2003 Project Abstract

FINAL REPORT

For the Period Ending June 30, 2006

TITLE: Biological Control of European Buckthorn

PROJECT MANAGER: Luke Skinner
ORGANIZATION: Minnesota Department of Natural Resources
ADDRESS: 500 Lafayette Road, Box 25, St. Paul, MN 55155-4025

FUND: Environment and Natural Resources Trust Fund
LEGAL CITATION: ML 2003, Chap.128, Sec. 9, Subd. 05i 1

APPROPRIATION AMOUNT: $109,000

Overall Project Outcome and Results

The purpose of this project was to continue the development of biological control for European buckthorn. The main objectives of this research were to carry out surveys in Europe for potential control agents, test the host specificity of selected control agents and to carry out a survey for insects associated with buckthorn in Minnesota.

Researchers surveyed over 80 buckthorn sites in Europe (Austria, Germany, Italy, Czech Republic, Switzerland and Serbia), collecting and identifying more than 900 arthropod samples (Gassmann et al. 2006). The community of specialized arthropods associated with European buckthorn, *Rhamnus cathartica*, and glossy buckthorn, *Frangula alnus,* is largely dominated by: Lepidoptera (22 species), Hemiptera (6 species), Diptera (4 species), Coleoptera (1 species) and mites (2 species). The complex of specialized arthropods is much higher on European than glossy buckthorn.

Nine insect species were subjected to host specificity testing. This included two stem borers, five leaf feeders, one sap feeder, and one flower/fruit feeder. Initial results eliminated three of these species (one stem borer and two leaf-feeders) for attacking a variety of buckthorn species, thus lacking the specificity needed for safety. Four of the nine species tested are considered high priority for continued testing as potential control agents. These include one stem borer, one leaf feeder, one sap feeder, and one flower/fruit feeder.

A total of eight buckthorn infestations were sampled for insect fauna in southeastern Minnesota. A total of 267 species representing 82 families and 13 orders were identified. Most herbivores collected were generalists and will feed on a variety of plants. There was no substantial damage to foliage found at any of the sampled sites. We surmise that insect herbivores will not interfere with the establishment of an introduced biological control agent. However, a large diversity of generalist parasitoids and predators were collected which potentially affect the establishment of a biological control agent for common buckthorn.

Project Results Use and Dissemination

Results of this project will be published in peer-reviewed scientific journals and also in special publications and newsletters. Results also will be presented at national, regional and state scientific meetings to peers in the field, as well as to resource managers and planners who will use the results of this project. Current research will guide future efforts to develop biological controls for buckthorn.

Final LCMR 2003 Work Program Report

Project Completion Date: June 30, 2006

PROJECT TITLE: Biological Control of European Buckthorn

Project Manager: Luke Skinner
Affiliation: Minnesota Department of Natural Resources
Mailing Address: 500 Lafayette Road, Box 25
City / State / Zip : St. Paul, MN 55155-4025
Telephone Number: 651-297-3763
E-mail Address: luke.skinner@dnr.state.mn.us
FAX Number: 651-296-1811
Web Page address: www.dnr.state.mn.us

Total Biennial LCMR Project Budget:		
	LCMR Appropriation:	**$109,000**
	Minus Amount Spent:	**$109,000**
	Equal Balance:	**$ 0**
	Other:	**$ 71,800**
	Other Balance:	**$ 0**

Legal Citation: ML 2003, [Chap.128], Sec.[9], Subd. 05i 1

Appropriation Language: 5 (i) Biological control of European Buckthorn and Spotted Knapweed. $99,000 the first year and $99,000 the second year are from the trust fund. Of this amount, $54,000 the first year and $55,000 the second year are to the commissioner of natural resources to evaluate potential insects for biological control of invasive European buckthorn species. $45,000 the first year and $44,000 the second year are to the commissioner of Agriculture to assess the effectiveness of spotted knapweed biological control agents. This appropriation is available until June 30, 2006, at which time the project must be completed and final products delivered, unless an earlier date is specified in the workprogram.

II. and III. FINAL PROJECT SUMMARY:

The purpose of this project was to continue the development of biological control for European buckthorn. The main objectives of this research were to carry out surveys in Europe for potential control agents, test the host specificity of selected control agents and to carry out a survey for insects associated with buckthorn in Minnesota.

Researchers surveyed over 80 buckthorn sites in Europe (Austria, Germany, Italy, Czech Republic, Switzerland and Serbia), collecting and identifying more than 900 arthropod samples (Gassmann et al. 2006). The community of specialized arthropods associated with European buckthorn, *Rhamnus cathartica*, and glossy buckthorn, *Frangula alnus,* is largely dominated by: Lepidoptera (22 species), Hemiptera (6 species), Diptera (4 species), Coleoptera (1 species) and mites (2

species). The complex of specialized arthropods is much higher on European than glossy buckthorn.

Nine insect species were subjected to host specificity testing. This included two stem borers, five leaf feeders, one sap feeder, and one flower/fruit feeder. Initial results eliminated three of these species (one stem borer and two leaf-feeders) for attacking a variety of buckthorn species, thus lacking the specificity needed for safety. Four of the nine species tested are considered high priority for continued testing as potential control agents. These include one stem borer, one leaf feeder, one sap feeder, and one flower/fruit feeder.

A total of eight buckthorn infestations were sampled for insect fauna in southeastern Minnesota. A total of 267 species representing 82 families and 13 orders were identified. Most herbivores collected were generalists and will feed on a variety of plants. There was no substantial damage to foliage found at any of the sampled sites. We surmise that insect herbivores will not interfere with the establishment of an introduced biological control agent. However, a large diversity of generalist parasitoids and predators were collected which potentially affect the establishment of a biological control agent for common buckthorn.

IV. OUTLINE OF PROJECT RESULTS:

Result 1: Survey and collection of potential natural enemies of buckthorn.

Description: Researchers from the Center for Applied Bioscience (CABI) in Switzerland will study the distribution of potential natural enemies of *Rhamnus* spp in Europe (i.e. to locate, identify and collect potential natural enemies of *Rhamnus cathartica* and *Frangula* alnus). This work is done in Europe where buckthorn is native and natural enemies present. The number of sites to be sampled will depend on how well the surveys go in May and June 2003 (Part of EPA Grant). All research efforts will be based on current findings from the EPA grant as not to duplicate efforts. Sampling will continue through 2004 adding additional regions of Europe to locate all potential agents known and potentially new agents discovered. Special attention will be given to a dozen of species of which are believed to be specific enough to deserve further according to previous studies and information from the literature. Arthropods of potential interest include include internal root and stem boring species such *Oberea pedemontana* (Col., Cerambycidae), *Synanthedon stomoxiformis* (Lep., Sesiidae) and *Sorhagenia janiszewskae* (Lep., Cosmopterygidae); leaf miners such as *Stigmella catharticella*, (Lep., Nepticulidae), *S. rhamnella*, *Bucculatrix frangullela* (Lep., Bucculatricidae), *B. rhamniella* and *Euspilapteryx quadrisignella* (Lep., Gracillidae); leaf-eating species such as *Sorhagenia lophyllera* (Lep., Cosmopterigidae), *Scotosia vetulata* (Lep., Geometridae) and *Bucculatrix frangullela*(in late larval instar); leaf suckers such as *Heterocordylus erythrophtalmus* (Het., Miridae), and *Psylla rhamnicolla* (Hom., Psyllidae); the leaf gallers *Tetra rhamni* (Acari, Eriophyiidae) and *Trichodermes walkeri* (Hom., Triozidae).

