Insect responses to invasive plant species

A case study about the effect of *Solidago canadensis* on the butterfly, hoverfly and carabid beetle diversity in the surroundings of Ljubljana, Slovenia

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Wageningen, November 2003

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Preface

When you travel through Central Europe by train of by car in august, it is quite likely that you will encounter large patches of a high, bright yellow plant along the road and the railways. This plant is *Solidago canadensis* and is a neophyte. A neophyte is a plant species which has its origine ouside Europe. Some neophytes are very aggresive and therefore very common and some are less aggressive and are restricted to a certain area. *Solidago canadensis* is an aggressive neophyte and therefore it can outcompete other (more specialized) plants and become a problem for nature conservationists.

When one takes a closer look at the activity of insects around and on *Solidago canadensis* he will find a lot of bees and flies and will surely conclude that this plant attracts a many of these insects. However, when seeing this another question will raise to your mind: If these bees and flies are attracted to *Solidago canadensis*, does it has other consequenses for other insects?

With this question in mind, I wanted to do a research about this topic. In Slovenia is a lot of *Solidago canadensis* and it therefore gives a good oppertunity to study this effect. The surroundings of Ljubljana, the capital of Slovenia, are taken as a research area, because a lot of *Solidago canadensis* can be found over here. I spent five months here to prepare and conduct my research. For this research I took three insect groups, butterflies, hoverflies and carabids to see what were the effects on them.

The answer to this question is now laying in front of you. The first chapter will show a more detailed description of the problem of neophytes and *Solidago canadensis* in particular. In the chapters after this one the methods, results, discussion and conclusions can be found. To find this answer I want to invite you to read this report.

Maarten de Groot

Summary

Neophytes can have a hughe effect on the ecosystem, due to a lack of natural enemies. Often an aggressive neophyte can manipulate the surrounding environment in a way that it becomes suitable for it. They are also occupying empty niches. Because of these advantages some neophytes which are opportunists spread fast in Europe. However, these plants still are depended on pollinators. One of the ways to attract them is to give a large proportion of nectar. Athough this is a positive effect of some neophytes there are also are negative implications. These plants can change the environment by there appearance, and therefore some insect species are not occuring here anymore. One of these neophytes is *Solidago canadensis*, which spreads with high speed through Europe. It occurs in disturbed areas, like abandonded agricultural land, and can form mono-cultures.

Due to this this research is started to see what the effect is of this species on the insect diversity. The following aspects are taken into account: The difference in insect diversity between Solidago fields and non-Solidago fields (reference plots), the difference in insect diversity in flowering and non flowering period, the cover, area and the height of the plant. Also the effect of the species richness of plants were taken into account.

Three groups were taken into account: butterflies (Lepidoptera: Rhopalocera, hoverflies (Diptera: Syrphidae) and carabids (Coleoptera: Carabidae). These groups were sampled over a Solidago and reference plot in five different habitats, three times over a period of May till August. These places were all in the region of Ljubljana, Slovenia. The butterflies and hoverflies were sampled in plots and the carabids with pitfalls. Also the number of plant species were counted in the plots.

The results show that the plant species richness decreases in *Solidago canadensis* monocultures compared to the reference areas. The species diversity of butterflies is decreasing when there is *Solidago canadensis* in comparison with reference plots over the whole year. The hoverflies show an increase of the species diversity when *Solidago canadensis* is flowering. In the non flowering period, in June, the species diversity was higher in the reference plot. The carabids, however, did not seem to show a special effect of S. canadensis, but were more affected by the place were there was collected. The cover and height show no correlation. The area shows a negative correlation in august for butterflies.

These results should be seen as an indication of the effect because the sample size is small, with five sample pairs. However, it can be said that the groups which were researched react differently to *Solidago canadensis*. However, hoverflies and butterflies are both negatively influenced by *S. canadensis*. The difference between them is that the hoverflies are more attracted by the flowers and the butterflies have a lower diversity over that part of the year .

These factors show that butterflies are vulnerable to the amount of plants and therefore suitable as an indicator. Although the syphids are attracted by the flowers of S. canadensis, this species has a late flowering period. Therefore other food resources are needed in the earlier part of the year.

The carabids are predators and have therefore a different strategy for habitat use, they did not seem to be affected by the factors, like cover, area or height of the plants. The results therefore suggest that other factors on the place itself are affecting the carabids then the vegetation itself, such as prey availibility.

Table of Contents

1. Introduction

Alien species often extend over a new range in a very short time (Hengeveld, 1989; Weber, 1998). According to some researches, these plant invasions, or the spread of exotic species, are due to global change (Mack, 1997; Vitousek et al., 1997). Mostly these alien species are more competitive for limiting resources (Callaway & Asschehoug, 2000; Tilman, 1997, 1999) or change the natural disturbance regime to the detriment of native ones (Gentle & Duggin, 1997). Because of this, invasive species have an impact on native species, communities and ecosystems (Sala et al., 2000; Stein et al. 2000). Due to the threat towards the native plants, several conferences have been on this topic (Brundu et al., 2000; Bradley 2000; Bergmans & Blom, 2001). And therefore it is a problem for the environment.

1.1 Effects on the environment

As already mentioned in the introduction, alien species can compete with native species, by changing the environment for native species. Alien species can also become invasive when they share traits which of the native species, or when they possess different traits and therefore can occupy empty niches (Mack, 1997; Levine & D'Antonio, 1999).

Alien species can respond differently to various environmental conditions, this is, the same species can have different impacts on different communities (Sakai et al., 2001). It is known that exotic invasive species have a huge effect on the plant species richness and communities where they occur (Ellingson & Andersen, 2002).

Also the species richness decreases with the increase of the density of the alien species (Meiners, 2001). This decrease is larger when there is an invasion of exotic species than of native species. Native species on the other hand have less impact on the species richness and most of them will disappear in the end of the invasion (Meiners, 2001). There are very aggressive invasive species and Solidago canadenis is one of them. Meiners (2001) did an experiment on the effect of invasive plant species on the local species in the United States of America. He found out that there was a significant effect of Solidago canadensis on the plant species richness, there was a loss of 4 species of the original plant community. During the experiment of Meiners S. canadensis was a native species. Meiners also concluded that the native species were less aggresive than the exotic ones. A management type to decline the density of invasive species is regular mowing. With this the plant community becomes more divers (Rebele & Lehmann, 2002).

However, not all communities have low resistance against invasion by invasive species. Species composition, the functional groups present in the community, trophic structure, and strength of interactions among trophic levels may affect the reaction of native species to the invasion of alien species in different ways. Resistance to invasion may be enhanced in species-rich communities or in communities with diverse functional groups (Tilman, 1997; Lavorel et al., 1999). Reduction in interspecific interactions may also explain why exotic species often flourish in new habitat, and become pests (Tilman, 1999)

1.2 Effects on insects

Insects and plants have at least a two-way relationship; plant species depend on insects for their pollination, while insects are dependent on plants for their habitat and food. Therefore there can be different effects of invasive plant species on insects.

Due to a greater diversity of resources, the insect diversity increases with the increase of plant diversity. Especially the diversity of phytophagous specialists increases (Siemann et al. 1998; Knops et al. 1999). The abundance of herbivores increases with the increase of plant species richness, plant biomass, and predator and parasitoid abundance and decreases with plant functional group richness and plant tissue C:N increase (Haddad et al., 2001). The abundance of chewing insects, primarly generalist grasshoppers, is most strongly and positively related to plant biomass. Higher plant diversity may increase the availability of alternate resources, including alternate hosts within a functional group for herbivores (within and among seasons) as well as vegetative and floral resources for species that require both (Price et al., 1980; Powell, 1986). Some traits towards insects gives them an advantage. For example, *Impatiens glandulifera*, an asiatic invasive species of European river banks, competes succesfully with native plants for pollinators, by offering substantially higher floral rewards (Chittka & Schurkens, 2001).

Another insect trophic group besides herbivores which shows a positive response to plant species richness are predators (Haddad, 2001). Positive relationship between insect species richness and plant diversity are found in different studies (Strong et al., 1984; Haddad, et al., 2001; Varchola & Dunn, 1999; Asteraki, 1994). Increasing vegetation complexity may enhance natural enemy populations directly by providing more niches to occupy, or indirectly, by increasing the available prey (Root, 1973; Letourneau, 1990; Marino and Landis, 1996). Finally, vegetation can also function as an overwintering place, e.g. a thick vegetation cover for carabids (Dennis et al., 1994).

On the other hand, certain insects can also influence the probability of an invasion of an alien species. Insects are key interactors in seed plant reproductive processes, principally as pollinators, but also as seed and flower predators, seed dispersers and vectors. Vectors are organisms which are carrying a disease causing organisms harm (Crawley, 1989).

The invasive plant can manipulate the insect by giving it a high amount of pollen to attract it. This can give a shift in the foraging behaviour of the pollinator (Ghazoul, 2002).

In a new site there are no seed predators, which gives alien species an advantage towards native plants (Cox & Elmqvist, 2000). On the other hand, the fact that there are no native pollinators for the alien species either, creates a disadvantage for alien species (Simberloff & Von Holle, 1999).

1.3 *Solidago canadensis*

Solidago canadensis and *S. gigantea* are american species, that occur in Europe already for a long time. These species were introduced in Europe in the 18th century and invaded large parts of it in the 19th and 20th century (Weeda, et al. 1991). In Slovenia, *S. canadensis* was confirmed for the first time in 1937 in Ljubljana.These species can quickly spread over large distances because of humans. Various ways are possible: by mechanical ways (e.g. cars, trains, etc.) or by escaping from gardens as an ornamental plant and then spreading by wind.

Although the current distribution already covers large parts of Europe, the potential distribution exceeds the current one (Weber, 2001). The distribution of *S. gigantea* is at its current northern range limit more scattered and with smaller populations and has its dense populations in Central Europe (Weber 1994). In Slovenia it also occurs, and can be found in the entire country. Because it is so common it has already become a pest in different parts of Slovenia influencing local plant species richness.

Nowadays, these two species are commonly found along riverbeds, open areas in forests, ruderal areas, landfills and railroads. The habitat of S. gigantea is mainly eutrophic and disturbed areas, which are not too dry and complety flooded (Weeda et al. 1991). The habitat of *S. canadensis*, on the other hand, is in drier places. *Solidago gigantea* grows underground sprouts from rhizomes. The plants are self compatible, fruits are numerous and wind-dispersed , and germinate easily on a wide range of soils (Voser-Huber, 1992). When a population establishes, it grows only by means of vegetative growth.

It is known that native Goldenrod communities in North America contain more than 122 phytophagous insects. From these 14 species are restricted to *Solidago spp.* and Aster (Compositae) (Fontes et al., 1994). In Switzerland, almost all insect species which expanded their host range to Solidago altissima are opportunistic and unspecialized ectophages, which are not attuned to the growth cycle of the host. In North America, in contrast, there are more specialists and endophages (Jobin et al., 1996).

