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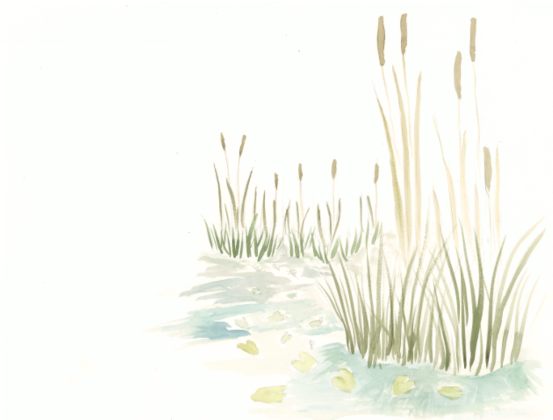

Invertebrate colonisation and diversity in constructed wetlands in Halland

A comparison between 2004 and 2006

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Biology, 15 credits

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Biology

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Bachelor's degree project in biology 15 hp
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1 Introduction:

1.1 Background

Wetlands are highly productive ecosystems and considered to be the most productive ecosystem in the world (1,2). They have once been a big part of the Swedish landscape and are today being reinstalled or reconstructed in larger and larger scale (3). Wetlands have a flora and fauna that in many ways differs from other ecosystems (4).

In Halland there are still many wetlands in the forested areas but they are often more sparse in the agricultural areas closer to the coast (5). One of the purposes of building constructed wetlands is to maintain ecological functions in the landscape and by this also keeping a rage of species not seen elsewhere (3). In the environmental objective, thriving wetlands, there are both national and regional goals. The goals for region Halland is to keep already existent wetlands and to conserve species and plants in already existing ones. An example of one of the goals is to create or recreate 700 ha of wetland areas to increase biological diversity (6).
My study addresses the question of diversity in wetlands by studying macroinvertebrate composition. It might be able tell us more about the first years in constructed wetlands and by this also be a part of planning wetland construction.

1.2 Purpose:

To get information on invertebrate colonization and diversity in constructed wetlands on a regional and local level the following general questions were used:

- What differences in invertebrate colonization can be seen between 2004 and 2006 in the factors, age, vegetation and dispersal in recently constructed researched wetlands?
- How much does the wetland invertebrate taxa composition change in two years?
- What are the changes in vegetation cover and dispersal of invertebrates in fairly young constructed wetlands?
- What are the differences in alpha, beta and gamma diversity levels?
- What impact does vegetation coverage have on number of taxa?
- Is it possible to see a peak in number of invertebrate taxa connected with wetland age?

2 Materials and methods

Five wetlands in Halland were studied as seen in fig 1. Three sites per wetland were sampled in 2004 and 2006 for macroinvertebrates as seen in Appendix, Table 5. In 2004 nine samples per wetland was also tested against three samples in 2006 due to the amount of time taken identifying invertebrates in 2006 being longer(See discussion: Invertebrate taxa interacting with age). Invertebrate fauna was collected with a net. Vegetation coverage was noted in % together with the most frequently occurring species of wetland plant.

2.1 Description of sampled wetlands

The five wetlands chosen were all permanent wetlands and located according to Figure 1 in the south part of Halland. They were named 027 in Vinberg, 137 in Steninge, 141 in Odensjö, 171 in Edenberga and 184 in Ränneslöv.

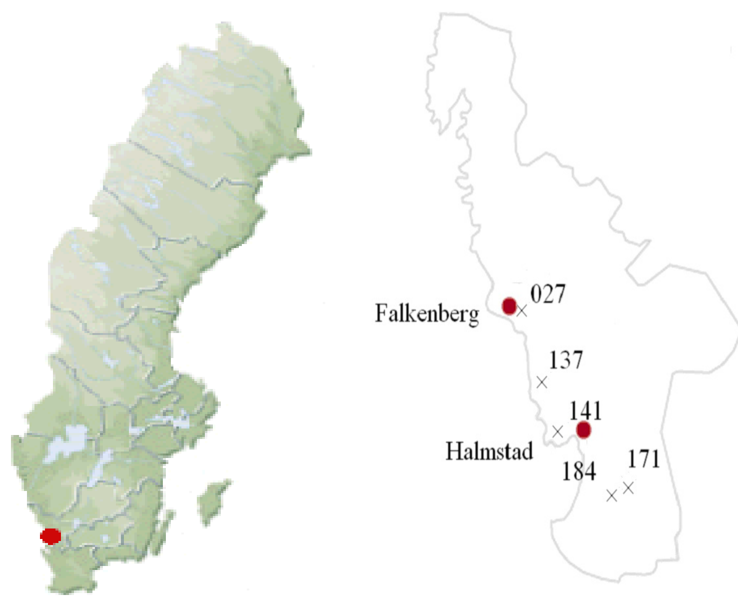

Figure 1. Location of Halland in Sweden (left) and location of wetlands in Halland marked with numbers (right)(7) The cities Falkenberg and Halmstad are marked with red dots.