Summary Budget Information for Result 1:	**LCMR Budget**	**$18,000**
	LCMR Balance	**$ 0**
	Other	**$ 20,000**
	Other Balance	**$ 0**

Completion Date: 9/30/2005

Final Report Summary (6/30/06)**:** Researchers surveyed over 80 buckthorn sites in Europe (Austria, Germany, Italy, Czech Republic, Switzerland and Serbia) and more than 900 field samples have collected and Identified. The community of specialized arthropods associated with common buckthorn, *Rhamnus cathartica*, and glossy buckthorn, *Frangula alnus,* in Europe is largely dominated by Lepidoptera (22 species), followed by Hemiptera (6 species), Diptera (4 species), Coleoptera (1 species) and mites (2 species). One of the most conspicuous results is that the complex of specialized arthropods is much higher on common buckthorn than glossy buckthorn (Gassmann et al. 2006).

Several species associated with European buckthorn have never been recorded on glossy buckthorn: leaf mining moths *Calybites quadrisignella*, *Stigmella catharticella* and *S. rhamnella*, leaf feeding moths *Sorhagenia lophyrella*, *S. rhamniella* and *Philereme vetulata* and jumping plant-lice *Cacopsylla rhamnicolla* and *Trichochermes walkeri.* In contrast, few species are exclusively associated with glossy buckthorn, e.g. the leafhopper *Zygina suavis* and probably the fruit gall midges *Contarinia rhamni* and *Dasyneura frangulae* (literature records). Two other species, the defoliating Lepidoptera *Gonopteryx rhamni* and *Ancylis apicella*, prefer glossy buckthorn to European buckhthorn. A few species have been equally recorded on the two target buckthorn species, i.e. the leaf-mining moth *Bucculatrix frangutella*, the shoot-tip mining moth *Sorhagenia janiszewskae* and the stem-boring beetle *Oberea pedemontana*. A root-boring moth *Synanthedon stomoxiformis* is probably associated with both target weeds in Europe as well.

Several insects associated with European buckthorn have also been recorded on other buckthorn species, but not or only rarely on glossy buckthorn (e.g. *Sorhagenia lophyrella*, *Stigmella rhamnella*, *Philereme vetulata* and *Triphosa dubitata*). This suggests rejection of glossy buckthorn by these species, which has also been observed in sites where European and glossy buckthorn co-occur. Of the four buckthorn species which have been covered in our surveys in Europe, Glossy buckthorn is the only species which prefers moist habitats and acid soils. This suggests that habitat preference may have played a role in the evolutionary history of host plant preference of several insect species.

Survey results provide us with a better understanding of the arthropod community on buckthorns in Europe. Researchers can now focus their efforts on those insect species that show a likelihood of being host specific base on their association with specific buckthorns observed in the surveys. Surveys are a necessary step to choosing potential control agents to test. See Gassmann et al. (2006) for all details regarding this result.

Result 2: Preserve and identify all potential natural enemies of buckthorns

Description: A representative sample of the insect species collected will be preserved in the field. All specimens will be mounted or preserved, and sent to the appropriate taxonomist for proper Identification. Proper identification of potential control agents is crucial to understanding plant/insect relationships and helps determine which plant will need to be tested as part of the host specificity testing.

Summary Budget Information for Result 2:	**LCMR Budget**	**$1,500**
	LCMR Balance	**$ 0**
	Other	**$ 800**
	Other Balance	**$ 0**

Completion Date: 12/30/05

Final Report Summary (6/30/06)**:** A representative sample of each insect collected has been preserved or pinned and added to the buckthorn insect collection. Any species needing further identification were sent to appropriate taxonomist identification (see Gassmann et al. 2006).

Result 3: Host specificity testing

Description: Preliminary host specificity studies will be initiated by CABI in Switzerland, on the 4 to 5 highest priority insect species. Insects will be prioritized based on their perceived potential to cause damage to buckthorn by impairing growth and/or reproduction, reduce vigor, or cause structural damage. These factors can potentially lead to buckthorn mortality. Once the highest priority species are selected, host specificity testing (make sure the insects will not eat plants native to MN and the U.S.) with native buckthorn species will be initiated. Most plants to be tested are not found in Switzerland. They will be shipped from the United States to Switzerland from various sources. Testing is done in Europe due to availability if insects and reduce risk of importing any species prior to release. Most species are collected from the wild as cuttings or as seed. Precautions are taken to ensure no soil or other plant parts are shipped with the test plants. The plants are then grown by the researcher in Switzerland and used in testing the insects. Testing procedure are determined once the insects have been identified.

Summary Budget Information for Result 3:	**LCMR Budget**	**$67,700**
	LCMR Balance	**$0**
	Other	**$51,000**
	Other Balance	**$0**

Completion Date: 6/30/06

Final Report Summary (6/30/06)**:** Insect species were prioritised for further studies and preliminary host specificity studies according to their food niche, period of

attack, visible damage to the host plant, potential availability, potential specificity and ease of rearing. Nine insect species were subjected to host specificity testing. This included two stem borers, *Synanthedon stomoxifomis* and *S. janiszewskae*; five leaf-feeders, *Ancylis apicella*, *A. derasana*, *Triphosa dubitata*, *Philereme vetulata,* and *P. transversata;* one sap feeder, *Trichochermes walkeri;* and one flowera/fruit feeder, *Wachtiella krumbholzi*.

In general, the assessment of field occurrence of the species tested matches the results of larval host suitability. For example, *Frangula alnus* and *F. caroliniana* were not suitable hosts for the leaf feeding geometrids *Triphosa dubitata* and *P. vetulata* which have not been found on *F. alnus* in most recent surveys.

The North American species *R. alnifolia* is a suitable host for larval development of most insect species tested and thus it seems to be closely related to *R. cathartica*. In contrast, European *R. alpina* is probably more distant to *R. cathartica* as indicated by the results of the preliminary screening tests and a recent phylogenetic work on buckthorns the main result of which supports the generic separation of *Frangula* as a well supported monophyletic sister clade to the rest of *Rhamnus* in its widest sense. In other words, European buckthorn, *R. cathartica*, is not as closely related to Glossy buckthorn, *Frangua alnus*, as we once thought and the insect communities are largely different between these two species.