Although some monitoring has already been done on the entomofauna of Solidago canadensis-comunities, no explicit research is found about the effect on the species diversity of the presence of these invasive species in Europe. Therefore the following questions are formulated.

1.4 Research questions

This research takes place in Slovenia. In Slovenia several plant species are accidentally or deliberately introduced. Two of the most common alien species are *Solidago canadensis* and S. gigantea. Because they are aggressive they form monocultures in agricultural landscapes.

During this research three groups of insects are surveyed: butterflies, hoverflies and carabids. These three groups are chosen because of their different feeding and oviposition strategies. Of butterflies many species are specialists for ovipation and flowerfeeding, the hoverflies are flowerfeeding and are parasitoids, the carabids are predators. Therefore different effects per group are expected:

- For butterflies it is expected that the diversity increases with the plant species diversity and they are expected to have a lower diversity in *Solidago canadensis* monocultures.
- The hoverflies are flowerfeeding and parasitoids and are therefore attracted by flowers but also prey and therefore are bounded to the place where they find the most nectar and prey. This is probably in the non-*Solidago canadensis* plots. However when hoverflies are looking for nectar the Solidago canadensis sites are expect to have a higher quantity when the Solidago canadensis is flowering.
- The carabids are ground-dwellers and predators, because they are mainly generalists, they are bound to the place were they find enough prey. Probably this is not a matter of *Solidago canadensis* sites or non-*Solidago canadensis* sites, but rather a difference between the areas they are situated in.

The research questions are as following:

1. What are the effects of *Solidago canadensis* on the local plant?
2. What are the effects of *Solidago canadensis* communities on butterflies, hoverflies and carab beetles?

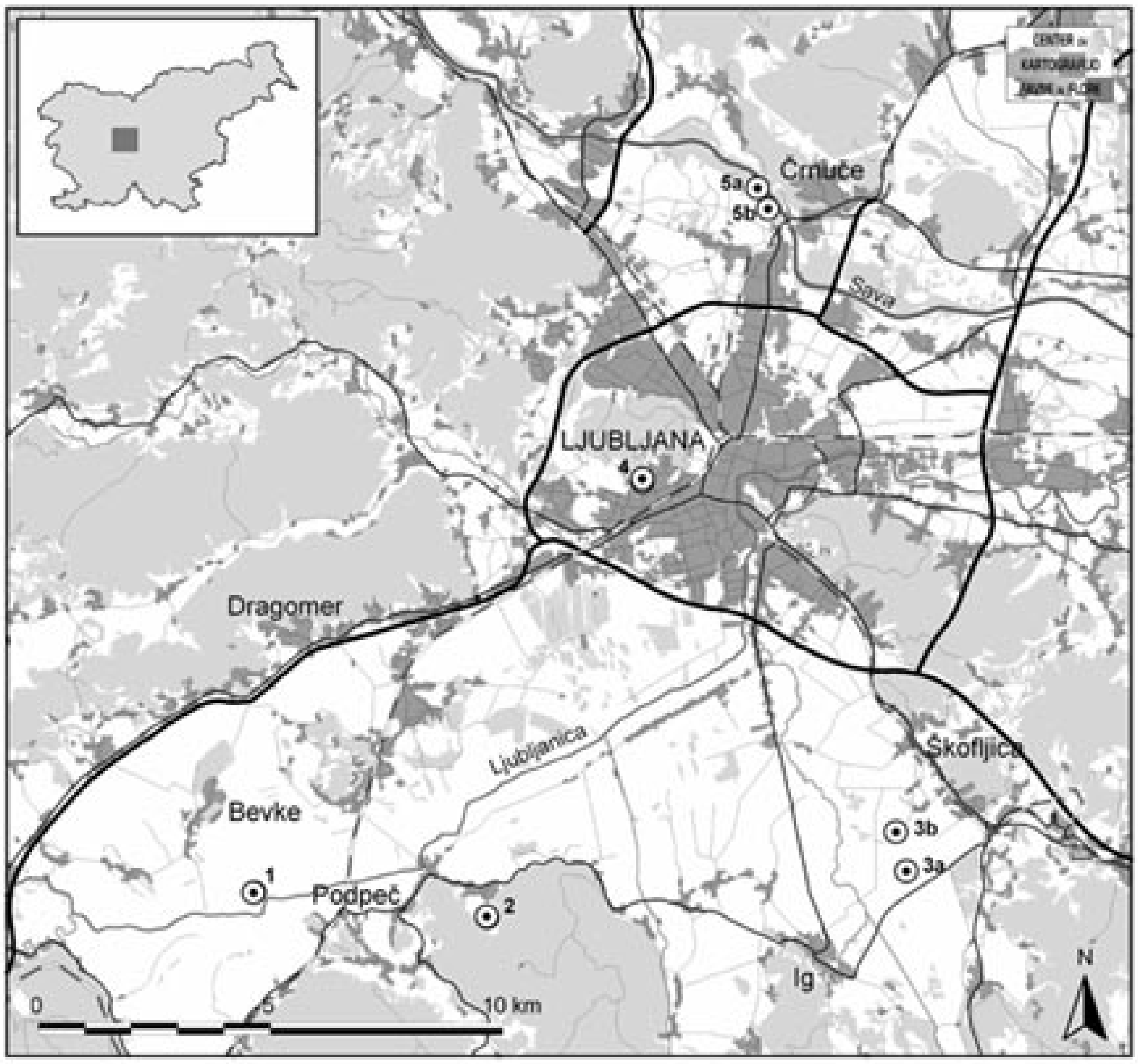
The second question can only be understood by asking the following subquestions:

1. What is the difference in diversity indices of butterflies, hoverflies and carabid beetles between Solidago communities and ‘original’ plant communities?
2. What is the difference in species composition of the insect groups between *Solidago canadensis* communities and ‘reference’ plant communities?
3. What is the effect of plant species richness on the species diversity indices of butterflies, hoverflies and carabid beetles ?
4. What is the effect of the area, cover and height of *Solidago canadensis* towards the diversity indices of butterflies, hoverflies and carabid beetles?
5. What is the difference in diversity indices of butterflies, hoverflies and carabid beetles between flowering and non-flowering *Solidago canadensis* community patches.

2. Research sites

During this research five sites were chosen with the following criterium: per site there is a different soil type. The database of the vegetation cartografie was used to find the plots in the area where *Solidago canadensis* grew. All research sites were divided in a plot with *S. canadensis* and a plot without *S. canadensis*, both plots had to be on the same soil type and have the same management type. When there was no option for a plot of original vegetation in the surrounding a similar place with the same characteristics would be found further away.

The research sites were, because of logistic reasons, established in a cirkel, with a diameter of 40 km, around Dragomer (See map 1), a town south east from Ljubljana. Two plots, Bevke and Ig were established in Ljubljansko barje; Podpec lays south of Ljubljansko barje, one in Ljubljana and one in the area of the Sava river. The maps are from the internet page "Interactivni Naravovarstveni Atlas". All x- and y-co-ordinates are from the Gauss Krueger projection. Pictures of the plots are in appendix 7.



Map 1: research sites around and in Ljubljansko barje

1. Bevke
2. Podpec

3a. Ig reference

3b. Ig *S. canadensis*

4. Ljubljana

5a. Sava reference

5b. Sava *S. canadensis*

The site ‘Bevke’ is established near the town Bevke in the middle of Ljubljansko barje. It is on a wall next to the bed of the river Ljubljanišca. Because of this the soil structure consists mainly out of clay. The plots are surrounded by bushes. The *S. canadensis* (BO) and reference plot (BS) are next to each other. The S. canadensis plot consists out of a large patch of S. canadensis surrounded by bushes of Salix sp. The reference plot consist mainly out of Carex acuta.

Coordinates of the start and end position of the plot

***S. canadensis* plot:**

Start:	X:91893.2	Y: 451692.8
End:	X: 91911.6	Y: 451687.4

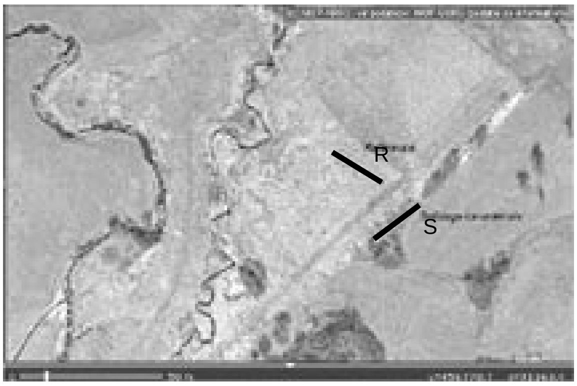
‘reference’ plot:

Start:	X:91896	Y: 451715
End:	X: 91912.5	Y: 451705.5

Map 2: Position of ‘S. canadensis’ (S) and ‘reference’ plot (R)

The site ‘Podpec’ is established near lake Podpec, also known as ¨Podpeško jezero¨. It is situated in the southern part of Ljubljansko barje. During the winter this area can be flooded. The soil is clayish and sandy. According to the Geographical Atlas of Slovenia the soil consists out of peat and clay. The plots are in the open field. Only the S. canadensis plot has bushes on the south western side *Salix spp*. Southern of it is an extensive mown grassland.

The S. canadensis (PS) and the reference plot (PO) are next to eachother. The *S. canadensis* plot consists out of a small patch of S. canadensis.



Coordinates of the start and end position of the plots

***S. canadensis* plot:**

Start:	X: 91371.9	Y: 456735.1
End:	X: 91358.7	Y: 456715.3

‘reference’ plot

Start:	X: 91378	Y: 45723.7
End:	X: 91393.8	Y: 456704.4

Map 3: Position of ‘*S. canadensis*’ (S) and ‘reference’ plot (R)

The site called ‘Ig’ is established between Ig and Škofljica, in the eastern part of Ljubljansko barje. These areas can be flooded during the winter. The soil consists out of peat and according to the Geographical Atlas of Slovenia it is a combination of peat and clay.

The *S. canadensis* (IS) and reference plot (IO) are separated for approx. 1 kilometer and are both abandonded fields. The S. canadensis plot consist out of a large patch of S. canadensis. Around the S. canadensis plot are fields of Maize (*Zea mais*) and an extensively mown grassland which is slowly overgrown by bushes. The most common plants in the reference plot are *Urtica dioica* and *Filipendula ulmeria*. The reference plot has several bushes around it. The S. canadensis plot has a bush of Salix on the south western side.

Map 5: *S. canadensis* plot lg

Map 6: Position of 'reference' transect

Coordinates of the start and end position of the '*S. canadensis'* plot:

Start: X: 93174.1 Y: 465554.7

End: X: 93192.1 Y: 465541.8

Coordinates of the start and end position of the 'reference' plot

Start: X: 92355,9 Y: 465554.7

End: X: 93192.1 Y: 465541.8

The site in Ljubljana is near the Faculty of Forestry. It lays in a gravelpit. The soil contains a lot of grevel and sand and is very dry. The Geographical atlas of Slovenia defines it as non calcereous rock with sand.

