DEPARTMENT OF BIOLOGICAL AND
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DECREASE OVER TIME IN SHANNON DIVERSITY OF LAND SNAILS

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Carychium minimum

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Abstract

With rising temperatures as a consequence of climate change, suitable habitats for land snails in the northern hemisphere may be shifting northwards. However, there is a lack of studies that explore the latitudinal effects that climate change has on land snails. Therefore, the aim was to see if there are any temporal changes in the species composition of land snails. This was done using sieve samples with land snails that had been repeatedly collected from two sites in southern Sweden. Latitudinal data was provided by two different databases regarding the northernmost and southernmost range limits of the species that were found at the sites. The latitudinal preference of the species composition at the sites was calculated using the latitudinal data. Simple linear regression was used to assess whether the Shannon diversity for the samples was predicted by precipitation, temperature, or year. Simple linear regression was also used to test whether the latitudinal preference of the species composition was predicted by year. It was shown that the Shannon diversity was significantly negatively correlated with year for both of the sites. However, no significant effects of the other predictor variables on the Shannon diversity were found. These results suggest that something is going on which is causing the Shannon diversity to decrease. Also, the results do not exclude that there could be a real effect of latitude, as the latitudinal data may not be sensitive enough to detect a change in latitudinal preference over time for the species composition. Therefore, in future studies, it would be relevant to put some extra effort into examining what is causing the decrease in Shannon diversity over time.

Keywords: Climate change, global warming, land snails, species composition

Abstrakt

Med ökande temperaturer till följd av klimatförändringar, kan lämpliga habitat för landlevande snäckor i den norra hemisfären förskjutas norrut. Däremot finns det en brist på studier som undersöker de latitudinella effekterna som klimatförändringen har på landlevande snäckor. Därför var syftet att ta reda på om det finns några temporala förändringar i artsammansättningen hos landlevande snäckor. Detta gjordes genom att använda sållprover med landlevande snäckor som under upprepade tillfällen hade samlats in från två lokaler i södra Sverige. Latitudinell data erhölls från två olika databaser gällande den mest nordliga och sydliga utbredningsgränsen för de observerade arterna i lokalerna. Den latitudinella preferensen för artsammansättningen på lokalerna beräknades utifrån den latitudinella datan. Enkel linjär regression användes för att ta reda på om Shannon-indexet för proverna förutspåddes av nederbörd, temperatur, eller år. Enkel linjär regression användes också för att se om den latitudinella preferensen för artsammansättningen förutspåddes av år. Shannon-indexet visade sig vara signifikant negativt korrelerad med år för de båda lokalerna. Däremot kunde inga signifikanta effekter påvisas för de andra prediktorvariablerna på Shannon-indexet. Dessa resultat indikerar att det finns något som får Shannon-indexet att minska över tid. Resultaten utesluter dessutom inte att det finns en verklig effekt av latitud, då den latitudinella data som användes kanske inte hade en tillräckligt hög precision för att finna en förändring i latitudinell preferens över tid, för artsammansättningen på lokalerna. I framtida studier hade det därför varit relevant att lägga extra vikt vid att undersöka vad som orsakar minskningen i Shannon-indexet över tid.

Nyckelord: Artsammansättning, global uppvärmning, klimatförändringar, landlevande snäckor

Introduction

Climate change

Anthropogenic impact on the environment may be one important aspect that is affecting the species diversity of land snails. What could alter such impacts are factors that are limited to the specific site, although the way this happens is still relatively unknown (Douglas et al., 2013). One of the main ways that humans impact the environment is through the emissions of greenhouse gasses, which in turn leads to climate change (Fawzy *et al.*, 2020). According to the Intergovernmental Panel on Climate Change (IPCC) (2014), climate change is "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer." (p. 120).

Different species are affected by climate change in a plethora of different ways. Through the introduction of new species and possibly also invasive species, by altering the precipitation patterns in an area, or by increases in temperature, distinct challenges might arise due to climate change. Subsequently, the species in a certain area might then have to deal with this to avoid extirpation (Pearce & Paustian, 2013).

The effects of climate change on land snails

With increasing temperatures due to climate change, suitable habitats for land snails will shift northward in the Northern hemisphere. It may also shift towards higher altitudes, as is the case in mountain regions (Pearce & Paustian, 2013). In the Northern hemisphere, range shifts have been recorded northward for several species as temperatures are rising (e.g. Kwon et al., 2014).

Due to the low mobility of land snails in general, they are sensitive to changes in their habitat (Douglas et al., 2013) and on top of this, habitat fragmentation may impede the dispersal of land snails (Gheoca *et al.*, 2021). The sensitivity to changes in the habitat is especially the case for smaller species of land snails, that on top of being rather immobile, also live in specific microhabitats (Douglas et al., 2013). This is also the case for species that move slowly and thus cannot keep up with the changes that occur in their habitat (Pearce & Paustian, 2013).

The ecology of land snails is relatively established (Astor *et al.*, 2017) and also well-studied (e.g. Barrientos, 2016; Davison *et al.*, 2004), but compared to other groups, terrestrial gastropods are a less frequently used model in ecological studies (Götmark *et al.*, 2008). There are almost no studies examining how land snails are affected by climate change (Beltramino *et al.*, 2015). The effects of climate change on land snails in mountain regions have been examined. There are some indications of climate warming posing a threat to land snails living near the top of mountain regions, as the suitable habitat at higher altitudes diminishes (Pearce & Paustian, 2013).

The focus here will be to examine the latitudinal effects of climate change on land snails. To do this, changes in Shannon diversity of land snails over time, as well as changes in their climatic preferences over time were studied. This was done using previously collected material of land snails from two different sampling sites in the province of Skåne, southern Sweden.

Aim

The main objective is to find out if there are any temporal changes in the species composition of land snails within the sites. In terms of community structure, given global warming, the hypothesis is that there will be indications that all the sites are becoming more dominated by southern species over time.

Materials and methods

Study sites

The study sites that were used are located in southern Sweden and they are called Lyadalen (56°24'37.0"N, 12°51'52.9"E, WGS8) and Dalahuset (56°24'25.9"N, 12°56'35.0"E, WGS84). Lyadalen is located within Lyadalens naturreservat and Dalahuset is located within Hallandsåsens nordsluttning, both of which are nature reserves (Fig. 1). The vegetation at the site Lyadalen consists of deciduous forest dominated by beech. While there are some fallen tree trunks on the ground, the area is mainly covered by stone blocks and leaf litter. The vegetation at Dalahuset contains deciduous forest, which includes a mix of mainly alder, elm, and ash. The ground consists of sticks, trunks and in some spots also mosses (Trafikverket, 2015). Over the final years of sampling, the Dutch elm disease has become more and more prevalent at Lyadalen. In 2019 when sampling took place in Lyadalen, almost all the elms were found dead and many of the tree trunks were laying on the ground. (Trafikverket, 2019).

Figure 1. Map illustrating the locations of Lyadalen as a black dot and Dalahuset as a gray dot (background map modified from ©Lantmäteriet).

The Hallandsås Tunnel is an infrastructure project that originally began construction back in 1992 and finished in late 2015. It was a project that had some challenges to overcome, such as water that was making its way inside where the drilling took place. For the site Lyadalen, which is located within the area, one major concern was that the drilling of the tunnel would alter the hydrologic conditions at Lyadalen. This was particularly fearsome as many snail species were present there, including Spermodea lamellata (T. von Proschwitz, personal communication. 2022-08-22). Spermodea lamellata is a species that is disfavored by any alterations to the hydrology (von Proschwitz, T. (2018). The other site, Dalahuset, is located outside the drilling area of The Hallandsås Tunnel (T. von Proschwitz, personal communication. 2022-08-22). A sampling of land mollusks was performed at the sites, along with the construction of the tunnel, and the analyses were then done using the already gathered data.

Sampling

Sieve samples were gathered during the same period of the year from the study sites, between August and October. The majority of land snails have their shells fully grown by the time the summer ends/during fall, which makes sampling at this time of the year ideal (Falkner *et al*., 2001a). In total, 17 samples from Lyadalen and 9 samples from Dalahuset were collected (Table 1).

Each sieve sample consisted of leaf litter and the volume was 20 l. The sieve samples were taken along a line of 10 meters which was marked and the sites were revisited for several years to collect more samples. Any snails within the squares that were visible to the naked eye were also included. Sampling a set amount of leaf litter, together with picking large specimens by hand is a common practice when sampling land snails (Cameron & Pokryszko, 2005). All the samples were collected by the same person using this semi-standardized method. While some limitations come with the method that is used to collect leaf litter, it is regarded as the best sampling method for land snails (Falkner *et al*., 2001a).

Table 1. *Months and days when sampling took place during the years between the period 1999-2019. Years, when no sampling took place, are marked with an X.*

	99	**00**	**02**	**03**	**04**	**05**	**06**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Lyadalen																			
Month	09	10	10	10	X	10	X	10	10	10	10	X	10	10	09	10	10	10	10
Day	08	23	15	23		28		30	28	23	20		26	30	01	15	25	26	23
Dalahuset																			
Month	X	10	10	X	10	X	10	10	X	10	X	10	X	10	08	X	X	X	X
Day		21	15		27		27	30		22		28		29	31				

The soil samples were taken from the field and placed on a tray indoors at room temperature for about one to two weeks to dry completely. The snails were then extracted by hand under a desk lamp with magnifying glass using entomological forceps. The material was examined two times to make sure no snails were left out. The method that was used to collect sieve samples including the steps used to extract the snails is also described in further detail by (Falkner *et al*., 2001a). The species of the snails were then determined using a stereo microscope, by using already identified species from the Gothenburg Natural History Museum collection as a reference. The samples were analyzed in random order to eliminate bias from the data, as the rate of error is expected to decline over time. The nomenclature used follows Falkner *et al*. (2001b).

Precipitation and temperature data

Data regarding both precipitation and temperature data was gathered from the Swedish Meteorological and Hydrological Institute (SMHI). The nearest active weather station to both Lyadalen and Dalahuset is Hallands Väderö A. This station has been classified as active throughout the sampling period and also has measurements for both precipitation and air temperature (SMHI weather data series, 2022).

The accumulated Precipitation measured in mm over the period Nov. 1 of the year before sampling-Aug. 1 of the year when sampling took place, was then calculated. The mean temperature over the same period was also calculated using data from the same station. This period was used as the earliest sampling took place in August and the latest sampling took place in October. For some months, data were missing for either temperature or precipitation. Therefore, for those months, the mean of the previous year and the following year of data for that month were used instead.

Statistical analysis

The two dependent variables are latitudinal preference and Shannon diversity, which is a diversity index that is predominantly shaped by species evenness. Species richness plays a lesser role when calculating Shannon diversity, accounting for only one-third or less, of what the evenness does (Strong, 2016). The Global Biodiversity Information Facility (GBIF) was used to get species occurrence data for Gastropoda. The median latitude for all the occurrences for each of the species was then calculated using GBIF occurrences, to get the distributional data for all the species of land snails (GBIF, 2022), which was used to estimate the latitudinal midpoint of the species composition. The latitudinal midpoint for all the individuals was calculated, to get a weighted mean for each sample when sampling took place at the sites. The reason why the weighted mean was used, instead of categorizing the species into northern- and southern species, is because some southern species are more southern than others. This was done to estimate if the latitudinal preference of the species composition shifted over time.

Along with using the GBIF data, the analysis was also done using species occurrence data provided by the Gothenburg Natural History Museum (GNM) instead. This was done partly because the GBIF database may include incorrect data. It was also done because, for some species, the Gothenburg Natural History Museum database provided data that covered the species distribution ranges more in-depth. The number of snails differed between the samples, as a result of the sampling of 20 l, rather than a fixed number of snails. When using the Shannon-Wiener diversity index to assess whether the diversity of a site is changing over the years, it will to some extent depend on the number of individuals in the samples. The maximum value that the Shannon diversity can get relates to the sample size, so it can get higher diversity with an increased sample size. Therefore, it was standardized by having 107 individuals randomly selected from all the samples, equaling the same number of snails that were found in the sample with the fewest number of individuals, and afterward, Shannon diversity was calculated for the sample. This step of sampling within the samples was then repeated 1000 times for each sample. This was done to standardize it, while at the same fully making use of the material, to generate different outcomes with species being included. Using the median Shannon diversity out of the 1000 iterations, simple linear regression was used to assess whether Shannon diversity was predicted by precipitation, temperature, or year. Also, simple linear regression was used to test if the latitudinal preference of the species composition was predicted by year.

Species abundance curves

Species abundance curves were made for all the samples from both of the sites. These plots were studied to see which species were common and which species were dominant elements at the sites. Species diversity was also calculated for the samples.

Results

In total, 30 species and 12 423 individuals of land snails were identified. One individual of *Vertigo angustior* was found in one sample from Dalahuset. This individual was excluded from the analyses, as Dalahuset does not contain the habitat where this species occurs. It was most likely recorded due to some mistake, e.g. being stuck in the sieve during previous sampling (T. von Proschwitz, personal communication. 2022-08-22).

Species abundance curves

The species abundance curves for Lyadalen depict slopes that for the most part are rather flat, which means that the site has a high species evenness (See Appendix 2). However, one exception to this is the species *Carychium tridentatum*. During some years, it can be a dominant feature, accounting for over 50% of the total number of individuals found at the site, which decreases the evenness (Fig. 2A). While during other years, it may be one of the species that are the least abundant. This means that the rate at which the species abundance curves decline for Lyadalen is primarily shaped by just one of the species, *Carychium tridentatum*. The species *Spermodea lamellata* had a stable relative abundance and the highest relative abundance was recorded in the later years of sampling (Fig. 2B). The species richness varied between 17 and 26 species in Lyadalen during the different years (Fig. 3A).

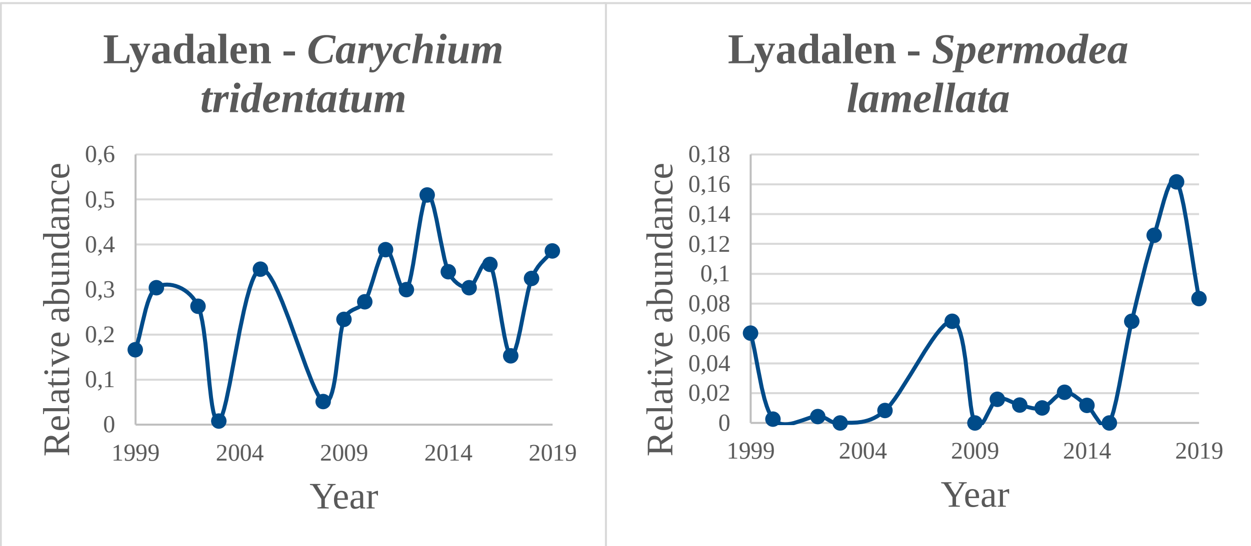

Figure 2. Relative abundance of species collected in Lyadalen during the period 1999-2019. (A) Left: relative abundance for *Carychium tridentatum*. (B): Right: relative abundance for *Spermodea lamellata*.

For Dalahuset, the species richness varied between 17 and 23 species over the period (Fig. 3B). The species abundance curves for Dalahuset are usually flatter than the curves for Lyadalen. This indicates a high species evenness. While *Discus rotundatus* accounts for 5 percent to roughly 25 percent of the total abundance, it is one of the common species at the site (Fig. 4B). Similar to Lyadalen, the abundance of *Carychium tridentatum* influences the way the curves are shaped and it is often a dominant part of the species composition (Fig. 4A).

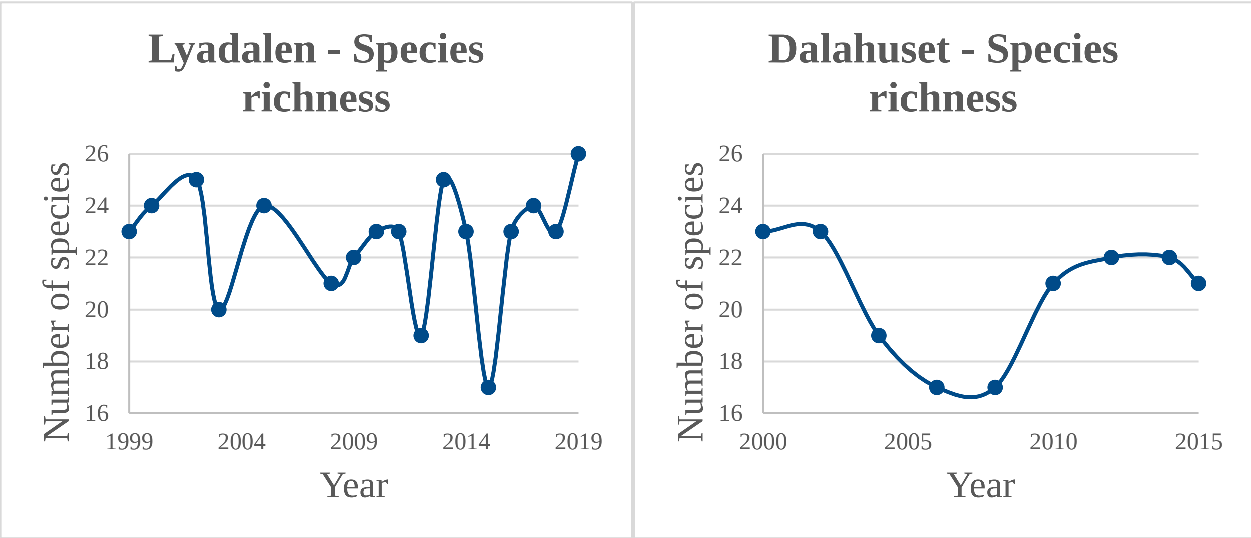

Figure 3. Species richness in the samples collected in (A): Left: Lyadalen. (B) Right: Dalahuset.