Three categories were made to separate wetland age:

- 2 years (027-2004 in vinberg,137-2004 in Steninge,141-2004 in Odensjö)
- 5-6 years (027-2006,137-2006,141-2006,184-2004 in Ränneslöv)
- 7-9 years (171-2006,184-2006)

2.2 Definition alpha, beta gamma diversity levels

To investigate species occurrence, diversity was divided into three levels according to Whittaker (8). As Whittaker talks of diversity of sites, variation of sites and diversity of a large number of sites I chose to se these sites as wetlands. My definition of alpha, beta and gamma diversity in regard to wetlands is seen below:

Alpha level:
Alpha (α) diversity is the diversity in species composition at individual sites. On this level every wetland is seen as one sample. Alpha diversity is usually expressed as number of taxa within an ecosystem or area (8).
Beta level:
Beta (β) diversity is the variation in species composition among sites in a geographic area. For instance, you can see these patterns in shared taxa between two groups that has the same factor. Beta level diversity compares diversity between ecosystems and is usually measured as the amount of taxa change between the ecosystems (8).
Gamma level:
Gamma (γ) diversity is the diversity of the whole region of interest in a study. In gamma level diversity all wetlands in a region are seen as one sample. In this thesis gamma diversity is compared in two different years and in regard to vegetation coverage.(8).

2.3 Macroinvertebrate sampling, identification and treatment of data

Macroinvertebrates was sampled with a net (with 25 cm, mesh size 2mm) that was moved in two "eights" near the shoreline. Each eight approximatively the length of half a meter. None of the samples were located further away from the shoreline than four meters. If there was a big amount of floating material this was briefly shaken in the net. After the invertebrates had been collected they were put in a white tray (40*50cm) and handpicked into jars containing 70% alcohol. Identification of taxa under stereomicroscope was made when all wetlands were sampled (9-16).

2.3.1 Listing of taxa

A list of taxa was put together for every wetland in 2004 and 2006. All taxa present was added to a list of taxa present in both years(Appendix, Table 6). The taxa were taken from nine samples in 2004 and three samples in 2006. This was due to the lower amount of time that was dedicated on sorting out the animals in every sample in 2004. These taxa were then compared with taxa in 2004 and some taxa determined 2006 were rearranged to taxa determined in 2004.

Grouping macroinvertebrates:
The macroinvertebrates were grouped to be used in statistics as follows:

- Annelida (Annelida, Lumbriculidae, *Herpobdella octoculata*)
- Coleoptera (Colymbetinae, *Brychius elevatus* larvae, *Helophorus sp.*)
- Diptera (Ceratopogoninae, *Chaoborus sp.* (PL), Tanypodinae, Chironomidae, Ephydridae)
- Tricoptera (*Trianodes sp.*, *Anabolia sp.*, Limnephilidae, *Holocentropus* sp.)
- Ephemeroptera (*Cloeon dipterum/ inscriptum*, *Caenis horaria*, *Leptophlebia vespertina*)
- Zygoptera (*Ischnura elegans*, Coenagrionidae, *Enalagma cyathigerum*, *Lestes sponsa*)
- Gastropoda (*Radix ovata*, *Bathyomphalus contortus*, *Gyraulus albus*, *Gyraulus crista*, *Valvata macrostoma*)
- Heteroptera (Corixinae, *Sigara sp.*, *Notonecta*)

- Other (*Asellus aquaticus*, Hydracarina, Pyralidae, *Sphaerium corneum*, *Planaria torva*)

In the group "other" none of the taxa could be placed in similar taxa. The group included taxa that origin from different orders or even phyla. Unable to put them in other groups without risking the classification getting to wide they were placed in one group together.

Dispersal potential:
A factor that was thought to affect the colonisation was dispersal. The taxa were sorted into three groups according to Geraldine Thiere pers. comm.:

- *Non flying*(Lumbriculidae, Annelida, Hydracarina, *Asellus aquaticus*, *Herpobdella octoculata*, *Planaria torva*, *Sphaerium corneum*, *Radix ovata*, *Bathyomphalus contortus*, *Gyraulus albus*, *Gyraulus crista*, *Valvata macrostoma*) (18)
- *Low dispersal potential* (Colymbetinae, *Brychius elevatus* larvae, *Helophorus sp*., *Trianodes sp* (19), *Anabolia* sp, Limnephilidae, *Holocentropus* sp., Ephydridae, Pyralidae)
- *High dispersal potential ability* (Ceratopogoninae, *Chaoborus* sp. (PL), Tanypodinae, Chironomidae, *Cloeon dipterum* (20)/ *inscriptum*, *Caenis horaria*, *Leptophlebia vespertina*, Corixinae, *Sigara* sp., Notonecta, *Ischnura elegans*, Coenagrionidae, *Enallagma cyathigerum*, *Lestes sponsa*)

The first group contained taxa that could not fly and therefore were vector or inflow dependent. The low dispersal potential group could be taxa with only a fraction winged adults, very heavy or known to disperse only small distances. The third group contained taxa with high dispersal potential. The taxa with high ability were either very light and therefore wind-borne, very good flyers, known to fly far or reproduce in high numbers or with many generations (21).

2.3.2 Criteria for comparing the presence of taxa:

To get a manageable dataset where the taxon were not likely to be present in the wetlands by chance, criteria were also set. This means fifteen samples in total both 2004 and 2006. A taxon was included in the statistics if:

1.) If it was present in two or more out of three areas in 2006
or 2.) If it was present in at least four samples out of nine in 2004.
or 3.) If it was present in four out of five wetlands it is used in the statistics.

After applying the criteria, 37 taxa was included in the analysis.