The *S. canadensis* (LS) and reference plots (LO) are near eachother. The *S. canadensis* plot consisted out of a large patch of *S. canadensis*. The reference plot has a lot of Erigeron annuus. The S. canadensis plot is surrounded by bushes. The reference, however, is more in the open, but has also trees around it.

Map 7: Position of 'S. canadensis' (S) and 'reference' plot (R)

Coordinates of the start and end position of the plots

'*S. canadensis*' plot

Start: X: 100783 Y: 460064.9

End: X: 100760 Y: 460075.5

'reference' plot

Start: X: 100844.7 Y: 460064.9

End: X: 100833.4 Y: 460070.5

The site called 'Sava' is near the village Crnuce, north of Ljubljana. These plots are established in or around the forest. The soil consists out of riverclay and stones. The Geographical atlas of Slovenia defines it as river clay with sand. The area is relatively dry.

The *S. canadensis* (SS) and reference plots (SO) are separated for approx 500m. The *S. canadensis* plot is a small patch an lays between the trees. The reference plot is a dry, species rich grassland in the forest.

Map 7: Position of '*S. canadensis*' plot

Coordinates of the start and end position of the '*S. canadensis*' plot

Start: X: 106661.9 Y: 462766.5

End: X: 106652.2 Y: 462775.3

Map 8: Position of 'reference' transect

Coordinates of the start and end position of the 'reference' plot

Start: X: 107088.2 Y: 462555.6

End: X: 107096.5 Y: 462539.2

3. Materials and methods

3.1 Research design

With the following design the research questions was tried to be answer. The research was divided in two types of plots: one with original vegetation and the other with *Solidago canadensis*. Five different habitat types were choosen for these pairs of plots according to the criteria shown in Chapter ‘Research area’. The sampling time was between May and August. And contained in total 3 rounds, done in the end of May, end of June and the beginning of August. These periods covered the non flowering period (May and June) and the flowering period (August) of *Solidago canadensis*. For all the plots vegetation was mapped and the groups Carabidae, Rhopalocera and Syrphidae were monitored. Also the environmental variables plant species richness, *Solidago canadensis* cover, *S. canadensis* height, *S. canadensis* area and flowering time were measured per plot.

3.2 Fieldwork

Identification

During the research all plants were identified with the help of the Exkursionsflora of Rothmaler (1995) and the Mala flora Slovenije (1999). During this research the nomenclature of Mala flora Slovenije was followed. The species which could not be identified, were brought to an expert botanist. The carabid species were identified with help of the key of Trautler & Geigenmueller (1987), the butterfly species with help of Tolman (1997) and the hoverflies with help of Sacks (1939) and a key from Internet (Veen, 2000) and Reemer (2000). Otherwise an expert of one of these groups or/and the available collections of these groups were consulted for comparison. The nomenclature of butterflies and carabids are according to the keys and fieldguides mentioned above. The hoverfly names, however, follow the nomenclature of Soos & Papp (1988).

This research is based on the determined specimens. Some taxonomical critical species are lumped in one genus, like *Amara sp*. or *Sphaerophoria sp*., because they can be only distinguished by genitalia, and the proper determination key was not available to determine them, or there were only females. In this case identification could only be done by male genitals. The species of the genera Amara and Sphaerophoria give a bias, because due to inclusion of different habitats it is likely that also more species of these genera are appearing in the plots. It is known that more species of the genus Sphaerophoria can co-exist with each other (Ssymank, 2002). *Sphaerophoria scripta* is the only species of the genus in this research which can be identified. Other species, which were obviously different but could not be reliable determined are shown as species 1, species 2, etc. However the diversity indices are not really biased; all the different species, which were found during the plot count or pitfall trapping, were taken into account.

Counts

The plant monitoring was conducted on the chosen areas. Every area had one pair of plots (*Solidago canadensis* present/absent). A plot was established randomly along the insect *plot*s, in the middle of the particular plant community. All plots were 9 m^2. The plots were next to the middle line of 20 m. The x and y co-ordinates of the plots were written down. All the plant species were identified in the plot. Also the area of the *S. canadensis* plot was estimated in square meters.

The butterflies, hoverflies and carabids needed different monitoring methods. All methods and monitoring of groups were conducted seperately. However, it was attempted to make the samples for the hoverflies and butterflies on the same day.

All plots were monitored 3 times during the research, once in May, July and August on the above mentioned groups. The butterflies and hoverflies were monitored in the middle of the plot, where there is as less influence of other vegetation types as possible. The butterflies were counted within the the smallest area of *S. canadensis*. For this research this meant that it was the area of 20 m by 5 m. The count takes 15 to 20 minutes, excluding time of determination. During this time all specimens of the species were counted. The monitoring was taking place between 10.00h and 16.00h with very sunny weather and a maximum cloud cover of 4/8. The butterflies were only counted when the sun shone (See appendix 6). All butterflies were counted without catching them, because butterflies are threatened in Slovenia (Celik & Rebuesek, 1996). However when a unknown species occurred the butterfly was caught and determined with help of the field guide or an expert. The time of catching was not included in the 20 minutes of the count. A problem with the method which was used is, that this research can be biased by the repeatedly in and going out of one specimen and not different specimens. The samples are still comparable because the same method is used for all the plots. The hoverflies were caught and killed for determination during the 20 minute count. Only species which are flying in the upper layer of the *S. canadensis* are taken into account.

The monitoring of carabids was based on pitfalls with large open surface (Works et all., 2002). A pitfall, with a content of salt-water solution, was put into the ground with an opening on the surface. To avoid rain or leaves coming into the open pitfall was covered by a ‘roof’. This roof was 10 by 10 cm and was made of carton surrounded with plastic. Along a line of 20 m in the areas, which described for the butterflies, six pitfall traps were placed every 3 meters. All pitfalls were placed on a distance of one meter on the right hand side of the middle of the area. The pitfalls were checked every seven days. Because of the environmental impact of leaving the plastic cups into the ground the pitfalls were removed after finishing the research.

Environmental variables

While monitoring the insects the height, cover and the area of the *Solidago canadensis* was measured. Also the plant species richness was measured per plot. The variable ‘cover’ of *Solidago canadensis* is more or less related to the species richness of plants, but also shows the space between the *S. canadensis* stems, which receive more sunlight and therefore give more possible niches for other plants and/or animals. Although the area and cover can give the same effect it was observed that there were also large sites where the cover of S. canadensis was less dense. During the year the plant of S. canadensis is changing its shape and can therefore change the environmental conditions The height of the plants was measured, with a measurer in centi-meters, every time the plot was monitored on butterflies and hoverflies. The cover is the precentage of the space it takes of a plot of 9 m^2, described in the plant monitoring. The area of the *Solidago canadensis* field were the plot was established was estimated.

3.3 Analysis

All the data were analysed with statistical tests using the Shannon Wiener index and the sample eveness. The differences and correlations were analysed by the statistical program SPSS.

The species diversity indices give a numerical value to the density of specimens per species to the different sites. A pioneer ecosystem has some species with a lot of specimen and a more complex system has more species with a equal rate of specimens (Townsend et al., 2000). This diversity index shows is sensitive towards rarer species (Waite, 2000). For this research was expected that the differences are made by the occurrence of some rarer species more attracted to other vegetation types than *Solidago canadensis*. The problem, however, can be that these rarer species which are caught in one plot also occur in the other plot, but not on the moment of sampling, but this has to do with the amount of sampling time. Another reason is that, because of remaining the uniform character of the research, there is chosen for only one diversity index, the Shannon Wiener index. The diversity is sampled in paired plots (reference/*Solidago canadensis*), the relative numbers of the diversity can therefore be compared with each other.

Shannon Wiener index (H'): $\Sigma -p_i \ln p_i$
Frequency (p_i): n_i/N
n_i: number of individuals of one species in one site
N: Number of individuals in one site
Sample evenness (J): H'/ln(S)
S: Number of species

The index was calculated as shown in the equation in the text box: The frequency of every species (p_i) per plots was calculated. This means that the number of specimens of the species was divided by the total number of specimens in the plot. Then the negative frequency was multiplied by the ln-number of the frequency and this result was summed with the results of the other species. This is the index of the plot per group. However, for the carabids, first the specimens of all the pitfalls in the plot were summed and then the procedure as described above was followed. After this also the eveness of the Shannon Wiener index was calculated.

The analysis was done per group, because the diversity was measured with different methods (eg. counts and pitfall traps) and could therefore not be lumped together. The butterfly data was divided in flying, visiting and the total number of butterflies. This division was made because the total species diversity is largely affected by the surrounding habitat.The visiting butterflies show that they are interested in *S. canadensis* plants and therefore gave a more direct effect of *Solidago canadensis*.

The data is analysed with the statistical program SPSS. For the first sub question the paired t-test (t) or the Wilcoxon test (Z) was used. The third and fourth sub questions are relations between the plant species richness and the area, cover and the height of the *Solidago canadensis* patch and the insect diversity; for this a Pearson (Pe) or Spearman test (S) was used, depending on the normal distribution of the independent variable. Only correlations are used in this research, because the sample size was to small to give a relation with regression. All correlations are only done with the data of periods 2 and 3.

The fifth question analyses the difference in the insect diversity between flowering and non-flowering *S. canadensis* area and for this a independed sampled t-test (t) or the Mann Withney test (U) was used. The second question, however, is not statistically tested. A similarity clustering by the program Syntax © was done between the plot using the Gower's index (Waite, 2000). Because this index takes the species richness and the abundance per species in account, this is a good measure of

Gowers index:
Gijk = sum S_{ijk} / sum W_{ijk}

the similarity between the sites. The index first sums the similarity values between sample j and sample k for all n variables i and divides this by the summed weighting or scaling factors for all n variables i. Further the lists of species per plot were compared with each other.

Before the real analysis started a test of normality was done with the Shapiro Wilk test, because it is robust and so it can also be used for a smaller sample size (Vocht, 1999) and it was attempted to transform the data. However the result would give the same as the original data. Therefore the original data were used.

4. Results

4.1 Plant species richness

Table 1: plant species richness per plot

	Reference	Solidago
Bevke	12	2
Podpec	12	2
Ig	5	2
Ljubljana	17	6

The plant species, that occurred in the plots are shown in appendix 1 and the species richness is shown in table 1. The species richness decreases significantly from non *Solidago canadensis* plots to *Solidago canadensis* plots (Z = -2.032, Asymp. p = 0,042). According to the appendix some species (still) occur together with *Solidago canadensis*. These species are for example grass-like species (eg. *Carex sp*., *Calamagrostis epigros*), high stem species (eg. *Filipendula ulmaria*, *Erigeron annuus*) or climbing species (eg. *Stellaria sp*.). A correlation between species richness and cover of *S. canadensis* does not give a significant result.

4.2 Insect diversity

In Fig. 1, 2 and 3 the diversity indices of respectively visiting butterflies, hoverflies and carabids are depicted. During the analysis the butterflies were differentiated in visiting, flying and total number specimens. The hoverflies and the carabids do not have such a classification and all specimens are taken into account.