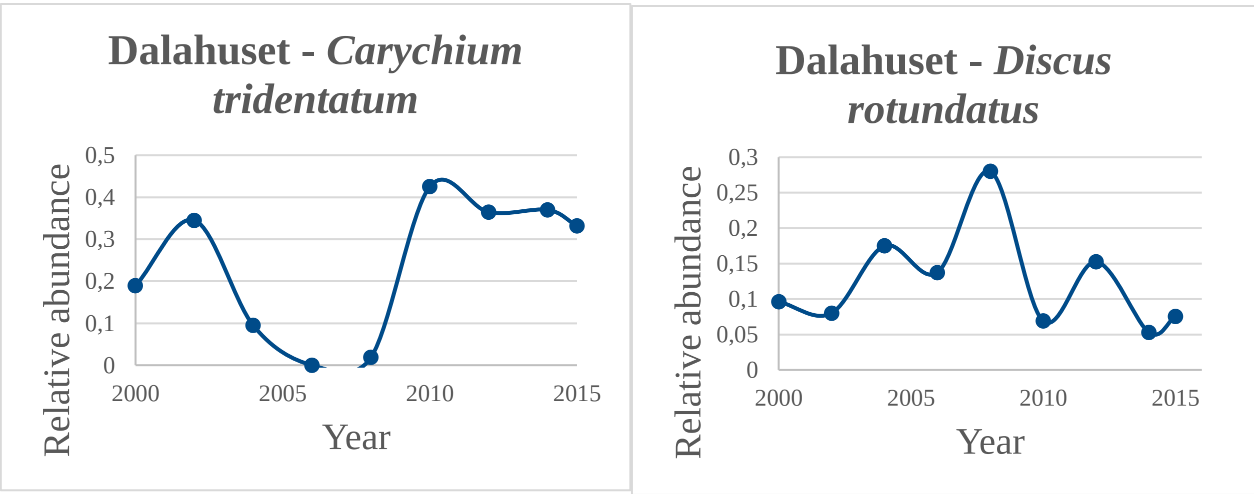

Figure 4. Relative abundance of species collected in Dalahuset during the period 2000-2015. (A) Left: relative abundance for *Carychium tridentatum*. (B): Right: relative abundance for *Discus rotundatus*.

Simple linear regressions

A simple regression model was used to test whether the different predictors significantly predicted Shannon diversity and latitudinal preference of the species composition (Table 2).

Table 2. *The results of the simple regression models along with the corresponding number of the figure for the results. a) The dependent variable is Shannon diversity. b) Calculated using occurrence data from GNM and the dependent variable is latitudinal preference. c) Calculated using occurrence data from GBIF and the dependent variable latitudinal preference.*

Site	**Predictor**	**Standardized effect size (± standard error of the slope)**	R^2	**p-value**	**Figure**
		a) Shannon diversity			
Lyadalen	Year	−0.494 (0.217)	0.244	0.0374	Fig. 5
Lyadalen	Precipitation	0.267 (0.241)	0.0714	0.284	Fig. 6A
Lyadalen	Temperature	−0.0269 (0.250)	0.000726	0.916	Fig. 6B
Dalahuset	Year	−0.708 (0.245)	0.501	0.0219	Fig. 7
Dalahuset	Precipitation	0.0988 (0.352)	0.00976	0.786	Fig. 8A
Dalahuset	Temperature	0.250 (0.342)	0.0625	0.486	Fig. 8B
		b) GNM			
Lyadalen	Year	−0.152 (0.247)	0.0231	0.547	Fig. 6C
Dalahuset	Year	0.00238 (0.354)	$5.68 * 10^{-6}$	0.995	Fig. 8C
		c) GBIF			
Lyadalen	Year	0.342 (0.235)	0.117	0.165	Fig. 6D
Dalahuset	Year	0.275 (0.340)	0.0758	0.442	Fig. 8D

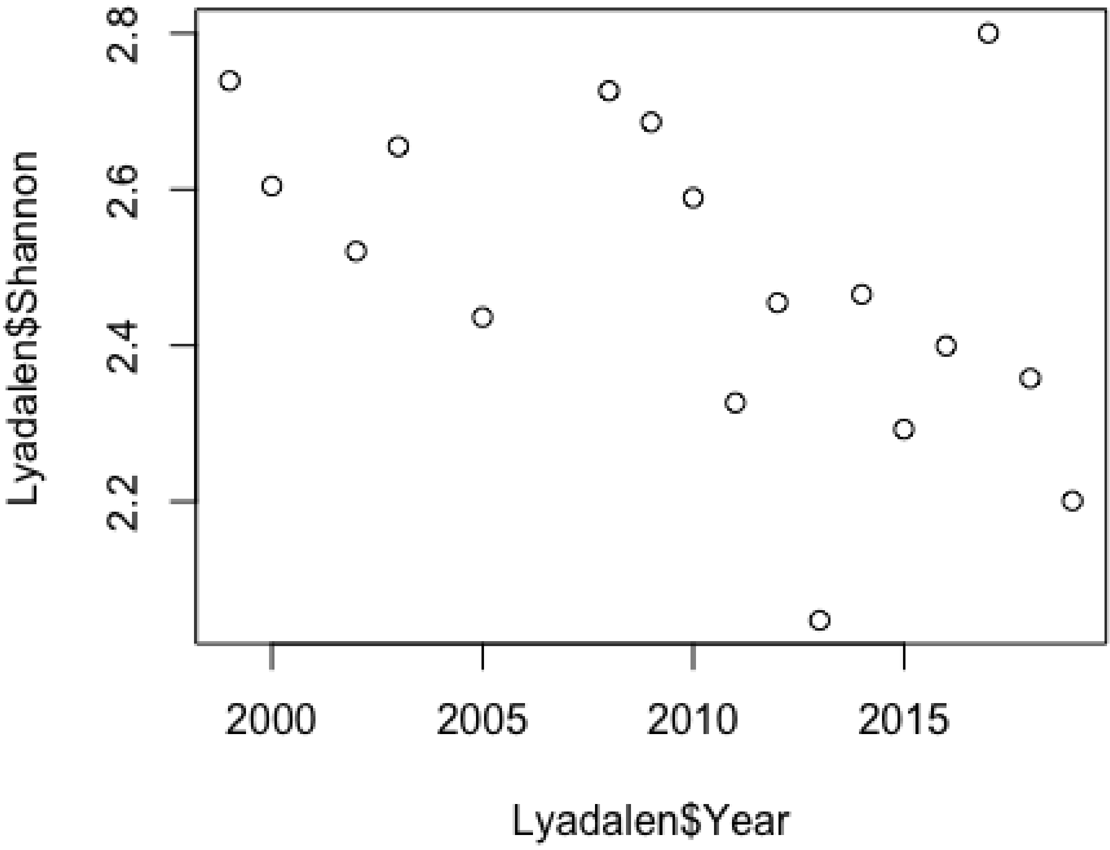

Figure 5. Simple linear regression analysis with Shannon diversity of the samples and Year at Lyadalen.

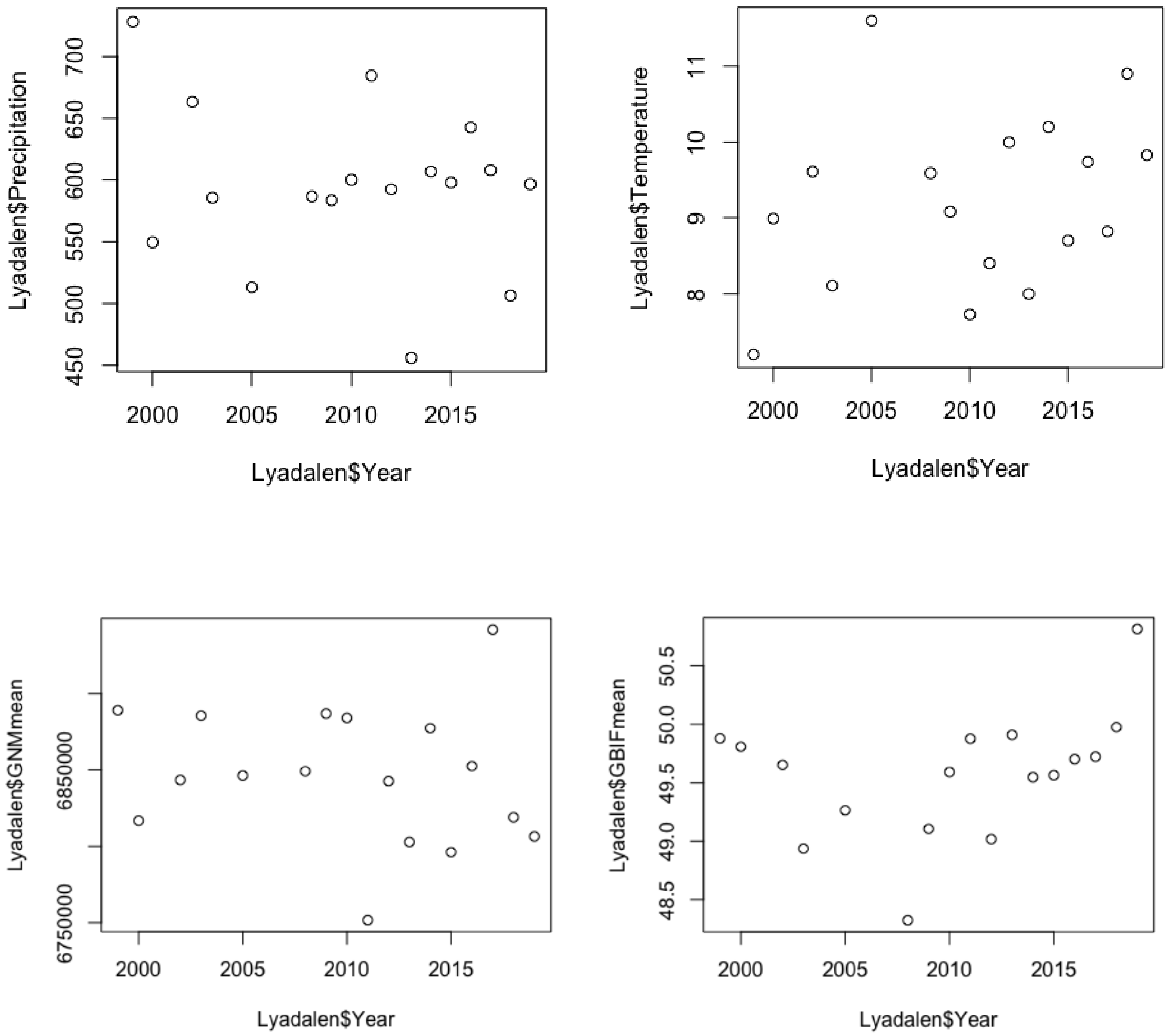

Figure 6. Simple linear regression analysis with Shannon diversity and latitudinal preference, using the samples from Lyadalen over the period 1999-2019. (**A**) Top left: accumulated Precipitation measured in mm over the period Nov. 1 of the year before sampling- Aug. 1 of the year when sampling took place (**B**) Top right: mean Temperature measured in degrees Celsius over the period Nov. 1 of the year before sampling- Aug. 1 of the year when sampling took place. (**C)** Bottom left: Weighted latitudinal midpoint for each sample in RT90 calculated using species occurrence data from Gothenburg Natural History Museum. (**D**) Bottom right: Weighted latitudinal midpoint for each sample, calculated using occurrence data from GBIF.

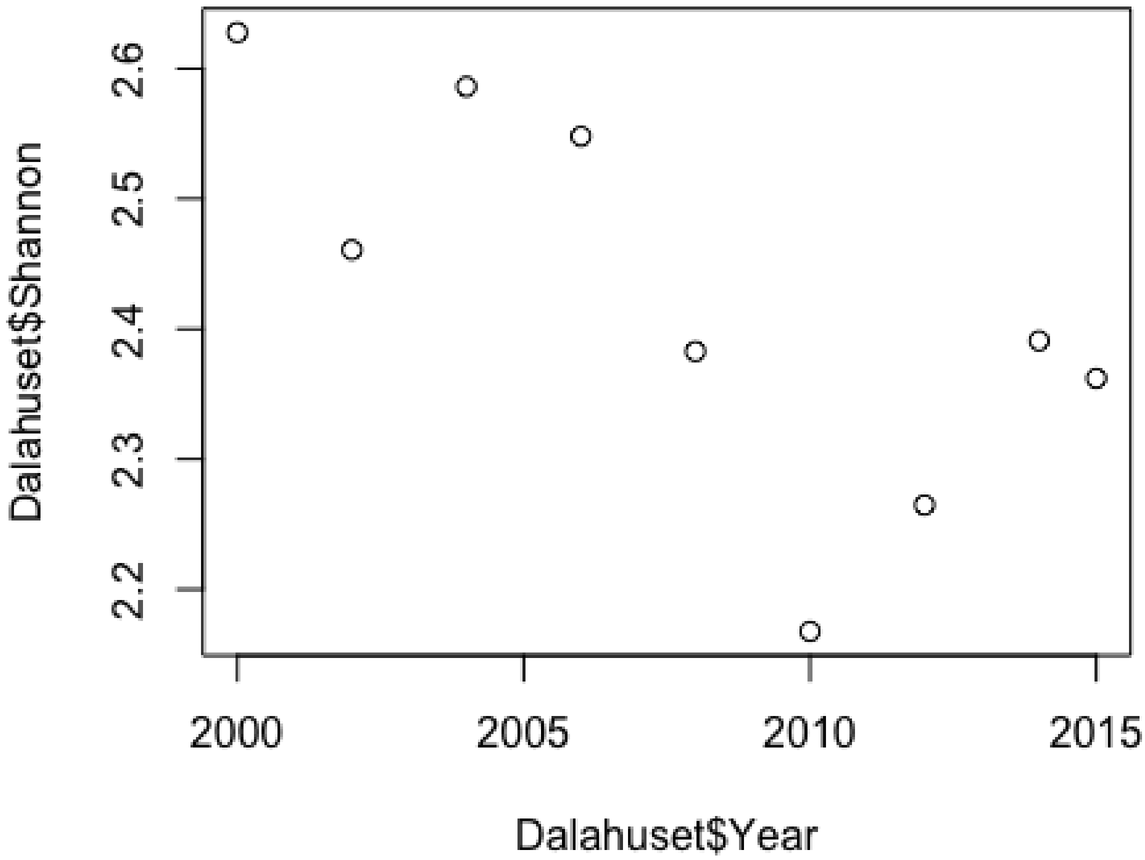

Figure 7. Simple linear regression analysis with Shannon diversity of the samples and Year at Dalahuset.

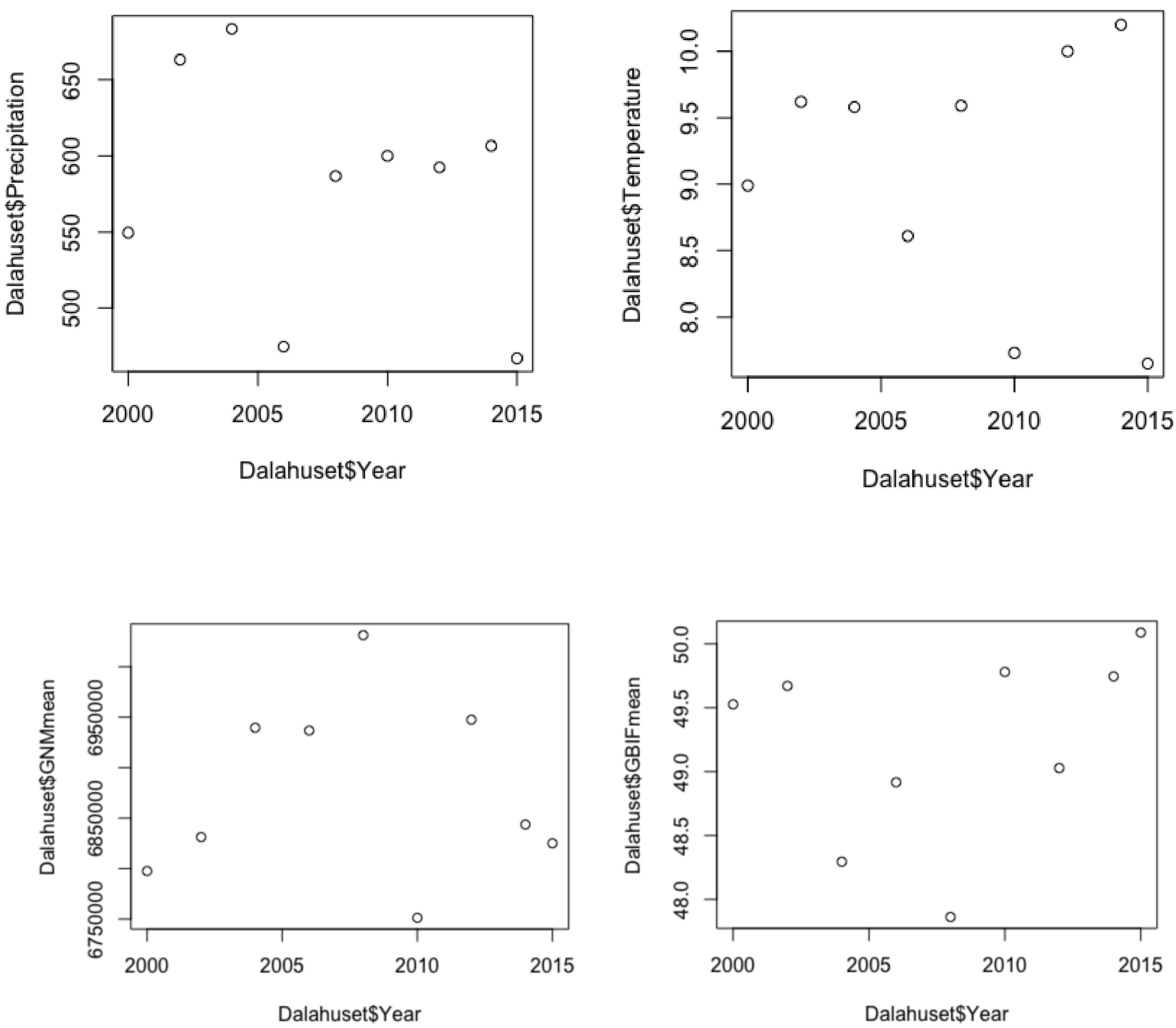

Figure 8. Simple linear regression analysis with Shannon diversity and latitudinal preference, using the samples from Dalahuset over the period 2000-2015. (**A**) Top left: accumulated Precipitation measured in mm over the period Nov. 1 of the year before sampling- Aug. 1 of the year when sampling took place. (**B**) Top right: mean Temperature measured in degrees Celsius over the period Nov. 1 of the year before sampling- Aug. 1 of the year when sampling took place. (**C**) Bottom left: Weighted latitudinal midpoint for each sample in RT90 calculated using species occurrence data from Gothenburg Natural History Museum. (**D**) Bottom right: Weighted latitudinal midpoint for each sample, calculated using occurrence data from GBIF.