2.4 Collecting vegetation data

The vegetation was recorded in the five wetlands. Macrophytes were sampled in August 2004 by Geraldine Thiere. 20 samples per wetlands were taken in both shoreline and open water zones. 10 Shoreline samples were taken on a transect starting from the shoreline and ending 4 m into the wetland. The angle between shoreline and the transect was 90 degrees. All species from the water surface down to the wetland bottom along the transect were recorded. Open water samples were taken at 10 random spots within the central area of each wetland. For the open water samples a rake was used if the depth was not more than 4 m. If the sampling spot was deeper a grab sampler on a rope was used instead. In 2004 all sites were given a vegetation type according to most frequently occurring plant species. The vegetation types were established in 2004 when a vegetation inventory was made.

Vegetation types:

- *Typha latifolia* (Bulrush) / *Phragmites australis* (Common reed)
- *Juncus bulbosus* (Bolbous rush)
- *Potamogeton berchtoldii* (Small pondweed)
- *Potamogeton natans* (Broad-leaved Pondweed).

In 2004 the vegetation and structure around all sampled spots were categorized (present/absent data) and this was redone in 2006. Present vegetation or structure was sorted into the following categories:

- Submerged plants ex. *Elodea canadensis* (Pondweed)
- Emergent plants ex. *Typha angustifolia/latifolia*, *Phragmites australis* (narrowleaf cattail, common reed)
- Various growth habitus plants. This included plants that could be both submerged and floating leaved plants. ex. *Nuphar luteum* (Yellow Water-lily)
- Floating-leaved plants ex. *Potamogeton natans* (Broad-leaved pondweed)
- Floating dead wood material
- Floating dead plant material
- Algae
- Free floating plants ex. *Lemna minor* (Common duckweed)
- Samples taken were there was no vegetation.

Vegetation coverage was noted on all sampling spots on the same transect as species of vegetation. If the coverage was under 30%, the vegetation coverage was named "vegetation coverage 1". If the coverage was between 30-70% it was named "vegetation coverage 2". Sampling sites with over 70% vegetation coverage was named "vegetation coverage 3". Vegetation coverage was noted for all sites in a vegetation diagram.

2.5 Choosing statistics

To tests effects of different factors (year and vegetation) on single variables (taxa number) univariate ANOVA was used.
To test the effects of the same factors on taxa composition (more than one variable, multivariate) discriminant analysis was used. Groups expected were the same as seen in 2.2.1 "grouping macroinvertebrates".
To test interactions between year and vegetation univariate ANOVA was used. (Vegetation was set as variable to year)
Wetland age and vegetation coverage was tested with correlation.
Alpha, beta and gamma diversity was investigated through mean values, matrix of shared taxa and number of total taxa.

2.5.1 Comparing taxa number with year and vegetation

Compiling data for univariate ANOVA:
Taxa number was tested to se if it was dependent or not dependent on the two factors year and vegetation coverage. Year was divided into 2004 and 2006. Vegetation was divided in vegetation cover type 1, 2 and 3 (see method; 2.3 Collecting vegetation data).
The average number of taxa in the wetlands was put as a variable against the two independent factors. This made comparing the data on an alpha level possible. In this case it meant seeing every wetland as a whole replica.

2.5.2 Comparing taxa composition with year and vegetation

Compiling data for discriminant analysis:
To see patterns in diversity in year and vegetation on a gamma level discriminant analysis was used. The year or vegetation was in the test put as the independent factor and the taxa number dependent on it. The analysis shows if there is a difference in the independent factors groupings. It gives likely group belonging by assigning priority to different groupings and then testing how much a group is held together as a whole by the data (17). Eigenvalue and Wilks' Lambda was noted.

First, the 35 taxa was put against the independent factors.
The degrees of freedom (Df) was restricted to by a low number of wetlands investigated. In some cases the amount of variables exceeded this value and therefore not all factors were taken into account. In the first case with all taxa set against the factor year not all taxa variables were able to be analysed. To get reliable results, a cross validation was done. The cross validation shows if groups, even if parted, still have the same likelihood of being grouped together. To get a more detailed picture of which groups or taxa were the differentiating ones and also to involve every taxa, two types of groupings were made. The groupings were made according to classification and dispersal potential in order to decrease the number of taxa looked at simultaneously.

2.5.3 Interactions between year and vegetation-Relative vegetation cover

In univariate ANOVA the relative vegetation cover was tested. The vegetation noted on every sampling site was not at first comparable since the number of vegetation samples in 2004 and 2006 were different. The numbers of samples were fifteen and five. To get a comparable number to evaluate the results the numbers were divided with the number of samples that year. This resulted in a relative vegetation cover which was used in the statistics.

2.5.4 Correlation between wetland age and vegetation

The relation between wetland age and vegetation coverage on sampling site was tested with a correlation test.

2.5.5 Alpha beta and gamma diversity

Diversity was investigated through mean values of taxa per wetland, shared taxa and total taxa count for different age and different vegetation type.

3 Results

After grouping including the criteria there were 37 taxa in the dataset. The number of taxa found in both 2004 and 2006 was 32. The total number of taxa in nine samples 2004 was 76.

3.1 Comparing taxa number with year and vegetation

3.1.1 Vegetation effect on taxa number

In univariate ANOVA the factor vegetation cover were grouped as 1, 2 and 3. Type 1 had a smaller mean value than 2 or 3 (see fig. 2). This value is not significantly lower p=0.122. The confidence interval (CI) was smallest in 1 and greatest in 2 which mean that there was a greater difference in taxa per wetland in type 2. There was an increase in taxa number between vegetation category one and two and an increase between one and three.