Results of preliminary host range studies with several species, progress in the knowledge of the biology of some species and the discovery of the seed feeding gall midge *W. krumbholzi*, suggest refining priorities for biological control of *R. cathartica* in North America. The selection of biological control agents which attack both *R. cathartica* and *Frangula alnus* in their native range will undoubtedly increase potential non-target impacts. Therefore, it may be necessary in the future to consider primarily biological agents that are associated with only one of these species in their native range. For biological control of *R. cathartica*, it is recommended to give priority in future screening tests to the shoot-boring moth, *Sorhagenia janiszewskae*, the leaf feeding moth *Philereme vetulata*, the leaf margin curled gall psylloid *Trichochermes walkeri* and the seed feeding midge *Wachtiella krumbholzi*. Biological control of *F. alnus* with species or genus specific agents will undoubtfully be more difficult. Additional field surveys are required before prioritizing potential biological agents for *F. alnus*.

These results have allowed researchers to further narrow the focus of the buckthorn biological control development. New efforts will target the recommended species for European buckthorn. Research will be focused on continued host specificity testing and impact studies. Work on glossy buckthorn, R. alnus, will be suspended until research in near completion with European buckthorn.

Please see Gassmann et al. (2004) for all details and results for result 3.

Result 4: Survey of insects on buckthorn in Minnesota

Description: Surveys will be carried out to determine what insect species currently utilize buckthorn in Minnesota. Such surveys are needed to determine if any native or non-native insect species are currently found on buckthorn or cause damage to buckthorn. Multiple sites will be surveyed periodically throughout the growing season to capture any insect species associated with buckthorn. Any immature insect collected will be allowed to complete development for identification purposes. A representative sample of each insect species collected will be mounted or preserved, and sent to the appropriate taxonomist for proper Identification.

Summary Budget Information for Result 3:	**LCMR Budget**	**$21,800**
	Balance	**$ 0**

Completion Date: 6/30/06

Final Report Summary (6/30/06)**:** The objective of this study was to carry out a comprehensive survey of all arthropod species associated with buckthorn, in various habitat types in Minnesota. This survey provides baseline information on the availability of feeding niches for potential control agents and threats by predators or parasitoids to agent establishment.

A total of 497 and 1239 adult specimens were collected in 2004 and 2005, respectfully. The higher number of specimens collected may be explained by an earlier sampling start in 2005 in order to collect insects that are only present in early spring when foliage is expanding. Also, 2004 data may be underestimated because one species, *Metcalfa pruinosa,* was very abundant (over 100 specimens) and collection of this species stopped halfway through the 2004 sampling year.

At the time of this report, Diptera have yet to be sorted and identified. Results that follow do not include these unsorted specimens. There are 267 different species found in 82 families and 13 orders represented in the collection. Hemiptera/Homoptera (83 species) was the most abundant, followed by Hymenoptera (75 species), and Coleoptera (56 species). Several species were found in abundance in both 2004 and 2005, including: *Graphocephala coccinea* (Homoptera: Cicadellidae), *Metcalfa pruinosa* (Homoptera: Flatidae), *Lasius alienus* (Hymenoptera: Formicidae) and *Harmonia axyridis* (Coleoptera: Coccinellidae). The two Homopterans are herbivore generalists and are known to feed on many different plants. *Lasius alienus* (an ant species) was found in abundance tending aphid colonies on buckthorn and searching for food. *Harmonia axyridis* (multi colored Asian ladybeetle) is a predator that typically feeds on aphids and which is known to prefer arboreal habitats.

Immatures of five insect species were reared on buckthorn and the adults were identified as: *Acanalonia conica* (Homoptera: Acanoloniidae), *Metcalfa pruinosa* (Homoptera: Flatidae), *Neoxabea bipunctata* (Orthoptera: Gryllidae), Tortricidae spp. (Lepidoptera), and *Gyponana quebecesseus* (Homoptera: Cicadellidae). In a literature search of these five species, all are categorized as generalist herbivores that include Rhamnaceae.

Overall, there was an abundance of herbivores collected. Despite finding high densities of a few herbivore species, there was no substantial damage that could be considered sufficient to limit the growth and reproduction of buckthorn. For most of the insect species, only a few specimens were collected during the study, suggesting that they are either transient or generalists that do not commonly utilize buckthorn.

A large diversity of generalist parasitoids and predators were collected which could be a source of biotic resistance, potentially affecting the selection and establishment of a biological control agent for common buckthorn. The high number of parasitoids and predators found on buckthorn in Minnesota are all considered generalists. The most abundant generalist predator was the Multi-colored Asian lady beetle, *H. axyridis*. This coccinellid is an abundant predator that could pose a threat to certain groups of insects like psyllids if selected as bio-control agents. This non-native coccinellid could be a source of biotic resistance with the introduction and establishment of a bio-control agent especially if a vulnerable life stage is present during times of *H. axyridis* high density. How much of an impediment *H. axyridis* may be needs further study and analysis.

Please see final report by Yoder et al. (2006) for all details regarding result 4.

V. TOTAL LCMR PROJECT BUDGET :

All Results: Other: $109,000. The majority of the budget is for a contract with CABI-Switzerland to carry out the research.

TOTAL LCMR PROJECT BUDGET: $109,000 (See Attachment A)

VI. PRESENT AND FUTURE SPENDING:

A. Past Spending:
Minnesota DNR, 2000-2001, $20,000; U.S. Environmental Protection agency, 2001-2003, $75,000

B. Current Spending:
We have received an additional $50,000 from the US EPA for this research. In addition, the DNR is contributing $21,800 toward a contract with CABI. These funds are listed as "Other" within the work program.

C. Required Match (if applicable): no match required

D. Future Spending: Attempts will be made at acquire future funding from federal and state sources(LCMR, $100,000), depending on the progress of the project.

VII. Project Partners:

A. Partners Receiving LCMR Funds:

The Majority of the research will be carried out by the Center for Applied Bioscience (CABI) in Delemont, Switzerland. A contract for $155,000 ($87,200 of LCMR funds) with CABI will be executed to carryout this project. Dr. Andre Gassmann, CABI, will spend 50% of his time on this project.

Dr. David Ragsdale, University of Minnesota, will carryout surveys for insects on buckthorn in MN ($21,800). Dr. Ragsdale will spend 5% of his time on this project while his graduate student will spend 50% of their time.

