1990). However, according to Frisch (1992), the record of *O. pedemontana* on *Lonicera* is probably due to the fact that *Lonicera* can occur in mixed stands with *F. alnus* and therefore adults of *O. pedemontana* have been collected as strays on *Lonicera*. Larvae make a gallery by boring along the centre axis of the branch. The species has a two or three year life cycle.

Two pairs that were reared from field collected *F. alnus* were subsequently successfully reared on *F. alnus*. Thus, rearing (including mating and oviposition) under confined conditions is possible. No oviposition and host suitability tests have been carried out so far.

Advantages: Field observations indicate that *O. pedemontana* is a very destructive species to the host trees (Lekic and Mihajlovic 1976; our observations). High level of parasitism in its native range suggests that populations of *O. pedemontana*, once established, could build up rapidly in the areas of introduction.

Disadvantages: According to literature records (see Annex 1), the beetle lacks specificity at the genus level unless the occurrence of host races can be demonstrated; it has a two- or three-year life cycle which could hamper its establishment in North America. The collection and rearing of *O. pedemontana* is an issue: larval sampling is very destructive for the host trees and adult rearing from field-collected larvae is problematic because of the multi-year life cycle of the species; in addition no adults have ever been collected on the host trees, perhaps due to a cryptic or nocturnal adult behaviour.

Prospects for biological control: Low

Potential future work: Molecular characterisation of *O. pedemontana* from *R. cathartica* and *F. alnus* to determine the possible occurrence of host races; in depth studies of the adult behaviour and the use of light traps to collect adult beetles; choice oviposition tests with native North American species.

Synanthedon stomoxiformis (Lep., Sesiidae)

Status: This root boring moth is widely distributed in the Palaearctic area (Doczkal and Rennwald 1992; Stadie, 1995; Bittermann, 1997). There are three subspecies which are all associated with *Rhamnus* and *Frangula* species in different geographical areas in Europe. *Synanthedon stomoxyformis* ssp. *stomoxiformis* is known from *R. cathartica* and *F. alnus* from central-southern Europe to Ural. According to literature records, *Sorbus aria* (Rosaceae) and more rarely *Corylus avelana* (Corylaceae) are alternative hosts of *S. stomoxyformis* ssp. *stomoxiformis* in upper Austria (Pühringer et al 1998; Spatenka et al. 1999).

Synanthedon stomoxiformis was found relatively commonly at several *R. cathartica* sites in the Deliblastiki Pesak and Pescara region in Serbia, where its presence has been confirmed by the use of pheromone traps. According to literature, larvae have a biennial life cycle (Stadie, 1995; Spatenka et al., 1999). Eggs are laid on the trunk and branches. Newly hatched larvae crawl down or fall from the oviposition site and start mining in the stem base or root. During the second year, larvae move down, boring into the roots. In autumn, the larva build a long and visible reddish exit tube above the ground made out of scraps, sawdust and silk out of which the adult emerges the following spring.

In no-choice larval feeding and development tests, best larval development was observed on *F. alnus* and *R. alpina*. Larval survival was lower on *R. cathartica* and similar to that recorded on the North American species *R. alnifolia* and *F. caroliniana*. These tests also revealed that *S. stomoxiformis* may complete development in one year. Larval development was much faster on *R. alpina* and an entire biennial life cycle was recorded on *R. cathartica* only. No larvae were found on any of the other 11 species tested outside the genera *Rhamnus* and *Frangula*. Mating was obtained only under open field conditions. No oviposition choice tests have been carried out so far.

Advantages: Although the impact of larval feeding to the trees is not obvious, *S. stomoxiformis* is an interesting species per se as it is the only root-boring species known on buckthorn.

Disadvantages: This species lacks specificity at the genus level. Given the larval biology, oviposition may not be a reliable indicator of host plant choice in mixed stands with desirable buckthorn species. The difficulty to get mating in confinement and a possible two year life cycle on *R. cathartica* could be a handicap for the establishment of this moth in North America.

Prospects for biological control: Low

Potential future work: larval choice tests and oviposition behavioural studies.

Sorhagenia janiszewskae (Lep., Cosmopterigidae)

Status: The larvae of *S. janiszewskae* mine in the current year's shoots of buckthorns. The species is found in most parts of Europe, except south of the Alps (Malicky and Sobhian 1971). The moth was found on *R. cathartica* and *F. alnus* in eastern Austria and on *F. alnus* in southwestern Switzerland. Our observations suggest that *S. janiszewskae* most probably does not overwinter in the adult stage as indicated in the literature, but in the egg stage. The species is univoltine.

Larval transfer tests gave inconsistent results but there are indications that the physiological host range of *S. janizewskae* from *F. alnus* includes both its field host and *R. cathartica*. However, the transfer of newly hatched larvae may likely produce false positive results. Therefore, host specificity tests should rely on oviposition tests in choice and no-choice conditions. The oviposition tests carried out so far gave poor results and did not show evidence of oviposition preference of *S. janiszewskae* from *F. alnus* and *R. cathartica* for its field host plant.

Advantages: The terminal leaves of the shoots attacked by *S. janiszewskae* wilt rapidly, later they may wither and fall off or they may recover. However, the attacked shoots show a reduced growth and are much smaller than unattacked ones.

Disadvantages: The species lacks specificity at the genus level. There is no consistent evidence of the occurrence of oviposition preference of the moth for its field host plant. It is difficult to accurately predict adult emergence in spring and hence best collection time. Cut shoot-tips decay or dry quickly and this may prevent the completion of larval development. The difficulty to carry out reliable oviposition tests is a serious handicap to determine the behavioural host range of this species.

Prospects for biological control: Low.

Potential future work: Additional surveys in western Europe to confirm the occurrence of the moth on *R. cathartica* and *R. alpina* (another host plant of *S. janiszewskae* according to Malicky et al. 1970); molecular characterisation of *S. janiszewskae* from *R. cathartica* and *F. alnus* and from different geographical areas to determine the possible occurrence of genetically distinct populations with distinct host preferences; in depth studies on adult oviposition behaviour to carry out reliable oviposition tests; study of the physiological host range of *S. janizewskae* from *R. cathartica.*

Other root/shoot boring species

There are no other internal root/shoot borers known on *R. cathartica* in Europe.

Defoliators

Ancylis apicella (Lep., Tortricidae)

Status: This species has a wide distribution in Europe. *Ancylis apicella* is bivoltine and overwinters as larva in a silk web in the soil. *Ancylis apicella* was collected more frequently on *F. alnus* than on *R. cathartica*. Malicky et al. (1970) found *A. apicella* on *R. cathartica*, *R. saxatilis*, *R. alaternus* and *F. alnus.* The species was also occasionally recorded on *R. alpina.*

Preliminary screening tests with neonate larvae indicate that *A. apicella* will develop on the North American *R. alnifolia* and *F. caroliniana* as well as on *R. alpina.*

Advantages: The impact is likely to be important at high population densities due to the bivoltine life cycle of the species.