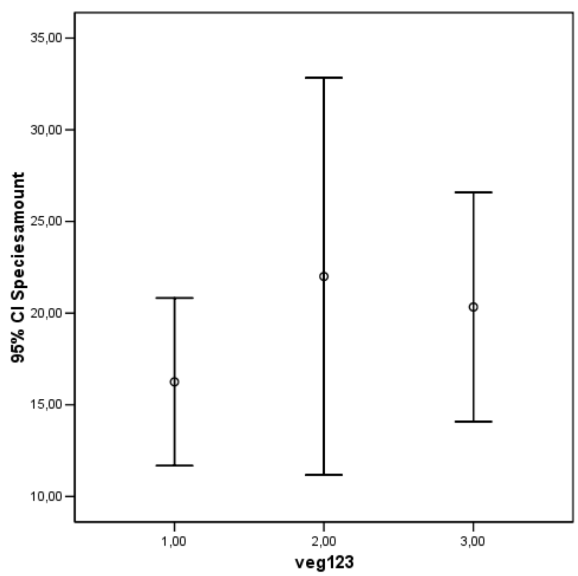

Figure 2. Amount of taxa with 95% confidence interval and mean in vegetation cover type 1, the least, 2, middle and 3, the most coverage.

3.1.2 Age effect on taxa number

General result:

Vegetation is steadily increasing every year. Mean relative vegetation coverage goes from under 5% year 2. Increases to 35% in year 5-6 and increases again to 50% in year 7-9. Taxa number increases from 2 years to 5-6 years but is then decreasing in the oldest wetlands.

Age aspect:

Looking at 9 samples in 2004 the number of taxa per wetland has decreased in 2006, although not significantly p=0.41 (fig 3). (see discussion for more information on 9 samples versus three)

On the alpha level the diversity has a higher mean value although not significantly higher. The Number of individual has decreased to ~half in 2006.

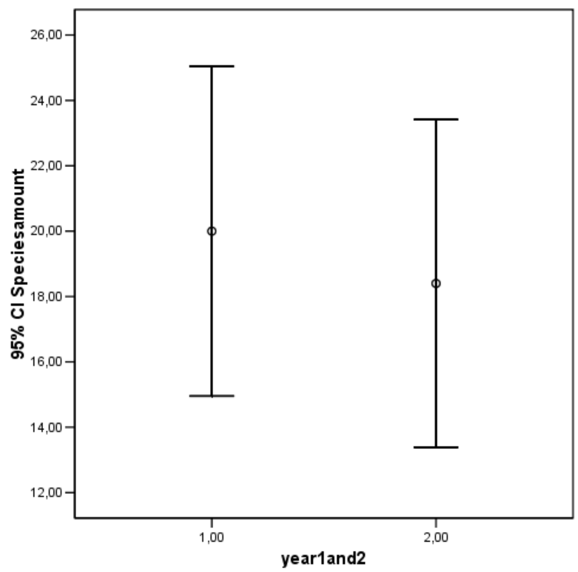

Figure 3. Amount of taxa with 95% confidence interval and mean in year 1, 2004 and year 2, 2006

3.2 Comparing taxa composition with year and vegetation

3.2.1 Age effect on community composition

Grouping taxa:

No group was more than 70% correctly grouped after cross validation (table 1). No groups had significant separation. Four groups, Coleoptera, Diptera, Tricoptera and Gastropoda had an Eigenvalue>1.

Table 1. Original and cross validated group percentages of taxa on year

	Coleoptera	Diptera	Tricoptera	Annelida	Ephemeroptera	Zygoptera	Gastropoda	Heteroptera	other
Dependent factors:	3	5	4	3	3	4	5	3	5
Original grouped [%]	80	80	90	80	70	80	100	60	80
Cross validated [%]	70	70	80	30	40	40	30	40	40

Coleoptera had a difference in number of individuals 2004 compared to 2006. The group colymbetine decreases in 2006 while the two other groups increased in 2006. Eigenvalue= 1,058, Wilks' Lambda= 0,486, P=0,196

The Diptera taxa (Ceratopogoninae, *Chaoborus* sp. and Tanypodinae) decreased in 2006. Chironomidae had both decreasing and increasing depending on underlying taxa. Ephydridae increased. The group on a whole decreased in every wetland. Eigenvalue= 2,228, Wilks' Lambda= 0,310, P=0,265

Tricoptera had the highest number of correctly classified groups. There are a higher number of individuals in 2004 but a lower taxa number. Eigenvalue= 1,695, Wilks' Lambda= 0,37, P=0,203.

Gastropoda had 30% correctly classified groups when cross validated and an Eigenvalue>1. Eigenvalue= 2,045 Wilks' Lambda= 0,328, P=0,294

None of the groups Ephemeroptera (Eigenvalue= 0,434 Wilks' lambda= 0,697 P=0,504), Zygoptera (Eigenvalue= 0,789 Wilks' lambda= 0,559, P=0.479), Heteroptera (Eigenvalue= 0,285, Wilks' Lambda= 0,778, P=0,653)or other (Eigenvalue= 0,565, Wilks' Lambda= 0,639, P=0,782) had significally separated groups.

Grouping dispersal potential:
Low dispersal potential and High dispersal potential were not markedly influenced by year as a factor for taxa number. The non flying dispersal potential group had 70% correctly grouped after cross validation(table 2) although not significant. In the group there are 12 taxa where of 8 were used in the statistics(due to degrees of freedom). No group was significally separated.