Discussion

The results indicate that the Shannon diversity is decreasing at both sites and the decline is even stronger in the site Dalahuset than in Lyadalen. When year was used as a predictor of Shannon diversity, significant results were found for both sites. When precipitation and temperature were used, no significant results were found. Also, when using year as a predictor for latitudinal preference of the species composition, no significant results were found. If the decline in Shannon diversity was driven by global warming, it would make more sense if the decline was also driven by rising temperatures. However, no significant results were found, which might be due to low sample sizes (n=16 samples for Lyadalen and n=9 samples for Dalahuset). The fact that a small number of samples were used and the lack of significant results do not necessarily mean that the other predictor variables do not have a significant effect on predicting the decrease in Shannon diversity. The case might also be that there is a temporal decline that is not related to global warming.

The Dutch elm disease

The Dutch elm disease, which eventually became more and more widespread in Lyadalen throughout the sampling period, meant that most elms died there. This may or may not have a similar effect on the land snail community as clear-cutting does. Also, one way of managing the Dutch elm disease is through clear-cutting (Phillipsen & Gkinis, 1981). Also, as shown by Götmark *et al.* (2008), the percentage of the visible sky from the ground is a negative predictor of the species richness of land snails. Therefore, since Shannon diversity is a measurement of both the species richness as well as evenness, it would be interesting to see if the decline in Shannon diversity at the sites also is predicted by the canopy cover at the sites. Especially so in Lyadalen, where the percent visible sky might have increased over time when the elms died and therefore might explain the decrease in Shannon diversity. If Dutch elm disease is the cause of the decline, it is a bit odd that there is also an even greater decline in Shannon diversity at Dalahuset, where the disease is not as apparent.

It has been shown that the abundance of land snail species initially decreased, following the event of clear-cutting of boreal stream-side forests (Ström *et al*., 2009). This however, Strayer *et al*. (1986) showed to soon be replaced by an increase, following the initial response to a clear-cutting event. Ström *et al*. (2009) concluded that initial declines following a disturbance usually do not remain a persistent threat to land snails over longer periods. In Dalahuset and Lyadalen, the periods used for sampling occurred over 15- and 20 years respectively. While (Ström *et al*., 2009) was studying even longer periods; 40-60 years. In this period, the land snail populations recovered and they concluded that biodiversity conservation of land snails should rely on the results of long-term studies, and management strategies should therefore be developed with these results in mind. Could the decline in Shannon diversity that was found in Lyadalen and Dalahuset be part of an initial decline, soon to be back to the previous Shannon diversity levels? It would be most relevant to do further research in the coming 20-40 years to see what happens to the Shannon diversity and also to monitor how this organism group, land snails, develops over time.

Implications for conservation

During the later years in Lyadalen, *Arion vulgaris*, which is a highly invasive slug, has been found. Also, *Impatiens glandulifera*, a plant species, has been increasing which indicates that there has been an increasing level of eutrophication at the site (Trafikverket, 2019). It would be interesting to follow up on this and see if the increase in new species at the site can predict the decrease in Shannon diversity over time.

Species abundance curves

One explanation as to why *Carychium tridentatum* might vary so much in abundance between samples is either due to it being found in only specific microhabitats at the sites or due to it having a patchy distribution within the site, as suggested by Gärdenfors (1992). This idea also seems to be in line with the results found in Lyadalen and Dalahuset. This is because the fluctuations in the relative abundance of this species were either a hit-or-miss when sampling; being the most abundant and dominant aspect of the site during one year, and being one of the least abundant species during the following year.

Since there are so big fluctuations in the relative abundance of *Carychium tridentatum* between the different years when sampling took place, it would be interesting to see if this is driving the pattern of the decrease in Shannon diversity. The evenness will decline during the years when this particular species has a high relative abundance, which results in that year being inferred to be a year with low Shannon diversity. Likewise, the Shannon diversity will be higher, when the relative abundance of *Carychium tridentatum* is low.

The situation in southern Sweden

Acidic rain has been prevalent in southern Sweden, as mentioned by Gärdenfors (1992). He also noticed that between the period of 1950-1990, snail populations at many studied sites in southern Sweden had declined a lot and that liming allowed the snail population densities to increase. This goes in line with the decrease in Shannon diversity at Lyadalen and Dalahuset, which also are located in southern Sweden. Many factors may very well correlate with the Shannon diversity and many things are happening at the same time at the sites. In future studies, one way of disentangling what relative contribution the different parameter has is by doing controlled experiments and by having each predictor changed independently of the others, as previously stated by (Gärdenfors, 1992).

Conclusions and recommendations

Temporal changes in the species composition of land snails, in terms of a significant decline in Shannon diversity at both sites. Giving explicit suggestions on how management should be done remains a challenge. To do that, further research is called for, to disentangle what is going on at the sites. With climate change in mind, the first step worth considering is to resume the sampling at the sites; long-term studies might be of great importance and may very well include some hidden gems.

Acknowledgments

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Appendix 1

This appendix contains the Popular scientific summary.

THE DIVERSITY OF LAND SNAILS IS DECREASING, BUT WHY...?

Did you know that land snail diversity is decreasing over time in some sites in southern Sweden? Well before anything, let us define what a decrease in diversity means here. In this case, there are indications that something is going on, which is causing the diversity to decrease in some sites in southern Sweden. Another way of looking at this is that the sites are becoming more and more dominated by a few species.

So how did we end up here? Simply by using samples collected between 1999-2019 and then extracting all of the land snails. All in all, that equates to about twelve thousand individuals. Then we have to identify which species the individuals belong to. While many of the snails in the samples are just a few millimeters long when they are adults, the juveniles may be much smaller.

Aegopinella nitidula or Aegopinella pura – a challenging genus

If you know for a fact that you are dealing with an individual of the genus *Aegopinella* and want to find out if it is *A. nitidula* or *A. Pura*, how do you do that?

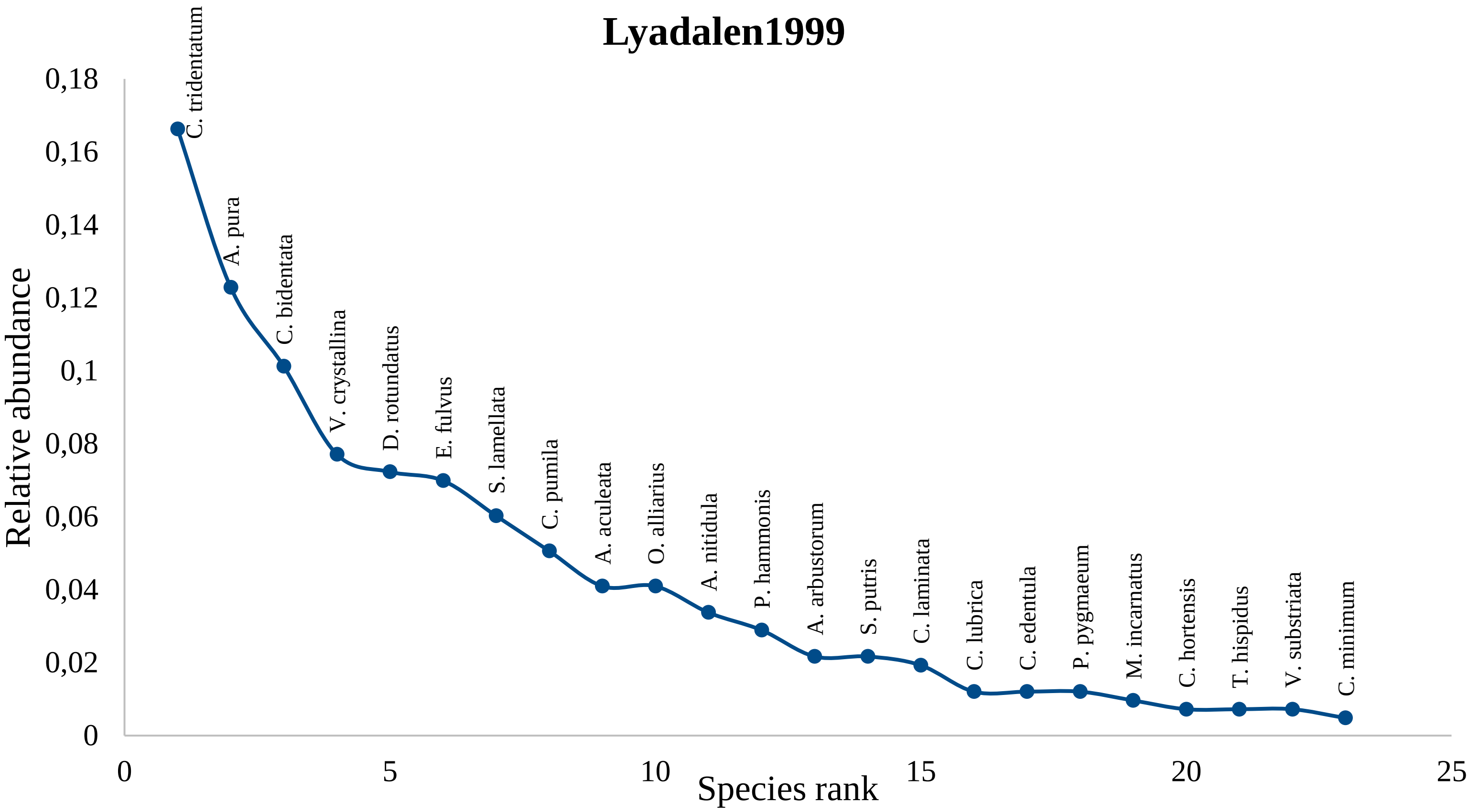
When they are adults, the height of A. pura is slightly lower. For juveniles, you may use already identified individuals as a reference and put them next to each other. *A. pura* will then appear as having a slightly lower height, although only when comparing it with juveniles of the same size.

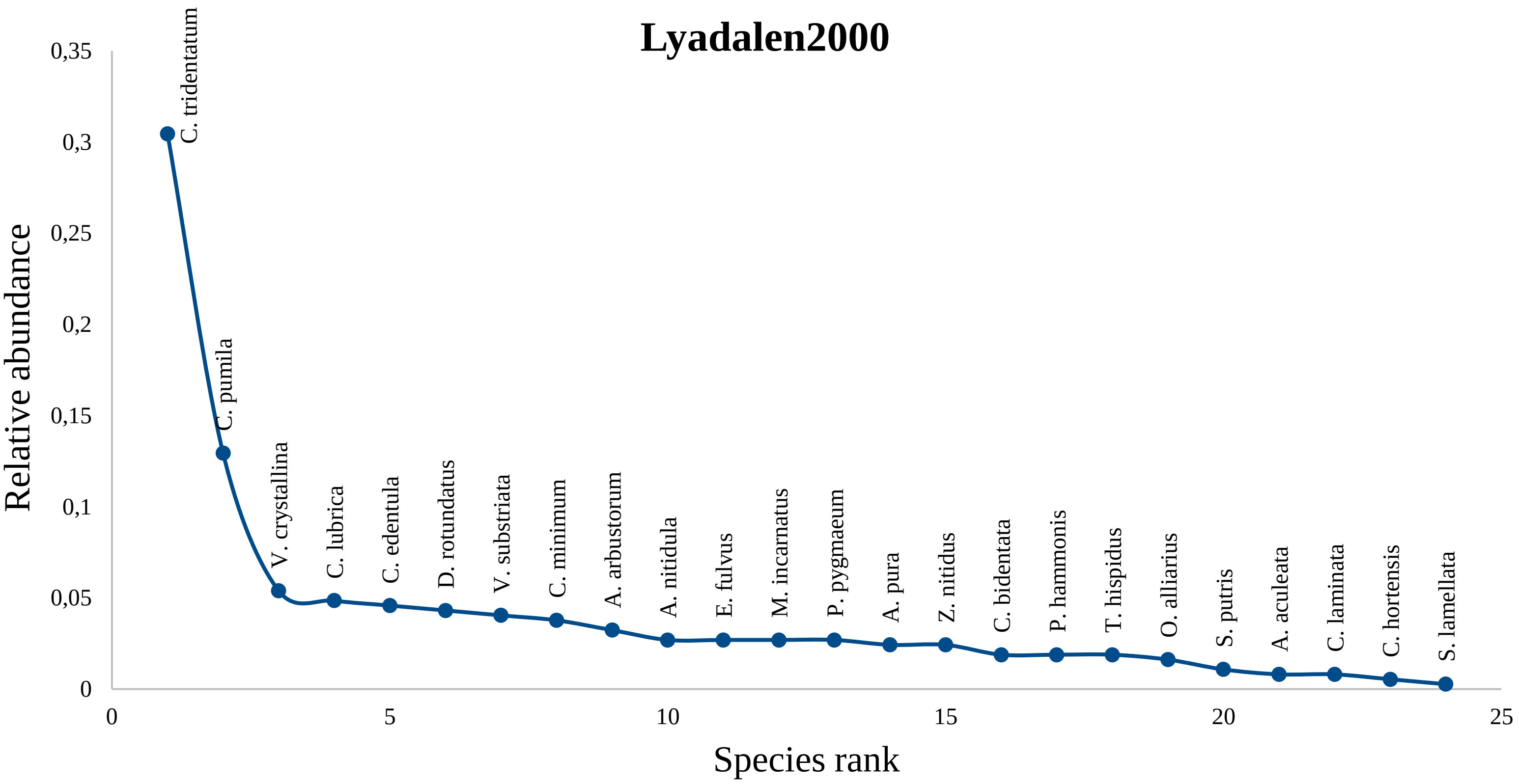
Now that you are more familiar with *Aegopinella*, we will take a look into what was tested using the identified species. The area where species are located may have limits in the north and the south, and we are then talking about what is known as range limits. With rising temperatures, the habitat for land snails may then be shifting northwards in the northern hemisphere, as has been recorded for many species. Therefore, we hypothesized that the sites would become dominated by more and more southern species of land snails over time.

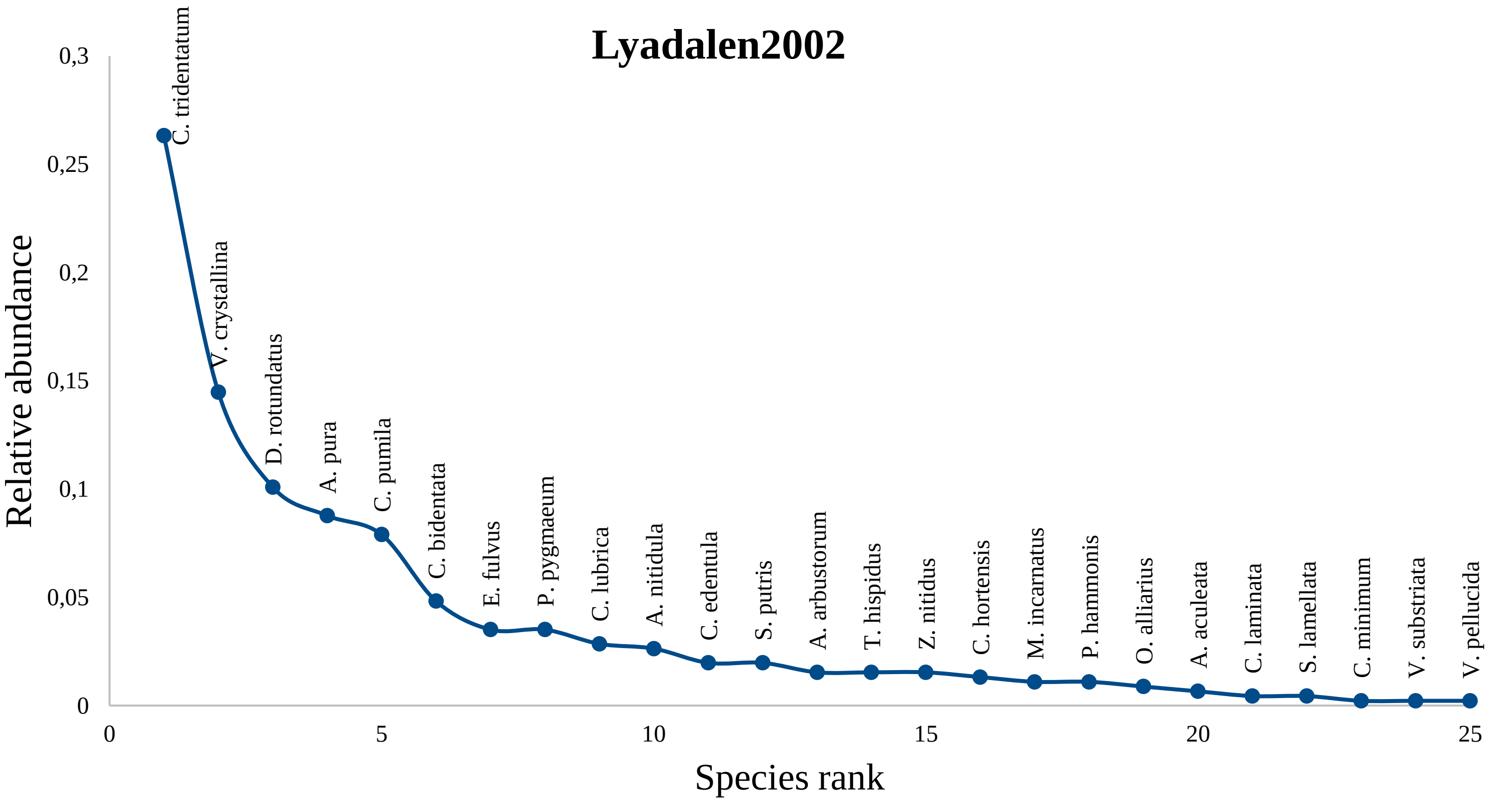
Indications of a decline in diversity over time were found for both of the sites and with an even stronger decline in Dalahuset. However, when using the latitudinal data, it was not able to predict the decline in diversity. This could be because the latitudinal data may be a bit too imprecise. The species *Carychium tridentatum* plays a major role in shaping the species communities of both sites and for many years, it is a dominant element. Over half the individuals found in a given sample may be just individuals of this particular species. This offers great opportunities for further research to look more into other factors that may explain the decline in land snail diversity at the sites.