Disadvantages: This species lacks specificity at the genus level. The oviposition behaviour is unknown.

Prospects for biological control: Low.

Potential future work: None.

Ancylis derasana (Lep., Tortricidae)

Status: This species has a wide distribution in Europe. *Ancylis derasana* is bivoltine and overwinters in the larval stage. The species prefers *R. cathartica* to *F. alnus*. No other field host is known in Europe. Malicky et al. (1970) recorded *A. derasana* exclusively from *R. cathartica*.

Preliminary no choice tests with neonate larvae indicate that *F. alnus*, *F. caroliniana* and *R. alpina* are less suitable hosts than *R. cathartica* and *R. alnifolia*.

Advantages: The impact is likely to be important at high population densities due to the bivoltine life cycle of the species.

Disadvantages: The species lacks specificity at the genus level. The oviposition behaviour is unknown.

Prospects for biological control: Low.

Potential future work: Study of the oviposition behaviour; oviposition choice tests with native North American buckthorn species to determine its likely ecological host range.

Triphosa dubitata (Lep., Geometridae)

Status: *Triphosa dubitata* was found in small numbers in nearly all surveyed areas in Austria, Germany, Switzerland and the Czech Republic. The species overwinters as an adult in natural caves (Cherix 1976; Jacobi and Menne 1991). According to Malicky *et al.* (1970), females mate prior to hibernation. Eggs and first instar larvae can be found in late April. The species is univoltine.

Triphosa dubitata was recorded exclusively on *R. cathartica* and *R. alpina* during our surveys. Malicky et al. (1970) also found *Triphosa dubitata* occasionally on *R. orbiculata* and on *F. alnus* at one location.

Preliminary no-choice larval feeding tests were carried out using field-collected eggs from *R. cathartica* and *R. alpina.* Larval survival to the pupal stage was higher on *R. alnifolia* than on *R. cathartica* and *R. alpina* in both populations. No larvae developed to the pupal stage on *F. caroliniana* and *F. alnus*.

Advantages: *Triphosa dubitata* is likely to be specific to the genus *Rhamnus.* High population densities could result in heavy defoliation of buckthorn in early spring.

Disadvantages: *Rhamnus alnifolia* is a more suitable host for *T. dubitata* from either field host (*R. cathartica* and *R. alnifolia*) in no-choice larval development tests. Oviposition preference tests would be needed to assess the potential behavioural host range of *T. dubitata.* However, this is hardly feasible considering the adult biology of the species.

Prospects for biological control: Low.

Potential future work: None.

***Phileremе transversata* (Lep., Geometridae)**

Status: *Phileremе transversata* is reported to be common across Europe (Carter 1987). According to Malicky *et al.* (1965), the larvae of *P. transversata* feed on the leaves of buckthorn, but unlike *P. vetulata*, do not web the leaves together. Pupation takes place in the soil. The species is univoltine and hibernates in the egg stage.

The species was found exclusively on *R. cathartica* during our surveys. *Phileremе transversata* was occasionally also found on *R. saxatilis*, *R. orbiculata* and on *F. alnus* at one location by Malicky *et al.* (1970).

No-choice larval development tests showed that Frangula alnus *and* F. caroliniana *are not suitable host plants for larval development of* P. transversata*;* R. alnifolia *seems to be a less preferred host than* R. cathartica *(no. of pupae and pupal weight are less on* R. alnifolia*), but this result will need to be confirmed.*

Advantages: *Phileremе transversata* is likely to be specific to the genus *Rhamnus*. High population densities could result in heavy defoliation of buckthorn in early spring.

Disadvantages: The rearing of *P. transversata* is not straightforward. The oviposition behaviour is unknown.

Prospects for biological control: Medium.

Potential future work: Continue to study the physiological host range of *P. transversata* and the suitability of native North American *Rhamnus* spp.; study the oviposition behaviour and carry out oviposition choice tests.

***Phileremе vetulata* (Lep., Geometridae)**

Status: Larvae feed within young folded leaves. *Phileremе vetulata* is univoltine and overwinters in the egg stage on the bark of its host plant.

Phileremе vetulata is exclusively associated with *R. cathartica* in Europe with the exception of one record on *R. alpina* (Malicky et al. 1965).

Larval feeding and development tests on potted plants indicated that survival to pupal and adult stage was similar on *R. cathartica*, *R. alpina* and *R. alnifolia*. However, *R. alpina* and *R. alnifolia* seem to be a slightly less optimal food source for *P. vetulata*. The pupae reared on *R. alnifolia* weighed significantly less than those reared on *R. cathartica* and *R. alpina*, and the time to pupation was significantly shorter on *R. cathartica* than on *R. alnifolia* and *R. alpina*. No larval establishment or damage was observed on *F. alnus* and *F. caroliniana.* No oviposition on the field host plant was obtained in confinement.

Advantages: *Phileremeb vetulata* is specific to the genus *Rhamnus*. High population densities could result in heavy defoliation of buckthorn in early spring.

Disadvantages: The oviposition behaviour is unknown and no oviposition was recorded on *R. cathartica* in confinement, thus making oviposition tests in cages difficult, if not impossible.

Prospects for biological control: Medium

Potential future work: Further studies are needed on the oviposition behaviour of *P. vetulata*; carry out open field oviposition tests; study the progeny of females reared on *R. alnifolia*.

Other defoliators

Status: An additional 13 defoliators are known from buckthorns in Europe (Annex 1). Of these, *Gonopteryx rhamni*, *Ancylis obtusana* and *Triphosa sabaudiata* are known from both *R. cathartica* and *F. alnus*. They are therefore not further considered for biological control of *R. cathartica* in North America.

Sorhagenia lophyrella, ***Odontognophos dumetata***, ***Acrobasis romanella*** and ***Trachycera legatea*** have only been recorded from *Rhamnus* spp. in Europe (Annex 1). Whether their host range is truly restricted to the genus *Rhamnus* would deserve further attention.

Five species (i.e. ***Bucculatrix frangutella***, ***B. rhamniella***, ***Calybites quadrisignella***, ***Stigmella catharticella*** and ***S. rhamnella***) mined in the leaves of buckthorn partially or during their entire life cycle. Among these, ***B. rhamniella*** and ***S. catharticella*** appear to be the most specific ones.

Advantages: High population densities of any of those species could result in heavy defoliation of buckthorn.

Disadvantages: Several of these species seem to be uncommon in the areas surveyed in Europe. Extensive additional surveys would therefore be necessary to collect workable populations. Studies carry out so far on several other defoliators suggest that monophagy on *R. cathartica* is unlikely.