Table 2. Original and cross validated group percentages of dispersal potential on year.

	Not flying	Low dispersal potential	High dispersal potential
Failing tolerance test:	4	1	6
Dependent factors:	8	8	8
Original grouped [%]	100	100	100
Cross validated [%]	70	40	20

The non flying group had a grouping with Eigenvalue well over 1 although not significant between year 2004 and 2006. (Eigenvalue= 3,103, Wilks' Lambda: 0,244, P=0,687)

The low dispersal potential group separated but there was a no significant effect of age on the group. (Eigenvalue= 5,596 Wilks' Lambda= 0,152 p = 0,479).

The group high dispersal potential separated but with there was no significant effect of age on the group. (Eigenvalue= 28,812 Wilks' Lambda= 0,034 p = 0,093)

3.2.2 Vegetation effect on community composition

Some groups had a high percentage correctly grouped but no group had a higher % after cross validation than 60%. (table 3). No groups had significant separatio

Table 3. Original and cross validated group percentages of taxa of vegetation coverage

	Annelida	Coleoptera	Gastropoda	Diptera	Ephemeroptera	Zygoptera	Tricoptera	Heteroptera	other
Dependent factors:	3	3	5	5	3	4	5	3	5
Original grouped [%]	60	70	80	90	70	70	80	60	60
Cross validated [%]	60	50	60	30	20	30	40	10	20

Annelida was 60 % correctly grouped in vegetation cover categories 1, 2 and 3. Taxa number had decreased with vegetation cover increasing to vegetation cover 3.

Coleoptera had less correctly grouped wetlands than Annelida. 50% was grouped correctly after cross validation. The Taxa number was approximately the same in the three vegetation types but the number of individuals had increased with higher coverage.

Gastropoda is the group with the highest percentage correctly classified wetlands. After cross validation 60% are correctly classified. The number of taxa was somewhat higher in the wetlands with lower vegetation cover but the number of individuals was much higher in high vegetation cover wetlands. This was mostly due to *Gyraulus albus*.

Grouping dispersal potential:
Two out of the three factors had been correctly classified groupings in a considerably high percentage. These two were the non flying and the group with high dispersal potential. The group with low dispersal potential showed no clear grouping (table 4).

Table 4. Original and cross validated group percentages of dispersal potential of vegetation coverage.

	Non flying	Low dispersal potential	High dispersal potential
Failing tolerance test:	4	1	6
Dependent factors:	8	8	8
Original grouped [%]	100	100	80
Cross validated [%]	60	10	70

Cross validation of the non flying group showed that 60% was correctly classified although not significant. In category one, with low vegetation cover, the number of taxa was twice as high as in category three. The number of individuals was increasing with vegetation. In this group there was a wide difference between taxa. Some taxa occurred in great numbers in vegetation type 1 (Annelida) and some in type 3 (Gastropoda).

High dispersal potential had 70% correctly classified groups**.** The number of individuals was the highest in the vegetation 1 group. The taxa most responsible for this is tanypodinae and ceratopogonidae. They both have very high number of taxa in vegetation group 1.

3.3 Interactions between year and vegetation-Relative vegetation

3.3.1 Vegetation cover

The coverage of vegetation did not increase significally (p= 0.079). Submerged and Floating leaved plants had decreased while all other vegetation types had increased. Dead plant material and emergent plants increased the most. Samples taken in areas with no vegetation had decreased in 2006.

There was an increase in three of the five wetlands investigated. In no case did the vegetation coverage decreased in one wetland when comparing the two years.

3.4 Correlation between wetland age and vegetation coverage

The correlation showed that there no connection between age and vegetation cover percentage. It is not significant. R^2=0.1028

3.5 Alpha, beta and gamma diversity level

Alpha diversity:

Taxa number has a peak in wetlands 5-6 years going from a mean of 17.7 taxa in 2 year old wetlands to a mean of 20.5 taxa in 5-6 year old wetlands. The number of wetlands decreased in 7-9 year old wetlands to a mean of 18.5 taxa. The same results are seen looking at the different years (2004 and 2006) The wetlands that were younger in 2004 (027,137 and 141) had an increase in mean of taxa from 17.7 to 18.33. In the older wetlands (171 and 184) mean number of taxa decreased from 23.5 to 18.5.

Beta diversity:

Looking at age in the younger wetlands (2 years in 2004) the number of shared taxa decreased after two years. Taxa present in all three wetlands (027,137, 141) decreased from 21 to 6 taxa. Taxa present in two of the three wetlands also decreased from 21 to 17 taxa. The number of shared taxa decreased in older wetlands (171,184) from 22 to 10. With vegetation coverage the shared number of taxa was the highest with vegetation cover type 2 (30-70%). 100% shared taxa for all wetlands (027,137,141,171,184) was 5 taxa in vegetation type 1 (>30%) to 18 taxa in vegetation type 2 and down to 6 taxa in vegetation type 3(<70%). The same pattern was seen in taxa with a lower shared rate.

Gamma diversity:

Number of sampled invertebrates was lower in 2006 than 2004 when looking at 9 samples 2004 versus 3 samples per wetland in 2006. Number of taxa going from 100 taxa in 2004 to 92 in 2006. Counting 3 samples per wetland in 2004 and 2006 the number of taxa increased from 72 to 92 (see discussion: Invertebrate taxa interacting with age). The total number of taxa for all wetlands have increased with higher vegetation coverage from 27 taxa per wetland in type 1 vegetation coverage to 32 taxa in type 2 and 33 taxa per wetland in type 3.

