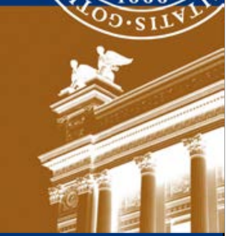

Biodiversity in constructed wetlands in Southern Sweden

- Evaluation of new wetlands within the Tullstorp Stream Restoration Project

Agnieszka Duma

2011

Environmental Science
Degree project, 15 hp
Bachelor of Science
Lund University

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Handledare:

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Abstract

Scania is a region in southern Sweden that used to be a region of wetlands. Nevertheless, due to human activities wetland loss is an established matter currently, and following from that, changes in biodiversity, water regime and nutrient retention. One purpose of creating new wetlands is to reinstate good status of biodiversity.

The study was based on data gathered in July 2011 from 13 newly constructed wetlands within the Tullstorp catchment area. The aim was to study a progress of biodiversity in that area using a new method developed by the County Administrative Board in Jönköping. The study gave clues on how to construct wetlands in order to increase biodiversity.

It was found that combination of wetland features may increase its biodiversity, however different components determines bird species richness, invertebrate species richness and the coverage of wetland vegetation. Large wetland surface area has a positive effect on the number of bird species, particularly when there are no predatory fish in the wetland. Increasing the age of wetland tend to have a positive influence on invertebrate species richness. There is no effect of the age of wetland and the number of birds. Predatory fish are likely to affect the species composition of invertebrates rather than taxon richness. In this study, large diving beetles were only present in wetlands without predatory fish whereas snails were more frequent in wetlands with predatory fish. Macrophytes increase in coverage with increasing age of wetland, but not if crayfish are present. Wetlands rated with poor biological status mostly did not get any points for vegetation, birds or invertebrates. In addition, morphometry and maintenance of the newly constructed wetlands included in this study are physical features that need to be improved in order to get higher scores.

Contents

Introduction

Most recently, people tend to straighten up the nature, control physical phenomena and biological processes to arrange a picture of landscape that they believe is attractive. Very often, these humans' creations perturb the biological balance in the world and damage the natural beauty, even though unintentionally (Feuerbach & Strand, 2010). However, people due to education and science are also able to support the environment by building water bodies maintaining biodiversity since the variation in nature is definitely highly desired.

Wetlands are very valuable resources per unit area because they provide ecosystem services, food, recreation and water supply (Hansson, Brönmark, Nilsson, & Åbjörnsson, 2005). Hence, the interest in wetlands has increased immensely. Wetlands may be created for several purposes like retention of nutrients, recreation, waste- or storm water treatment, food production and biodiversity (Brönmark & Hansson, 2005). Depending on demands they may be built to fulfill all that goals or their role could be emphasized on one of the factors. For example, in some watersheds the role of preserving biological diversity is the most important one (France, 2003).

Nowadays, when various direct and indirect human activities pose threats to ecological systems, enhancement of biodiversity is an important global issue. On the topic of defining biodiversity Brönmark and Hansson (2008, p.209) state that it could be specify as "the variety and variability among living organisms and the ecological complexes in which they occur" (Brönmark & Hansson, 2005). Wetlands are places with a unique fauna and flora, many species of animals are restricted only to these areas, which concerns a vast species of birds (Valk, 2006). They use them for breeding, nesting, and as a source of shelters, particulary if any islands occur. In turn, shallow water of these water bodies can establish diverse vegetation. Presence of macrophytes results in an increase in the diversity of invertebrate and fish, and thereby the complexity of wetlands, however they capture most of the entering solar energy. Species diversity as well as species composition may determine the function and dynamics of ecosystem. According to MacArthur and Wilson and their island theory the bigger island area the larger population of species. Applying that hypothesis to wetlands, the key role of great area of wetland is to increase biodiversity, as the number of species is predicted to rise with the area (Brönmark & Hansson, 2005).

Over eight million square kilometers of worldwide lands are covered with wetlands (France, 2003). In the world, about 50% of wetlands have been lost during last decades. What is more, there are regions where number of losses increased up to 99% (Valk, 2006). In the south of Sweden, even though since 1990 there were 500 new created wetlands, the lost reached 40% (Nyström, 2011). Watercourses in Scania have been straightened out, modified and put in pipes. In addition, in over half of the region, groundwater level was lower by 1-2 meters (Berndtsson & Hansson, 2010). That is alarming to biodiversity, above all to threatened species since as many as 15% of them are found only in wetlands (Nyström, 2011).

People have mistreated wetlands throughout history. They changed them into harbors or home sites. About forty years ago, there were even incidents when persons not familiarized with the meaning of the word ‘wetland’ misinterpreted it with a word ‘wasteland’ (France, 2003). In addition, current modernization of agricultural sector has a significant impact on an environment and biodiversity conservation through degradation of wetlands (McCracken, 2010). The majority of wetland losses consequence either from drainage or from clearing for agriculture (France, 2003). Since agricultural areas cover over 45% of lands in European Union and intensification of farming methods has increased during last years, due to increase their productivity, the prevention in further decline in biodiversity became a matter of concern. Questions about how to target that issue were posed and followed by several actions (McCracken, 2010). Construction or restoration of wetlands is one of the natural ways to solve the problem of falling biodiversity in farmlands.

The idea of constructing wetlands was implemented, among others, in Scania in Sweden. In that area, where natural wetlands were drained for agriculture, many animals and plants became rare. That, combined with nutrient retention issue, gave a rise to a unique restoration project.

Within the Tullstorp Stream Project there are 13 new wetlands created since 2009 for the purpose of reducing nutrient transport and promoting biodiversity and there are 37 more planned to be constructed. The project is partly-financed by The European Agricultural Fund for Rural Development and is one of sectors of the sustainability project of Trelleborg Municipality - The Wetlands, Algae, Biogas, a South Baltic Sea Eutrophication Counteract

Project (WAB) (Persson, 2009). The main aim of WAB is to create sustainable solutions which, among others, means creation of wetlands, that benefit both land and marine environment along Baltic Sea and decrease nutrient leakage as well as simulate biodiversity (WAB, 2010). A secret of individuality of the Tullstorp Project is that people of the municipality are aware of environmental issues since they are really involved. All landowners along the stream joined an association in order to fill the major targets of project such as reduce the outflow of nutrients from land to the sea, lessen flooding and erosion, increase biological diversity, reach good status of water according to the European Union Framework Directive (Persson, 2009).