Prospects for biological control: Low-medium.

Potential future work: Extensive surveys in Europe and preliminary host-specificity tests with those species known only from the genus *Rhamnus* in Europe.

Sap-suckers

Trichochermes walkeri (Hom., Triozidae)

Status: The leaf margin curl galler *Trichochermes walkeri* is known only from *R. cathartica* in Europe. It is also one of the most common insect species on *R. cathartica* and certainly one of the most conspicuous. The galls of *T. walkeri* seem to be aggregated on certain trees, while within a tree they appear to have a more normal distribution. The species overwinters at the egg stage. Eggs are laid on leaf buds axils.

Overwintering eggs do not survive on cut shoots. The transfer of first instar larvae or older larvae from young galls onto the leaves of potted plants gave very low survival rates and therefore does not provide conclusive results to assess the physiological host range of *T. walkeri*. Therefore, host specificity tests should rely on oviposition tests and subsequent larval and gall development.

No-choice adult feeding tests indicated slightly prolonged longevity (6-7 days) on non target hosts as compared to the no-food control (5 days), suggesting that feeding probes on the non target plants may have occurred. Females fed on *R. cathartica* lived up to 60 days.

Because oviposition usually starts 3-4 weeks after adult emergence, oviposition on non target hosts can be excluded in field situations where *R. cathartica* does not occur since *T. walkeri* females will die long before oviposition starts. No-choice tests carried out with females, which had been previously exposed to *R. cathartica* for three weeks, resulted in very little oviposition on non target hosts (i.e. *R. alnifolia* and *R. alpina*). Oviposition on non target hosts was also very low in sequential no-choice tests with *R. cathartica* but also lower on the field host probably due to the fact that the adults could not feed continuously on their normal field host *R. cathartica*. Surprisingly, no eggs were obtained in single choice field cage oviposition tests with *R. catharti*ca and *R. alnifolia.*

The number of eggs laid on non target hosts (*R. alnifolia* and *R. alpina*) was too low to obtain conclusive results as to whether any gall would develop the following year.

Advantages: *Trichochermes walkeri* is most likely monophagous on *R. cathartica.* High population densities could result in heavy leaf gall formation on buckthorn in spring thus hampering the photosynthetic process.

Disadvantages: Field observations indicate that populations of *T. walkeri* can be highly fluctuating. The probability of potential disease transmission has not yet been evaluated.

Prospects for biological control: High.

Future work needed: Repeat single choice oviposition tests and no-choice adult feeding tests with native North American *Rhamnus* spp. Potential disease transmission will need to be evaluated (see also below).

Other sap-suckers

Status: Another seven Hemiptera and four Eriophyidae are known from *R. cathartica* and *F. alnus* (Annex 1).

Based on their potential host range and availability, ***Cacopsylla rhamnicolla*** **(Hom., Psyllidae)** and ***Trioza rhamni*** **(Hom., Triozidae)** seem to be the most promising potential agents for a further phase of the project.

Advantages: There are several cases, in which Homopterans have successfully been used as biological control agents against invasive weeds. One example is the excellent control of *Mimosa invisa* by the psyllid *Heteropsylla spinulosa* released in 1993 in Papua New Guinea (Kuniata and Korowi 2004). Also, the broom psyllid *Arytainilla spartiophila* has been introduced with some success in New Zealand in 1992 and in Australia in 1994 for biological control of scotch broom *Cytisus scoparius* (http://www.landcareresearch.co.nz/research/biocons/weeds/broom/Broom_psyllid1.asp; http://www.csiro.au/resources/ps22n.html).
More recently the psyllid *Boreioglycaspis melaleucae* was successfully released in 2003 in Florida against *Melaleuca quinquenervia* (Gioeli and Neal 2004). In Europe, the psyllid *Aphalara itadori* has been studied for biological control of *Fallopia japonica* (Shaw et al. 2007). This species has been shown to be highly specific and potentially damaging, and a petition for release is in preparation. Psyllids can also be serious pests of trees such as in the case of *Leucaena leucocephala* in South-East Asia (Chazeau 1987).

Disadvantages: Homopteran can also transmit diseases as in the case of the Asian citrus psyllid, *Diaphorina citri*, and the citrus greening disease (Halbert and Manjunath 2004).

Prospects for biological control: High.

Future work needed: Collect and study the biology and host range of *C. rhamnicolla* and *T. rhamni*; carry out a literature review and gather expert advice on psyllid and triozid disease transmission from both pest and beneficial species; study the presence or absence of potential diseases;

Collect and identify eriophyid mites associated with *R. cathartica* in Europe.

Fruit and seed feeders

Wachtiella krumbholzi (Dipt.; Cecidomyiidae)

Status: Not much is known about this insect which was identified by Dr. M. Skuhrava. Interestingly, with the exception of a few specimens reared from *R. cathartica* in the Czech Republic, M. Skuhrava has not found this species during 50 years of investigations on Cecidomyiidae in 1800 European localities (Simova-Tosic et al. 2000, 2004; Skuhrava et al. 2005). According to Skuhrava (pers. com. 2005), *W. krumbholzi* cannot be considered to be cecidogenous. Field observations in Serbia also suggest that *W. krumbholzi* is a seed feeder rather than a gall maker. The main characteristic of attacked fruits is similar to early fruit maturation with changes in colour. Attacked fruits become dark-red black while healthy fruits are still green. Casual observations revealed up to nine midge larvae per fruit and three larvae in one seed. The midge larvae leave the fruits and go into the soil to prepare a larval cocoon made of silk and debris.

Host range tests will rely entirely on oviposition tests. Preliminary work indicates that the midge mates and oviposits in confinement.

Advantages: Work done on midges in Europe for decades by Skuhrava and co-authors suggest that *W. krumbholzi* is specific to *R. cathartica*. The reduction of the seed production of *R. cathartica* will be a key element to reduce the spread of buckthorn in North America.

Disadvantages: Not much is known on *W. krumbholzi*, in particular its geographical distribution in Europe. The main difficulty will be to get the test plants at the right phenological stage at time of oviposition, i.e. most likely at the very early fruit development stage.

Prospects for biological control: High

Future work needed: Study the oviposition behaviour and phenological (?) requirements for successful oviposition and larval development; study the geographical range of the species in Europe and make extensive collections of fruit samples of other *Rhamnus* species to determine the field host range of *W. krumbholzi* in Europe.

Other fruit and seed feeders

Status: Another midge species known from the fruits of *R. cathartica*, ***Lasioptera kosarzewskella***, was found in the Ukraine in 1957 (M. Skuhrava pers. comm. 2004). This species should also be considered as a potential biological control agent of *R. cathartica*.