4 Discussion

4.1 Invertebrate taxa interacting with vegetation

Comparing wetlands of similar age:

While the vegetation coverage is steadily increasing the macroinvertebrates seems to have a peak in number of taxa in wetland with an age of 5-6 years. If this is applicable for other wetlands it means that reconstruction of wetlands has to be done before the period when species decrease, if high diversity is the goal. The reason for fewer taxa in older wetlands might be that some species of vegetation are more abundant and therefore less species thrive in the wetland. Contradicting this few differences were seen in wetland vegetation regarding age according to White and Halpin (22). Contradicting White and Halpin differences in number of species of vegetation can vary tenfolds between wetlands (23) and surrounding environment has probably a greater importance than age (24).

Taxa number:

There was no significant increase in taxa in older wetlands. Vegetation coverage does not show plant species diversity. Taxa number does not necessarily responds to more vegetation by increasing as it would with higher species number(25). The group with medium vegetation cover had the highest taxa number mean. This could be a result of the oldest wetland being in that group. The variation is wide in the group which could be caused by difference in wetland ages. In younger wetlands(1-2 years) number of macroinvertebrate species would be more likely to increasing with vegetation since there was no species before the construction. While the younger wetlands are still evolving and a lot of taxa are added, the result from the composition of taxa is different from wetland to wetland. The wetlands might be evolving into different types and therefore contain different taxa number depending on other factors than vegetation coverage(26).

Taxa and vegetation:

Annelida, Coleoptera and Gastropoda had a high percentage in correctly grouping although not significant. This still means that they were closer to each other in the demand of special vegetation type than the other groups. The number of individuals are higher for expected later colonizers such as Gastropoda, which colonizes after algae establishes in the wetland since they need them to graze (3).This sometimes only take a year but mostly longer than that. The Gastropoda species often get out concurred in older wetlands (27). Coleoptera, of which many are late colonizer, is not always present in the youngest wetlands (27). Among Coleoptera the taxa richness increased with age of wetland (28).

Dispersal and colonization:

The non flying group showed different need of vegetation. Annelida, being recorded more often in low vegetation cover wetlands, a probable early colonizer while Gastropoda were much more common in higher vegetation cover. According to Książkiewicz et al., for Gastropoda in general, the abiotic factors were more important than vegetation composition. Factors such as shadowing, groundwater level and litter moisture (23). In the case of Annelida the open areas of sediment is not as common in wetlands with high vegetation coverage and also the samples were not taken in sediment, where they live (29) (exception leeches), when vegetation was present. The two are logically not in need of the same system and therefore often found in different vegetation types. High dispersal potential is as expected found in greatest numbers in low vegetation types. This is most obvious for two Nematocera taxa (Tanypodinae and ceratopogonidae). They are examples of the ability to colonize new wetlands and also being able to stay after initial dispersal (27).

4.2 Invertebrate taxa interacting with age

There is an increase of invertebrate taxa in total in 2006 if counting three sites sampled per wetland. In 2006 more time was taken collecting invertebrates. To have the same amount of time gathering data per wetland 9 samples was set against three. This might have been a slightly high number of samples and a mean between 9 and 3 samples would have been closer in time used.

Number of taxa in different aged wetlands:

The general result for Coleoptera is an increase in 2006 which indicates they need an older wetland to thrive. Coleoptera, being a complex insect order were many species evolved after or alongside other species, might need an already functioning ecosystem (30). Coleoptera are often regarded active disperses and would therefore be pioneers in wetland communities (31). Species with high dispersal potential are mainly seen during the first year after construction. Since the wetlands were between 68 and 80 months in 2006, first hand colonizers might already have been out concurred in some of the wetlands. The actual species present are of greater importance than recording the orders or families present. No species list was put together in either 2004 or 2006. The order Coleptera included species that are generalists as well as specialist. Generalists are often early colonizers and specialists tend to colonize later (24). The number of individuals for Tricoptera and Diptera was higher in 2004. They both were early colonizers in wetlands. The Phyrganeidae of Tricoptera complete their aquatic stage of their lifecycle early (32) and might have been excluded in the later samplings in 2006. Annelida were found in larger individual amounts in young wetlands. This may be due to low demands on surrounding environment. If so, this is in this case a more important factor than the dispersal potential.

4.3 Alpha, beta and gamma diversity:

Alpha level:

The younger wetlands had a bigger difference between 2004 and 2006 than the older did.The increase in 5-6 years could depend on the filling of function groups. This is probably not ready after two years and therefore the increase is continuing after that. These functional groups might be filled after 5-6 years and therefore no increase in number of taxa after this age. In oppose to this, and according to Duma 2011, no effect of age after the first year on invertebrate taxa number was shown in constructed wetlands in southern Sweden (34). Other studies show less presence of groups with lower dispersal potential in constructed wetlands. Groups such as Hemiptera, Crustaceae, Coleoptera, Diptera and Tricoptera were found in lower amounts in constructed than natural wetlands (24).