Over all the periods only the visiting butterfly diversity and evenness are significantly negatively influenced by *S. canadensis* (resp. Z = -3.296, p = 0.001; Z = -1.977, p = 0.048) (Fig. 1) In the first sampling period only the total butterfly diversity shows a significant difference (Z = -2.023, p = 0.043). In the second sampling period, the *S. canadensis* plots have a significant negative influence on the visiting butterflies (Z = -2.023, p = 0.043). In the third period there is a significant difference between *S. canadensis* and non *S. canadensis* plots for the evenness for the total count of butterflies and the visiting butterfly diversity (resp. t = -2.783, p = 0.05; t = 3.650, p = 0.022).

Table 2: Results of difference analysis between *Solidago canadensis* and reference plots
* = p<0.05, ** = p<0.01, *** = p<0.001, ns = not significant

Solidago canadensis	flowering period	all periods	period 1	period 2	period 3
butterfly diversity	ns	ns	*	ns	ns
butterfly eveness	ns	ns	ns	ns	*
visiting butterfly diversity	ns	***	ns	*	ns
visiting butterfly eveness	ns	*	ns	ns	*
syrphid diversity	**	ns	ns	*	ns
syrphid eveness	*	ns	ns	ns	ns

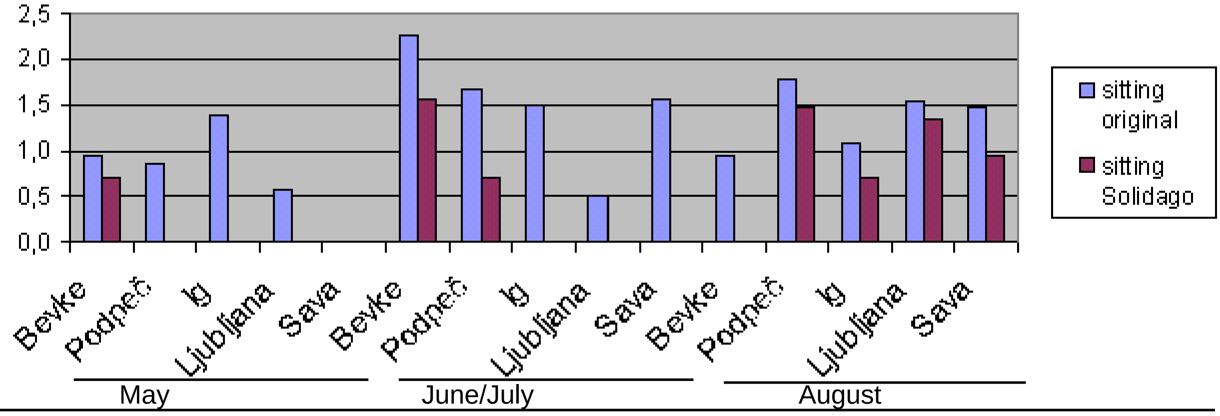


Fig 1 : Difference in visiting butterfly diversity between *Solidago canadensis* and reference plots; a and b represent the significant different groups.

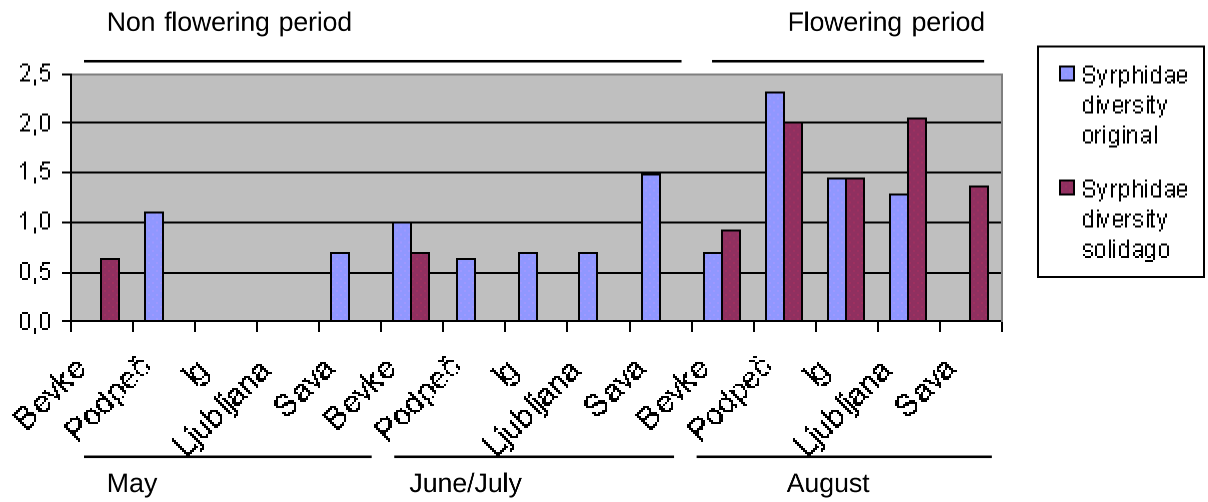


Fig 2 : Difference in syrphid diversity between Solidago and reference plots; c and d represent the significant different groups in Solidago canadensis between period 2 (June/July) and 3 (August).

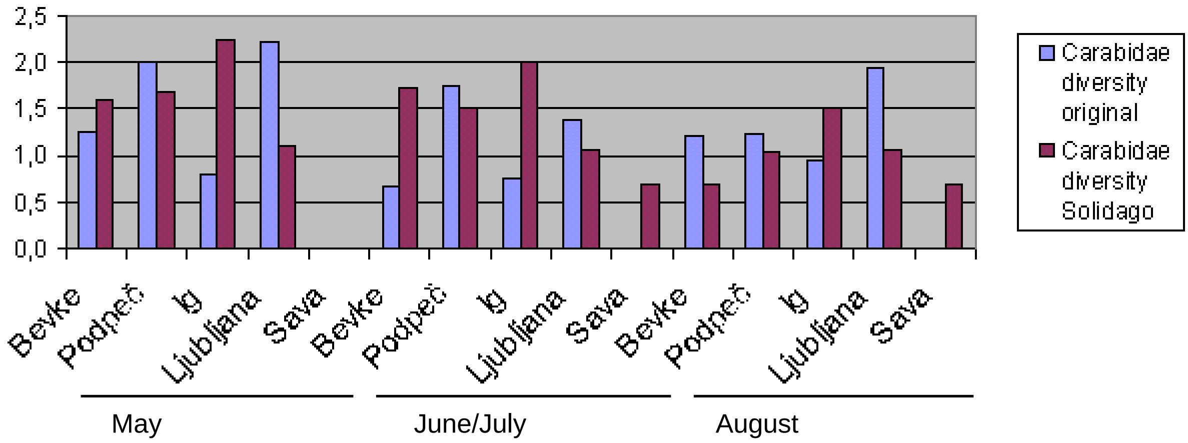


Fig 3 : Difference in carabid diversity between Solidago and reference plots; the pairs f and g and h and i represent the significant different groups.

The *S. canadensis* has a significant negative influence in the second period (Z = -2.23; p = 0.043) on syrphid diversity (Fig 2). The third period gives no significant difference, however, except for plots in Podpec and Ig, the graph indicates a positive effect of *Solidago canadensis* on hoverflies.

There seems no significant general influence of *Solidago canadensis* on carabids. Although there seems to be the same effect over the periods per area. The area Ljubljana show a lower diversity for *S. canadensis* (U = 0.00, asymp p = 0.05), Ig shows a higher diversity for *S. canadensis* (U = 0.00, asymp p = 0.046). The areas Bevke, Sava and Podpec show no significant different, although in figure 3 the areas Sava and Podpec indicate a respectively a positive and negative influence of *S. canadensis*. In the reference area in Sava no carabid specimens were found. Because of suspected human interference, a pitfall trap was placed, covered in the grass. After one week still no carabid specimens were found in this trap. Later the other traps in the Sava reference plot showed no signs of human influence and therefore the measurement were taken as they were. This means there were no empty and uncovered traps. Carabids were caught in traps in other plots, therefore it is probably not a methodological error, but it has a ecological reason.

4.3 Insect composition

Altogether during this research, there were 125 species of insects found, of which 33 were butterfly species, 36 syrphid species and 56 carabid species. Some species, which could not be identified were grouped under a genus or family name, like *Amara sp.* and *Lycaenidae sp.*.

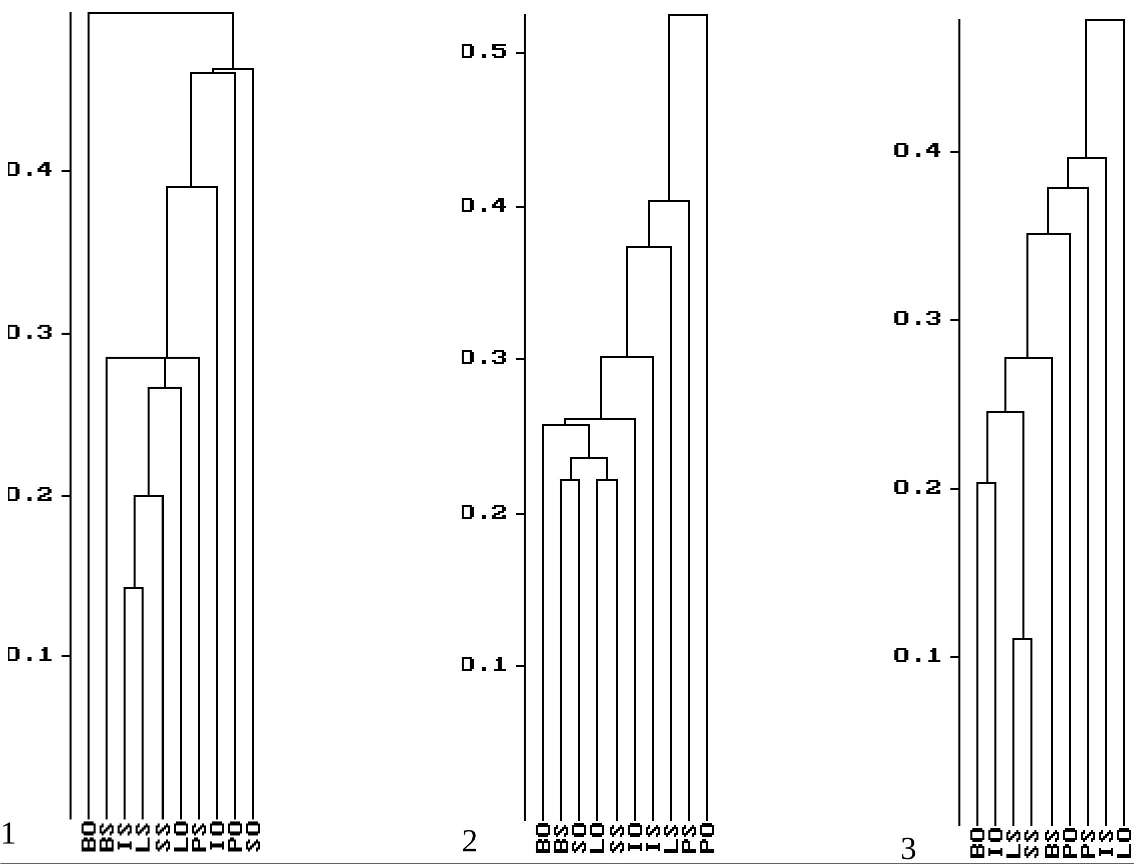


Fig 4 : UPGMA clustering with the Gower's similarity index of the groups:

1.Visiting butterflies; 2. Hoverflies; 3. Carabids

BO: Bevke reference; BS: Bevke Solidago; PO: Podpec reference; PS: Podpec Solidago; IO: Ig reference; IS: Ig Solidago; LO: Ljubljana reference; LS: Ljubljana Solidago; SO: Sava reference; SS: Sava Solidago

The numbers of hoverflies, carabids and visiting butterflies are displayed in the tables in appendix 2, 3, 4. It shows that there are different compositions in *Solidago canadensis* and orginal plots for butterflies, carabids and visiting butterflies.