Neither ***Sorhagenia rhamniella (Lep., Cosmopterigidae)*** nor ***Hysterosia sodaliana (Lep., Tortricidae)***, which are known to feed in the fruits or the flowers of *R. cathartica* and *F. alnus* have been found during our surveys. However, none of them appears to be genus specific to be considered for biological control of *R. cathartica*.

Summary Table

A summary of 10 priority species for future work on biological control of *R. cathartica* and recommendations is provided in Table 1.

Table 1. Reassessment of the potential for biological control of *Rhamnus cathartica* based on work done in 2002-2007.

Species	Feeding guild	Field hosts	Experimental host range	Issues and comments
High priority species				
Trichochermes walkeri (*Hom., Triozidae*)	Sap-sucker/ leaf gall inducer	*R. cathartica*	*R. cathartica* / only a very few eggs were laid on *R. alnifolia* in no-choice and sequential-choice tests	1. Uncertainty regarding oviposition behaviour in large confined areas and feasibility of choice oviposition tests; 2. Potential risk of disease transmission needs to be evaluated; 3. Unstable population dynamics ?
Cacopsylla rhamnicola (*Hom., Psyllidae*	Sap-sucker	*R. cathartica*; occurrence on *F: alnus* needs to be confirmed	Not studied yet. This is a new species proposed for biological control of *R. cathartica*	1. *Psyllids* can be very damaging to their host plants; 2. Potential risk of disease transmission needs to be evaluated
Trioza rhamni (*Hom., Triozidae*)	Sap-sucker / pit-gall inducer	*R. cathartica*	Not studied yet. This is a new species proposed for biological control of *R. cathartica*	1. *Triozids* can be very damaging to their host plants; 2. Potential risk of disease transmission needs to be evaluated
Wachtiella krumbholzi (*Dipt.; Cecidomyiidae*)	Seed-feeder	*R. cathartica /*	Not studied yet	1. An important species to reduce the spread of R. cathartica; 2. Host range studies will rely on oviposition tests; 3. The main challenge will be to get test plants at the right phenological stage for oviposition tests
Lasioptera kosarzewskella (*Dipt. ; Cecidomyiidae*)	Seed-feeder	*R. cathartica*	Not studied yet	1. Additional field surveys to determine the distribution and field host range of the species
Medium priority species				
Philereme transversata (*Lep., Geometridae*)	Defoliator	*R. cathartica* / *Rhamnus* spp. / one old record on *F. alnus*	Larvae develop on *Rhamnus* spp. / *R. alnifolia* seems to be a much less suitable host than the *R. cathartica* /no oviposition tests have been carried out yet	1. Additional larval development tests need to be carried out to confirm the physiological host range; 2. Oviposition behaviour unknown; 3. Oviposition tests should be carried out; 4. Open field tests should be carried out
Philereme vetulata (*Lep., Geometridae*)	Defoliator	*Rhamnus cathartica* / *Rhamnus* spp.	Larvae develop on *Rhamnus* spp.; / Frangula spp. unsuitable for larval development	1. Oviposition behaviour unknown; 2. No oviposition occurred on the target host in confinement; 3. Additional oviposition trials should be attempted; 4. Open field tests should be carried out; 5. Study the progeny of females reared on non-target species

Bucculatrix rhamniella *(Lep., Bucculatricidae)* *Stigmella catharticella* *(Lep., Nepticulidae* *Sorhagenia lophyrella* *(Lep., Cosmopterigidae)*	Leaf miners and / or defoliators	*Rhamnus cathartica / Rhamnus* spp.	These are new species proposed for biological control of R. cathartica among several other potentially genus specific leaf feeding Lepidoptera species	1. Species probably uncommon in the areas already surveyed; 2. Additional contacts needed with lepidopteran experts in order to restrict the areas targeted for future surveys
Eryiphyidae	Sap-sucker	*R. cathartica*	Not studied yet	Determine the availability and the feasibility of working with mites associated with R. cathartica in Europe with the help of a mite expert in Serbia and Italy.

Reassessment of the potential for biological control of *Frangula alnus* (2002-2007)

This reassessment is based on the assumption that candidate biological control agents should be monospecific to *F. alnus* or their host range should be restricted to a few species in the genus *Frangula*.

Status and summary: The leaf-hopper ***Zygina suavis*** was the only species found on *F. alnus* but not on *R. cathartica*, although the literature lists *R. cathartica* as a host of *Z. suavis* (Ossiannilsson, 1981). No work has been done yet with Z. suavis.

In addition to *Z. suavis*, literature records indicated five additional arthropod species known from *F. alnus*, i.e. the gall midges ***Contarinia rhamni*** and ***Dasyneura frangulae***, the mirid bug ***Lygocoris rhamnicolla***, the Gelechiid moth ***Aristotelia pancaliella*** and the mite ***Eriophyes rhamni*** (Annex 1).

Extensive additional surveys would be needed to find and to assess the field host range of those species. The discovery of genus or species specific potential biological control agents for *F. alnus* will undoubtfully be difficult in Europe. Priority should be given to the **two fruit and seed feeding midges** which are likely to be specific at the species or genus level according to field records in Europe.

Other tasks

1. To prepare a test plant list and to submit it to TAG.

2. To start collecting and growing plant material. This task has proven to be difficult during the past years and additional considerable efforts will be needed to obtain plant material for host range testing. The difficulty is enhanced by the occurrence of the sudden oak death (*Phytophthora ramorum*) on *Frangula californica* and *F. purshiana* in North America and the need to import cuttings or rootstocks "found free from non-European isolates of *Phytophthora ramorum*" into Switzerland. It is likely that part of the host range screening will need to be done in the United States.

PART II

Summary of work done in 2007

1 *Philereme vetulata* (Lep., Geometridae)

The leaf-feeding moth *Philereme vetulata* is exclusively associated with *R. cathartica* in Europe with the exception of one record on *R. alpina* (Malicky et al. 1965). Although *P. vetulata* was found in about 20% of surveyed populations, it is usually relatively common or abundant where it occurs (Gassmann et al. 2006). Larvae of *P. vetulata* feed within folded leaves.

Collections and adult emergence

Following field collections, larvae were reared on leaves of *R. cathartica* in ventilated plastic boxes lined with moist paper to keep leaves fresh. Boxes were stored in an outdoor shelter. Pupae were kept in ventilated plastic cups half filled with vermiculite for adult emergence. A total of 112 males and 94 females emerged from the 380 larvae collected between 29 April and 3May 2007 in Switzerland (Fig 1).

In addition, 12 males and five females were reared from eggs obtained in 2006, which were transferred for larval development onto young folded leaves of potted *R. alnifolia* plants. Similarly, eight males and two females were reared from *R. alpina* from eggs obtained in 2006. These adults were used for rearing and oviposition.