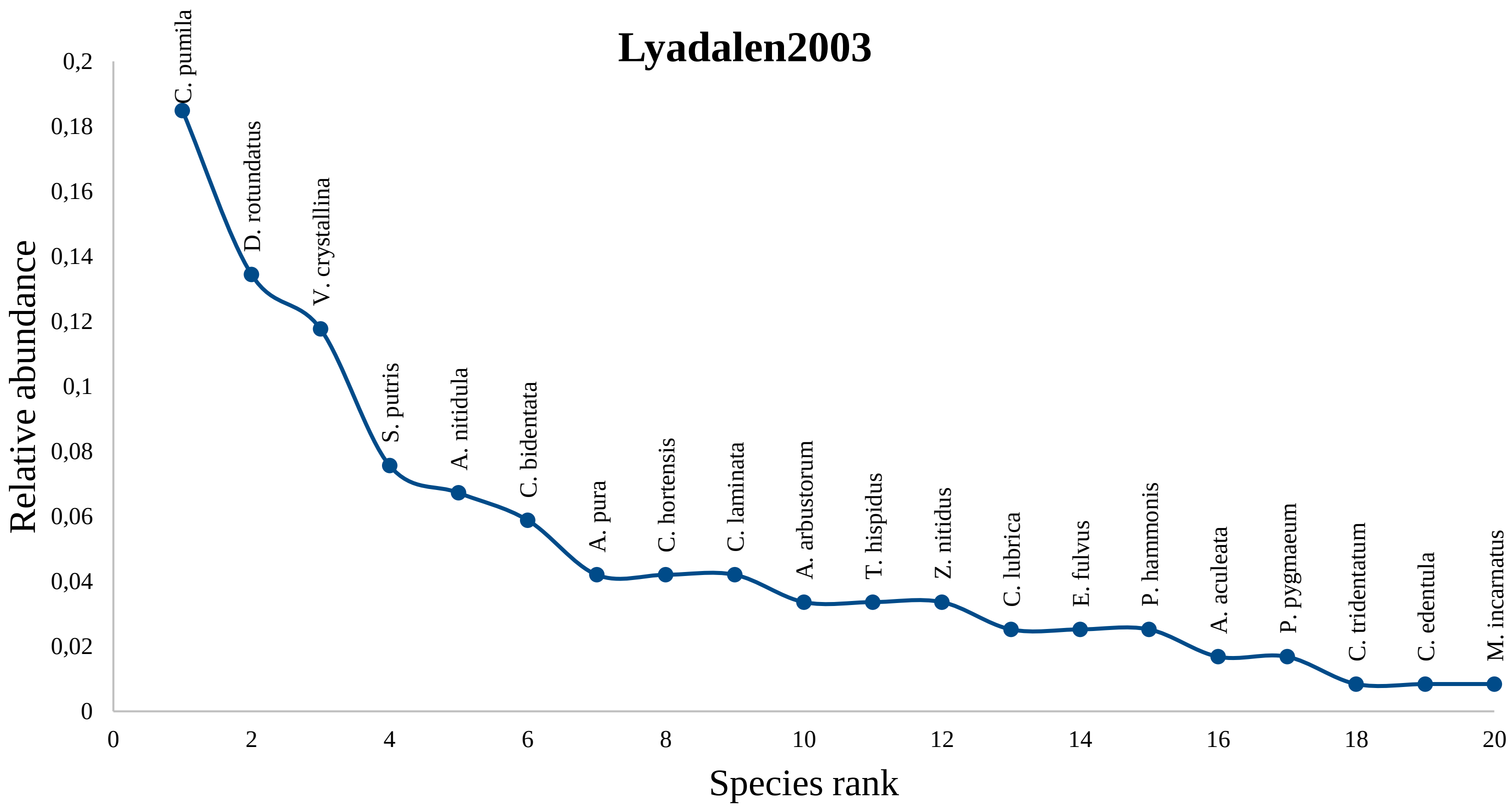
Appendix 2

This appendix illustrates the species abundance curves for all the samples from Lyadalen and Dalahuset.




Lyadalen2000
Relative abundance
Species rank
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
C. pumila
V. crystallina
C. lubrica
C. edentula
D. rotundatus
V. substriata
C. minimum
A. arbustorum
A. nitidula
E. fulvus
M. incarnatus
P. pygmaeum
A. pura
Z. nitidus
C. bidentata
P. hammonis
T. hispidus
O. alliarius
S. putris
A. aculeata
C. laminata
C. hortensis
S. lamellata


Lyadalen2002
Relative abundance
Species rank
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
V. crystallina
D. rotundatus
A. pura
C. pumila
C. bidentata
E. fulvus
P. pygmaeum
C. lubrica
A. nitidula
C. edentula
S. putris
A. arbustorum
T. hispidus
Z. nitidus
C. hortensis
M. incarnatus
P. hammonis
O. alliarius
A. aculeata
C. laminata
S. lamellata
C. minimum
V. substriata
V. pellucida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Relative abundance
Species rank
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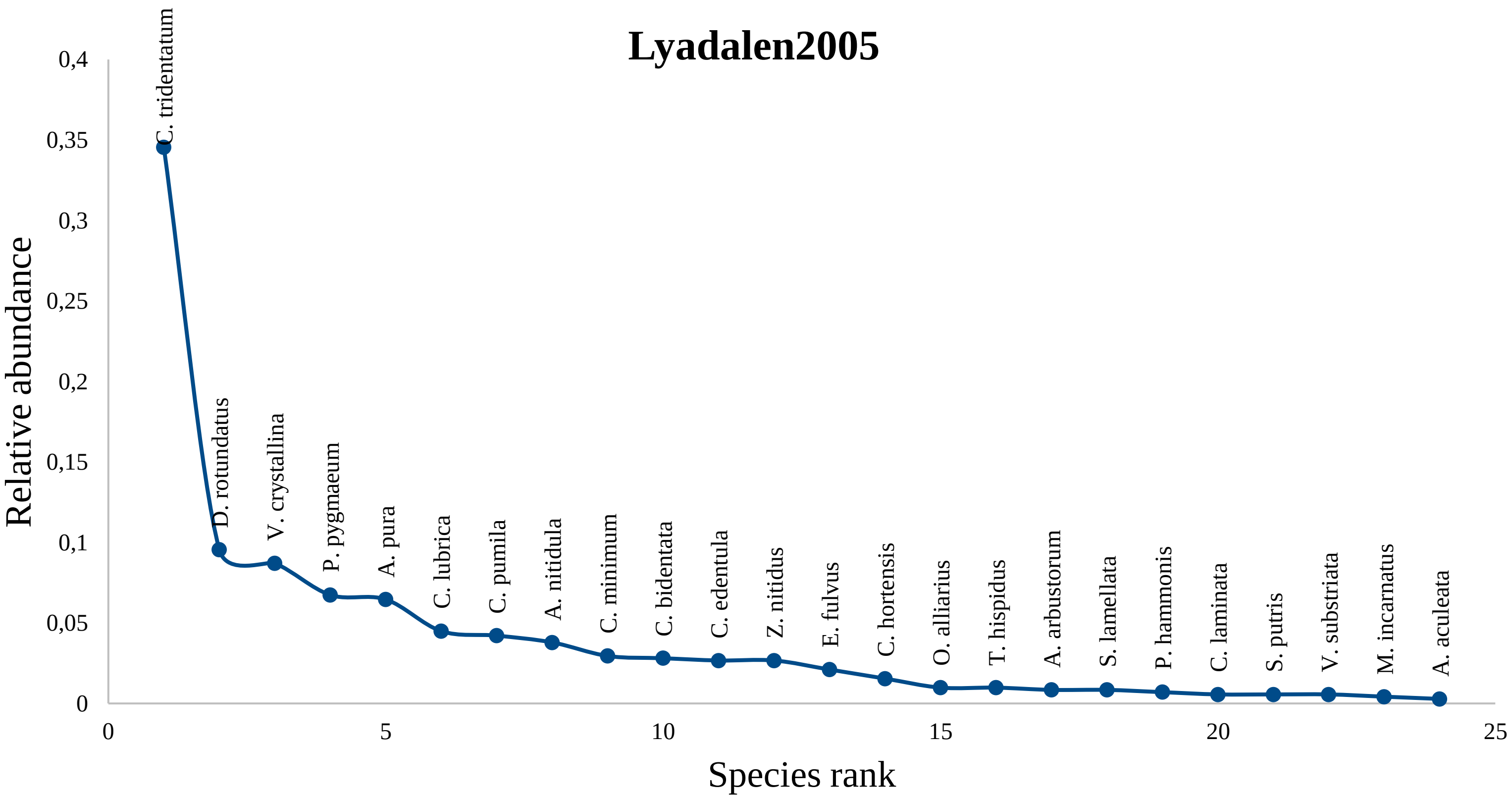
D. rotundatus
V. crystallina
S. putris
A. nitidula
C. bidentata
A. pura
C. hortensis
C. laminata
A. arbustorum
T. hispidus
Z. nitidus
C. lubrica
E. fulvus
P. hammonis
A. aculeata
P. pygmaeum
C. tridentatum
C. edentula
M. incarnatus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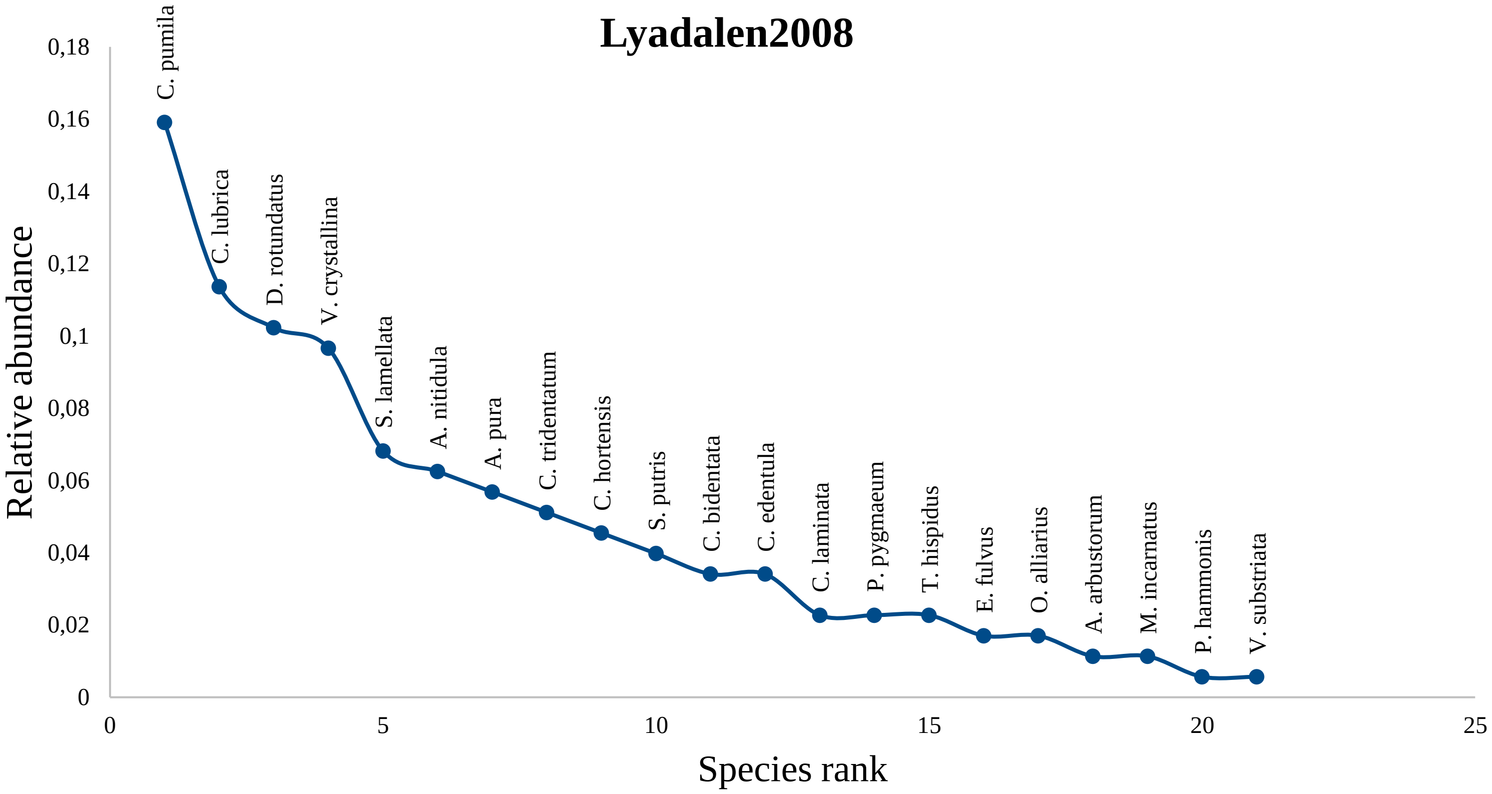
Relative abundance
Species rank
C. tridentatum
D. rotundatus
V. crystallina
P. pygmaeum
A. pura
C. lubrica
C. pumila
A. nitidula
C. minimum
C. bidentata
C. edentula
Z. nitidus
E. fulvus
C. hortensis
O. alliarius
T. hispidus
A. arbustorum
S. lamellata
P. hammonis
C. laminata
S. putris
V. substriata
M. incarnatus
A. aculeata


Lyadalen2008
Relative abundance
Species rank
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0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
0
5
10
15
20
25
C. pumila
C. lubrica
D. rotundatus
V. crystallina
S. lamellata
A. nitidula
A. pura
C. tridentatum
C. hortensis
S. putris
C. bidentata
C. edentula
C. laminata
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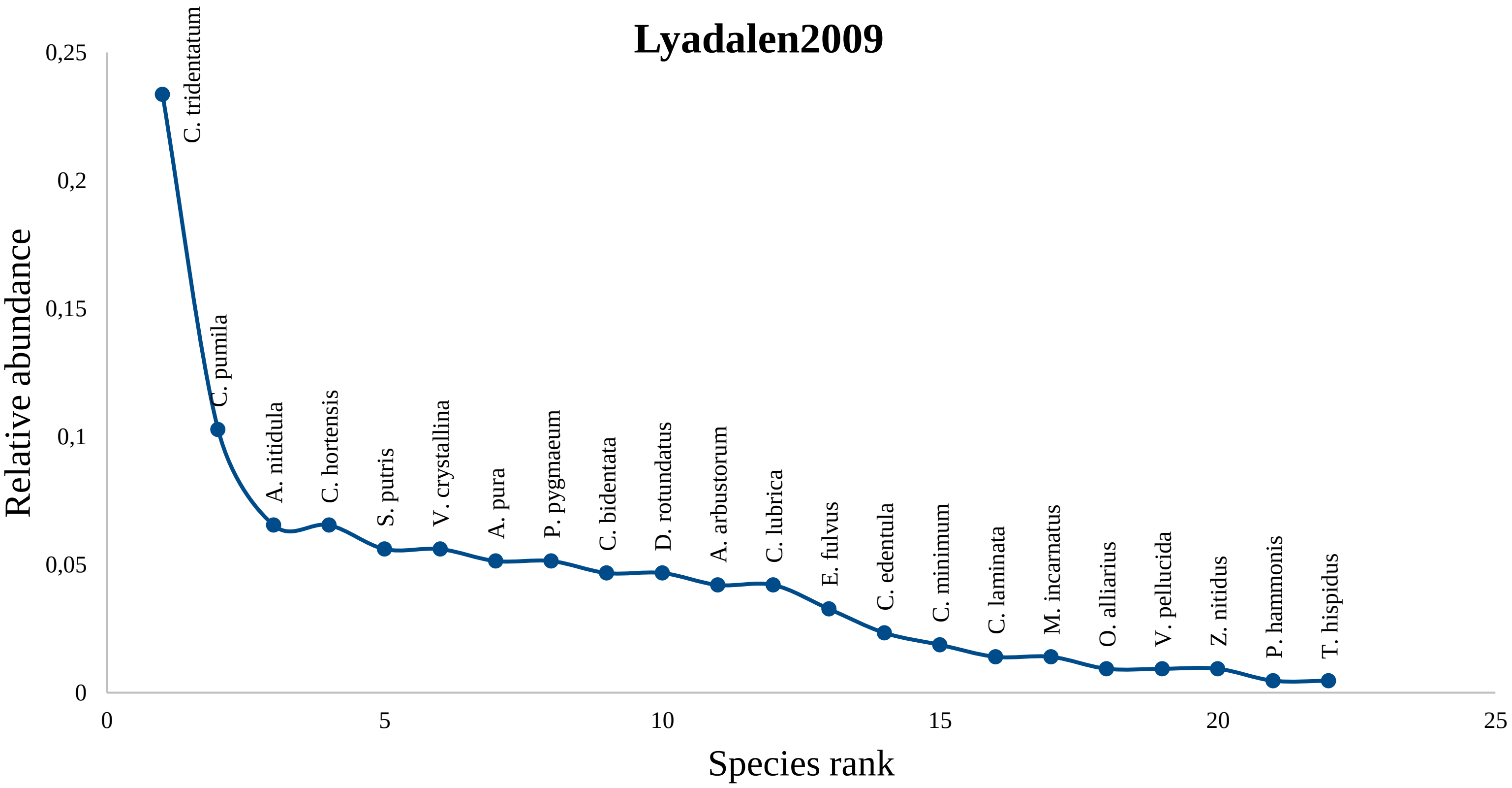
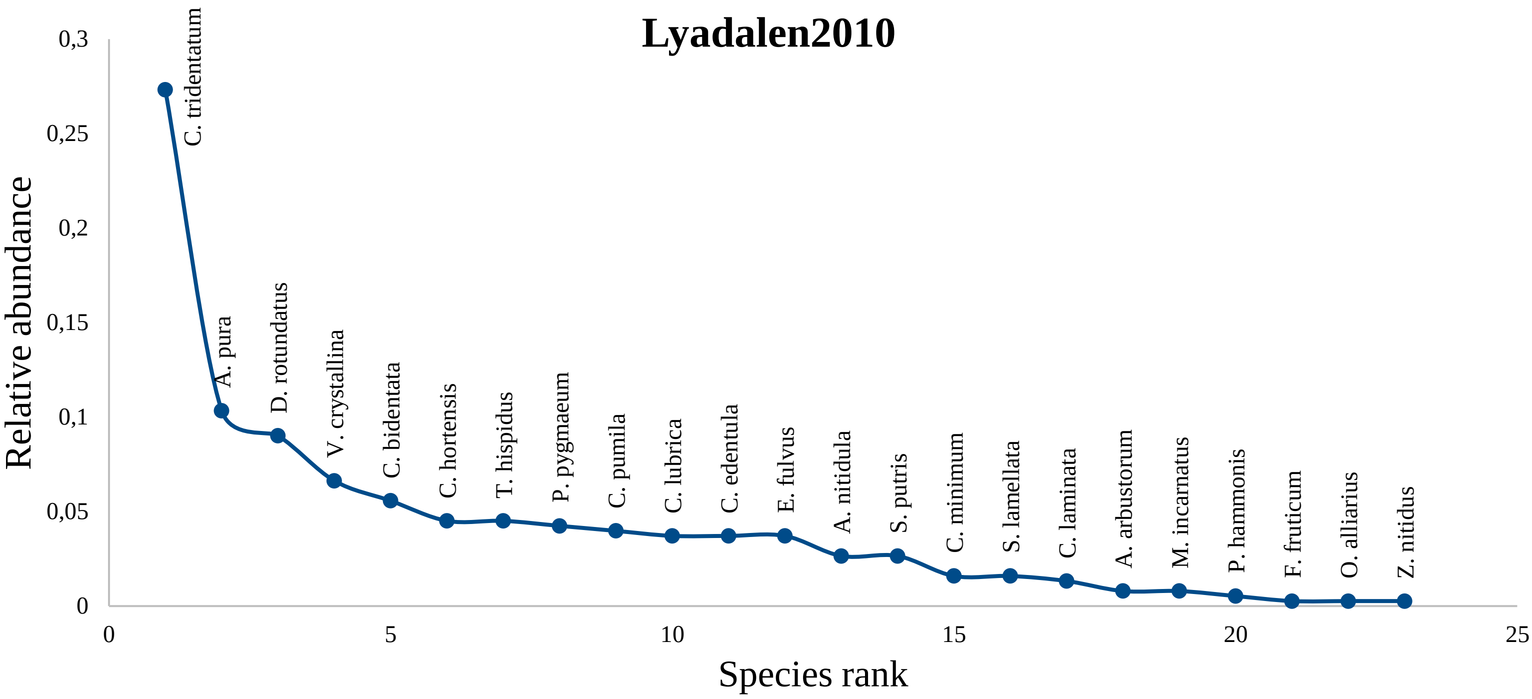
T. hispidus
E. fulvus
O. alliarius
A. arbustorum
M. incarnatus
P. hammonis
V. substriata