Although for carabids can be said that when a species is occurring in large numbers in one plot the same species is also occurring in the other site but in less abundance.

The result of a cluster analysis with the help of the Gower's similarity index, shows that most of the plots do not have a great similarity. In figure 4.1 the similarity in butterfly species composition is depicted. The most similar group contains the S*olidago canadensis* site of Ljubljana (LS), Ig (IS), Sava (SS), Bevke (BS) and Podpec (PS) and the original site of Ljubljana (LO). The other plots give a low similarity of composition of species. In the *Solidago canadensis* sites mainly common species, like *Maniola jurtina,Vanessa cardui, Artogeia rapae* and *Artogeia napi* occur. None of the species occur in all of the *Solidago canadensis* plots. Furthermore most of the species were not abundant in these plots. The reference plots contained other species like *Lysandra coridon, Lycaena dispar* and *Melanargia galathea,* for the most these species were more abundant in or only observed in the reference sites.

The cluster analysis for hoverflies is depicted in figure 4.2. The figure shows that there is not an obvious clustering. The only groups that are similar in hoverfly composition are the *S. canadensis* site of Bevke (BS) and the reference site of Sava (SO) and the reference site of Ljubljana together with the *Solidago canadensis* site of Sava. All other sites are less similar (similarity index less than 0.2). The hoverflies *Sphaerophoria sp.* and *S. scripta* were present in almost all plots. Other species occured only in a few sites. *Helophilus trivittatus* is presented only in plots with *Solidago canadensis,* however there are only three specimens observed.

In Figure 4.3 the carabids can be distinguished in two groups. The first group is the *Solidago canadensis* site of Ljubljana (LS) grouped with the solidago site of Sava (SS). Both of these sites contains a low number of species. The other group contains the reference sites of Bevke (BO) and Ig (IO). All other plots are less similar from each other (similarity index > 0.2). The carabid species do not show any obvious preference for *Solidago canadensis*. In the reference site of Ig the species *Pterostichus melanarius* and to a less stronger extent also *Carabus granulatus* occur in large numbers (appendix 3).

4.4 Flowering versus non flowering

The *Solidago canadensis* plot was separated in flowering and non flowering periods. The flowering period of *Solidago canadensis* was in the third period and the flowering period of non *Solidago canadensis* was in the second and third period. The syrphid diversity show a significant difference between the non flowering and flowering period (resp. U = 0.000, p = 0.007) and therefore seem to be affected by the flowering period of *S. canadensis*.

Also a positive correlation between visiting butterflies and hoverflies was found (S = 0.765, p. = 0.001) (Fig 5.1).

4.5 Insect diversity and correlations

In table 3, all the measured emvironmental variables are given. The area of the *Solidago canadensis* fields ranged from 211 to 9896 m^2. In this range only one significant negative correlation was found. This was for the visiting butterflies in the third period (P = -0.910, p = 0.032) (Fig. 5.2), which was also the flowering period of the *Solidago canadensis*

The coverage of *Solidago canadensis* in the plots ranged from 80 till 100%. No significant

Table 3: Data of coverage, area and height

Plots	Coverage Solidago (%)	Area Solidago (m2)	Height (m) period 1	Height (m) period 2	Height (m) period 3
Bevke	100	9896	0,9	1,4	2
Podpe?	80	212	0,7	1,15	1,7
Ig	100	1862	0,6	1,2	1,65
Ljubljana	90	406	0,6	1,4	1,8
Sava	95	473	0,7	1,25	1,6

Table 4: Results of correlation analysis of the plant species richness and area

	Plant species richness	Area *Solidago canadensis* (m2)
Syrphidae diversity third period	ns	ns
Butterfly diversity third period	ns	*** (-)**
Syrphid diversity second period	*** (+)**	ns
Height	ns	ns

* = p<0.05, ** = p<0.01, *** = p<0.001, ns = not significant, (-) = negative correlation, (+) = positive correlation

correlations were found. Some correlations are almost significant though: total butterfly evenness for the first resp. (S = 0.505, p = 0.055) and the third period (P = 0.828, p = 0.083) and the third period of the syrphid evenness (S = -0,872; p = 0.054) and the syrphid diversity (P = -0,858, p= 0.063). The coverage shows a relation with the area of *Solidago canadensis* as depicted in fig. 7.

The height of *S. canadensis* ranged from 0.60 till 2.00 m. No significant correlations were found. The correlation between the days of the year and the height of *Solidago canadensis* is a highly significant (S = 0.94, p = 0.00) (Fig. 6.2).

The species richness only shows a significant positive correlation with the syrphid diversity in the second sample period (P = 0.752, p = 0.012, N = 10) (Fig 6.1). The other groups in every period have no significant correlation.

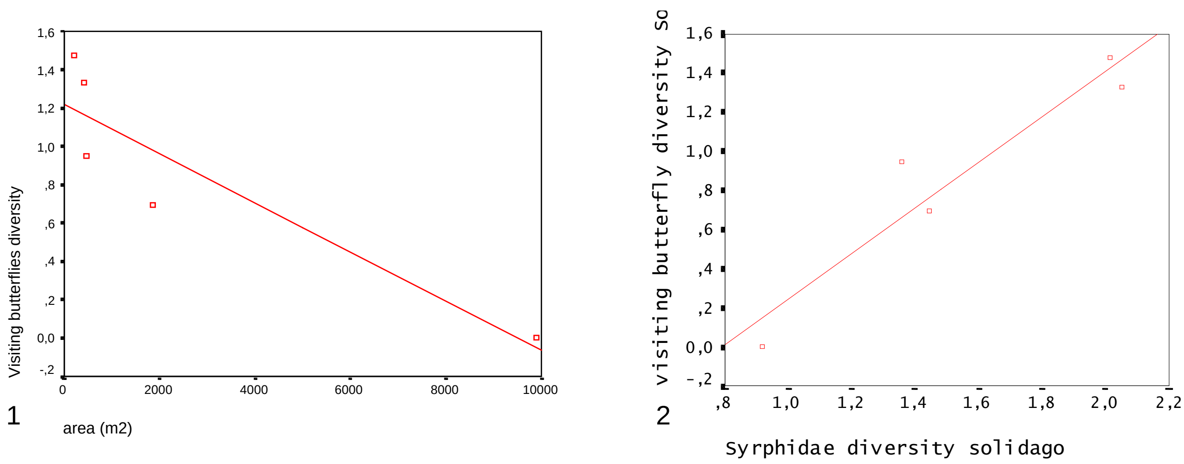


Fig 5 : Correlation between 1. visiting butterflies and syrphid diversity in the third period and 2. Visiting butterfly diversity in the third period and area.

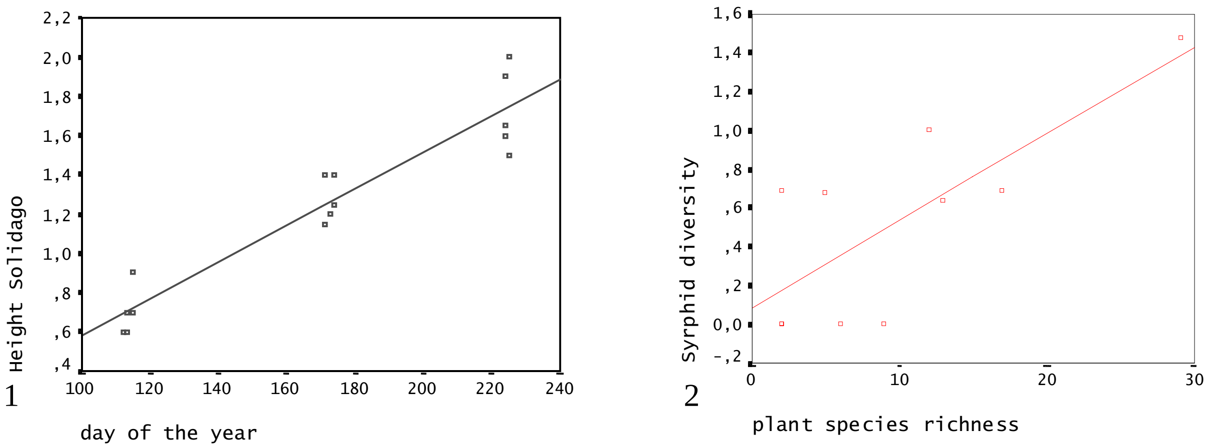


Fig 6: Correlation between 1. the syrphid diversity and plant species richness in the second period and 2. day of the year and the height of *Solidago canadensis*

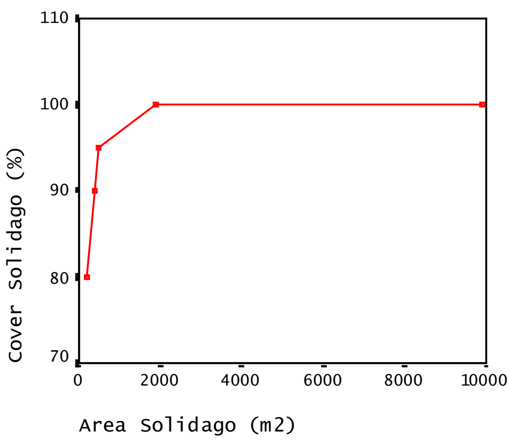


Fig 7: relation between the cover and the area of *Solidago canadensis*

5. Discussion

This research shows some clear results, however in this chapter it will be explained in which context this should be seen. The experimental design of the research is based on the fact that *Solidago canadensis* outcompete other species (Weber, 1998; Sakai, et al., 2001). During this research a comparison was made between the places where *Solidago canadensis occurs* and a reference site which contains all the species when no *S. canadensis* occurred. However, *S. canadensis* occurs on several habitat types (Weeda, 1994), also the question is , what the influence is between the areas. Therefore the research was spread over different soil types, which often indicate the habitat type. However, including these different types of habitats into this research would show less obvious results, because only one pair of plots is taken per habitat type.The chosen sites will give an indication of the effect.