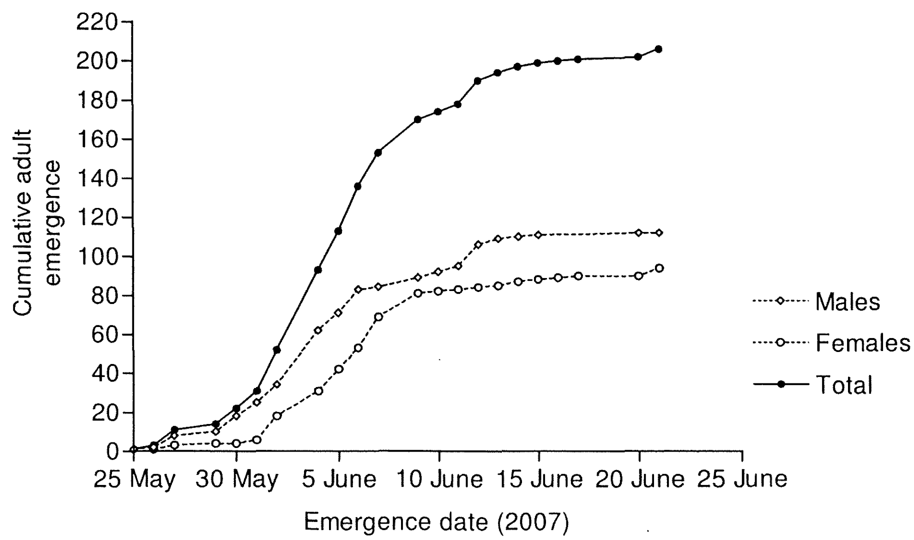

Fig 1. Emergence of *Philereme vetulata* adults reared from field collected larvae in 2007.

Adult rearing and oviposition

Between 25 May and 6 August, 50 pairs of *P. vetulata* reared from *R. cathartica* were kept individually in 50 cardboard and plastic cylinders (11cm x 15/25 cm) in an outdoor shelter. A total of 1,906 eggs were obtained of which 77% (1459 eggs) were fertile. Average fecundity per female was 38 eggs, i.e. in general lower than in previous years (Gassmann et al. 2006; 2007). Five pairs of *P. vetulata* reared from *R. alnifolia* and kept under similar conditions, laid a total of 220 eggs of which 68% (150 eggs) were fertile. Average fecundity per female was 44 eggs. No eggs were laid by two pairs of *P. vetulata* reared from *R. alpina.*

Eggs will be overwintered in an outdoor shelter and at 1°C for mass rearing on *R. cathartica* and to study the progeny by females reared on *R. alnifolia* in 2007.

Larval development

Rhamnus cathartica plants infested with newly hatched larvae were regularly dissected and larval head capsules measured. *Philereme vetulata* has four larval instars (Fig. 2). The second instar is reached after only 4-5 days at 20°C, and the third instar after 9-10 days. The last larval instar is reached during the third week.

Larval survival could not be assessed, since larvae were regularly killed to measure the head capsule size. Average pupal weight on *R. cathartica* within five days after pupation was 0.053 ± 0.01 mg (N=20). This was significantly higher than pupal weights of *P. vetulata* reared on *R. alnifolia* (0.042 ± 0.01mg; N=7; T-test; P<0.05). These data are similar to those obtained in 2006.

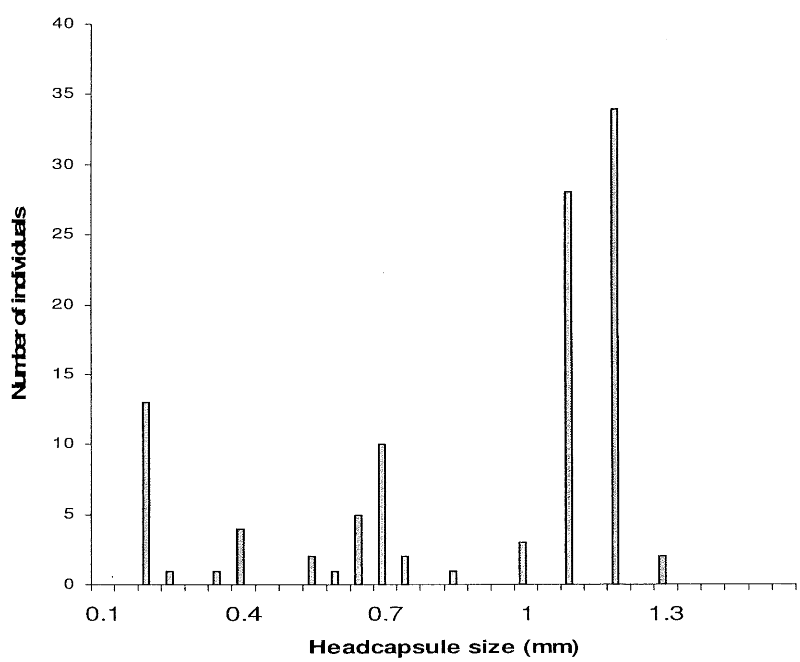

Fig 2. Headcapsule diameters of larvae of *P. vetulata* reared on *R. cathartica*

No-choice and single-choice field cage oviposition tests

In the field in Europe, *P. vetulata* has been recorded almost exclusively on *R. cathartica*. It has never been found on *F. alnus* (the single record from 2004 turned out to be a sampling mistake) and only once on *R. alpina* (Malicky et al. 1970). No-choice larval feeding and development tests carried out in 2006 (Gassmann et al. 2007) and in 2007 (data not shown) indicate that *R. alnifolia* and *R. alpina* are suitable host plants for *P. vetulata*. However, both plants seem to be providing a slightly less optimal food source for *P. vetulata* than *R. cathartica*. The pupae reared on *R. alnifolia* weighed significantly less than those reared on *R. cathartica* and *R. alpina*, and the time to pupation was significantly shorter on *R. cathartica* than on *R. alnifolia* and *R. alpina*. No larval establishment and larval damage was observed on *F. alnus* and *F. caroliniana*.

The oviposition host range was evaluated in three 2m x 2m x 1.6m field cages. All cages were protected from excess of rain and sun by green gauze covers. Tests were established between 1 and 5 June. Two cages contained three potted *R. cathartica* (about 80-100 cm high) each to check the feasibility of cage oviposition tests. The third cage contained two *R. cathartica* and two *R. alnifolia* of about the same size. Twelve pairs of *P. vetulata* were released into each cage. *Philereme vetulata* hibernates in the egg stage on the bark of its host plant (Malicky et al 1970). Therefore, the bark of all branches and trunks as well as the leaves and leaf buds were carefully checked for eggs by the end of July. No eggs were found in any of the three cage oviposition tests.