This study evaluated a new protocol for measuring biological diversity in wetlands because it is crucial to get a comparable and accurate way of assessing biodiversity. Data gathered during assessments of 13 newly constructed wetlands in Scania (Sweden) gave also the opportunity to make an analysis of their current biodiversity as well as investigate patterns influencing biodiversity. According to MacArthur and Wilson theory of island biogeography, wetland area should be positively correlated to the number of species. In this case I focused on wetland birds and macroinvertebrates. Furthermore, I also tested if colonization of wetlands was influenced by the age of wetlands. Since predatory fish may have negative effects on large macroinvertebrates (Brönmark, 1994), wetland birds (Wagner & Hansson, 1998) and amphibians (Nyström, Birkedal, Dahlberg, & Brönmark, 2002), fish was included as a factor in most analysis.

Methods

All fieldwork was done by myself, Per Nyström, Pia Hertonsson and Marika Stenberg from Ekoll AB. Data were collected on three occasions in a time period of two weeks. The first collection of data was on 6th July, next two were performed on 11th and 13th July. All investigated wetlands were within the catchment of Tullstorp Stream in the south of Scania in Sweden (Figure 1). A localization of each of them was found with GPS based on given coordinates. A method used to assess biodiversity in constructed wetlands had been developed by the County Administrative Board in Jönköping. The reason for that is not only the fact that the method is quite new giving a chance to test the method itself but also achieved results are supposed to be standardised. The methodology is based on an inventory of physical facilities that wetlands provide the biological values for habitants. Another important aspect is that the assessment of wetlands using the method from Jönköping does not require any particular skills so any biologist can implement it. Essentially, the only thing that should be done is completing a survey protocol for biodiversity in wetlands, which is divided into three main parts. Hence it includes a general object information section where there is space to add information such as name of water body, date of a visit, year of construction, purpose of creating wetland, type of inlet and outlet. That is followed by a physical part where wetland area, morphometry, landscape location, maintence etc. are defined. The survey protocol ends with a biological part that contains elements such as vegetation, birds, invertebrates and fish diversity. A simplified version (amphibians and fish not included in the evaluation) of original survey protocol (Jönköping, 2010) was used and translated to English by Pia Hertonsson (Appendix III).

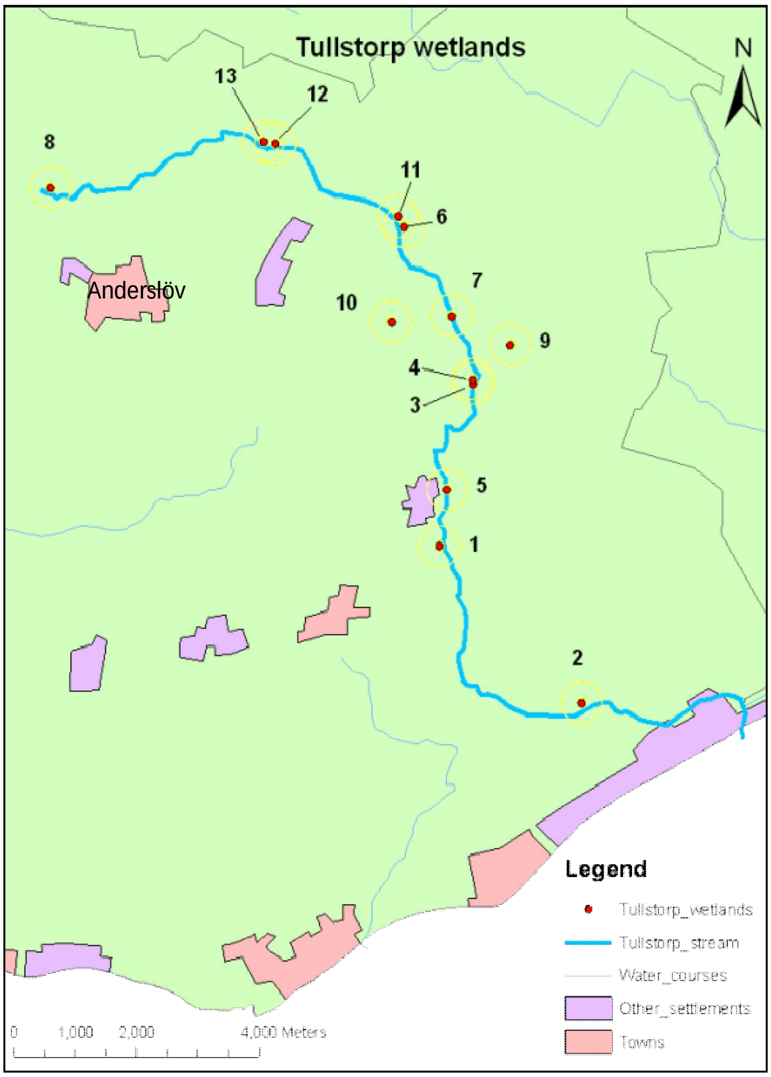
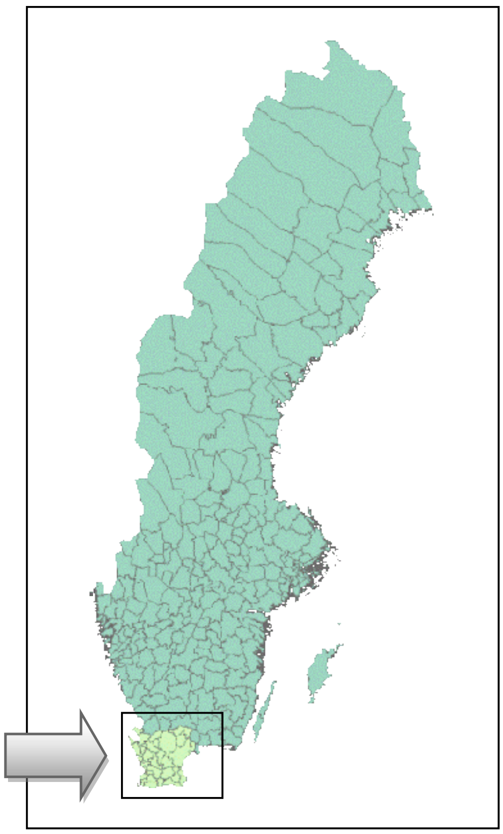


Figure 1 Localization of 13 new constructed wetlands within the Tullstorp catchment area in Scania, Sweden.