B. Project Cooperators:

See Above

VIII. DISSEMINATION: It is expected that the results of this project will be published in peer-reviewed scientific journals and also in special publications and newsletters. Results also will be presented at national, regional and state scientific meetings to peers in the field, as well as to resource managers and planners who will use the results of this project

IX. LOCATION: Research will take place throughout Western Europe, with main research being carried out in Delemont, Switzerland. Surveys within Minnesota will take place in the central and southeastern portion of the state.

X. REPORTING REQUIREMENTS: Periodic work program progress reports will be submitted not later than January 2003, July 2004, January 2005, July 2005 and January 2006. A final work program report and associated products will be submitted by June 30, 2006.

XI. RESEARCH PROJECTS: See Attachment B.

Attachment A: Budge , for 2003 Projects - Summary and a Budget page for each partner **Date: 06/30/06**

Proposal Title: Biological Control of European Buckthorn, ML 2003, [Chap.128], Sec.[9], Subd. 05i 1

Project Manager Name: Luke Skinner

LCMR Requested Dollars: $ $109,000 (An additional $50,000 from U.S. Environmental Protection Agency and $21,800 from the Minnesota Department of Natural Resources has been combined with the LCMR funding to carryout the research)

2003 LCMR Proposal Budget	Result 1 Budget:	Amount Spent *(date)*	Balance (06/30/06)	Result 2 Budget:	Amount Spent *(date)*	Balance (06/30/06)	Result 3 Budget:	Amount Spent *(date)*	Balance (06/30/06)	Result 4 Budget:	Amount Spent *(date)*	Balance (06/30/06)	
	Survey and collection of natural enemies of buckthorn			Preserve and identify all potential natural enemies of buckthorns .			Host specificity testing			Survey of insects on Buckthorn in MN			
BUDGET ITEM													TOTAL FOR BUDGET ITEM
Contracts													
Professional/technical: Center for Applied Bioscience-Switzerand for results 1-3; University of MN for result 4	$18,000	$18,000	$0	$1,500	$1,500	$0	$67,700	67700	$0	$21,800	21800	$0	$109,000
Other contracts *(with whom?, for what?) list out: personnel, equipment, etc.*													
Space rental: NOT ALLOWED	X			X			X			X			X
Other direct operating costs *(for what? – be specific)*													
Equipment / Tools *(what equipment? Give a general description and cost)*													
Office equipment & computers *(be specific)*													
Other Capital equipment *(list specific items)*													
Land acquisition *(how many acres)*													
Land rights acquisition *(less than fee)*													
Printing													
Advertising													
Communications, telephone, mail, etc.													
Office Supplies *(list specific categories)*													
Other Supplies *(list specific categories)*													
Travel expenses in Minnesota													
Travel outside Minnesota *(where?)*													
Other land improvement *(for what?)*													
Other *(Describe the activity and cost)*													
COLUMN TOTAL	$18,000	$18,000	$0	$1,500	$1,500	$0	$67,700	$67,700	$0	$21,800	$21,800	$0	$109,000

Final Report for Result 4
(2003 LCMR- Biological Control of European Buckthorn)

Survey of Arthropod Fauna on European Buckthorn, *Rhamnus cathartica*, in Minnesota

BY

M. YODER[1], D.W. RAGSDALE[1] AND L. C. SKINNNER[2]

[1]Department of Entomology, University of Minnesota
219 Hodson Hall, 1980 Folwell Ave, St. Paul, MN 55108

[2]Minnesota Department of Natural Resources
500 Lafayette Road, St. Paul, MN 55155-4025

August 2006

Abstract

The objective of this study was to carry out a comprehensive survey of all arthropod species associated with buckthorn, in various habitat types in Minnesota. This survey provides baseline information on the availability of feeding niches for potential control agents and threats by predators or parasitoids to agent establishment. A total of eight different buckthorn infestations were sampled for insect fauna in southeastern Minnesota. In two years of sampling, a total of 267 species representing 82 families and 13 orders were collected (excluding unidentified Diptera). The majority of the species collected are represented by only a few specimens. Most herbivores collected were generalists and will feed on a variety of plants. There was no substantial damage to foliage found at any of the sampled sites. In addition, there appear to be no insects that have a feeding niche specific to common buckthorn in Minnesota. We surmise that insect herbivores will not interfere with the establishment of an introduced biological control agent. However, a large diversity of generalist parasitoids and predators were collected which could be a source of biotic resistance, potentially affecting the selection and establishment of a biological control agent for common buckthorn.

Introduction

Common buckthorn or European buckthorn, *Rhamnus cathartica* L., is non-native tree capable of growing 30 feet tall (Godwin 1943). In North America, it was originally sold as hedging; however, buckthorn's competitive abilities have allowed it to out-compete many of North America's native forest species. Buckthorn can form dense under-stories in forest habitats out-competing native plants including tree seedlings such as oaks, maples, and birches (Archibold *et al.* 1997, Catling 1997). The presence of common buckthorn has a broad range of effects on the natural ecosystem ranging from changes in soil composition to increased predation on songbirds (Heneghan *et al.* 2002, Heneghan *et al.* 2004, Schmidt and Whelan 1999). The Minnesota Department of Agriculture has placed common buckthorn on the restricted noxious weed list, which regulates the possession, transport and sale of this plant.

Multiple methods of control are currently being used against buckthorn including cut stump treatments, foliar herbicide applications and burning (Archibold *et al.* 1997, Moriarty 2005). Such control efforts are expensive (labor and materials) and for the most part are only effective on a small scale. In an attempt to develop a long-term solution for managing buckthorn, the Minnesota Department of Natural Resources initiated research on the potential for classical biological control. The initial phase of this research is to survey for potential agents in the native range of common buckthorn. Working in collaboration with CABI Bioscience Center, Switzerland, research was initiated in Europe in 2001. The goal is to introduce host specific biological control agents from Europe that can reduce the growth and abundance of buckthorn.

Prior to the introduction of any biological control agent, researchers must understand what insect species are currently utilizing common buckthorn in North America and how this may affect their establishment and control success. Biological control establishment and control success may be limited due to feeding niches occupied by native or non-native insects. Another potential threat to successful establishment could occur if a closely related insect already exists in North America and if so, if the natural enemies (parasitoids, predators, pathogens) of this native insect can attack the candidate biological control agent. Our objective was to conduct a survey of all arthropod species associated with buckthorn, with a specific focus on various Minnesota habitats known to harbor large buckthorn infestations in Minnesota. This information will provide key information in understanding the availability of feeding niches for potential control agents and provide insights on threats to agent establishment in various site types in Minnesota.