Beta level:
In 2004 the number of shared taxa was higher in older than in younger wetlands. Although looking at the same wetlands again after two years both the younger and the older wetlands had a decrease in number of shared taxa. The problem with comparing 2004 and 2006 is that they almost overlap in age. There is no big leap in age between young and old wetlands and there may therefore be overlapping in number of taxa too. It might also be the case of different taxa staying och colonizing the wetlands. There might be an exchange from generalists to specialists in some wetland and in others the generalist might be more successful (3). This would generate the decrease in shared taxa seen in 2006.
Regarding vegetation coverage the increase of species of vegetation might be the reason for higher vegetation coverage. More species can live in a rich environment with more vegetation since there is more microhabitats and niches present (25,36). On the other hand, if a few plant species take over, the vegetation coverage increase while the species number might decrease for both plants as well as invertebrates. This might be the case in the group with highest vegetation cover. Some species need open water surfaces. All species that use atmospheric oxygen need to be able to reach the water surface for respiration. Other groups that use the open water surfaces are Gerridae and Gyrinidae(3). With higher vegetation coverage there are less open water surfaces which might lead to less species.
Since the number of shared taxa decreased in the oldest wetlands this indicates that wetlands had different species colonization which might be due to different species of vegetation promoted by some invertebrate species but not others.

Gamma level:
There is an increase in number of invertebrate taxa from 2004 to 2006 for all wetlands combined. The oldest wetland in my study is almost 9 years old. With age comes higher diversity (26) although my results for the older wetlands show a slowdown in number of taxa for the oldest group.

4.4 Comparing taxa composition with year and vegetation

Although no separation of taxonomic or dispersal potential groups were significant, some groups did show a good separation and separated to a high % and with high Eigenvalues. Why the values are not significant is probably due to the fact that age and vegetation coverage affect other groups (36,24,37) more than the taxonomic and dispersal potential groups in my thesis.

Future research:
One important thing to look at would be a greater number of wetlands with a greater differences in younger and older wetlands. Taking very young wetlands in to account (under one year) would give more knowledge of which species are present in the wetland, the first colonizers. To include more characteristics of the invertebrates would give better knowledge as to how they can be grouped. Species and not only higher taxa, as in this survey, would say more about dispersal than orders or families do. To do this, a lot of time is needed to understand the function of different species. To look at the surrounding ecosystems, inflowing streams and connected populations and their importance for

species assemblage would give greater knowledge of later occurring vegetation and invertebrate species.

I found that number of invertebrates peaked in the researched constructed wetlands aged 5-6 years. Even though vegetation coverage steadily increased, number of taxa did not. On the opposite, taxa number decreased in the oldest wetlands of the research. It seems as though invertebrate taxa number in constructed wetlands needs moderate vegetation and a few years after construction to reach culmination.

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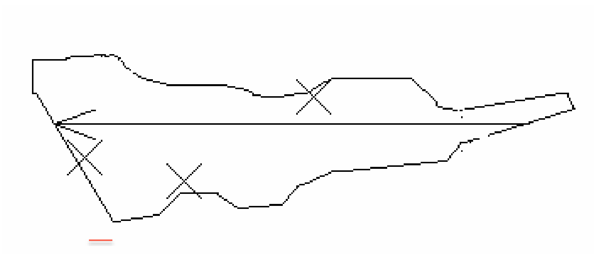
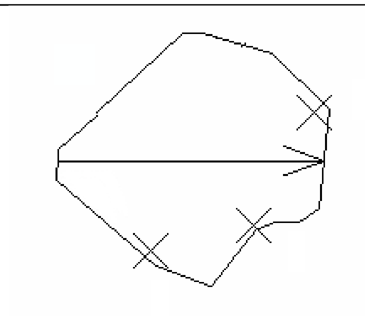
6 Appendix

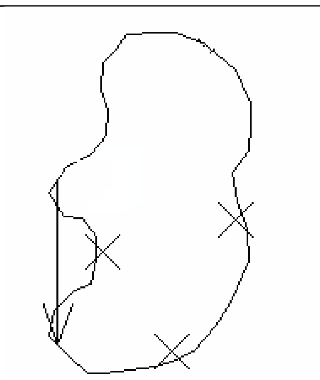
Table 5. Characteristics of wetlands sampled in 2006.



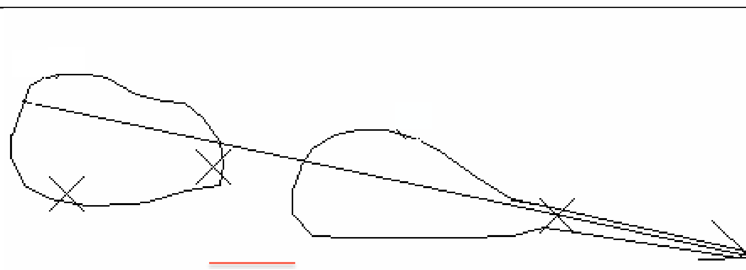
Wetland	27
Age 2006 [months]	70
Vegetation cover 2006 [%]	60
Majority Vegetation 2006 *	EV/DPM
Vegetation type 2004	Typha/phragmites
Size [m2]	6594
Average depth [m]	0,86
Location	Vinberg



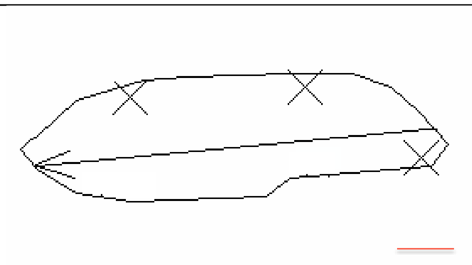
Wetland	137
Age 2006 [months]	69
Vegetation cover 2006 [%]	56
Majority Vegetation 2006 *	DPM
Vegetation type 2004	Juncus bolbosus
Size [m2]	1669
Average depth [m]	0,56
Location	Steninge