Lyadalen2009
Relative abundance
Species rank
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
C. pumila
A. nitidula
C. hortensis
S. putris
V. crystallina
A. pura
P. pygmaeum
C. bidentata
D. rotundatus
A. arbustorum
C. lubrica
E. fulvus
C. edentula
C. minimum
C. laminata
M. incarnatus
O. alliarius
V. pellucida
Z. nitidus
P. hammonis
T. hispidus


Lyadalen2010
Relative abundance
Species rank
C. tridentatum
A. pura
D. rotundatus
V. crystallina
C. bidentata
C. hortensis
T. hispidus
P. pygmaeum
C. pumila
C. lubrica
C. edentula
E. fulvus
A. nitidula
S. putris
C. minimum
S. lamellata
C. laminata
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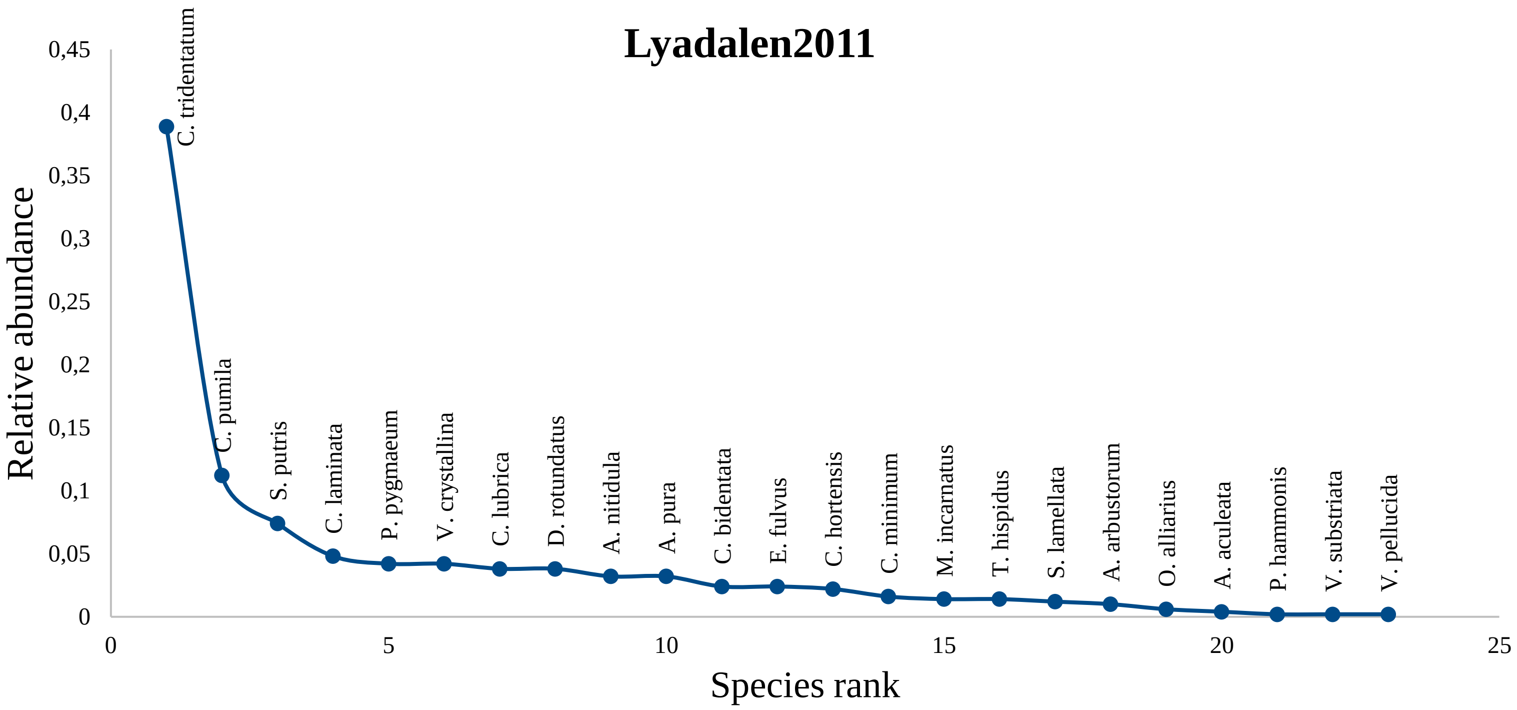
M. incarnatus
P. hammonis
F. fruticum
O. alliarius
Z. nitidus


Lyadalen2011
Relative abundance
Species rank
C. tridentatum
C. pumila
S. putris
C. laminata
P. pygmaeum
V. crystallina
C. lubrica
D. rotundatus
A. nitidula
A. pura
C. bidentata
E. fulvus
C. hortensis
C. minimum
M. incarnatus
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S. lamellata
A. arbustorum
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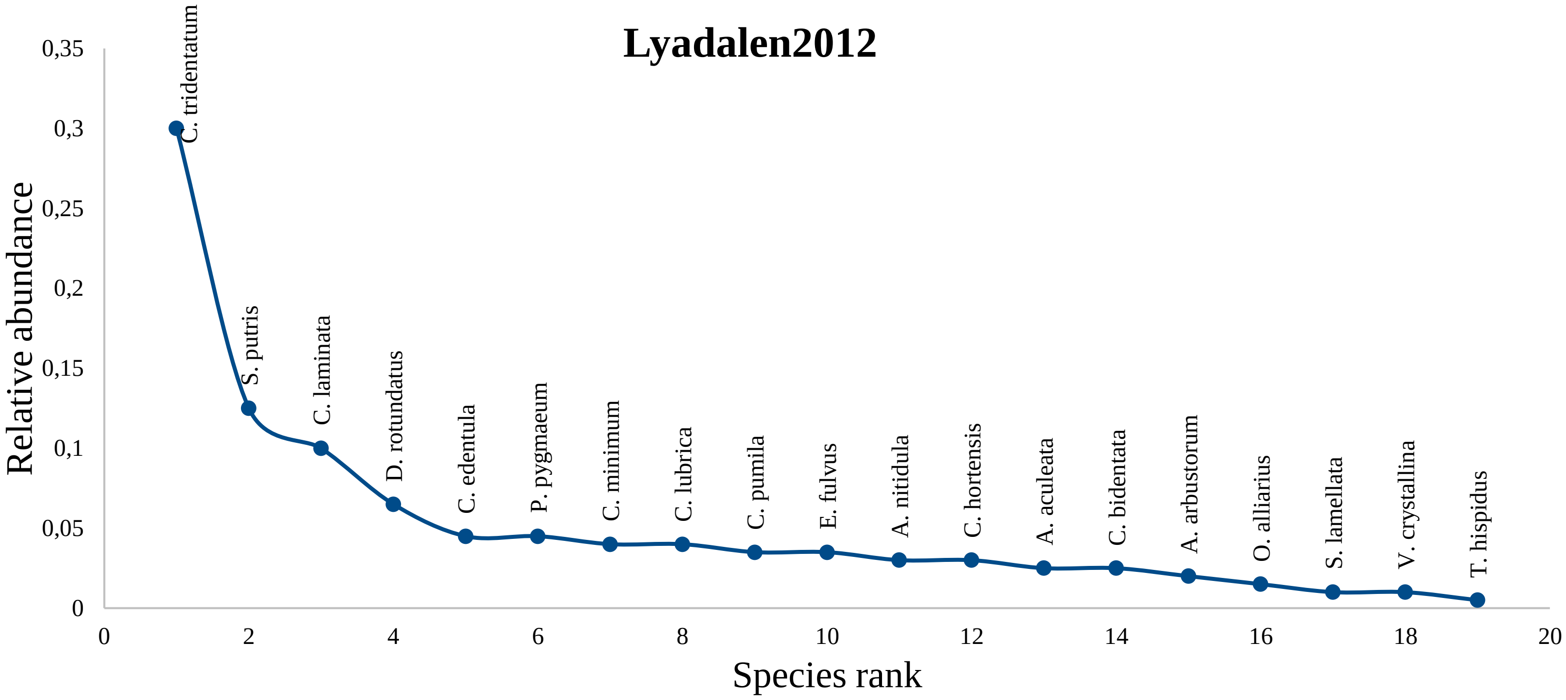
V. substriata
V. pellucida


Lyadalen2012
Relative abundance
Species rank
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
2
4
6
8
10
12
14
16
18
20
C. tridentatum
S. putris
C. laminata
D. rotundatus
C. edentula
P. pygmaeum
C. minimum
C. lubrica
C. pumila
E. fulvus
A. nitidula
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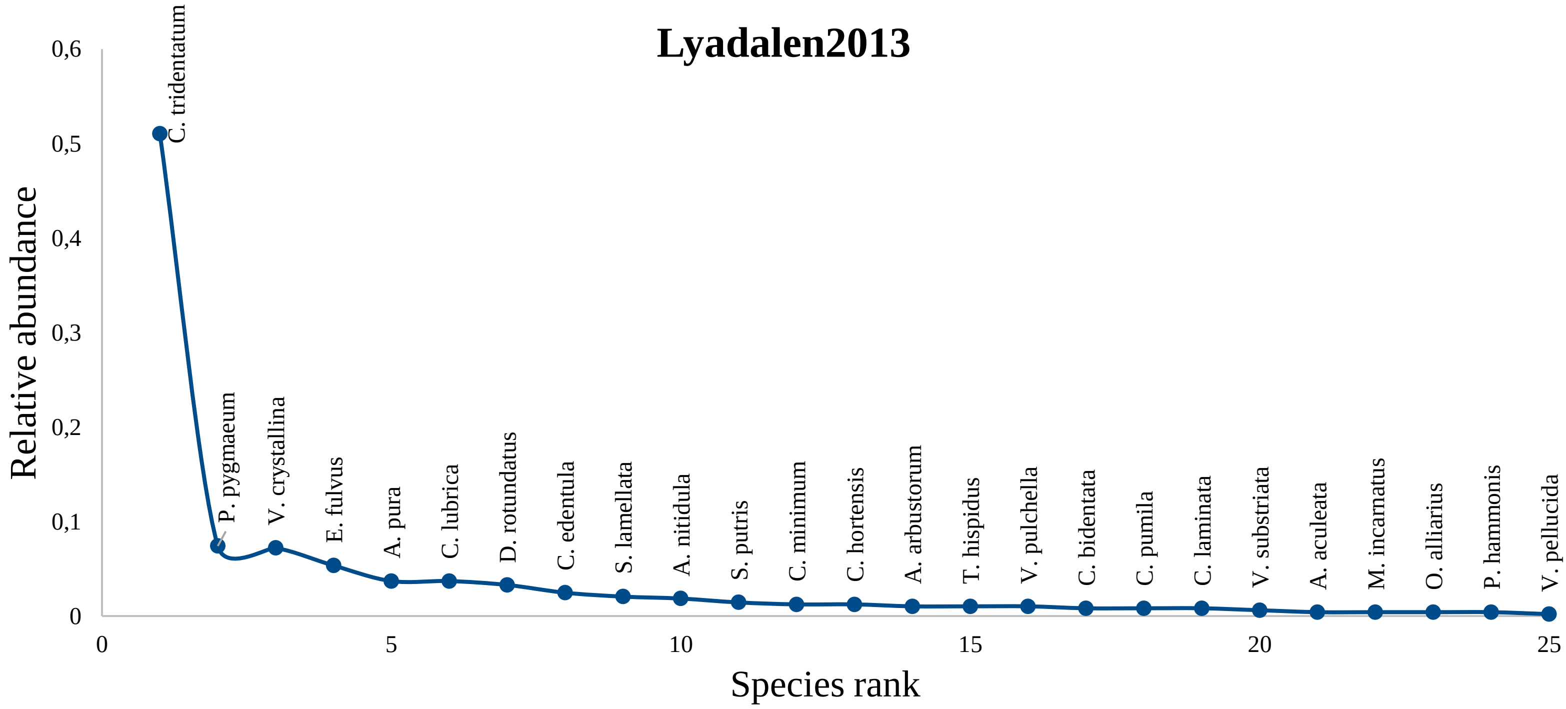
T. hispidus


Lyadalen2013
Relative abundance
Species rank
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0,5
0,4
0,3
0,2
0,1
0
0
5
10
15
20
25
C. tridentatum
P. pygmaeum
V. crystallina
E. fulvus
A. pura
C. lubrica
D. rotundatus
C. edentula
S. lamellata
A. nitidula
S. putris
C. minimum
C. hortensis
A. arbustorum
T. hispidus
V. pulchella
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C. laminata
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A. aculeata
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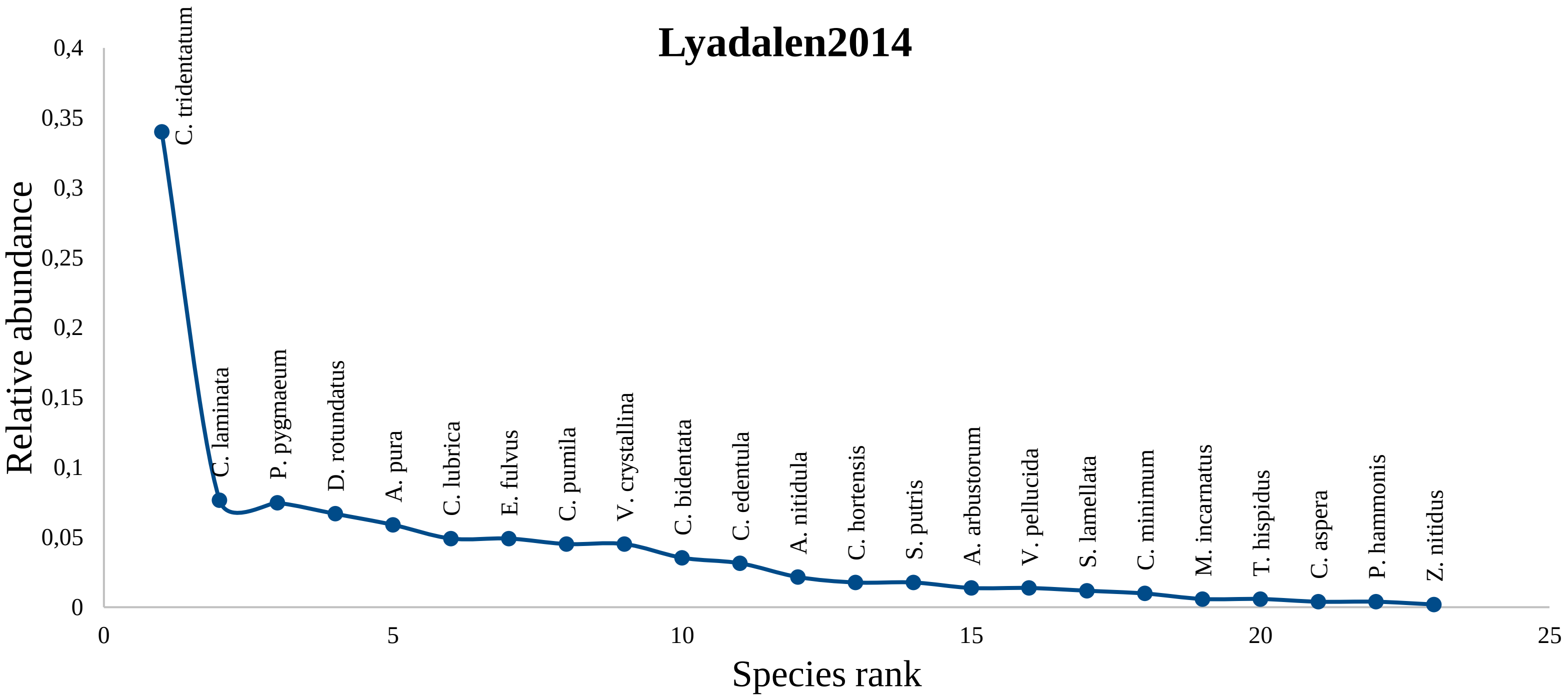
P. hammonis
V. pellucida