Materials and Methods

Field sites:

Seven buckthorn infestations in 2004 and six buckthorn infestations in 2005 were selected in southeastern Minnesota, for studying insect fauna on buckthorn (Table 1). Because sampling protocol was changed between years, sampled sites varied between years. Three urban landscapes included: University of Minnesota St. Paul Campus, Ramsey County (2004 only); Tierney Wood's and Hyland Park in Three Rivers Park

District, Hennepin County. Two Mississippi river basin sites were Battle Creek Park, Ramsey County; and Frontenac State Park, Goodhue County. Agricultural landscapes, located south of the Twin Cities metro area were UMORE Park, University of Minnesota Outreach, Research- Experiment station, Dakota County; Courthouse Park, Waseca County (2004 only); and Sakata State Park, Le Sueur/Rice County (2005 only).

2004 Sampling protocol:

At each site, twelve common buckthorn plants were marked for repeated sampling, four in each of three size categories, small (<1m in height), medium (1-3m), and large (>3m). All branches or all reachable branches for large trees were visually surveyed every two weeks for insect fauna, following procedures developed by collaborators at CABI, Delemont, Switzerland. At each site, two transects were surveyed monthly during the growing season. The first transect consisted of 25 consecutive buckthorn trees growing parallel to path, roadway or other opening where buckthorn had full exposure to the sun. The second transect of another 25 consecutive buckthorn trees was laid out perpendicular to the first transect. The second transect included plants growing in the under-story where seedlings grew in shade or filtered sunlight

All trees selected were visually sampled for approximately one minute. Any insect found in that time were collected and identified. Immature insects were reared to adult in the laboratory for identification. Some insects experienced high mortality rates when confined to small rearing containers with buckthorn cuttings. In these cases a sleeve cage made of "no-see-um" netting was placed over the tree to exclude predators and to contain the insects of interest until the insects molted to the adult stage in the field. Once insects in the sleeve cages reached the adult stage, representatives are collected and identified. Soft bodied insects and any immature insects that failed to reach the adult stage during rearing were preserved in vials containing 70% ethanol. Records were maintained on each insect including the site, date collected, and individual tree number for comparison between sites and among sites and years.

2005 Sampling protocol:

At each site, 50 buckthorn trees were selected for sampling; 25 consecutive trees along a roadside or path which receives direct sunlight and 25 consecutive trees located in the shaded under-story which receives shade or filtered sunlight. Each buckthorn tree was sampled for approximately 2 minutes. Insects and eggs that were found were removed, returned to the laboratory and placed into Petri dishes to allow development to the adult stage. Records were maintained on each insect relating to the location and date collected. As adults emerge, insects were preserved and identified.

For each sampling site, a survey of site characteristics was conducted which will aid in comparing the diversity and abundance of insects collected in the insect fauna survey. At each site, 10 randomly selected 1m by 1m plots were sampled. Data collected in each plot included: percent shade coverage, diameter of surrounding trees within 1m radius of plot, diameter of buckthorn trees, percent buckthorn coverage, percent native vegetation coverage and native vegetation abundance/diversity.

Results

In 2004, surveys began 24 May and ended on 24 September. In 2005, surveys began 9 May and ended on 10 September. Identified species collected on buckthorn can be found in Table 2. A total of 497 and 1239 adult specimens were collected in 2004 and 2005, respectfully. The higher number of specimens collected may be explained by an earlier sampling start in 2005 in order to collect insects that are only present in early spring when foliage is expanding. Also, 2004 data may be underestimated because one species, *Metcalfa pruinosa,* was very abundant (over 100 specimens) and collection of this species stopped halfway through the 2004 sampling year.

At the time of this report, Diptera have yet to be sorted and identified. Results that follow do not include these unsorted specimens. There are 267 different species found in 82 families and 13 orders represented in the collection. Hemiptera/Homoptera (83 species) was the most abundant, followed by Hymenoptera (75 species), and Coleoptera (56 species). Several species were found in abundance in both 2004 and 2005, including: *Graphocephala coccinea* (Homoptera: Cicadellidae), *Metcalfa pruinosa* (Homoptera: Flatidae), *Lasius alienus* (Hymenoptera: Formicidae) and *Harmonia axyridis* (Coleoptera: Coccinellidae). The two Homopterans are herbivore generalists and are known to feed on many different plants. *Lasius alienus* (an ant species) was found in abundance tending aphid colonies on buckthorn and searching for food. *Harmonia axyridis* (multi colored Asian ladybeetle) is a predator that typically feeds on aphids and which is known to prefer arboreal habitats.

We had little success in rearing immature insects to adults. Table 3 is a list of immature insects that died in the rearing process. Immatures of five insect species were reared on buckthorn and the adults were identified as: *Acanalonia conica* (Homoptera: Acanoloniidae), *Metcalfa pruinosa* (Homoptera: Flatidae), *Neoxabea bipunctata* (Orthoptera: Gryllidae), Tortricidae spp. (Lepidoptera), and *Gyponana quebecesseus* (Homoptera: Cicadellidae). In a literature search of these five species, all are categorized as generalist herbivores that include Rhamnaceae.

Discussion

One main of this study was to identify major herbivores present on common buckthorn in Minnesota. Overall, there was an abundance of herbivores collected. Despite finding high densities of a few herbivore species, there was no substantial damage that could be considered sufficient to limit the growth and reproduction of buckthorn. For most of the insect species, only a few specimens were collected during the study. This research does not show any herbivore abundant or specific enough to buckthorn that would be affected by the removal of buckthorn from Minnesota. For most of the insect species, only a few specimens were collected during the study, suggesting that they are either transient or generalists that do not commonly utilize buckthorn.

A second objective of this study was to identify possible sources of biotic resistance, like parasitoids and predators that might interfere with establishment of an introduced biological control agent. The high number of parasitoids and predators

found on buckthorn in Minnesota are all considered generalists. These parasitoids and predators may interfere with establishment and expansion of a biological control agent if abundant prey is available. The most abundant generalist predator was the multi-colored Asian lady beetle, *H. axyridis*. This coccinellid is an abundant predator that could pose a threat to certain groups of insects like psyllids if selected as bio-control agents. This non-native coccinellid could be a source of biotic resistance with the establishment of a bio-control agent especially if a vulnerable life stage is present during times of *H. axyridis* high density. How much of an impediment *H. axyridis* may be needs further study and analysis.

In summary, although there is large insect guild associated with common buckthorn in Minnesota, availability of feeding niches seems likely due to the lack of insect specificity and lack of damage to buckthorn observed in the field. The large diversity of parasitoids and predators, may hinder establishment of potential biological control agent. More research, however, would be required to determine if biotic resistance could play a significant role is the success of biological control for common buckthorn.

Acknowledgements

Funding for this project was provided by the Minnesota and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources (LCMR).

Literature Cited:

Archibold, O.W., D. Brooks, and L. Delanoy. 1997. An investigation of the invasive shrub European Buckthorn, *Rhamnus cathartica* L., near Saskatoon, Saskatchewan. *Canadian Field-Naturalist* 111(4):617-621.