5.1 Plant species richness and *Solidago canadensis*

The plant species richness is less in *Solidago canadensis* fields then in the reference sites. Other studies already have shown that *Solidago canadensis* outcompete other species (Meiners et al., 2001; Rebele & Lehmann, 2002).

5.2 Insect diversity

There is a negative influence of *Solidago canadensis* on the visiting butterflies. This effect is shown as well for the number of butterflies in agricultural and non agricultural lands (Fleishman et al., 1999). However in the same research the species richness does not differ. An habitat criterium for a butterfly in fields are the occurrence of larval host plants (Clausen, 2001). None of the butterfly species are known to the author for having *S. canadensis* as a larval host plant.

Although *Solidago canadensis* was not yet flowering in June and July, butterflies were already observed in the plots. This can be due to visiting butterflies, which have other activities than foraging, like thermo-regulation (Holl, 1996).Also the sample evenness shows a similar trend such as the diversity. This is in accordance with some other studies (Fleishman et al., 1999).

There seems no significant influence of *Solidago canadensis* on hoverflies compared with the reference habitat. Only in the non flowering period of the second measurement period shows a significant difference in hoverfly diversity. The anthropogenic disturbance gives an higher amount of migrants (Ssymank, 2002). The research was about invasive plant species, *Solidago canadensis* can also be seen as a disturbance to the environment. This would offer a possible reason why there is a decrease in species diversity in the non flowering period. Although hoverflies can be seen as an indicator species (Ssymank, 2002), this research has a low amount of samples and therefore it cannot be said what the effect is for the particular species. There is little known about the abundance in this region of this group, and therefore there is no literature on it. However the species diversity can be used as an indicator of the effect of *S. canadensis* in the environment.

For carabid beetle diversity, other studies show that in simple ecosystems, in contrast with more complex ecosystems the diversity is lower (Varcheola & Dunn, 1999). *S. canadensis* fields are less complex, but these fields show that some sites have a higher species diversity. It is possible that the less complex ecosystem offer possibilities for the carabids to be very mobile and therefore are able to travel easily through it, in contrast to more complex fields where it is more difficult to travel through.

The influences of *S. canadensis* sites differ per area. This was also speculated by other authors (Kowarik, 2003). These influences can be due to different favourable environmental variables (Otteson, 1996), or to an increase of vegetation complexity, which offer more niches to occupy, furthermore they have an influence on surrounding habitats or on the availability of prey (Varcheola & Dunn, 1999).

The plots were chosen in different habitats, which differ from each other, the effect of these different influences seems to be the case for this research as well. The latter cause for the availability of prey can also be the case for either non-occurrence or low abundancy of carabids in the reference plot of Sava. Observations have shown that the pitfall traps did not contain much potential prey, only some spiders, which are a predator as well. The same goes for *S. canadensis* plot in Sava. More studies on this topic would be useful to gain more knowledge upon the influence of prey availability in *S. canadensis* fields. Prey availability depends upon the availability of different habitats. Another reason can be that the reference area was situated in the forest, this can be due to the fact that some carabid species are specialised species (Irmler, 2001) and that the reference site was isolated from the meadows. Therefore there were no carabids found. However other research show that there are also species which occur in both grassland as well as in woodland (Turin et al., 1991). Also the communities of clearances existed out of small non-forest species (Sklodowski, 2001).

5.3 Insect composition

When a comparison is made between the species composition of the reference plot and the *S. canadensis* plot for all insect groups means that, it should be taken into account that some species, which are very rare, still can occur in this plot. Although, they are not found during this research because of stochastic reasons.

In species composition the Solidago sites look more or less similar. This can be due to the fact that only the more common species and generalists are attracted to these *Solidago canadensis* plots. Also some species are avoiding the agricultural lands (Fleishman et al., 1999; Kocher et al, 1999), the *S. canadensis* plots are mostly based on abandoned agricultural and therefore more disturbed. These abandoned agricultural lands are deleterious for butterfly species, which have early successional grassland and meadows as primary habitat (Stoltze, 1994 in Dewenter & Tscharntke, 1997). In between is also the reference site of Ljubljana. Probably this is because Ljubljana is an urban site and for urban sites it is known that they contain less species and in lower numbers and some species also avoid urban areas (Blair & Launer, 1997). The reference sites were selected upon their ‘original’ vegetation; because these plots differ in vegetation it was expected that they will also differ in butterfly composition. Greater dissimilarity in species composition between the reference sites reflects greater vegetation difference in the reference plots (Holl, 1996)

Carabid communities forms distribution continuums rather than distinctive associations (Ottesen, 1996). This is also shown in the results. Some environmental variables are more important than specific plant associations (Ottesen, 1996). None of the species seems to be specialised on *Solidago canadensis.* However it seems that there are less specimens in *Solidago canadensis* than in the reference plot. The large specialised forest species *Carabus violaceus*, which does not cross the forest field boundary (Ricken & Raths, 1996), only in places with shade (Sklodowski,

2001) like it was found on the edge of the forest under *S. canadensis*. However, other species like *Pterostichus melanarius* are very mobile and can walk large distances (Carcamo et al., 1995). Which ,as a consequence , is also found in more habitats.

5.4 Flowering vs non flowering

The syrphid diversity is higher within the plots with flowering *Solidago canadensis.* It was already known that hoverflies were attracted by this plant (Schwabe & Kratochwill, 1991 in Kowarik, 2003). However there are no differences between *S. canadensis* and other plants in the flowering period. They are mainly attracted by the amount of flowers (Sutherland et al., 2001) and the color intensity of the flowers (Ruppert & Mothan, 1991). Species like *Sphaerophoria scripta* and *Sphaerophoria sp.* seemed to be attracted by *Solidago canadensis* in comparison with the reference plots. However in other research, the species *S. scripta* did not show a preference for the yellow colour (Ssymank, 2002). *Eristalis pertinax* has a high preference for yellow colour (Ssymank, 2002), nevertheless this species is only found in one *S. canadensis* plot with one specimen. This species was found commonly in other parts of Slovenia. *Eristalis tenax* is considered as a species which has a lower preference for yellow colour, during this research the species were more found in the reference plot Podpec, were no yellow flowers were found.

5.5 Correlations

The results show that not many correlation was found for several factors, like the surface of the mono-culture of *Solidago canadensis*, coverage of *Solidago canadensis* and the height of *S. canadensis* size. Often there were some correlations which were almost significant. This can be due to a small sample size. This correlation can only be found in the range of the sample measurements. For instance, the cover show only a percentage between 80 % till 100%. A positive correlation can be observed between area and cover of *Solidago canadensis* , the graph depicts a logistic curve. However, this can be due to the methodology of this research, where only mono-cultures of *Solidago canadensis* were taken into account and the sample size can be too small to predict anything. It was observed that there were also large areas with less dense cover. Probably also the age of the S. canadensis is influencing the cover (Rebele & Lehmann, 2002).

Although in many researches a relation is found between the species richness in plants and the species diversity of butterflies (Knopps et al., 1999; Haddad et al, 2001), in this research none of the periods show a correlation between the species richness of plants. However in the species richness of plants also non flowering and less productive plants are included. It is known that there is a difference in insects species that occur between the low productive and high productive plant groups (Haddad et al., 2001).

The area of the mostly mono-culture fields of *Solidago canadensis* influences the diversity in the flowering time negatively. The flowering *S. canadensis* did not seem to influence the butterflies significantly, although the flowers give more food resources, which are important for the butterflies (Clausen, 2001; Fleishman et al., 1999). The graph however shows an increase of butterfly diversity from July to August.

The positive correlation between plant species richness and insects can be due to an increase of alternative food resources (Haddad et al., 2001).

Although S. canadensis attracts a lot of pollinators, also other native plants can compete with *S. canadensis*. In this research for instance, *Mentha aquatica* and *M. longifolia* caused the peak in the third period in the plot of Podpec (fig.2).

Also before the flowering period species were occuring over here, that can be caused by thermoregulation or searching for species to parasitoid on. There was a positive correlation between the diversity of butterflies and hoverflies. This is, probably because of the same use of food resources, namely, nectar.

The abundance of carabids in reality have a positive relation with the plant species richness (Varcheola & Dunn, 1999). However this seems not to be the case in this research. The reason for appearance should be found in other environmental variables, like soil humidity, soil chemistry, nutrient status, substrate porosity, shadiness of habitat and altitude (Ottesen, 1996). However no correlation was found between the carabid diversity and the area, cover and height of *Solidago canadensis*. Empirical observations of the author were that the plant of *Solidago canadensis* gives a lot of shade and the humidity between the plants seem to be higher that in some reference plots.

5.6 Solidago canadensis, a general effect?

In sum, *Solidago canadensis* mono-cultures have different effects on the investigated groups: The butterfly diversity was lower in places with a mono-culture of *S. canadensis*, the hoverflies were attracted by the flowers and carabids reacted different to *S. canadensis* in different places.
Therefore the only group which is over the whole year negatively affected by this plant, are butterflies. In spatial sense the increasing area of *S. canadensis* has in the flowering period decreasing effect on butterfly diversity. These factors show that butterflies are vulnerable to these plants and therefore suitable as an indicator species.
However the hoverflies are attracted to the flowers and are abundant at that time on the plant, when *S. canadensis* is flowering late in the season. This will have consequences for the hoverflies which are occurring early in the year, when the plant is not yet flowering. Therefore other food resources are needed, which are found in other flowering plant occurring in that time of the year. The plant can have therefore a large impact in spatial sense to the occurrence of hoverflies in the landscape, when it outcompetes other plant species, which are the food resources. The species, which are occurring in August and September profit from the flowers. However, the consequence for the latter species (over the September period), are not taken into account.
The carabids are predators and therefore have a different strategy for habitat use, they did not seem to be affected by factors like, cover, area or height of the plants. The results therefore suggest, that other factors than the vegetation itself on the site are affecting the carabids, such as prey availibility. Some forest species can use the *Solidago canadensis* as an extension of their (forest) habitat.

Although the latter assumption can be taken from the results, it only is an indication of the effect of *Solidago canadensis*. More research on the effects of this plant species should be done.

6. Conclusions

During this study the research questions can be answered by the results. These are stated below by research question:

- The plant species richness is higher in local communitie then in Solidago candensis communities
- *Solidago canadensis* monocultures have a general negative effect on butterflies. It has only a negative effect on hoverflies in June. The carabids show no effect.
- For butterflies it seemed that the more common species were more attracted to *Solidago canadensis* communities. For carabids and hoverflies only a few species occured in all the fields.
- There is a correlation between hoverflies and plant species richness in June. None of the other groups show an correlation with plant species richness
- For butterflies there was only an effect of the area of *Solidago canadensis* in August. None of the environmental variables had an influence on the other groups.
- There are more hoverflies in flowering *Solidago canadensis* than on non flowering *Solidago canadensis*. Butterflies and carabids show no preference for flowering *Solidago canadensis*.