When rearing *P. vetulata* in cardboard or plastic cylinders and in smaller cages (40x40x70 cm), eggs were always found on the bottom of the rearing containers or cages. No eggs have ever been found on the cylinder/cage walls, or on smaller potted plants, branches or hanging paper provided as a support for oviposition. The field cage oviposition tests confirm that *P. vetulata* apparently does not oviposit on its host plant in confinement. Open field tests should be carried out to tentatively determine the oviposition preference of *P. vetulata*.

Trichochermes walkeri (Hom., Triozidae)

The leaf margin gall psyllid *T. walkeri* has one generation per year. Females lay small orange eggs during late summer. The nymphs hatch in spring from overwintering eggs. First-instar nymphs migrate to the leaves, feed and induce rolling of the leaf margin.

Collections and adult emergence

A total of 90 adults of *T. walkeri* emerged from 1,500 leaf margin curl galls collected between 25 July and 3 August in the Jura Mountains and in western Switzerland (Fig 3). As in previous years, galls collected in the Jura Mountains matured earlier and gave a better adult emergence rate (12%) as compared to the galls collected in western Switzerland (4%). In general, the number of adults emerged was much lower than in

2006 and 2005. The sex ratio of emerged adults was nearly 1:1. The adults were used in single-choice oviposition field cage tests.

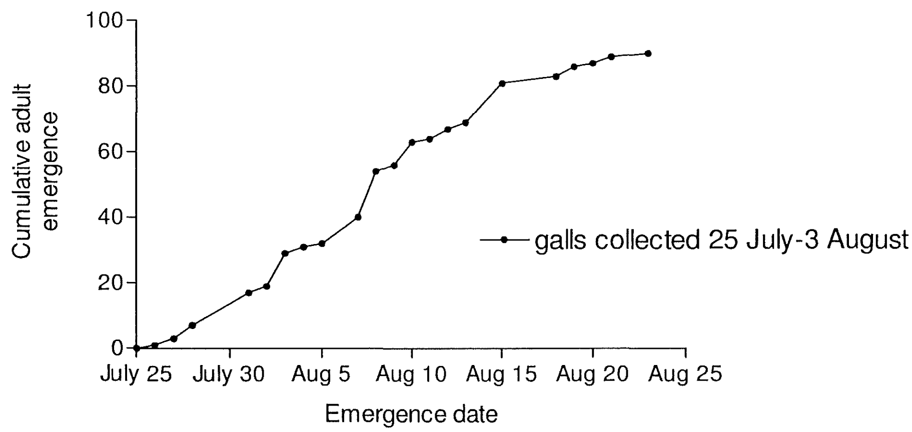

Fig 3. Emergence of *T. walkeri* adults in 2007.

Oviposition and gall development 2006-2007

Branches (n=41) of 26 potted *R. cathartica*, onto which 716 eggs of *T. walkeri*, had been laid in autumn 2006 (Gassmann et al. 2007) were protected from natural oviposition under a large gauze tent in a greenhouse until the end of November 2006, and then kept outdoors until early July 2007. The number of galls and larvae was counted during the second week of July, i.e. before the larvae leave the galls to pupate nearby on the leaves. A total of 63 galls and 51 larvae were obtained from the 716 eggs laid in 2006. A quarter of the galls (15) did not contain any larvae. Thus, only 7.1% of the eggs developed successfully into mature larvae in well developed galls. On almost half of the branches (n=19) no galls developed although 253 eggs had been laid. Gall and larval development were less successful than in 2005-2006 (Gassmann et al. 2007). Only 16 eggs and 20 eggs had been laid in 2006 on R. alnifolia and R. alpina respectively and no galls developed on these plants in 2007.

Single choice field cage oviposition tests

In 2005 and 2006, little oviposition occurred on R. alnifolia in no-choice tests, without gall and larval development recorded the following year. Single-choice oviposition tests were therefore evaluated in three 2m x 2m x 1.6m field cages All cages were protected from excess of rain and sun by green gauze covers. The tests were set-up between 30 July and 10 August. Two cages contained two potted *R. cathartica* and two potted *R. alnifolia* each, and one cage only one potted plant each of *R. cathartica* and *R. alnifolia*. Care was taken to expose plants of similar size (60-80 cm). Twelve newly emerged *T. walkeri* were released into each cage. The first cage was checked for eggs on 19 September, i.e. seven weeks after set-up. Oviposition in the other two cages was checked on 5 November. Unfortunately, no eggs were found in any of the three oviposition tests.

At this stage, it is difficult to explain why no oviposition was recorded in this trial. Oviposition tests in previous years were designed to allow close contact between the insect and its host plant in either small cages (about 40x40x70 cm in size), ventilated plastic cylinders (∅ 11.0cm, height 15cm) or even smaller ventilated plastic cups (∅ 7.0 cm, height 8.5 cm). Therefore, the absence of oviposition might result from a typical "cage effect" negatively influencing insect behaviour and oviposition. Another reason could be that too few pairs of *T. walkeri* were released. In all previous tests, about 50% adult mortality was recorded prior to oviposition, which probably resulted in only few adults surviving, to mate and to oviposit in particular under adverse weather conditions. Due to low adult emergence in 2007, we were not able to release more adults.

Conclusions and outlook: *Trichochermes walkeri* overwinters as eggs which are laid usually on the leaf axil. The manipulation and overwintering of eggs on cut material and the transfer of first instar larvae or older larvae from young galls onto the leaves of potted plants are not feasible to assess the physiological host range of *T. walkeri*. Therefore, host specificity tests should rely on oviposition tests and subsequent larval and gall development. Additional single-choice oviposition tests should be carried out in 2008 using more adults and/or smaller cages.

Wachtiella krumbholzi (Dipt.; Cecidomyiidae)

In 2004, preliminary collections of flowers and fruits of *R. cathartica* were carried out in Austria, Germany, Switzerland and Serbia and an important population of the midge *Wachtiella krumbholzi* was discovered in the fruits of *R. cathartica* in northeastern Serbia. According to Skuhrava (pers. com. 2005), *W. krumbholzi* cannot be considered to be cecidogenous. Field observations in Serbia also suggest that *W. krumbholzi* is a seed feeder rather than a gall maker. The main characteristic of attacked fruits is similar to early fruit maturation with changes in colour. Attacked fruits become dark-red black while healthy fruits are still green. Gall swelling is not visible on damaged fruits. In the laboratory, the midge larvae leave the fruits and go into the soil to prepare a larval cocoon made of silk and soil debris in August.