Fieldwork

While collecting data a schematic pattern was developed and repeated at each wetland. Birds were the first object of interest, immediately upon arriving to the wetland area, since any noise or sudden movement could have startled them. They were localised from a requisite distance of thirty to fifty meters with the naked eye and binoculars. That enabled us to identify them to species level using Bruun and Singer (1984). Only bird species that really live in or forage in the wetland were included in the survey. Using a camera with magnifying lens, pictures of spotted birds were taken as well as general pictures of wetland itself to record vegetation cover and landscape so that any empty boxes in the survey could be filled. Name, water body-ID, purpose of creating the wetland and other object information were completed if known from available database - aerial photographs from 2009. Otherwise wetlands were given a unique name. However for this study real names or identification numbers of wetlands were substituted with numbers from 1 to 13 (Appendix I). Area of each wetland as well as water depth was estimated visually in the field. If any islands were observed they were also noted in the protocol since they are important for many wading birds. Invertebrates were sampled by netting with a 0.25 m diameter hand-net with a flat bottom (0.5 mm mesh size) as follows: ten samples from different parts of wetland were taken by sweeping the net below the water surface, close to the bottom, often through vegetation, and each sample was identified at site. The netting was interrupted if during last two nettings, which mean in both samples nine and ten, no new taxa were found. Otherwise, netting was continued in order to get additional five samples. The taxa were classified at site after each netting using a tray filled with water. That made samples more easy to classify. Then the number of different taxa were reported in the survey. During netting we also made notes of amphibian larvae that were caught and these were identified to species level. Fish and crayfish were noted and classified in exactly the same way, during hand netting, or if they were observed visually. At the end, based on observations, the rest of the physical information was completed such as surrounding land type, vegetation appearance and source of water supply to the wetland. In instance of any doubts regarding to a way of filling in the survey protocol, the survey manual for assessing biodiversity in wetlands by the County Administrative Board in Jönköping was used (Jönköping, 2010).

Biodiversity points assignation

Methods for assessing biodiversity in wetlands, developed by the regional council in Jönköping, was designed to evaluate wetlands based on fieldwork and calculations. While filling in the survey protocol every factor get values identifying their status like figures 0,1,2,3; Yes/No answers or other records. Each value from the survey protocol has assigned number of points for spider webs in Proposal of weighting (Appendix III). That is because one set of data is adjusted to contribute more in the final outcome than others what emphasize its importance and gives more weight, rather than each variable in the data apportioning equally. According to weighting of wetland there were two spider webs created for each wetland, separately for physical and biological part (Appendix II). Physical part consists of five main components: size, morphometry, surrounding land, landscape location and maintenance, whereas three main ingredients follow biological part: birds, invertebrates and vegetation. Under each part, there are several information elements for which measurement number or Yes/No factors were given in the protocol. Through reviewing filled boxes, proper numbers of points were assigned to each of element, to afterward sum them up getting a result of Total Points. Depending on that number, a proper number of Spiderweb Points was given (Table 1). In addition, in case of invertebrates and birds, not only their diversity measured by a number of found species was essential, but also names of species were on the interest since there were extra points allocated to any birds listed in Natura 2000 List (Abenius, Aronsson, Haglund, Lindahl, & Vik, 2005) or Red-listed species (ArtDatabanken Swedish Species Information Centre, 2010).

Part	Total Points	Spiderweb Points
Size	20<	5
	17-20	4
	13-16	3
	9-12	2
	1-8	1
	0	0
Morphometry	4<	5
	3-4	4
	2	2
	1	1
	0	0
Surrounding land	150<	5
	101-150	4
	76-100	3
	51-75	2
	26-50	1
	0-25	0
Landscape location	20<	5
	17-20	4
	13-16	3
	9-12	2
	4-8	1
	<4	0
Maintenance	51<	5
	41-50	4
	31-40	3
	16-30	2
	1-15	1
	0	0
Birds	21<	5
	16-20	4
	11-15	3
	5-10	2
	1-5	1
	0	0
Vegetation	9<	5
	8-9	4
	6-7	3
	4-5	2
	3	1
	<2	0
Invertebrates	29<	5
	24-29	4
	16-23	3
	11-15	2
	6-10	1
	<5	0

Table 1 Main components of physical and biological part in wetland weighting, possible total points and corresponding them spiderweb points.

Statistics

I used analysis of covariance (ANCOVA) to test if age or area (covariates) had any general linear effect on bird or invertebrate taxon richness (dependents variables) when the presence or absence of fish was included as a main factor. Cehi-square (Chi2) tests were performed to analyse if the frequency of wetlands with amphibian reproduction, snails or large diving beetles were dependent on the presence of predatory fish.

Statistical program IBM SPSS Statistics 19 was used to make the statistical analysis.

Results

General wetland characteristics

Water surface area of the 13 studied wetlands varied between 6 m^2 and 1.45 ha. All of them were young varying in age between 3 and 28 months. Predatory fish (pike, perch) were found in five wetlands, wetland birds were observed in all apart from two wetlands and invertebrates were found in all of them. Evidence of amphibian reproduction (e.g. Rana esculenta, Triturus cristatus, Triturus vulgaris) was found in 46% of the constructed wetlands (Table 2). The crested newts was found in wetlands 5 and 7 (Figure 2) and Signal crayfish (Pacifastacus leniusculus) in wetland 8 (Appendix II).

	Range	Mean	SD
Wetland area [ha]	0.0006-1.45	0.54	0.51
Wetland age [months]	3-28	17.46	7.86
Bird species	0-13	5.07	3.59
Invertebrates species	4-31	18.54	6.85
Fish presence [%]		38.46	
Amphibian reproduction [%]		46.15	

Table 2 Ranges and means of selected features of thirteen wetlands.