The following conclusions can be drawn from these results:

- The butterflies show a lower diversity in *Solidago canadensis* monocultures.
- The hoverflies are flowerfeeding and parasitoids and are therefore attracted to the place where they find the most nectar and prey. This is probably in the non *Solidago canadensis* plots. However when the *Solidago canadensis* is flowering these sites have a higher diversity when the *Solidago canadensis*.
- The carabids have no preference to *Solidago canadensis* sites or non *Solidago canadensis* sites, but more for a difference between the areas they are situated in.

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Appendices

1. Data plant species
2. Data butterflies
3. Data hoverflies
4. Data carabids
5. Species diversity indices and eveness
6. Weather conditions, sampling date and time
7. Sites
8. Vegetation monitoring form
9. Butterfly counting form
10. Hoverfly counting form
11. Carabid counting form

Appendix 1: Plant species data

Bevke reference	Bevke solidago	Ig reference	Ig Solidago	Ljubljana reference
Carex acuta	*Solidago canadensis*	*Equisetum palustre*	*Solidago canadensis*	*Plantago major*
Galium album	*Carex sp.*	*Urtica dioica*	*Calanagrostis epigros*	*Rumex obtifolius*
Galium verum		*Filipendula ulmaria*		*Trifolium repens*
Betonica officinalis		*Galium aparine*		*Poa pratensis*
Ranunculus acris		*Galeopsis speciosa*		*Bromus hordeaseus*
Achillea millefolium				*Erigeron annuus*
Ranunculus acris				*Carex hirta*
Potentilla erecta				*Agrostis stolinivira*
Carex pallescens				*Plantago lanceolata*
Centauria jacra				*Poa trivialis*
Molinia caerulea				*Cirsium sp.*
Hypericum perforatum				*Taraxum officinale group*
				Juncus tenius
				Juncus inflexus
				Poa compressa
				Leontodon hispidus
				Lolium multiflora

Ljubljana solidago	Podpec reference	Podpec solidago	Sava reference	Sava solidago
Solidago canadensis	*Filipendula ulmaria*	*Filipendula ulmaria*	*Bupthalmum salcifolium*	*Solidago canadensis*
Equisetum arvense	*Calta palustris*	*Solidago canadensis*	*Dactylis glomerata*	*Rubus caesius*
Ranunculus acris	*Betonica officinalis*		*Listera ovata*	*Galium album*
Stellaria sp.	*Carex elata*		*Brachpodium pinnatum*	*Melanpyrum nemorosum*
Calystegia sepium	*Iris pseudacorus*		*Angelica sylvestris*	*Erigeron annuus*
Arrhenatherum elatius	*Minta longifolia*		*Koeleria pyramidata*	*Veronica sp.*
	Minta aquaticus		*Tussilago farfara*	*Hypericum perforatum*
	Lysimachia vulgaris		*Carex flacca*	*Origanum vulgare*
	Lysimachia punctata		*Thymus serpyllum*	*Ranunculus sp.*
	Cisircium oleraceum		*Briza media*	
	Peucedanum palustre		*Centauria jacea*	
	Selinum carbifolium		*Cornus sanguinum*	
			Ranunculus acris	
			Lotus corniculatus	
			Hippocreppis comosa	
			Achillea millefolium	
			Lembotropis nigricans	
			Asperula cyanchica	
			Crataegus monogyna	
			Categus monogina	
			Clematis recta	
			Minta sp.	
			Lentodon hispidus	
			Lolium multiflora	
			Pimpernella saxifraga	
			Astragalus sp.	
			Origanum vulgare	
			Centaurea scobiosa	
			Coranila varia	

Appendix 2: Data visiting butterflies

species	BO1	BS1	BO2	BS2	BO3	BS3	IO1	IO2	IO3	IS3	LO1	LS1	LO2	LS2	LO3	LS3	PO1	PS1	PO2	PS2	PO3	PS3	SO1	SS1	SO2	SS2	SO3	SS3
Aglias urticae	1						1																					
Araschnaria levana				1																		1						
Argynnis paphia						1															1							
Artogeia napi			2	2			4	3							1													
Artogeia rapae									3												2							3
Brenthis daphne																			1									
Celestrina argiolus																									1			
Clossiana dia			2																1						1			
Clossiana selene	3	1																1										
Coenonympha glycerion							1		2													1						
Coenonympha pamphilus									2												1						1	
Colias crocea															1													
Cupido minimus					1																							
Erynnes tages																							3					
Everes argiades			1									1			2													
Gonepteryx rhamni			2	1							1																	
Inachis io			2					2		1													1	1				
Leptidae sinapis/reali			2		3																1					4		
Lycaena dispar																	1											
Lycaenidae sp 1																												1
Lycaenidae sp.																							1					
Lysandra coridon																											2	
Maniola jurtina			2					1		1			8	1	1	2			2	1	3	3			1		1	
Melanargia galathea			2					1											1						1			
Melicta cinxia	1																											
Mellicta athalia																	4				4				2			
Minois dryas																											4	1
Ochlodes venatus				2									2		1				3									
Pieris brassicae							1																					
Plebejus argyrognomon																											2	
Polygonum c-album																						1						
Polyommatus icarus					1						3	1			5		1				1	1						
Thymelicus sylvestris			1																1	1								
Vanessa atalanta								1																				
Vanessa cardui			3	1			1					1																

Appendix 3: Data hoverflies

species	BO1	BS1	BO2	BS2	BO3	BS3	IO1	IS1	IO2	IS2	IO3	IS3	LS1	LO2	LS2	LO3	LS3	PO1	PS1	PO2	PS2	PO3	PS3	SO1	SS1	SO2	SS3
Cheilosia barbata				1																							
Cheilosia sp. 1								1																			
Cheilosia sp. 2																		1				1					
Cheilosia sp. 3														1													
Chrysotoxum bicinctum			1													1						1	1				
Chrysotoxum festivum																						2	1				
Chrysotoxum vernale																		1									
episyrphus balteatus			1			1					3											1					
Eriozona syrphoides																		1	1								
Eristalinus sepulchralis									1																		
Eristalis arbustorum					1												3					2					1
Eristalis pertinax																	1										
Eristalis tenax												1					1					5					
Eumerus strigatus																								1		1	
Eupeodes luniger																							1				
Eupeodes lapponicus												2															
Helophilus pendulus		2										1					1										
Helophilus trivittatus																						1					
Heringia virens		1																					1		1	1	
Melanostoma mellinum	1																									1	
Merodon aenea																	1							1			
Merodon bessarabia (?)																							1				
Merodon constans																											2
Merodon haemorrhoidalis																				1	1						
Merodon sp. 1																				2							
Merodon sp. 2																						1					
Merodon tenera																2	6					1					
Myatropa florea																	1					2	1				
Sphaerophoria scripta				1		4			1		6	8				2	4					1	2			3	1
Sphaerophoria sp.					1	6	1		7	1	2	5		1	2	4	1						6			1	5
Sphaerophoria taeniata (?)																							1				
Syritta pipiens			6								2						3					1	4				1
Syritta sp.												1															
Syrphus ochromstoma			1																								
Volucella bombylans													1														
Xanthogramma pedissequum											1																

Appendix 4: Data carabids

species	BO1	BS1	BO2	BS2	BO3	BS3	IO1	IS1	IO2	IS2	IO3	IS3	LO1	LS1	LO2	LS2	LO3	LS3	PO1	PS1	PO2	PS2	PO3	PS3	SS1	SS2	SS3
Abax ater														1													1
Abax carinatus														1		2		2								1	
Abax parallelus														1		2		2									
Agonum dorsale																	2										
Agonum sp.				5																1							
Amara fulva									1																		
Amara sp.									4				2						1	4	5	3					
Badister sodalis																			1								
Badister unipustulatus		1		1																	1						
Bembidion lampros													2														
Brachinus sp.													5														
Bradycellus harpalinus										2												2					
Bradycellus sp.								1		1					1												
Carabus granulatus	3	4				2	24	2	3	5	8	3									1						
Carabus violaceus																											1
Clivinia fossor	1	4		2			1												6	1	1						
Diachromus germanicus													1			1		1									
Drypta dentata								1																			
Dyschirius sp.				1																1							
Harpalaus melancholicus													1														
Harpalus aeneus								1																			
Harpalus atratus	1		2				1	1		2			1		2		4								1		
Harpalus attenuateus							1																				
Harpalus marginellus																	1										
Harpalus sp. 1																	3										
Harpalus sp. 2													1														
Harpalus sp. 3										1																	
Harpalus tardus								1																			
Harpalus tenebrosus													1														
Metaphonus cradatus																								1			
Metaphonus subquadratus													4														
Nebria brevicollis																						1					
Olisthopus rotundatus				1																							
Oodes helopioides		1																	6	1	7						
Panagaeus crux-major																					2	7	1				
Pardileus calceatus								1																			
Poecilus cupreus					2			2				1			6		2					1	1				
Poecilus versicolor					4			2	3	3	9	13	5				1		2		11	1	3	2			
Pseudophonus rufipes											1	9					1										
Pterostichus anthracinus																						1					
Pterostichus cursor?																				1							
Pterostichus gracilus																			1								
Pterostichus melanarius								1	47	1	39	7			1							1		1			
Pterostichus melas		1			1						1																
Pterostichus niger				1																							
Pterostichus nigrita					1																						
Pterostichus sp.																			1								
Pterostichus strenuus																			2	1			1				
Pterostichus vernalis		5		1		2				1					2				2	2	5	2	7				
Stenolophus sp													4														
Stomis pumicatus	1						4		2																		
Synachus nivalis										1																	
Trechus quadristriatus																										1	
Trechus sp.																			1								

Appendix 5: Species diversity indices and eveness

Species diversity indices and eveness reference plot

period	plot	Total butterfly diversity	Butterfly eveness	Visiting butterfly diversity	Visiting butterfly eveness
1	Bevke	0,950270539	0,864973521	0,950270539	0,864973521
1	Podpeč	0,867563228	0,789690082	0,867563228	0,789690082
1	Ig	1,386294361	0,861353116	1,386294361	0,861353116
1	Ljubljana	0,562335145	0,811278124	0,562335145	0,811278124
1	Sava	0,908908735	0,827324384	0	0
2	Bevke	2,238186937	0,972032236	2,260233853	0,98160709
2	Podpeč	2,014035524	0,968546354	1,676987774	0,935944697
2	Ig	1,943041054	0,884316093	1,494175138	0,928383212
2	Ljubljana	1,164364512	0,839911454	0,500402424	0,721928095
2	Sava	2,079441542	0,94639463	1,560710409	0,9697239
3	Bevke	1,487816716	0,83036632	0,950270539	0,864973521
3	Podpeč	1,680767984	0,863743881	1,778233306	0,913831148
3	Ig	1,116367075	0,805288622	1,078992208	0,982141033
3	Ljubljana	1,724242094	0,886085154	1,540305825	0,859661049
3	Sava	1,721402322	0,8846258	1,470808476	0,913864688
		Syrphidae diversity	**Syrphidae eveness**	**Carabidae diversity**	**Carabidae eveness**
1	Bevke	0	0	1,242453325	0,896240625
1	Podpeč	1,098612289	1	2,019842185	0,877206315
1	Ig	0	0	0,794681741	0,573241703
1	Ljubljana	0	0	2,220635154	0,964409594
1	Sava	0,693147181	1	0	0
2	Bevke	1,002718265	0,723308334	0,673011667	0,970950594
2	Podpeč	0,636514168	0,918295834	1,754722939	0,843843361
2	Ig	0,683738906	0,622365973	0,746119868	0,46359034
2	Ljubljana	0,693147181	1	1,387604603	0,862167215
2	Sava	1,475076311	0,916516443	0	0
3	Bevke	0,693147181	1	1,213007566	0,875
3	Podpeč	2,302014103	0,926398625	1,234267866	0,766893744
3	Ig	1,437701444	0,893294132	0,952700937	0,591946374
3	Ljubljana	1,273028337	0,918295834	1,933809999	0,929966032
3	Sava	0	0	0	0