Lyadalen2014
Relative abundance
Species rank
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0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
C. laminata
P. pygmaeum
D. rotundatus
A. pura
C. lubrica
E. fulvus
C. pumila
V. crystallina
C. bidentata
C. edentula
A. nitidula
C. hortensis
S. putris
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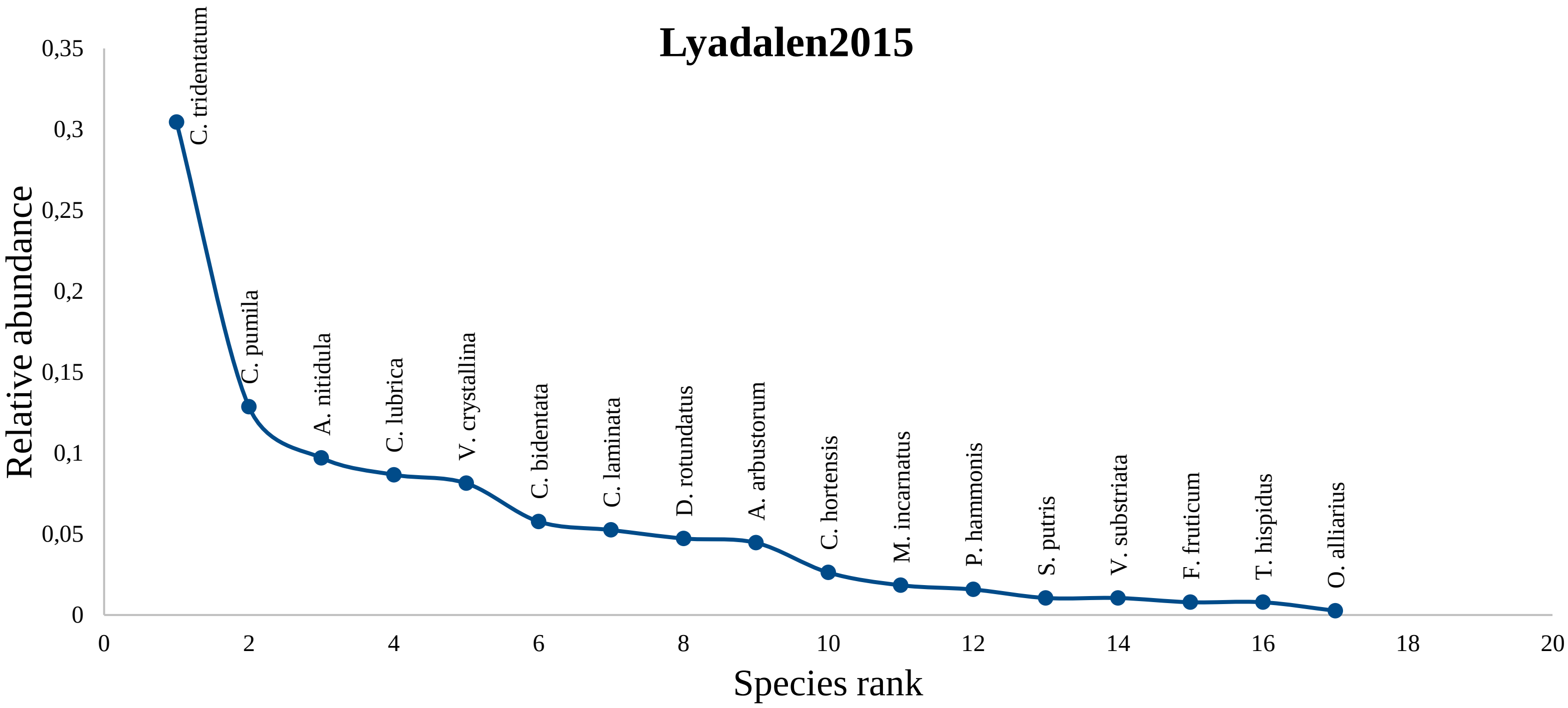
Z. nitidus


Lyadalen2015
Relative abundance
Species rank
0,35
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0,2
0,15
0,1
0,05
0
0
2
4
6
8
10
12
14
16
18
20
C. tridentatum
C. pumila
A. nitidula
C. lubrica
V. crystallina
C. bidentata
C. laminata
D. rotundatus
A. arbustorum
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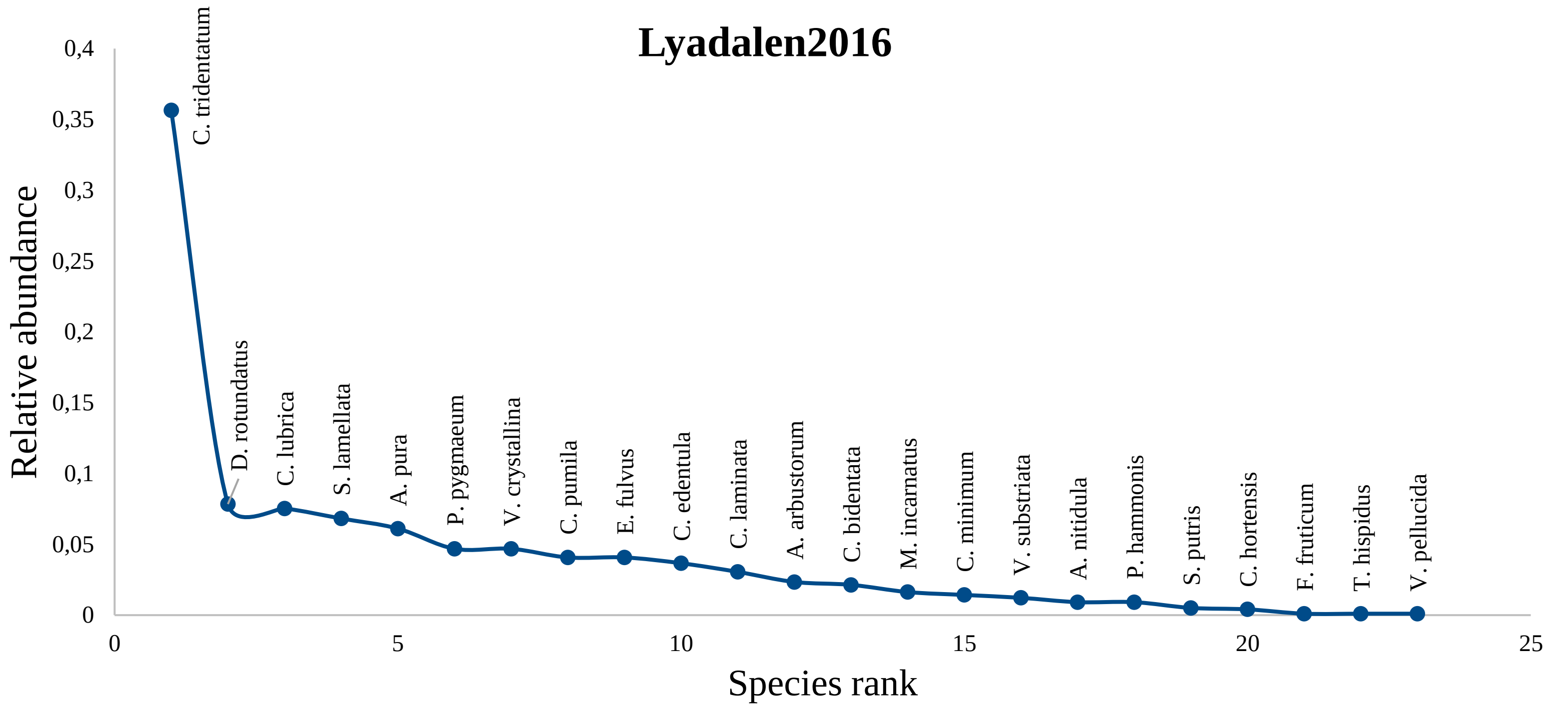
S. putris
V. substriata
F. fruticum
T. hispidus
O. alliarius


Lyadalen2016
Relative abundance
Species rank
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0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
D. rotundatus
C. lubrica
S. lamellata
A. pura
P. pygmaeum
V. crystallina
C. pumila
E. fulvus
C. edentula
C. laminata
A. arbustorum
C. bidentata
M. incarnatus
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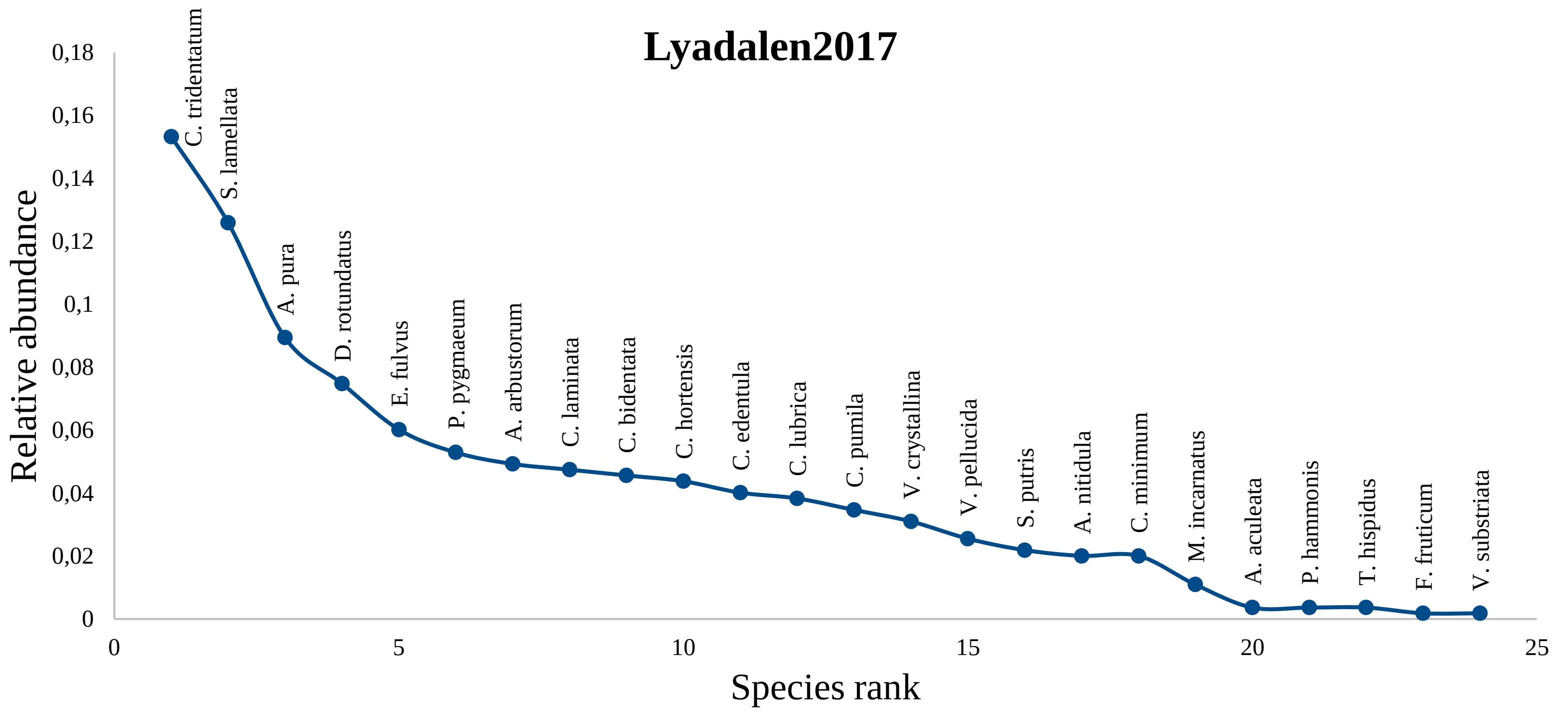
C. hortensis
F. fruticum
T. hispidus
V. pellucida


Lyadalen2017
Relative abundance
Species rank
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
0
5
10
15
20
25
C. tridentatum
S. lamellata
A. pura
D. rotundatus
E. fulvus
P. pygmaeum
A. arbustorum
C. laminata
C. bidentata
C. hortensis
C. edentula
C. lubrica
C. pumila
V. crystallina
V. pellucida
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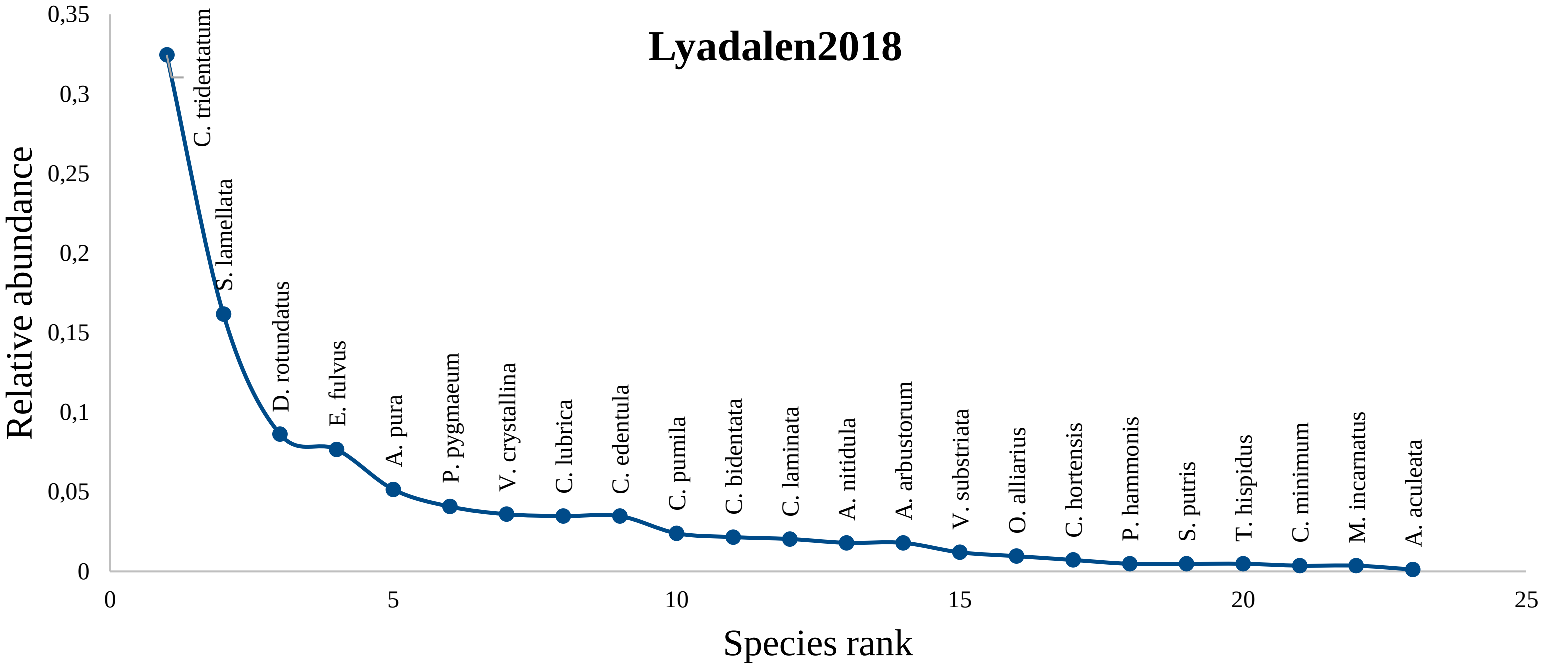
F. fruticum
V. substriata


Lyadalen2018
Relative abundance
Species rank
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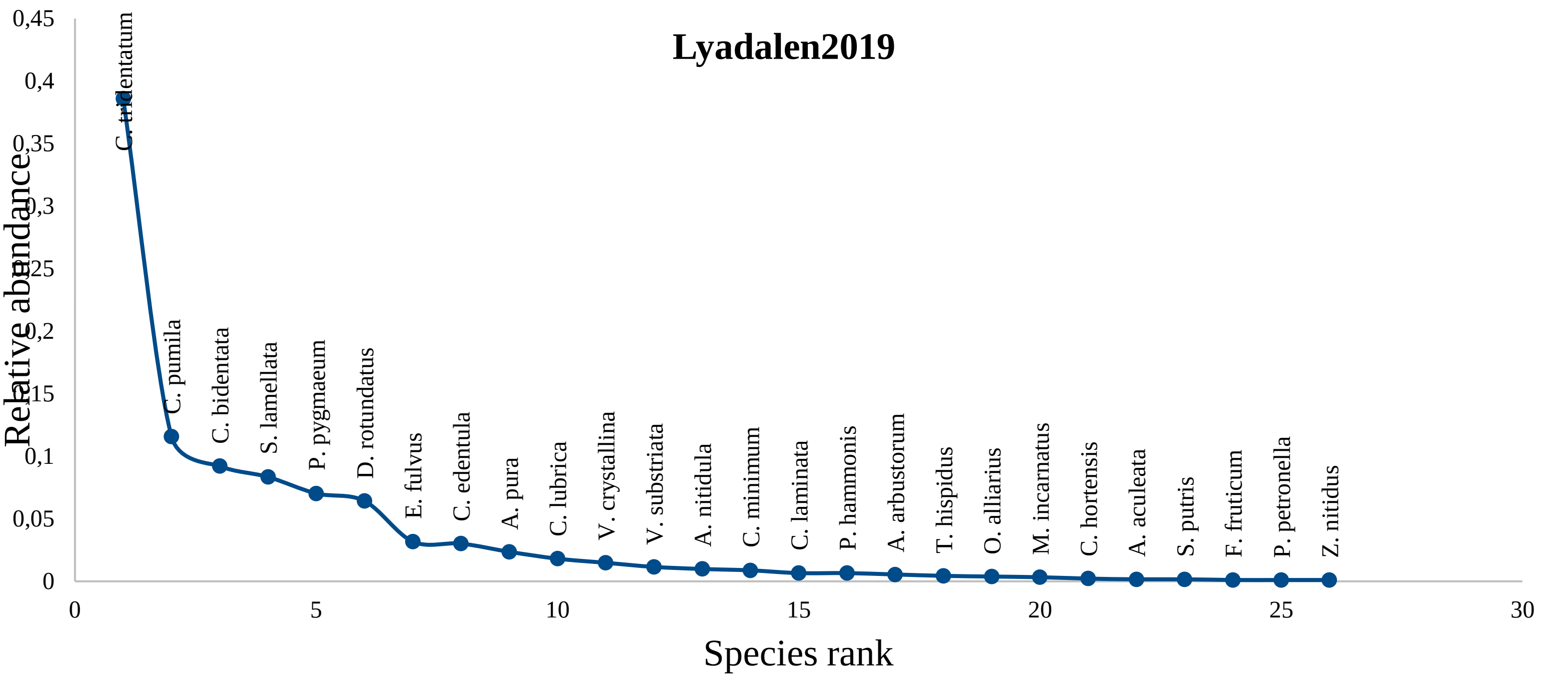
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
S. lamellata
D. rotundatus
E. fulvus
A. pura
P. pygmaeum
V. crystallina
C. lubrica
C. edentula
C. pumila
C. bidentata
C. laminata
A. nitidula
A. arbustorum
V. substriata
O. alliarius
C. hortensis
P. hammonis
S. putris
T. hispidus
C. minimum
M. incarnatus
A. aculeata