Catling, P.M. 1997. The problem of invading alien trees and shrubs: some observations in Ontario and a Canadian checklist. *Canadian Field-Naturalist* 111: 338-342.

Heneghan, L., C. Clay, and C. Brundage. 2002. Rapid decomposition of buckthorn litter may change soil nutrient levels. *Ecological Restoration* 20(2):108-111.

Heneghan, L., C. Rauschenberg, F, Fatemi, and M. Workman. 2004. European Buckthorn (*Rhamnus cathartica*) and its effects on some ecosystem properties in an urban woodland. *Ecological Restoration* 22(4):275-280.

Godwin, H. 1943. Biological flora of the British Isles: Rhamnaceae. *Journal of Ecology* 31:66-92.

Moriarty, J. 2005. Conventional management of buckthorn species. In L.C. Skinner (ed), *Proceedings: Symposium on the biology, ecology, and management of Garlic Mustard (*Alliaria petiolata) *and European Buckthorn* (Rhamnus cathartica), 17-18 May 2005, University of Minnesota, St. Paul, MN, pp53-54.

Schmidt, K.A., and C.J. Whelan. 1999. Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation. *Conservation Biology* 13(6):1502-1506.

Table 1. Locations of common buckthorn infestations included in arthropod surveys.

Site	County	GPS location		Site type	Sampling years
Battle Creek Park	Ramsey Co.	44.93028°N	93.02241°W	River Basin	2004-2005
Courthouse Park	Waseca Co.	44.02383°N	93.52713°W	Agriculture	2004
Frontenac State Park	Goodhue Co.	44.50360°N	92.32187°W	River Basin	2004-2005
Hyland Lake Park	Hennepin Co.	44.83088°N	93.36778°W	Urban Forest	2004-2005
Saint Paul Campus	Ramsey Co.	44.98912°N	93.18786°W	Urban Forest	2004
Sakata State Park	Le Sueur Co.	44.21834°N	93.58220°W	Agriculture	2005
Tierney Woods Park	Hennepin Co.	44.85396°N	93.39247°W	Urban Forest	2004-2005
UMORE Park	Dakota Co.	44.70401°N	93.07005°W	Agriculture	2004-2005

Table 2. Insect species collected from *Rhamnus cathartica* in Minnesota.

		No. of Specimens		
Order	**Family *Genus species***	**2004**	**2005**	**Total**
Collembola		14	51	65
	Entomobryidae sp. a	1	5	6
	Entomobryidae sp. b	11	13	24
	Entomobryidae sp. c	1	0	1
	Isotomidae sp. a	0	1	1
	Isotomidae sp. b	1	0	1
	Sminthuridae sp. a	0	6	6
	Sminthuridae sp. b	0	25	25
	Sminthuridae sp. c	0	1	1
Orthoptera		18	15	33
	Acrididae *Melanoplus viridipes*	2	1	3
	Acrididae *Melanoplus walshii*	0	1	1
	Gryllidae *Neoxabea bipunctata*	10	5	15
	Gryllidae *Oecanthus fultoni*	3	1	4
	Gryllidae *Oecanthus niveus*	0	2	2
	Tettigoniidae *Amblycorypha oblongifolia*	0	2	2
	Tettigoniidae *Conocephalus fasciatus*	1	1	2
	Tettigoniidae *Orchelimum nigripes*	0	1	1
	Tettigoniidae *Scudderia furcata*	1	1	2
	Tettigoniidae *Scudderia* sp.	1	0	1
Phasmida		2	1	3
	Heteronemiidae *Diapheromera femorata*	2	1	3
Thysanoptera		0	1	1
	Phlaeothripidae	0	1	1
Psocoptera		41	62	103
	Psocoptera sp. a	5	5	10
	Psocoptera sp. b	5	2	7
	Psocoptera sp. c	1	0	1
	Psocoptera sp. d	23	29	52
	Psocoptera sp. e	5	15	20
	Psocoptera sp. f	0	2	2
	Psocoptera sp. g	1	0	1
	Psocoptera sp. h	1	0	1
	Psocoptera sp. i	0	9	9
Hemiptera / Homoptera		149	470	619
	Anthocoridae *Orius insidiosus*	0	2	2

Miridae *Agnocoris rubicundus*	1	0	1
Miridae *Ceratocapus fuscinus*	2	1	3
Miridae *Ceratocapus modesta*	2	1	3
Miridae *Diaphnocaris provancheri*	1	1	2
Miridae *Hyaliodes harti*	7	6	13
Miridae *Hyaliodes vitripennis*	3	2	5
Miridae *Lygocoris caryae*	1	0	1
Miridae *Lygocoris viburni*	0	1	1
Miridae *Metriorrhynchomiris dislocatus*	1	0	1
Miridae *Paraproba capitata*	6	8	14
Miridae *Phytocorus spicatus*	2	4	6
Miridae *Psallus morrisoni*	1	0	1
Miridae *Reuteria bifurcata*	2	0	2
Miridae *Reuteria fuscicornis*	0	1	1
Miridae *Reuteria querei*	0	1	1
Miridae *Taedia scrupeus*	1	0	1
Miridae *Taedia pallidulus*	1	0	1
Nabidae *Lasiomerus annulatus*	10	15	25
Pentatomidae *Acrosternum hilare*	1	1	2
Pentatomidae *Banasa calva*	0	1	1
Pentatomidae *Banasa dimidiata*	1	2	3
Pentatomidae *Euschistus tristigmus*	8	9	17
Pentatomidae *Holcostethus abbreviatus*	1	0	1
Pentatomidae *Podisus maculiventris*	0	1	1
Reduviidae *Zelus luridus*	0	1	1
Reduviidae *Acholla multispinosa*	1	0	1
Rhopalidae *Boisea trivittatis*	4	0	4
Saldidae *Saldula pallipes*	0	1	1
Tingidae *Corythuca pergandei*	0	5	5
Acanaloniidae *Acanalonia bivattis*	0	1	1
Acanaloniidae *Acanalonia conica*	9	11	20
Aphididae *Aphis glycines*	7	17	24
Aphididae *Aphis glycines / nasturtii*	0	39	39
Aphididae *Aphis nasturtii*	0	26	26
Aphididae sp. a	0	1	1
Aphididae sp. b	0	1	1
Aphididae sp. c	0	1	1
Aphididae sp. d	1	0	1
Aphididae sp. e	1	0	1
Aphididae sp. f	1	2	3
Aphididae sp. g	3	0	3
Aphididae sp. h	0	2	2
Aphididae sp. i	0	2	2
Aphididae sp. j	0	1	1
Aphididae sp. k	0	1	1
Cercopidae *Clastoptera obtusa*	0	7	7
Cercopidae *Philaenus spumarius*	2	8	10