Species diversity indices and eveness Solidago plot

period	plot	Total butterfly diversity	Butterfly eveness	Visiting butterfly diversity	Visiting butterfly eveness
1	Bevke	0,693147181	1	0,693147181	1
1	Podpeč	0,636514168	0,918295834	0	0
1	Ig	0,693147181	1	0	0
1	Ljubljana	0	0	0	0
1	Sava	0	0	0	0
2	Bevke	1,716784686	0,958155777	1,549826046	0,962961065
2	Podpeč	2,319574997	0,933465648	0,693147181	1
2	Ig	0,857174044	0,618320371	0	0
2	Ljubljana	1,560710409	0,9697239	0	0
2	Sava	1,039720771	0,94639463	0	0
3	Bevke	1,889159164	0,970835763	0	0
3	Podpeč	1,594166699	0,889721375	1,475076311	0,916516443
3	Ig	1,078981783	0,982131543	0,693147181	1
3	Ljubljana	1,695742534	0,946411928	1,33217904	0,960964047
3	Sava	1,893788232	0,91071963	0,950270539	0,864973521
		Syrphidae diversity	**Syrphidae eveness**	**Carabidae diversity**	**Carabidae eveness**
1	Bevke	0,636514168	0,918295834	1,611472204	0,899379762
1	Podpeč	0	0	1,676987774	0,935944697
1	Ig	0	0	2,245035274	0,975006431
1	Ljubljana	0	0	1,098612289	1
1	Sava	0	0	0	0
2	Bevke	0,693147181	1	1,73265872	0,890410444
2	Podpeč	0	0	1,516185337	0,632298397
2	Ig	0	0	2,000085221	0,910278013
2	Ljubljana	0	0	1,054920168	0,960229718
2	Sava	0	0	0,693147181	1
3	Bevke	0,916464886	0,834202289	0,693147181	1
3	Podpeč	2,013805894	0,874584787	1,039720771	0,94639463
3	Ig	1,442093077	0,478397943	1,520329803	0,944634019
3	Ljubljana	2,050705726	0,890610181	1,054920168	0,960229718
3	Sava	1,359236701	0,844541246	0,693147181	1

Appendix 6: Effort and weather conditions

Plant monitoring

location	place on the transect (m)	date	time	surface (m)	cover (%)
Bevke original	2,3484	11-jun	8:15		
Bevke solidago	19,4624	12-jun	8:00	550	100
Podpeč original	8,6722	12-jun	11:05		
Podpeč solidago	18,76	12-jun	11:21	90	80
Ig original	7,3536	13-jun	20:10		
Ig solidago	9,908	13-jun	19:40	182	100
Sava original	4,63	11-jun	10:56		
Sava solidago	1,109	11-jun	12:49	70	90
Ljubljana original	2,9742	11-jun	13:30		
Ljubljana solidago	7,79	11-jun	13:46		95

Butterflies

Butterflies **first period**	date	time	clouds	temperature (C)	windstrength (beaufort)
Bevke original	25-mei	10.01 - 10.11	0,375	25	0
Bevke solidago	25-apr	9.30 - 9.40	0,25	25	0
Podpeč original	25-mei	12.23 - 12.42	0,5	25	1
Podpeč solidago	25-mei	11.58 - 12.07	0,375	25	0
Ig original	22-mei	14.06 - 14.20	0,5	23	2
Ig solidago	22-mei	13.15 - 13.27	0,375	23	1
Ljubljana original	23-mei	13.43 - 13.51	0,125	25	1,5
Ljubljana solidago	23-mei	14.09 - 14.19	0,125	25	1
Sava original	23-mei	11.25 - 11.38	0,125	20	1,5
Sava solidago	23-mei	12.12 - 12.22	0,125	25	0
second period					
Bevke original	20-jun	9.44 - 10.05	0	28	1
Bevke solidago	20-jun	9.23 - 9.43	0	25	1
Podpeč original	20-jun	12.00 - 12.20	0,125	30	2,5
Podpeč solidago	20-jun	12.51 - 13.11	0,125	30	2,5
Ig original	22-jun	11.43 - 12.03	0,125	30	0
Ig solidago	22-jun	12.46 - 13.06	0,125	32	1
Ljubljana original	23-jun	11.21 - 11.41	0	28	3
Ljubljana solidago	23-jun	12.29 - 12.49	0	34	1
Sava original	19-jun	14.25 - 14.45	0,5	25	1
Sava solidago	19-jun	16.16 - 16.35	0,5	23	3
third period					
Bevke original	13-aug	13.16 - 13.36	0,125	34	0
Bevke solidago	13-aug	12.28 - 12.48	0	34	1
Podpeč original	13-aug	10.10 - 10.30	0	30	1
Podpeč solidago	13-aug	11.04 - 11.24	0	30	1
Ig original	12-aug	9.47 - 10.13	0,375	28	1
Ig solidago	12-aug	10.54 - 11.14	0,375	25	1
Ljubljana original	10-aug	14.00 - 14.31	0,375	30	1
Ljubljana solidago	12-aug	12.38 - 12.58	0,25	30	0
Sava original	12-aug	15.27 - 15.47	0	33	1
Sava solidago	12-aug	14.35 - 14.55	0	33	1

Hoverflies

Syrphidae					
first period	date	time	clouds	temperature (C)	windstrength (beaufort)
Bevke original	25-mei	10.20 - 10.53	0,375	25	0
Bevke solidago	25-mei	9.42 - 9.54	0,25	25	0
Podpeč original	25-mei	11.43 - 11.58	0,375	25	1
Podpeč solidago	25-mei	12.09 - 12.19	0,375	25	1
Ig original	23-mei	14.30 - 14.40	0,5	23	2
Ig solidago	23-mei	13.30 - 13.40	0,375	23	1
Ljubljana original	23-mei	13.54 - 14.04	0,125	25	1,5
Ljubljana solidago	23-mei	14.21 - 14.31	0	25	1
Sava original	23-mei	11.44 - 11.58	0,125	22	1
Sava solidago	23-mei	12.24 - 12.38	0	25	0
second period					
Bevke original	20-jun	10.10 - 10.30	0	30	1
Bevke solidago	20-jun	10.43 - 11.03	0	30	1
Podpeč original	20-jun	12.21 -12.45	0,25	30	2
Podpeč solidago	20-jun	13.18 - 13.38	0,25	30	2
Ig original	22-jun	12.05 - 12.25	0,125	32	1
Ig solidago	22-jun	13.06 - 13.26	0,125	32	1
Ljubljana original	23-jun	11.41 - 12.01	0	28	3
Ljubljana solidago	23-jun	14.28 - 14.51	0	34	1,5
Sava original	19-jun	14.56 - 15.21	0,5	25	1
Sava solidago	23-jun	9.49 - 10.10	0	27	2,5
third period					
Bevke original	13-aug	12..55 - 13.15	0,125	34	0
Bevke solidago	13-aug	12.06 - 12.27	0	34	1
Podpeč original	13-aug	9.29 - 9.49	0	30	1
Podpeč solidago	13-aug	10.36 - 10.56	0	30	1
Ig original	12-aug	10.15 - 10.35	0,375	28	1
Ig solidago	12-aug	11.17 - 11.37	0,375	25	1
Ljubljana original	12-aug	13.30 - 13.50	0,375	30	1
Ljubljana solidago	12-aug	13.00 - 13.20	0,25	30	0
Sava original	12-aug	16.06 - 16.26	0	33	1
Sava solidago	12-aug	14.56 - 15.15	0	33	1

Carabids

location	first period	second period	third period
Bevke original	19.5 - 26.5	17.6 - 24.6	3.8 - 10.8
Bevke solidago	19.5 - 26.5	17.6 - 24.6	3.8 - 10.8
Podpeč original	19.5 - 26.5	17.6 - 24.6	3.8 - 10.8
Podpeč solidago	19.5 - 26.5	17.6 - 24.6	3.8 - 10.8
Ig original	20.5 - 27.5	17.6 - 24.6	3.8 - 10.8
Ig solidago	22.5 - 29.5	17.6 - 24.6	3.8 - 10.8
Ljubljana original	21.5 - 28.5	16.6 - 23.6	2.8 - 9.8
Ljubljana solidago	21.5 - 28.5	16.6 - 23.6	2.8 - 9.8
Sava original	21.5 - 28.5	16.6 - 23.6	2.8 - 9.8
Sava solidago	21.5 - 28.5	16.6 - 23.6	2.8 - 9.8

Appendix 7: Pictures of the plots

Bevke

Reference plot

Solidago canadensis plot

Podpec

Reference plot

Ig

Reference plot

Solidago canadensis plot

Ljubljana

Reference plot

Solidago canadensis plot

Sava

Reference plot

Appendix 8: Vegetation monitoring form

Name observer: **Date:** **Time:**

Weather:

Transect no.: **Plot: Original / Solidago**

Distance of vegation plot on the transect (m):

Surface of Solidago patch (m^2):
Cover (%):

Relative abundance of plant species counted in a plot of 4 m by 4 m

Species	Cover (%)	Species	Cover (%)

Apendix 9: Butterfly counting form

Name observer: **Date:**

Time start: **finishing time:**

Weather:

Transect no.: **Plot: Original / Solidago**

Height of Solidago (m):

Counted butterfly species per transect

Species	number	Species	number

Appendix 10: Hoverfly counting form

Name observer: **Date:**

Time start: **finishing time:**

Weather:

Transect no.: **Plot: Original / Solidago**

Height of Solidago (m):

Counted Hoverfly species per transect

Species	number	Species	number

Appendix 11: Carabid counting form

Name observer: **Date:**

Time start: **finishing time:**

Weather:

Transect no.: **Plot: Original / Solidago**

Height of Solidago (m):

Counted Carabid species per transect

Species	**Pitfall no. per transect**					
	1	2	3	4	5	6