Figure 2 Photo of Great Crested Newt (*Triturus cristatus)* by Per Nyström on July 2011

Distribution of bird species and invertebrate species among wetlands

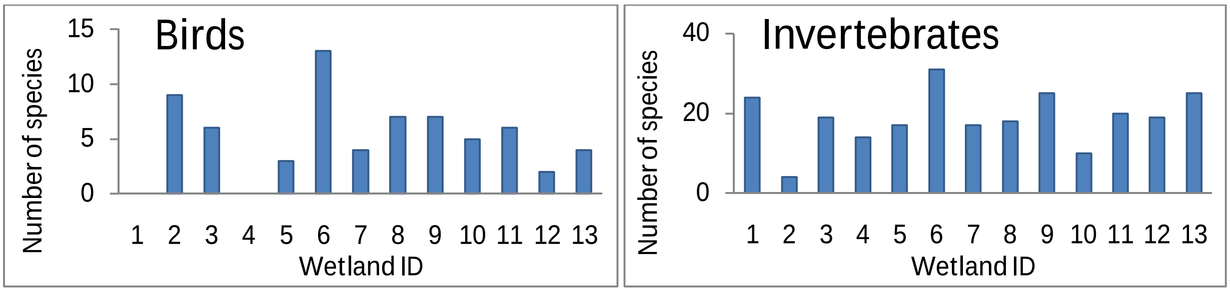


Figure 3 Number of bird and invertebrate species in each wetland

Figure 4 Photo of Red-necked Grebe (*Podiceps grisegena)* by Per Nyström on July 2011

The species richness turned out to be the highest in wetland 6 since both number of bird species (13) and number of invertebrate species (31) that have been found there are the highest. There were no birds observed in wetlands 1 and 4 (Figure 3). The most frequently occurring indicator birds were Common Sandpiper and Common Redshank. Among other species observed (Figure 5) some were Red-listed species as well as species from Natura 2000 List, or listed as most valuable and threatened species in Europe. Examples were Yellow Wagtail (Motacilla flava), Wood Sandpiper (Tringa glareda), Western Marsh Harrier (Circus aeruginosus), Red-necked Grebe (Podiceps grisegena) (Figure 4). These were mainly found in wetland 6 and 5. All the names of bird species in English, Swedish and Latin are listed in Appendix I. In turn, among the invertebrates, the most often found taxa were Chironomids, Freshwater mites and Water boatmen. No medicianal leeches, spiders or stone flies were observed (Table 4).

Status of biodiversity	Physical part	Biological part
Poor	0-5	0-3
Unsatisfactory	6-10	4-6
Moderate	11-15	7-9
Good	16-20	10-12
High	21-25	13-15

Table 3 Spider web points parenthesis for biodiversity conditions

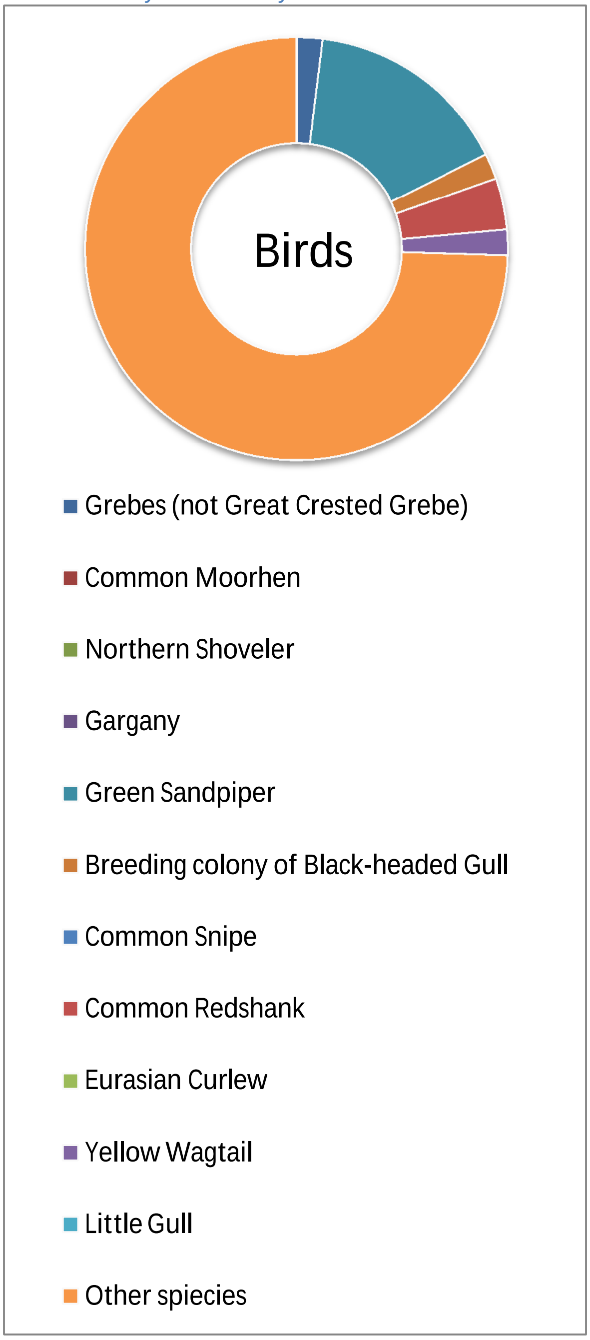


Figure 5 Percentages of various bird species founded in wetlands

Spider webs for wetlands - some examples

The sum of spiderweb points allows assessing the biodiversity conditions at wetlands, separately for biological and physical part according to marked parenthesis (Table 3).

The results for all wetlands from total sum of spider web points together with their pictures are given in Appendix II. Incontrovertibly the highest score in both physical and biological part according to Jönköping method got wetland 6 - Sillesjö South resulting in a total number of 31 points (Figure 6). Wetlands 2 (Sånarp) and 8 (Stora Markie) got the lowest scores in consideration of both parts resulting in only 10 points.