Wetland	141
Age 2006 [months]	68
Vegetation cover 2006 [%]	22
Majority Vegetation 2006 *	EV
Vegetation type 2004	Juncus bolbosus
Size [m2]	3265
Average depth [m]	0,73
Location	Onsjö



Wetland	171
Age 2006 [months]	81
Vegetation cover 2006 [%]	50
Majority Vegetation 2006 *	EV
Vegetation type 2004	Potamogeton berchtoldii
Size [m2]	2203
Average depth [m]	0,69
Location	Edenberga



Wetland	184
Age 2006 [months]	107
Vegetation cover 2006 [%]	56
Majority Vegetation 2006 *	EV
Vegetation type 2004	Potamogeton natans
Size [m2]	1447
Average depth [m]	1,02
Location	Ränneslöv

* EV=Emergent Vegetation, DPM= Dead Plant Material

—— = 10m (the wetlands are not displayed in the same scale)

Table 6. Taxa present in both 2004 and 2006.

(A) Annelida	(L) Chironomini typ 3
(A) Annelid typ 1 (minst)	(L) Orthocladinae
(A) Annelid typ 2 (mellan)	(L) Anopheles
(A) Annelida 2 land+duenn	(L) Culicoides sp.
(A) Lumbriculidae	(L) Dixa sp.
(A) Stylaria lacustris	(L) Baetis sp.
(A) Helobdella stagnalis	(L) Cloeon dipterum /Inscriptum
(A) Erpobdella octoculata	(L) Caenis horaria
(A) Glossiphonia complanata	(L) Ephemera danica
(A) Hydracarina	(L) Nemoura sp.
(A) Limnesia fulgida	(L) Nemoura cinerea
(A) Hydrachnellae	(L) Cataclysta lemnata
(A) Hydrachna globosa	(P) Cataclysta pupae
(A) Hydrozetes sp.	(L) Elophila nymphaeata
(A) Asellus aquaticus	(L) Nymphula stagnata
(A) Curculionidae	(L) Acentria ephemerella
(A) Bagous sp.	(L) Holocentropus sp.
(A) Bagous sp typ 2	(L) Mystacides azurea
(A) Hydrophiloidae/Hydraenidae	(L) Athripsodes sp.
(A) Cymbiodyta sp.	(L) Triaenodes sp.
(A) Anacaena sp.	(L) Triaenodes bicolor
(A) Enochrus sp.	(L) Leptophlebia vespertina
(A) Hydrochus sp.	(L) Glyphotaelius pellucidus
(A) Hydrochara carabidoides	(L) Limnephilus rhombicus
(A) Helophorus sp.	(L) Limnephilus sp.
(L) Elodes sp. (Helodidae)	(L) Limnephilus sp. 2
(L) Brychius elevatus	(L) Anabolia sp. typ 1
(L) Brychius sp.	(L) Anabolia sp. typ 2
(A) Haliplus sp.	(L) Anabolia sp. typ 3
(A) Haliplus liaphilus	(L) Anabolia sp. typ 4
(A) Hygrotus sp.	(L) Anabolia sp.
(A) Hygrotus versicolor	(L) Anabolia nervosa
(L) Colymbetinae larvae	(L) Anabolia concentrica
(A) Laccobius sp.	(L) Phryganea striata
(A) Laccophilus sp.	(L) Ischnura elegans
(A) Hyphydrus ovatus	(L) Lestes sp. (Lestes sponsa)

(A) Graphoderus sp.	(L) Coenagrionidae
(A) Agabus sp.	(L) Coenagrion sp.
(A) Porhydrus lineatus	(L) Coenagrion puella/pulchellum
(L) Dytiscus sp.	(L) Coenagrion hastulatum
(L) Dyticinae	(L) Enallagma cyathigerum
(L) Dyticidae	(L) Sympetrum sp.
(L) Scirtes sp. larvae	(L) Aeshna sp.
(A) Noterus clavicornis	(L) Aeshna mixta
(L) Ephydridae	(A) Micronectidae
(L) Pediciidae	(A) Hesperocorixa
(L) Bezzia sp	(A) Paracorixa
(P) Ceratopogonidae pupae	(A) Corixidae
(P) Ceratopogonidae pupae typ 2 (stor)	(L) Corixinae larvae
(L) Ceratopogoninae	(A) Corixa punctata
(L) Serromyia sp.	(A) Sigara lateralis
(P) Chaoborus sp.	(A) Sigara sp.
(L) Chaoborus sp.	(A) Callicorixa sp.
(L) Tanypodinae	(A) Notonecta glauca
(L) Tanypodinae typ 1	(L) Notonecta larvae
(L) Tanypodinae typ 2	(A) Plea leachi
(L) Tanypodinae2 gross	(A) Sphaerium corneum
(L) Tanypus sp.	(A) Acrouxus lacustris
(L) Tanitarsini	(A) Galba truncatula
(L) Tanitarsus sp.	(A) Radix ovata
(L) Chironomidae	(A) Radix peregra
(L) Chironomidae (lång antenn)	(A) Bathyomphalus
(P) Chironomidae pupae	(A) Valvata macrostoma
(L) Chironominae	(A) Gyralus albus
(L) Chironomini typ 1	(A) Gyralus crista cristatus
(L) Chironomini typ 2	(A) Planaria torva

Nature intrigues me!

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