Lyadalen2019
Relative abundance
Species rank
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0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
30
C. tridentatum
C. pumila
C. bidentata
S. lamellata
P. pygmaeum
D. rotundatus
E. fulvus
C. edentula
A. pura
C. lubrica
V. crystallina
V. substriata
A. nitidula
C. minimum
C. laminata
P. hammonis
A. arbustorum
T. hispidus
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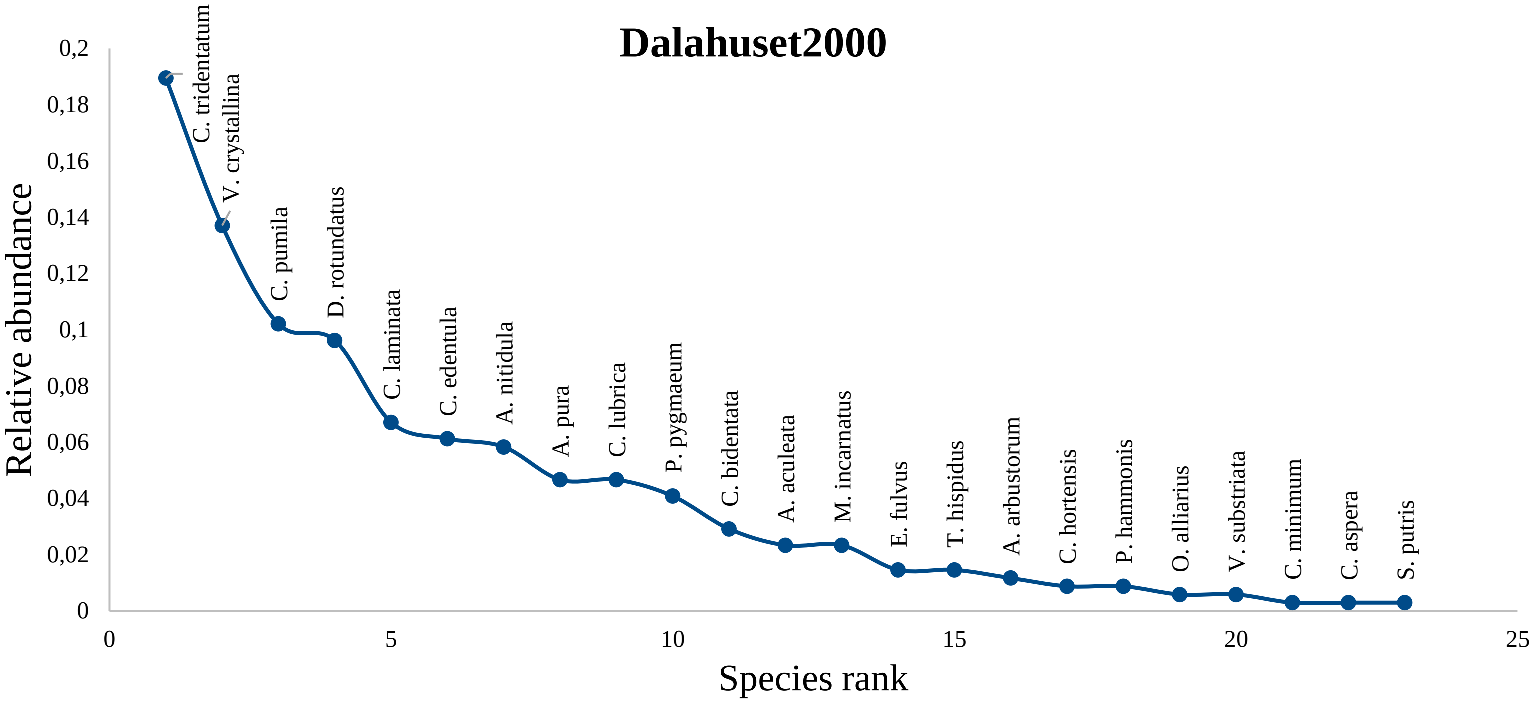
C. hortensis
A. aculeata
S. putris
F. fruticum
P. petronella
Z. nitidus


Dalahuset2000
Relative abundance
Species rank
0,2
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
0
5
10
15
20
25
C. tridentatum
V. crystallina
C. pumila
D. rotundatus
C. laminata
C. edentula
A. nitidula
A. pura
C. lubrica
P. pygmaeum
C. bidentata
A. aculeata
M. incarnatus
E. fulvus
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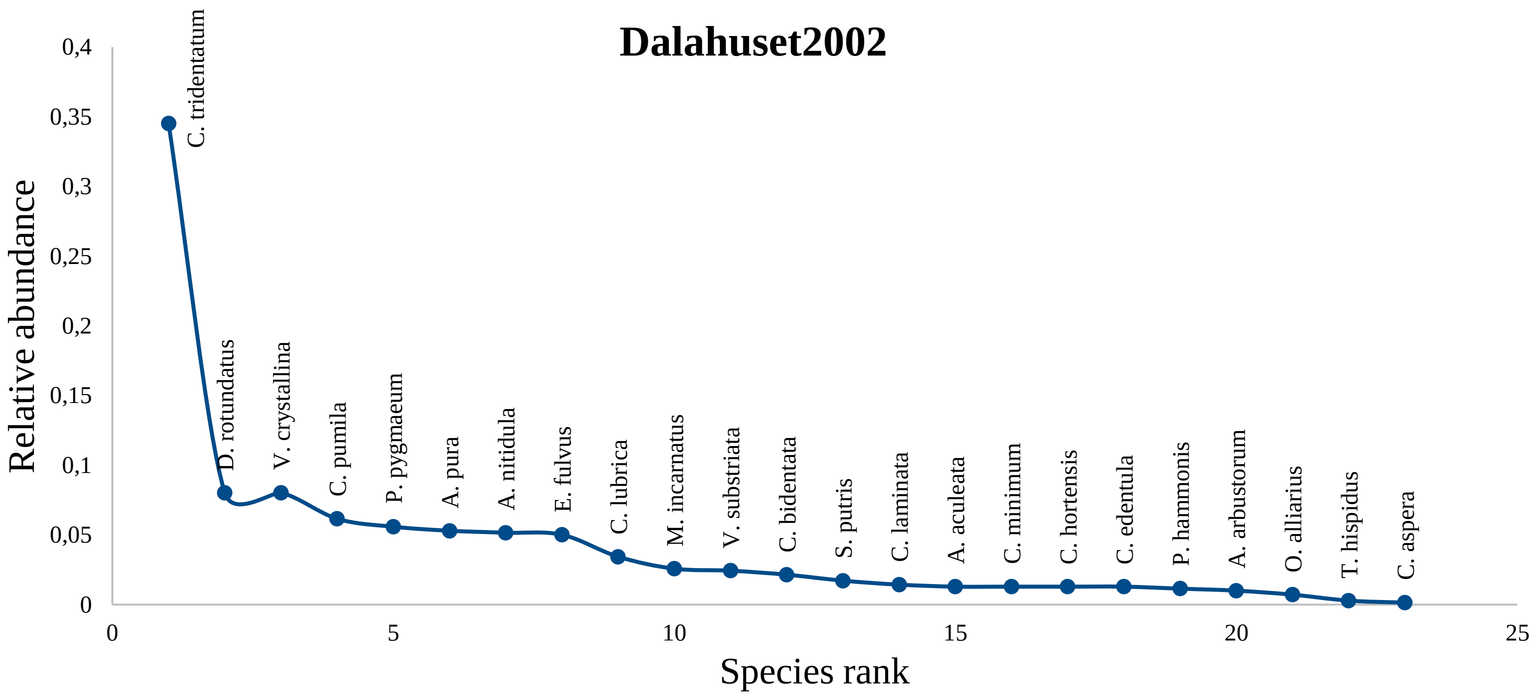
P. hammonis
O. alliarius
V. substriata
C. minimum
C. aspera
S. putris


Dalahuset2002
Relative abundance
Species rank
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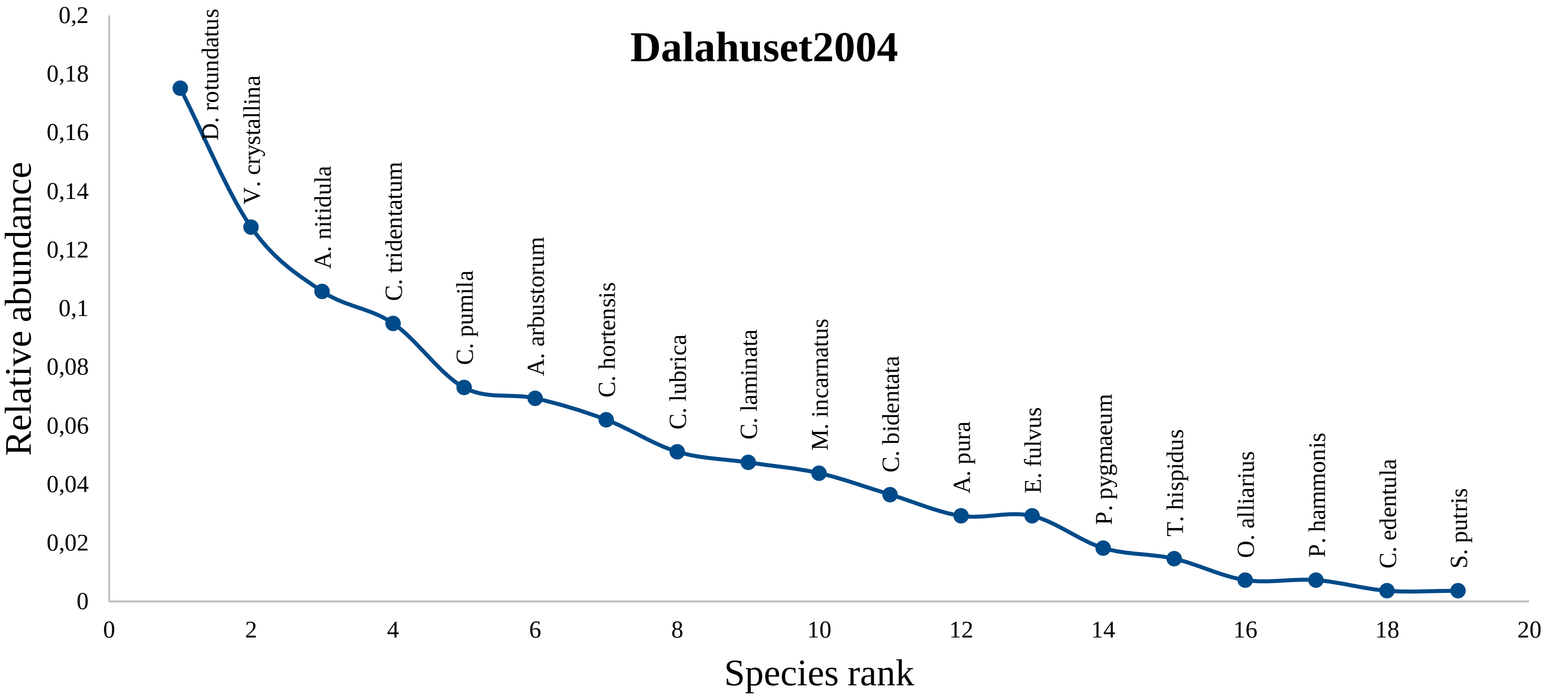
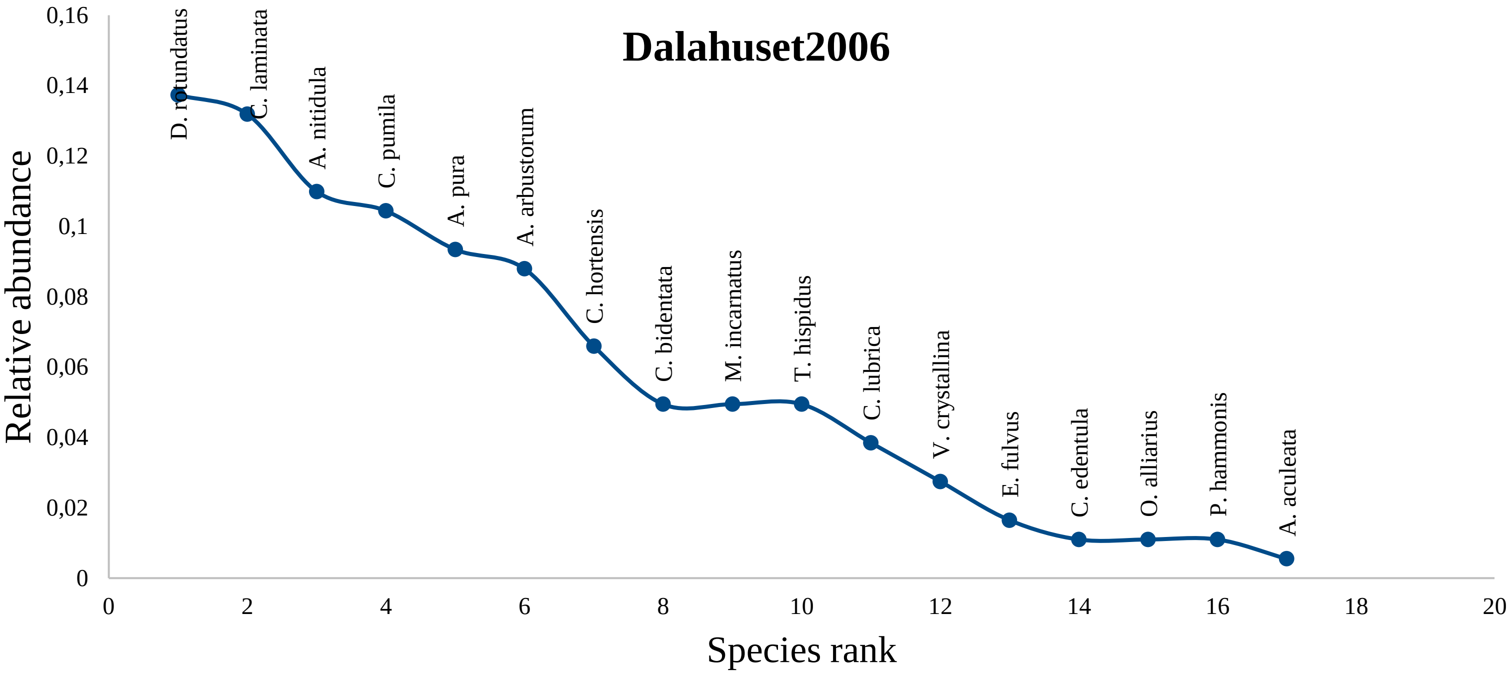
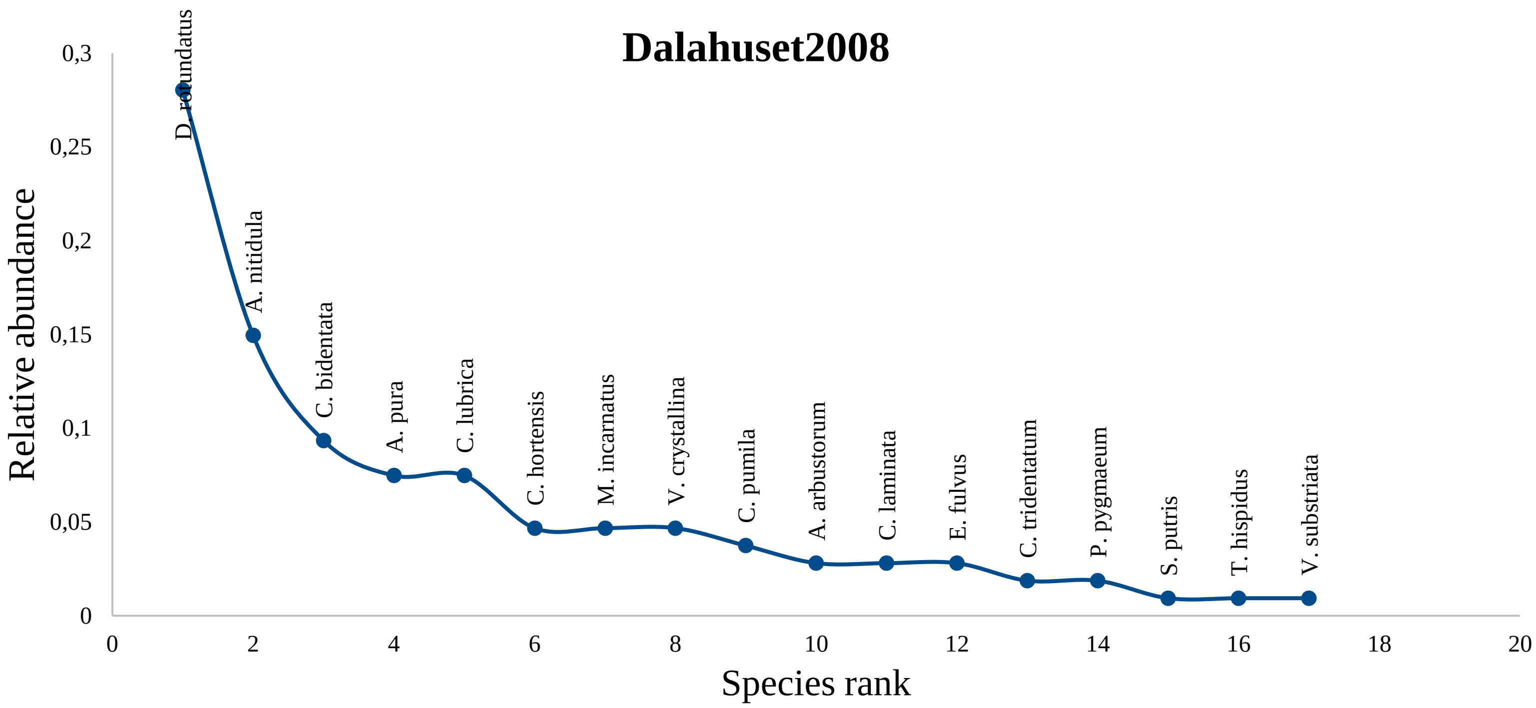
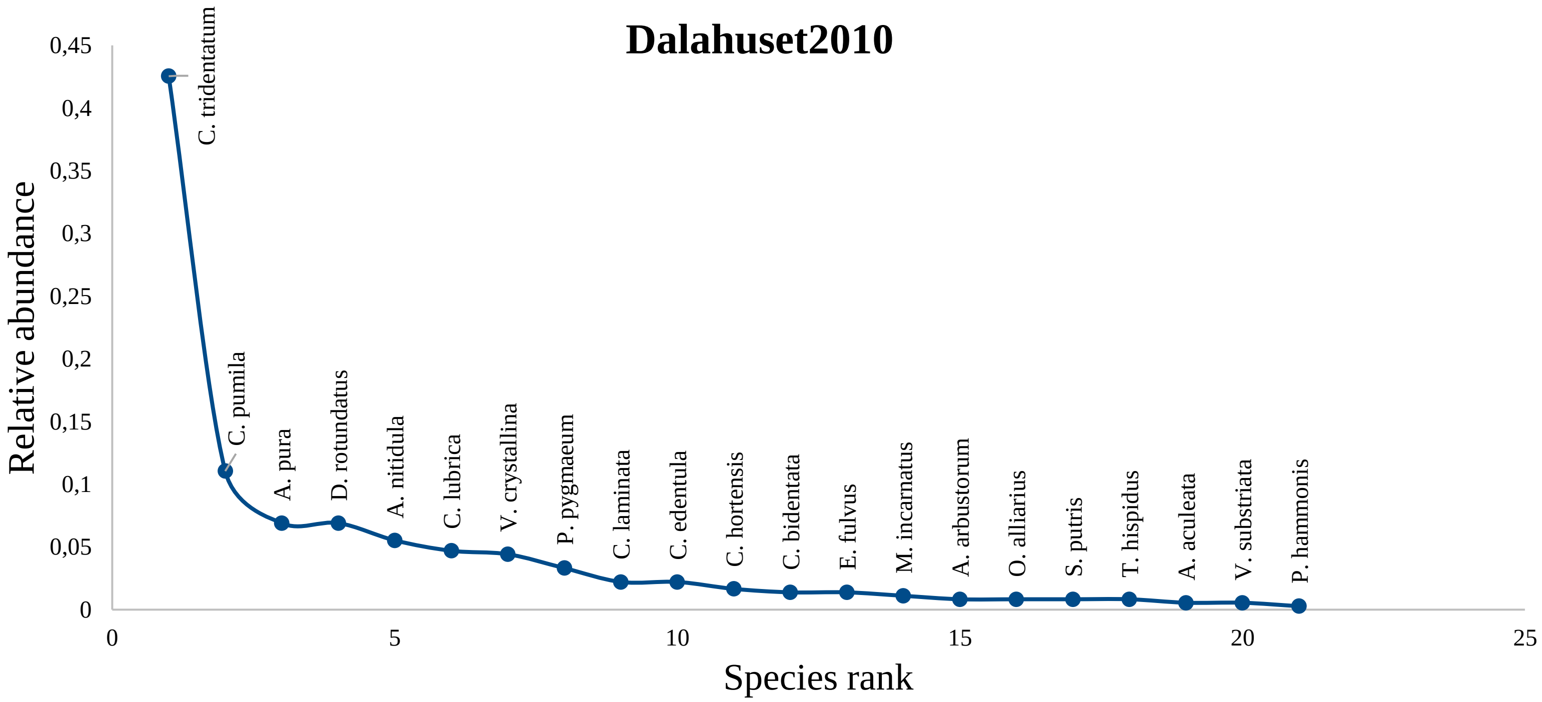
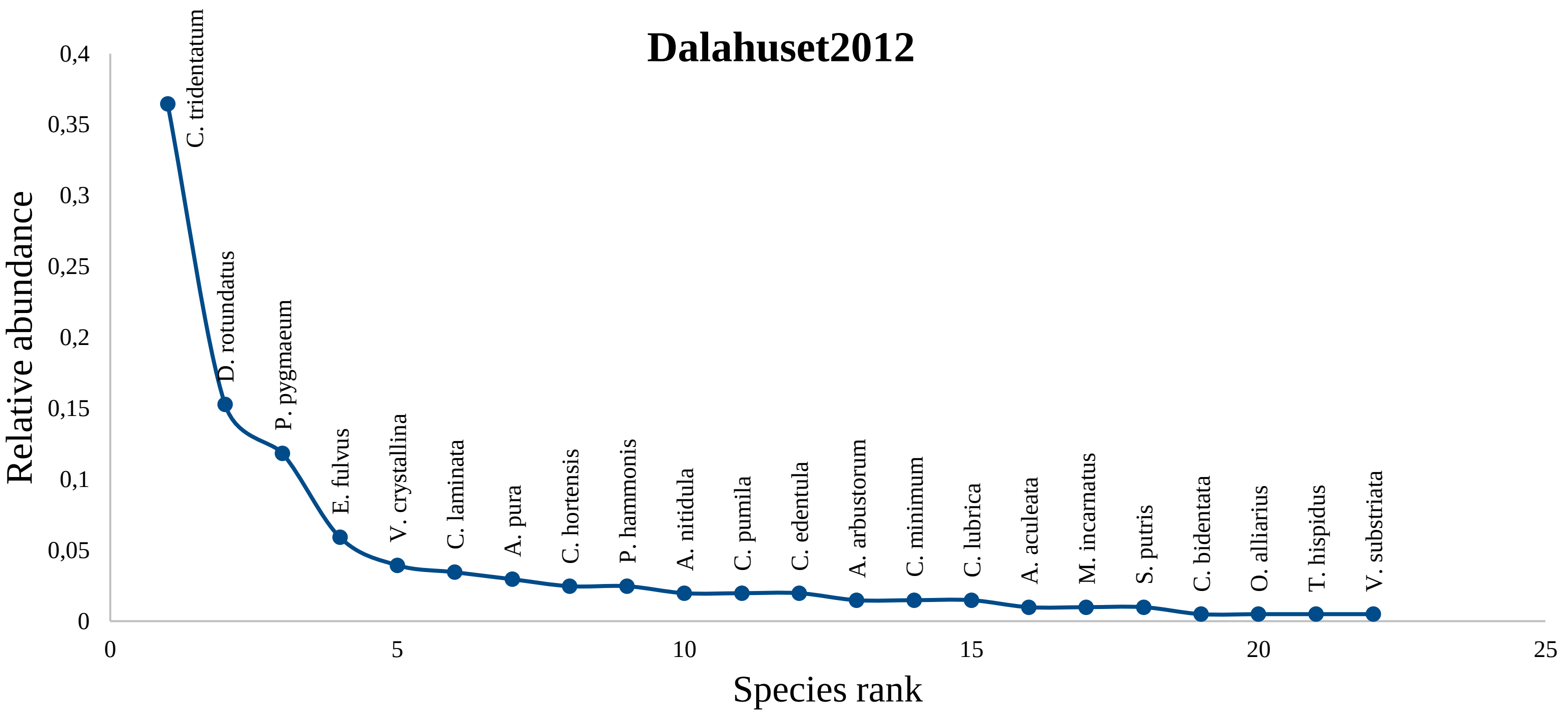
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
D. rotundatus
V. crystallina
C. pumila
P. pygmaeum
A. pura
A. nitidula
E. fulvus
C. lubrica
M. incarnatus
V. substriata
C. bidentata
S. putris
C. laminata
A. aculeata
C. minimum
C. hortensis
C. edentula
P. hammonis
A. arbustorum
O. alliarius
T. hispidus
C. aspera