Sillesjö South wetland received the highest number of points for biological as well as physical part scoring 17 out of 25 possible points for physical part and 14 out of 15 possible points for biological part. Thereby physical status of its diversity is good and biological status is estimated as "high biodiversity" (Figure 6, Table 4). None of the wetlands got a maximum feasible number of points, thus that is the highest result among all thirteen examined wetlands in Scania. According to Figure 7 it is notable that landscape location, surrounding land and size got very good results in this wetland but morphometry got merely 1 point. Unlike the physical part, the biological part proves nearly perfect biodiversity conditions scoring almost maximum number of points.

INVERTEBRATES	
Flatworms	1.24
Oligochaets	2.89
Medicinal leech	0.00
Glossiphoniids (leeches)	1.65
Other leches	4.13
Mussles	2.07
Pulmonate snails	3.72
Planorbidae snails	4.96
Prosobranch snails	0.83
Freshwater isopods	3.72
Freshwater amphipods	2.48
Spiders	0.00
Freshwater mites	7.44
Alderflies	0.41
Butterfly larvae	1.65
Free-living caddiesflies	1.24
Case-building caddiflies	4.13
Dragonfiles	3.72
Damselflies	2.89
Mayflies	4.96
Stoneflies	0.00
Saucer bug	2.48
Backswimmer	4.55
Water boatmen	6.20
Water scorpion	2.48
Water stick-insect	0.41
Pond skater	1.24
Phantom midge larvae	1.65
Chironomids	11.16
Biting midges	2.48
Black flies	0.41
Crane flies/fly larvae	0.41
Other water beetles	5.79
Large diving beetles	1.65
Small diving beetles	4.96

Table 4 Percentages of various invertebrate species founded in wetlands

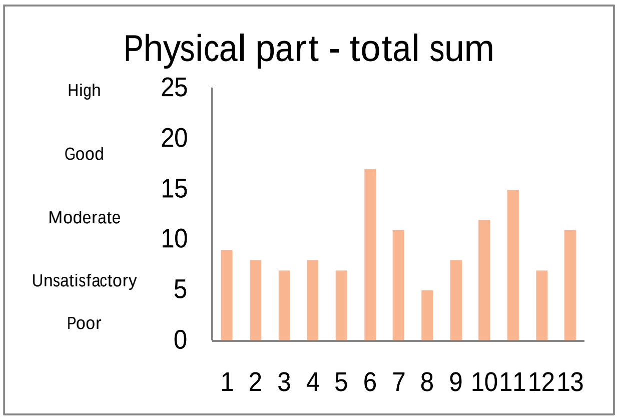


Figure 6a Physical status of 13 wetlands in the Tullstorp catchment based on points from Jönköping method

Below in Figure 8 are illustrated results for biodiversity in wetlands with the lowest scores among all newly constructed wetlands. It can be seen that the biological part in Sånarp having 2 points is much poorer than the physical part with 8 points, so physical conditions are unsatisfactory whereas biological conditions are poor (Table 3). No points for maintenance, invertebrates or vegetation were given. The biodiversity conditions of Stora Markie are more balanced but both parts are assessed as unsatisfactory, as this wetland got 5 points for each part. Nevertheless, no points for vegetation and maintenance were given.

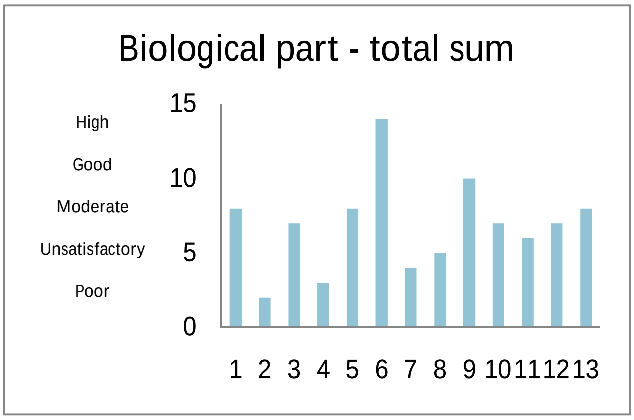


Figure 6b Biological status of 13 wetlands in the Tullstorp catchment based on points from Jönköping method

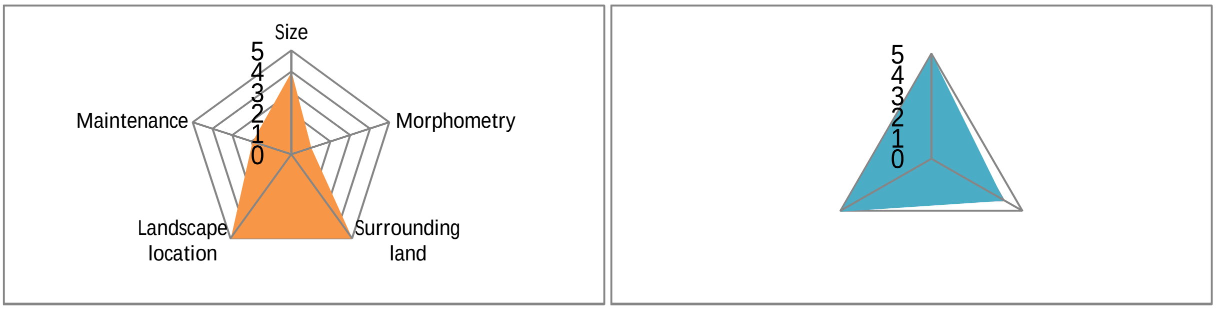


Figure 7 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Sillesjö South (wetland 6)