	Cicadellidae *Agalliota quadripunctata*	1	2	3
	Cicadellidae *Conenus intricatus*	1	0	1
	Cicadellidae *Empoasca distracta*	0	3	3
	Cicadellidae *Empoasca fabae*	0	1	1
	Cicadellidae *Empoasca pergrada*	0	1	1
	Cicadellidae *Empoasca sp.* a	1	0	1
	Cicadellidae *Empoasca sp.* b	0	5	5
	Cicadellidae *Empoasca sp.* c	0	4	4
	Cicadellidae *Empoasca sp.* d	1	1	2
	Cicadellidae *Empoasca sp.* e	0	2	2
	Cicadellidae *Empoasca sp.* f	0	1	1
	Cicadellidae *Empoasca sp.* g	0	1	1
	Cicadellidae *Empoasca sp.* h	0	4	4
	Cicadellidae *Graphocephala coccinea*	21	64	85
	Cicadellidae *Gyponana quebecesseus*	4	9	13
	Cicadellidae *Idiocerus formosus*	2	0	2
	Cicadellidae *Idiocerus levis*	2	0	2
	Cicadellidae *Jakradia olitorius*	9	6	15
	Cicadellidae *Osbornellus auronitens*	0	1	1
	Cicadellidae *Penthimia americana*	1	2	3
	Cicadellidae *Ponana puncticollis*	2	0	2
	Cicadellidae *Scaphytopius acutus*	0	1	1
	Cicadellidae *Typhlocyba gillellei*	0	1	1
	Derbidae *Anotia kirkaldyi*	0	1	1
	Derbidae *Anotia robertsoni*	1	0	1
	Derbidae *Cedusa incisa*	8	2	10
	Derbidae *Otiocerus wolfii*	1	0	1
	Flatidae *Metcalfa pruinosa*	11	164	175
	Membracidae *Ceresa bubalus*	0	1	1
	Membracidae *Ceresa dicevos*	0	1	1
	Membracidae *Cyrtolobus pictus*	0	1	1
	Psyllidae *Cacopsylla negundinis*	0	4	4
	Psyllidae *Livia maculipennis*	0	1	1
	Psyllidae *Pachypsylla celtidus*	0	2	2
	Psyllidae *Psylla floccosa*	2	0	2
Neuroptera		3	3	6
	Chrysopidae *Chrysoperla plorabunda*	2	1	3
	Chrysopidae *Chrysoperla rufilabris*	0	1	1
	Hemerobiidae *Hemerobius humilinus*	1	1	2
Coleoptera		89	140	229
	Anobiidae *Protheca* sp.	1	0	1
	Apionidae *Apion* sp.	0	1	1
	Attelibadae *Eugnemptus angustatus*	0	1	1
	Buprestidae *Agrilus* sp.	1	0	1
	Cantharidae *Cantharis bilineatus*	1	0	1

Cantharidae *Podabrus punctulatus*	0	1	1
Cantharidae *Podabrus rugulosus*	5	0	5
Cantharidae *Polemius laticornis*	2	0	2
Cantharidae *Rhagonycha dichrous*	1	0	1
Carabidae *Lebia* nr. *pomula*	0	1	1
Cerambycidae *Molorchus bimaculata*	0	1	1
Cerambycidae *Strangalia luteic*	1	0	1
Chrysomelidae *Diabrotica longicornis*	1	5	6
Chrysomelidae *Altica chalygea*	1	2	3
Chrysomelidae *Chaetocnema pulicaria*	2	0	2
Coccinellidae *Chilocoris stigma*	1	1	2
Coccinellidae *Coccinella septempunctata*	2	0	2
Coccinellidae *Coleomegilla maculata*	3	2	5
Coccinellidae *Harmonia axyridis*	44	68	112
Coccinellidae *Hippudamia parenthesis*	0	1	1
Coccinellidae *Psyllobora vigintimaculata*	0	2	2
Coccinellidae *Scymnus kansanus*	2	2	4
Coccinellidae *Scymnus rubricandus*	0	1	1
Corylophidae *Corylophodes marginicollis*	1	1	2
Curculionidae *Anametis granulata*	0	1	1
Curculionidae *Conotrachelus* nr. *elegans*	1	0	1
Curculionidae Entiminae	0	1	1
Curculionidae Molytinae	0	1	1
Curculionidae *Polydrosus sericeus*	2	5	7
Curculionidae *Tachypterellus quadrigibbus*	1	1	2
Curculionidae *Thysandenemis fraxini*	1	2	3
Curculionidae *Tychius picirostris*	0	1	1
Curculionidae *Tychius stephensi*	1	0	1
Melyridae *Attalus confusus*	1	1	2
Elateridae *Melanotus similis*	1	0	1
Elateridae *Athos brightwelli*	0	1	1
Elateridae *Hemicrepidius hemipodis*	0	4	4
Eucnemidae *Deltometopus amoenicorins*	0	2	2
Lampyridae *Lucielota atra*	0	1	1
Lampyridae *Lucielota punctata*	1	1	2
Lampyridae *Photinus ignitus*	1	1	2
Lampyridae *Pyractonema borealis*	0	1	1
Lampyridae *Pyractonema lucifera*	1	0	1
Lathridiidae *Melanophthalma* sp.	1	14	15
Lathridiidae *Stephostethus* sp.	0	1	1
Melandryidae *Anaspis* sp.	0	1	1
Melandryidae *Canifa* sp.	0	1	1
Mordellidae *Tolidomordella discoidea*	0	1	1
Mycetophagidae *Litargus tetraspilotus*	1	0	1
Nitidulidae *Glischrochilus quadrisignatus*	1	0	1
Pedilidae *Pedius lugubris*	0	3	3
Pedilidae *Pedius impressus*	1	4	5
Phalacridae *Olibrus* sp.	1	0	1