Adult emergence from larvae collected in 2006: In early July 2006, over 5,000 fruits of *R. cathartica* apparently attacked by *W. krumbholzi* were collected in Serbia and sent to Switzerland on 14 July. Some 800 larvae have been reared from this material and transferred to Petri dishes filled with a mixture of sterilized sifted soil and vermiculite. In late August, the soil was checked and 685 larval cocoons recovered (86%). Batches of 50 larval cocoons were placed in 9x9x9 cm ventilated plastic boxes half filled with a mixture of sterilized sifted soil and vermiculite. Cocoons were either being kept in an incubator at 3°C (N=400) for overwintering or in an outdoor shelter (N=285). All fruits were kept in an outdoor shelter for emergence of additional midges or other fruit feeding insects.

Emergence of gall midge adults kept in an outdoor shelter started on 10 May 2007, i.e. at the same time as in 2006 (Gassmann et al. 2007), and was completed on May 22. Percent of emergence was low (10%), as in previous years. Adults (N=66) of an as yet undetermined braconid species emerged from the same batches of larval cocoons.

Another 150 midge adults (43♂ and 107♀) emerged from the decaying fruits overwintered in the outdoor shelter.

No-choice oviposition tests: On 18 May 2007, 20 females and 8 males of *W. krumbholzi* were released on one large R. cathartica plant with developing fruits covered with a gauze bag. On 11 July, the one fruit that was produced was dissected and one gall midge larva was found. This result is encouraging, as it indicates that *W. krumbholzi* mates and oviposits in confinement. Unfortunately, no additional oviposition tests could be carried out, because the majority of our mature *R. cathartica* trees were male trees (although they were sold as females trees), and because of the difficulty to have the female flowers pollinated. Consequently, we have bought a set of mature female *R. cathartica* trees to be used in the following years. It is also planned to keep mature trees of both sexes in a greenhouse or in large cages and to use honey bees for pollination. Hand pollination will also be considered.

Collection of gall midge larvae in 2007: Another unexpected difficulty was encountered this year as no attacked fruits could be found in Serbia in 2007. This is probably due to the high parasitism rate of the 2006 midge generation and to the extreme warm spring conditions which have occurred in the Balkans this year and which might have provoked a much earlier emergence of the adult midges. However, midge larvae have been found in the fruits of R. cathartica in southern Germany and in western Switzerland. No sign of attack was found in the fruits of *F. alnus* in the Swiss site where *R. cathartica* and *F. alnus* co-occur. A few midge larvae are being kept in an outdoor shelter for adult identification in 2008.

Shipment of plant material

In 2007 we started collaborating with Dr. Ryan Stewart, University of Illinois, and Dr. Theresa Culley, University of Cincinnati, on a preliminary project to determine the genetic structure of *R. cathartica* and *F. alnus* in the U.S. and in Europe. *Rhamnus cathartica* has been sampled at two sites in Switzerland (Geneva and Neuchâtel) and at one site in southern Germany (Zienken). *Frangula alnus* has been sampled at Neuchâtel in Switzerland where *F. alnus* and *R. cathartica* grow together. *Rhamnus cathartica* was also sampled at four sites in North, Central and East Serbia.

At each site, a few newly expanded leaves per tree were sampled and dried in silica gel. Ten trees were sampled per population/site, and one herbarium voucher specimen kept per site. GPS coordinates were recorded and digital images of the trees sampled were taken. The samples from Switzerland and Germany were sent on 18 June 2007, and the material from Serbia on 25 July 2007.

Acknowledgements

We would like to thank the Groupe d'étude et de gestion (GEG) de la Grande Caricaie for providing permission to access the natural reserve area; the Fondation rurale jurassienne (FRI) for providing meteorological data. The financial support of the Minnesota Environment and Natural Resources Trust Fund as recommended by the

Legislative Commission on Minnesota Resources (LCMR), and the Minnesota Department of Natural Resources is greatly acknowledged.

References

Baronio, P., Marini, M., Sama, G., 1988. Studies on Oberea pedemontana Chevrolat 1856 (Coleoptera, Cerambycidae) (in Italian). Monti e Boschi 39: 45-52.

Bittermann, J., 1997. Beitrag zur Kenntnis der Bionomie, Verbreitung und Gefährdung des Faulbaum-Glasflüglers *Synanthedon stomoxiformis* (Hübner, 1790). Bayern Beiträge zur Bayerischen Entomofaunistik 2: 131-139.

Carter, D. J., 1987. Raupen und Schmetterlinge Europas und ihre Futterpflanzen. *Hamburg und Berlin, Verlag Paul Parey.*

Catling, P. M., Porebski, Z. S., 1994. The history of invasion and current status of glossy buckthorn (*Rhamnus frangula*) in Southern Ontario. Canadian Field Naturalist 108: 305-310.

Chazeau, J., 1987. The *Leucaena* psyllid in south-east Asia and the Pacific: the problem and prospects of control (*Leucaena leucocephala* Lam. de Wit - *Heteropsylla cubana* Canford). Quarterly Newsletter, Asia and Pacific Plant Protection Commission, FAO, Thailand, Vol. 30, No. 3-4, pp. 31.

Cherix, D., 1976. Remarques a propos d'un Lepidoptere Trogloxene. Mitteilungen der Schweizerischen Entomologischen Gesellschaft **49**: 45-50.

Converse, C. K., 2001. Element Stewardship Abstract for *Rhamnus cathartica*, *Rhamnus frangula* (syn. *Frangula alnus*). The Nature Conservancy. Arlington, Virginia.

Demelt, C. v., Franz, H. 1990. Ein systematisches Verzeichnis aller auf oesterreichischem Gebiet festgestellten Tierarten. Coleoptera, Fam.: Cerambycidae. *Wien, Verlag der Oesterreichischen Akademie der Wissenschaft.*

Doczkal, D., Rennwald, E., 1992. Observations on the habits, distribution, and endangerment of the clearwing moth *Synanthedon stomoxiformis* (Huebner, 1790) in Baden-Wuerttemberg (Lepidoptera: Sesiidae) (in German). Atalanta Marktleuthen 23(1-2): 259-274.

Frisch, J., 1992. Ein neuer Bockkäfer für die Fauna Kärntens - *Oberea pedemontana* Chevrolat 1856 (*Coleoptera, Cerambycidae*). Carinthia II 182: 637-642.

Gale, S. W., 2001. Control of the invasive exotic *Rhamnus cathartica* in temperate North America forests. http://www.hort.agri.umn.edu/h5015/00papers/gale.htm.

Gassmann, A., Tosevski, I., Kiefer, B., Rheinhold, T., Maia, G., 2004. Biological control of buckthorns (*Rhamnus cathartica* and *Frangula alnus*). Report 2002-03. Unpublished Report, CABI Bioscience Switzerland Centre, Delémont, Switzerland, 98 pp.