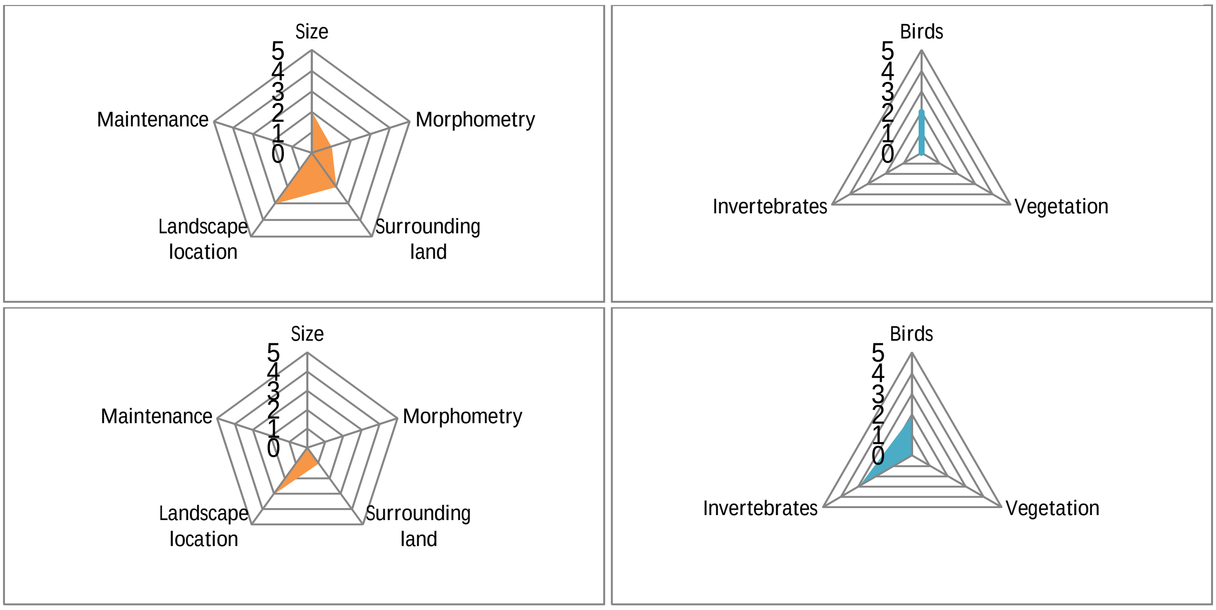


Figure 8 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Sånarp (wetland 2, up) and Stora Markie (wetland 8, down)

Relationship between area and bird species number

The results from ANCOVA with area as the covariate showed a general effect of area on bird species number (F=25.874; p=0.001). However a significant interaction between the area and fish (F=6.178; p=0.035) means that bird species number increase less in wetlands with fish than in wetlands without fish (Figure 9).

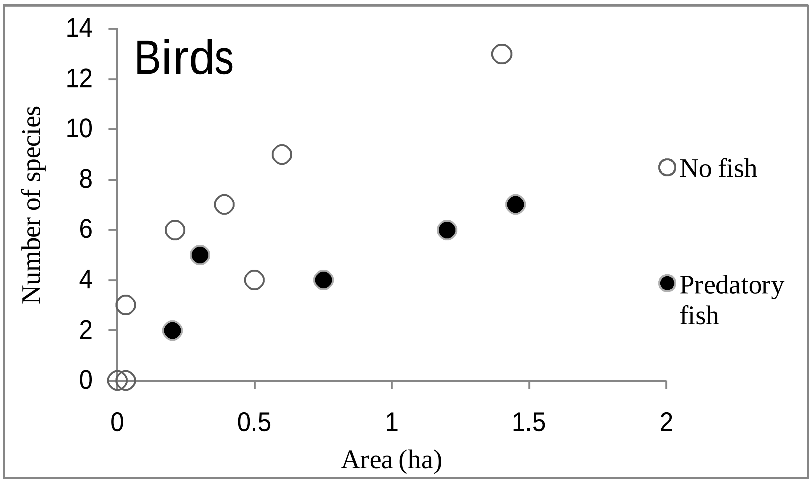


Figure 9 Effects of area and fish on bird species number

Relationship between area and invertebrate species number

According to Figure 10 there is a trend for number of invertebrate species to increase with area of wetland, regardless from fish presence. The ANCOVA shows however no significant general effect of area on invertebrate species numbers (F=0.026; p=0.875). Furthermore, the interaction between wetland area and fish was not significant (F=2.835; p=0.127). However, more notably is that not the number of invertebrate species but rather their composition is related to fish factor. Some invertebrate species like large diving beetles occurred only where there were no predatory fish (Figure 11). In addition the Chi2 test resulted in p=0.057, hence it is close to be statistically significant indicating that the occurrence of large diving beetles I dependent on the presence of predatory fish. In comparison, other invertebrate species, like snails, are more frequently occurring in wetlands with predatory fish (Chi2, p= 0.024), (Figure 12).

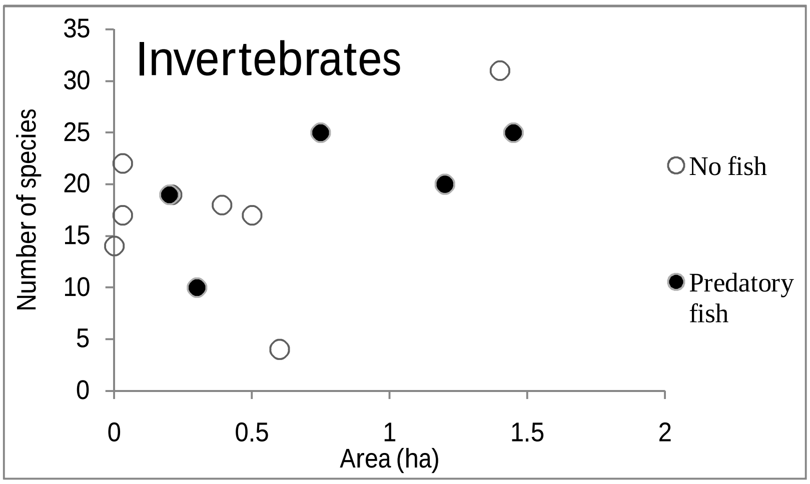


Figure 10 Effects of area and fish on invertebrate taxa number

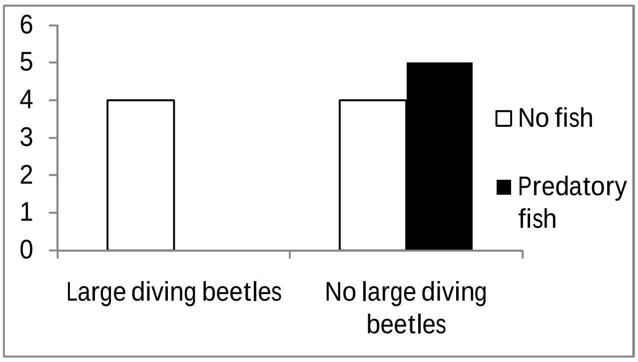


Figure 11 Frequencies of large diving beetles in wetlands with and without predatory fish