	Phalacridae *Phalacruis* sp.	0	1	1
	Scarabaeidae *Dichelonyx subuittata*	1	0	1
	Staphylinidae *Atheta* sp.	3	0	3
Mecoptera		4	1	5
	Bittacidae *Bittacus strigosus*	3	0	3
	Panorpidae *Panorpa helena*	1	1	2
Tricoptera		2	0	2
	Leptoceridae *Trianades* sp.	2	0	2
Lepidoptera		16	36	52
	Arctiidae *Haploa lecontei*	1	0	1
	Arctiidae *Spilosoma virginica*	0	10	10
	Pterophoridae *Platyptilia carduidae*	1	0	1
	Lymantriidae *Orgyia leucostigma*	0	1	1
	Noctuidae *Eupsilia devia*	0	2	2
	Psychidae *Thyridopteryx ephemeraeformis*	0	4	4
	Torticidae *Acleris subnivana*	0	1	1
	Torticidae *Aethes promptana*	1	0	1
	Torticidae *Choristoneura rosaceana*	4	5	9
	Torticidae *Machimia tentoriferella*	2	3	5
	Torticidae *Pandemis lamprosana*	1	1	2
	Torticidae *Olethreutes appendicea*	0	1	1
	Pyralidae *Crambus agitatellus*	1	0	1
	Pyralidae *Parapoynx badiusalis*	1	0	1
	Argyresthiidae *Argyresthia oreasthia*	2	0	2
	Gracillariidae *Phyllonorycter caryaealbella*	2	6	8
	Geometridae *Ennomos subsignaria*	0	1	1
	Geometridae *Eupithecia miserulata*	0	1	1
Diptera*		47	123	170
	Anthomyidae	6 (3)*	0	6 (3)*
	Calliphoridae	1	0	1
	Cecidomyiidae	2 (2)*	0	2 (2)*
	Chironomidae	10 (6)*	46(22)*	56 (25)
	Chloropidae	13 (6)*	0	13 (6)*
	Dolichipodidae	2 (2)*	0	2 (2)*
	Empididae	6 (4)*	0	6 (4)*
	Otitidae	1	0	1
	Muscidae	0	2 (2)*	2 (2)*
	Sciaridae	1	0	1
	Syrphidae	0	2 (2)*	2 (2)*
	Tipulidae	5 (2)*	8 (4)*	13 (5)*
	Unknown	0	57 (40)*	57 (40)*
Hymenoptera		112	336	448

Braconidae *Aliolus* sp.	0	1	1
Braconidae *Apanteles* sp.	1	0	1
Braconidae *Austrozele uniformis*	1	0	1
Braconidae *Blacus* sp.	1	0	1
Braconidae *Bracon niger*	1	0	1
Braconidae *Dinotrema* sp.	0	1	1
Braconidae *Diolcogaster* sp.	0	1	1
Braconidae *Glyptocolastes* sp.	0	1	1
Braconidae *Heterospilus* sp. a	0	2	2
Braconidae *Heterospilus* sp. b	0	1	1
Braconidae *Meterorus hyphantriae*	1	0	1
Braconidae *Meterorus indagator*	0	1	1
Ceraphionidae *Ceraphron* sp.	1	0	1
Cynipidae *Diplopepsis* sp. a	0	9	9
Cynipidae *Diplopepsis* sp. b	0	1	1
Cynipidae *Liodora* sp. a	0	7	7
Cynipidae *Liodora* sp. b	0	1	1
Diapriidae *Monelata* sp.	0	1	1
Diapriidae *Oxylabis* sp.	0	1	1
Dryinidae *Crovettia* sp.	1	0	1
Encyrtidae *Encyrtus* sp.	1	1	2
Eulophidae *Aprostocetus* sp.	0	1	1
Eulophidae	0	1	1
Eupelmidae *Anastatus* sp.	1	0	1
Figitidae *Kleidotoma* sp.	0	1	1
Figitidae *Melanips* sp.	0	1	1
Formicidae *Camponotus nearcticus*	0	2	2
Formicidae *Camponotus noveboracensis*	1	1	2
Formicidae *Formica argentea*	3	7	10
Formicidae *Formica neogagates*	0	2	2
Formicidae *Formica nitidiventris*	0	2	2
Formicidae *Lasius alienus*	24	101	125
Formicidae *Lasius neoniger*	2	0	2
Formicidae *Leptothorax ambiguus*	1	13	14
Formicidae *Leptothorax longispinosis*	0	2	2
Formicidae *Myrmica emeryana*	0	3	3
Formicidae *Prenolepis imparis*	8	30	38
Ichneumonidae *Cratichneumon nigritarius*	0	1	1
Ichneumonidae *Cratichneumon paratus*	1	0	1
Ichneumonidae *Diaglyptidae* sp.	1	0	1
Ichneumonidae *Diplazon bradleyi*	0	1	1
Ichneumonidae *Endasys praerotundiceps*	0	2	2
Ichneumonidae *Exochus* sp.	0	1	1
Ichneumonidae *Gelis* sp. a	0	1	1
Ichneumonidae *Gelis* sp. b	0	3	3
Ichneumonidae *Gelis* sp. c	0	1	1
Ichneumonidae *Gelis* sp. d	0	1	1

Ichneumonidae *Phaeogenes* sp. a	0	1	1
Ichneumonidae *Phaeogenes* sp. b	0	1	1
Ichneumonidae *Itoplectis conquisitor*	1	0	1
Ichneumonidae *Lissonota* sp.	1	0	1
Ichneumonidae *Pimpla aequalis*	1	1	2
Ichneumonidae *Polyaulon* sp.	0	1	1
Ichneumonidae *Pristomerus* sp.	1	0	1
Ichneumonidae *Sinophorus* sp.	1	0	1
Ichneumonidae *Theronia atlantae*	0	1	1
Mymaridae	1	1	2
Platygasteridae *Leptacis* sp. a	0	1	1
Platygasteridae *Leptacis* sp. b	0	1	1
Platygasteridae *Leptacis* sp. c	0	8	8
Platygasteridae *Leptacis* sp. d	0	1	1
Platygasteridae *Leptacis* sp. e	0	1	1
Platygasteridae *Leptacis* sp. f	0	4	4
Platygasteridae *Leptacis* sp. g	0	1	1
Platygasteridae *Leptacis* sp. h	0	1	1
Platygasteridae *Platygaster* sp. a	0	2	2
Platygasteridae *Platygaster* sp. b	0	3	3
Platygasteridae *Trichacis* sp. a	0	2	2
Proctotrupidae *Phaneroserphus* sp.	0	1	1
Scelionidae *Idris* sp.	18	0	18
Scelionidae *Trissolcus* sp. a	37	39	76
Scelionidae *Trissolcus* sp. b	0	38	38
Sphecidae *Stigmus fraternus*	0	1	1
Tenthredinidae *Heterarthrinae fenusa*	0	19	19
Tiphiidae *Myrmosa unicolor*	1	0	1
Total	497	1239	1736

*We were unable to provide a species identification for a few specimens, these specimens were identified to family or genus and then assigned a letter to distinguish from other unidentified specimens (example Cicadellidae *Empoasca* sp. b = specimen is in the family Cicadellidae, genus *Empoasca*, species "b" or the second *Empoasca* in collection unable to determine to species.) Diptera are not identified to species, they are separated and counted as morpho-species. In the table, the number of different morpho-species are given as (#)* which can be found next to the number of specimens collected.

Table 3. List of the orders that contained immature insects collected from *Rhamnus cathartica* that died during rearing.

	Number of Specimens		
Order	2004	2005	Total
Orthoptera	43	37	80
Psocoptera	11	7	18
Hemiptera/Homoptera	99	127	226
Neuroptera	1	10	11
Coleoptera	0	5	5
Lepidoptera	98*	73*	171
Total	252	259	511

*Several caterpillars from collected egg masses.