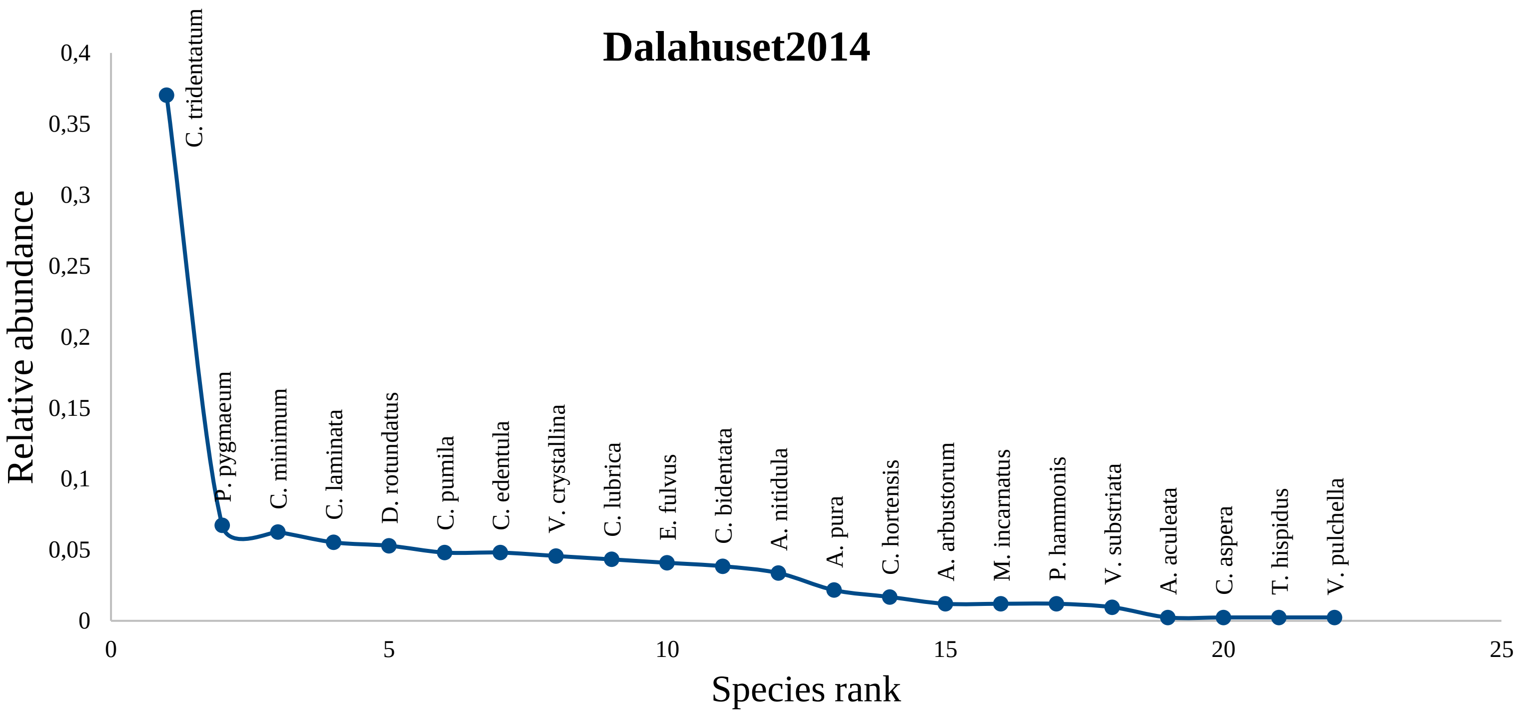

Dalahuset2004
Relative abundance
Species rank
D. rotundatus
V. crystallina
A. nitidula
C. tridentatum
C. pumila
A. arbustorum
C. hortensis
C. lubrica
C. laminata
M. incarnatus
C. bidentata
A. pura
E. fulvus
P. pygmaeum
T. hispidus
O. alliarius
P. hammonis
C. edentula
S. putris

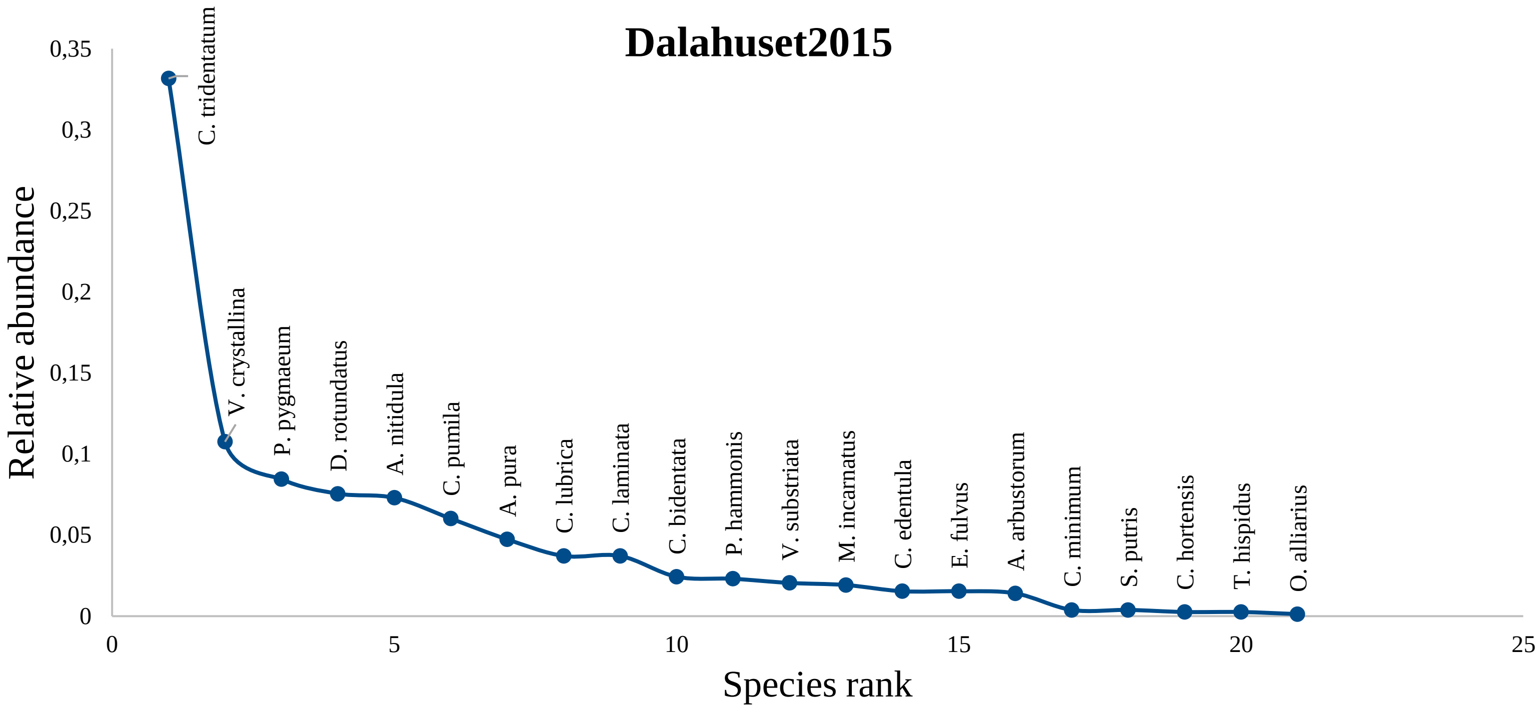

Dalahuset2006
Relative abundance
Species rank
D. rotundatus
C. laminata
A. nitidula
C. pumila
A. pura
A. arbustorum
C. hortensis
C. bidentata
M. incarnatus
T. hispidus
C. lubrica
V. crystallina
E. fulvus
C. edentula
O. alliarius
P. hammonis
A. aculeata


Dalahuset2008
Relative abundance
Species rank
0,3
0,25
0,2
0,15
0,1
0,05
0
0
2
4
6
8
10
12
14
16
18
20
D. rotundatus
A. nitidula
C. bidentata
A. pura
C. lubrica
C. hortensis
M. incarnatus
V. crystallina
C. pumila
A. arbustorum
C. laminata
E. fulvus
C. tridentatum
P. pygmaeum
S. putris
T. hispidus
V. substriata


Dalahuset2010
Relative abundance
Species rank
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
C. tridentatum
C. pumila
A. pura
D. rotundatus
A. nitidula
C. lubrica
V. crystallina
P. pygmaeum
C. laminata
C. edentula
C. hortensis
C. bidentata
E. fulvus
M. incarnatus
A. arbustorum
O. alliarius
S. putris
T. hispidus
A. aculeata
V. substriata
P. hammonis


Dalahuset2012
Relative abundance
Species rank
0
0,05
0,1
0,15
0,2
0,25
0,3
0,35
0,4
0
5
10
15
20
25
C. tridentatum
D. rotundatus
P. pygmaeum
E. fulvus
V. crystallina
C. laminata
A. pura
C. hortensis
P. hammonis
A. nitidula
C. pumila
C. edentula
A. arbustorum
C. minimum
C. lubrica
A. aculeata
M. incarnatus
S. putris
C. bidentata
O. alliarius
T. hispidus
V. substriata


Dalahuset2014
Relative abundance
Species rank
0
0,05
0,1
0,15
0,2
0,25
0,3
0,35
0,4
0
5
10
15
20
25
C. tridentatum
P. pygmaeum
C. minimum
C. laminata
D. rotundatus
C. pumila
C. edentula
V. crystallina
C. lubrica
E. fulvus
C. bidentata
A. nitidula
A. pura
C. hortensis
A. arbustorum
M. incarnatus
P. hammonis
V. substriata
A. aculeata
C. aspera
T. hispidus
V. pulchella


Dalahuset2015
Relative abundance
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
5
10
15
20
25
Species rank
C. tridentatum
V. crystallina
P. pygmaeum
D. rotundatus
A. nitidula
C. pumila
A. pura
C. lubrica
C. laminata
C. bidentata
P. hammonis
V. substriata
M. incarnatus
C. edentula
E. fulvus
A. arbustorum
C. minimum
S. putris
C. hortensis
T. hispidus
O. alliarius