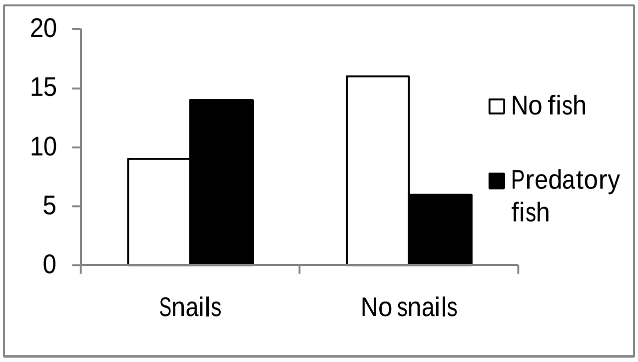


Figure 12 Frequencies of snails in wetlands with and without predatory fish

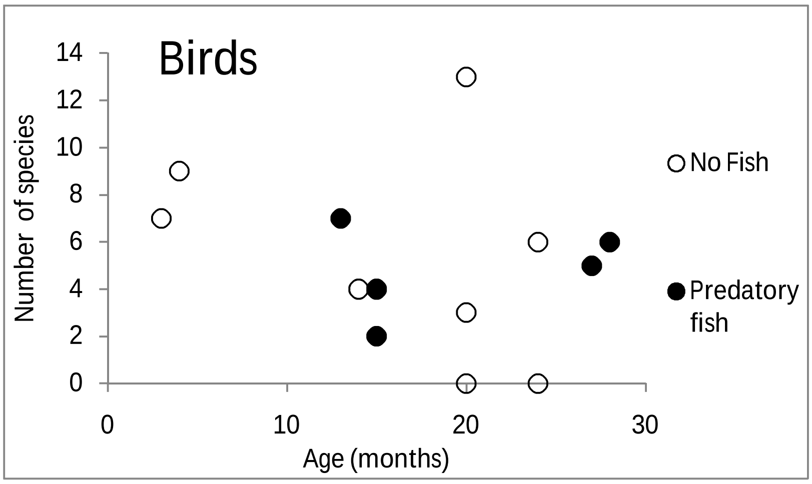


Figure 13 Effects of age and fish on bird species number

Relationship between age and bird species number

An ANCOVA did not detect any significant effect of age on bird species richness (F=0.717; p=0.419). so differences of bird species among wetlands do not vary as function of an age. In addition there is no significant interaction between the age and predatory fish in prediction of bird species number (F=0.717; p=0.419), (Figure 13).

Relationship between age and invertebrate species number

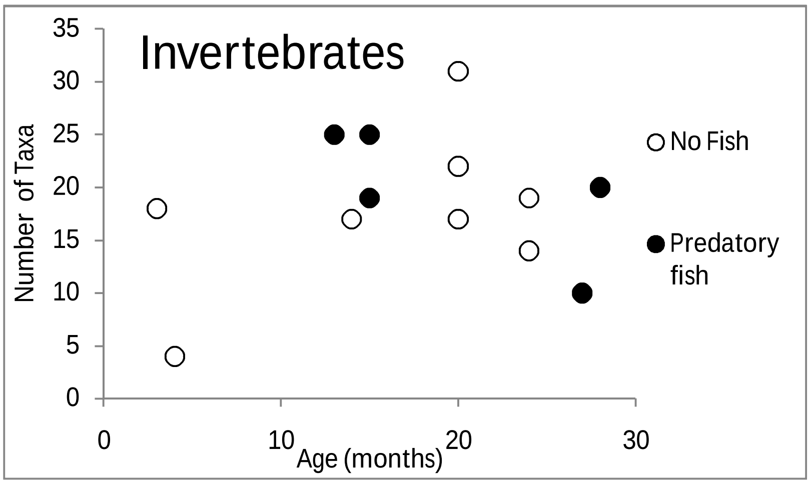


Figure 14 Effects of age and fish on invertebrate species number

The results from ANCOVA with age as the covariate did not show an effect of age on invertebrate species number (F=0.096; p=0.0.763). An interaction between an age and predatory fish in prediction in species richness of invertebrates is close to significant (F=3.587;

p=0.091). Thus, differences on invertebrate species number are near to vary as a function of the age (Figure 14).

There is no strong trend among wetlands regarding to its age and predatory fish on the invertebrate number, however the number of invertebrates in wetlands where there are no fish tends to increase with an age. In wetlands occupied with predatory fish, thereby ones older than 15 months or connected to streams or existing wetlands, the taxa number is slightly decreasing but not significant.

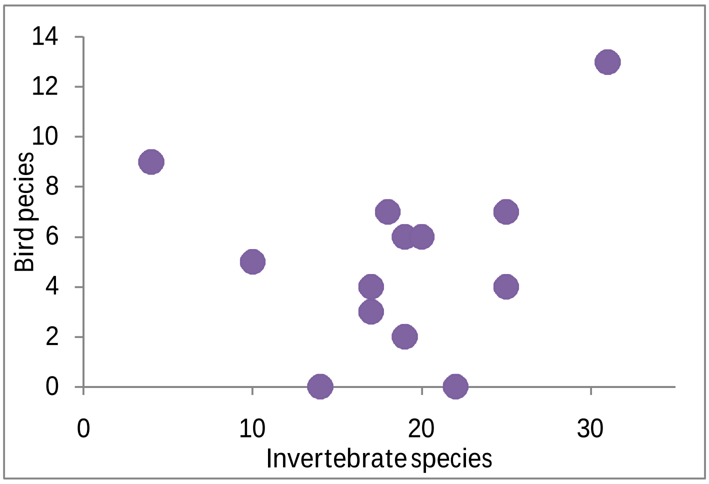


Figure 15 Correlation plot between the number of bird species and the number of invertebrate species