Gassmann, A., Tosevski, I., Appleton, A., Cortat, G., Péré, C., Rheinhold, T., 2006. Biological control of buckthorns (*Rhamnus cathartica* and *Frangula alnus*), Report 2004-05. Unpublished Report, CABI Bioscience Switzerland Centre, Delémont, Switzerland, 62 pp.

Gassmann, A., Tosevski, I., Van Brussel, S., Schneider, H., Cortat, G., 2007. Biological control of buckthorns (*Rhamnus cathartica* and *Frangula alnus*),

Annual Report 2006. Unpublished Report, CABI Bioscience Switzerland Centre, Delémont, Switzerland, 23 pp.
Gassmann, A., Tosevski, I., Skinner, L., 2008. 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. Biological Control (Accepted).
Gioeli, K.T., Neal, A.S., 2004. Biological control of *Melaleuca quinquenervia* in Florida's natural and man-made landscapes. Proc. Fla. State Hort. Soc. 117:254-255.
Gourley, L. C., 1985. A study of the ecology and spread of buckthorn (*Rhamnus cathartica L.*) with particular reference to the University of Wisconsin arboretum. Dept. of Landscape Architecture, University of Wisconsin, Madison, Wisconsin, USA.
Haber, E., 1997. Invasive exotic plants of Canada. Fact sheet No. 6. Glossy Buckthorn - *Frangula alnus* P. Mill. http://infoweb.magi.com/~ehaber/factcbck.htlm, National Botanical Services, Ottawa, ON, Canada.
Halbert, S.E., K.L. Manjunath, K.L., 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease in citrus: a literature review and assessment of risk in Florida. Florida Entomologist 87: 330-353.
Horion, A. D., 1974. Faunistik der Mitteleuropaeischen Kaefer. Cerambycidae. Bodensee, Ueberlingen.
Jacobi, K., Menne, B., 1991. Reproductive biology of the troglophilic looper moth *Triphosa dubitata L.* (*Lepidoptera, Geometridae*). Carolinea **49**: 129-130.
Kuniata, L. S., Korowi, K.T., 2004. Bugs offer sustainable control of *Mimosa invisa* and *Sida* spp. in the Markham Valley, Papua New Guinea. Proceedings of the XI International Symposium on Biological Control of Weeds, Canberra, Australia, 27 April - 2 May, 2003, 2004, pp. 567-573.
Lekic, M., Mihajlovic, L., 1976. A contribution to the investigation of the ecology of Oberea pedemontana Chevrolat on *Rhamnus cathartica* as a host plant (in Serbian). Glasnik Sumarskog Fakulta Serbia **50**: 67-72.
Louda, S.M., Kendall, D., Connor, J., Simberloff, D., 1997. Ecological effects of an insect introduced for the biological control of weeds. Science 277: 1088-1090.
Malicky, H., Sobhian, R., Zwoelfer, H., 1965. Phytophagous insects attacking Rhamnaceae in Europe, Commonwealth Institute of Biological Control, European Station, Delémont, Switzerland**:** 24 pp.
Malicky, H., Sobhian, R., Zwölfer, H., 1970. Investigations on the possibilities of biological control of *Rhamnus cathartica* L. in Canada: Host ranges, feeding sites, and phenology of insects associated with European Rhamnaceae Zeitschrift für angewandte Entomologie 65: 77-97.
Malicky, H., Sobhian, R., 1971. Untersuchungen über Bionomie, Präimaginalstadien und Verbreitung der europäischen Sorhagenia-Arten. Beitr. Ent. **21**: 179-190.
Ossiannilson, F., 1981. The Auchenorrhyncha (Homoptera) of Fennoscandinavia and Denmark. Vol. 7, Part 2: The families Cicadidae, Cercopidae, Membracidae, and Cicadellidae (excl. Deltocephalinae), Scandinavian Science Press Ltd, 584-586.
Pemberton, R.W., 2000. Predictable risk to native plants in weed biological control. Oecologia 125: 489-494.

Pühringer, F., Ortner, S., 1998. Interessante Glasflüglernachweise aus dem Salzkammergut mit zwei für des Bundesland Salzburg neuen Arten und Anmerkungen zur Biologie (*Lepidoptera, Sesiidae*). Beitr. Naturk. Oberösterreichs 6: 133-138.

Rameau, J.C., Mansion, D., Dumé, G., Timbal, J., Lecointe, A., Dupont, P., Keller, R., 1989. Flore forestière française. Guide écologique illustré. 1. Plaines et collines. Institut pour le Développement Forestier. Ministère de l'Agriculture et de la Forêt.

Randall, J. M., Marnelli, J., 1996. Invasive plants: weeds of the global garden., Brooklyn Botanic Gardens, Inc. Brooklyn, N.Y., 111 pp.

Sama, G., 1988. Fauna D'Italia - Coleoptera, Cerambycidae, Cataloguo topographico e sinonimico. Bologna, Edizioni Calderini.

Shaw, R., Djeddour, D., Tanner, R., Seier, M., 2007. Japanese knotweed project. Progress Report, May 2007.

Simova-Tosic, D., Skuhrava, M., Skuhrava, V., 2000. Gall midges (*Diptera: Cecidomyiidae*) of Serbia. Acta Entomologica Serb. 5: 47-93.

Simova-Tosic, D., Skuhrava, M., Skuhrava, V., 2004. Gall midges (*Diptera: Cecidomyiidae*) of Croatia. Acta Soc. Zool. Bohem. 68: 133-152.

Skuhrava, M., Skuhrava, V., Dauphin, P., Coutin, R., 2005. Gall midges of France - Les Cécidomyies de France (*Diptera: Cecidomyiidae*), Mémoires de la Société Linnéenne de Bordeaux. Vol 5, 212 pp.

Spatenka, K., Gorbunov, O., Lastuvka, Z., Tosevski, I., Arita, Y., 1999. Handbook of Palearctic Macrolepidoptera. Vol. 1 Sesiidae - Clearwing Moths. Wallingford, England, Gem Publishing Company.

Stadie, D., 1995. Lebensweise und Verbreitung des Kreuzdornglasflüglers *Synanthedon stomoxiformis* (Hübner, 1790) in Thüringen und Sachsen-Anhalt (Lep., Sesiidae). Entomologische Nachrichten und Berichte 39: 219-223.

USDA/NRCS, 2001. The PLANTS Database, Version 3.1. http://plants.usda.gov, National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Annex 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) (from Gassmann et al. 2008).

Species	Host plants	Specificity[1]	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. & Schiff.	*R. cathartica*, */**/ *R. alpina***	O	leaf chewer	(Forster and Wohlfahrt, 1981; Skinner, 1984)
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	leaf chewer	(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. (= *A. 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, pers. com. 2005)

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