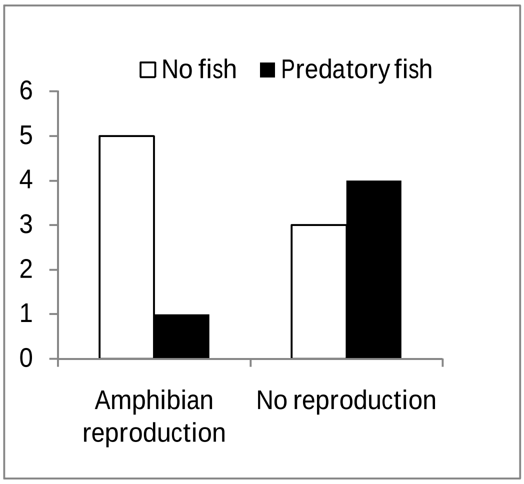


Figure 16 Frequencies of amphibian reproduction in wetlands with or without predatory fish

Correlation between number of bird and number of invertebrate species

There is no correlation between number of bird species and number of invertebrate species (Figure 15). Points in the plot are distributed randomly, which would suggest that different mechanisms affect the number of birds and the number of invertebrate species in new wetlands. The correlation coefficient r is equal to 0.19, proving no relationship between invertebrate taxa number and bird species number, the p-value of 0.31 makes the result not statistically significant.

Amphibian reproduction and fish presence

Although wetlands without predatory fish had a higher chance to contain amphibian larvae than wetlands with predatory fish, the difference was not statistically significant due to a chi-square test (p=0.135).

Discussion

Wetlands may be constructed for various purposes. Contingent on necessity they work as nutrient taps reducing nutrient transport from land to the sea, decrease a loss of biodiversity in the agricultural landscapes, work as flooding areas and have many other functions like irrigation or recreation. Loss of wetlands and hence biodiversity can be faced with the familiarity about their construction.

Although, there is a technical knowledge on how to increase nutrient retention in wetlands, there is still a shortage of information about how to increase wetland biodiversity. What is more, these two purposes are often in conflict (Hansson, Brönmark, Nilsson, & Åbjörnsson, 2005). In that study, wetland biodiversity with focus on birds and invertebrates is an issue.

Presented results show that there are some essential features influencing biodiversity in new wetlands. Firstly, area of wetlands proved to have a positive effect on species richness, in particular birds, supporting the initial hypothesis. The MacArthur and Wilson theory (Brönmark & Hansson, 2005, pp. 209-218) turned out to be applicable to the data obtained in this study since there was a relationship between area and number of bird species. The best illustration of veracity of that examined hypothesis is a tested object itself - Sillesjö South wetland scoring with the highest bird and invertebrate diversity while having a large area. Wetland 10 Hönsinge, which is slightly bigger, has high species richness likewise. Additionally, the only wetlands where no birds were observed were wetlands with little area surfaces.

In addition to area, birds turned out to be influenced by predatory fish presence, as they were more abundant in wetlands where no fish were present. Although, that can not be applied to invertebrates due to lack of noted interactions between their richness and fish presence, however there is a relationship between predatory fish and the composition of invertebrate species in wetlands. This study showed that large diving beetles are present only if there are no predatory fish in a wetland, nevertheless, snails do occur in spite of predatory fish presence. These results are in accordance with other findings (Brönmark, 1994) which showed that perch rarely include snails in their diet even if they occur in force as well as that they are efficient predators on large predatory invertebrates like large diving beetles. This mechanistic field experiment support the patterns observed in created wetlands.

Previous studies demonstrated that in wetlands younger than 8 years the fish biodiversity is low suggesting that they may need a long time to become inhabitants of constructed wetlands (Hansson, Brönmark, Nilsson, & Åbjörnsson, 2005). To confirm that finding, the same study should be performed in few years since at present Tullstorp wetlands are not older than 3 years old, although it was observed that fish were present only in wetlands either older than 15 months or ones connected to other water bodies.

This study found the trend for interaction between wetland age and the number of invertebrate species, being statistically close to significant. Whereas, other researches confirm a hypothesis of positive correlation between these two factors (Brönmark & Hansson, 2005, pp. 209-218). Moreover, they pointed out that to reach maximum invertebrate species richness, at least 4 years are needed, however, it can not be verified in this study due to young ages of wetlands. Giving as an example wetland 2 in which there is clear shortage of invertebrate species richness, an importance of the very young age of wetlands can be illustrated since Sånarp had been constructed just 4 months before the study was done. Hence, in order to test any hypothesis here, same data collection in 2 years would be required.

In turn, bird species richness does not vary with wetland age (VanRees-Siewert & Dinsmore, 1996). This is in accordance with our findings since the ANCOVA showed no general effect of wetland age on bird species numbers. Instead, the quite long distance from main roads and disturbances together with large area and abundant aquatic vegetation may cause presence of rare bird species in Sillesjö South. In addition, as France (2003) stated, animal abundance increases with the number of wetlands in a neighborhood, therefore, since Sillesjö South is situated very close to wetland 11, that could be a comprehensible explanation not only for bird richness but also for the general good biodiversity conditions.

In order to have more indicator and rare bird species at wetlands, they should be created in view of some factors affecting bird species richness. According to Hansson's *et al.* (2005) findings, to have high bird species richness it is relevant to create a large shallow wetland with high shoreline complexity. Wetlands within the Tullstorp catchment confirm that advice, together with idea of wetlands with suitable nest sites for breeding, preferably with islands and not surrounded by trees. Tress provide good observation sites for birds of prey.

There was no relationship between invertebrate taxon richness and bird species numbers in this study, however according to some scientific sources invertebrates do influence foraging site selection of birds due to their abundance depend among others on food resources. That was stated by Safran *et. al* (1997) who tested locations of nine wetland birds in relation to invertebrates density. The investigation showed that wetland birds are influenced by the presence of benthic invertebrates.

There was no statistically significant relationship found between predatory fish and amphibians reproduction, although amphibians had a bigger chance to reproduce in wetlands without fish. According to this study they are not related to each other, however previous experiments - (Hartel, o.a., 2007) showed that they are. It was found that in ponds with predatory fish the amphibian richness was much lower than in ponds do not containing predatory fish at all, resulting in a theory that some amphibian species are negatively associated with the presence of predatory fish. Moreover, in constructed wetlands in Scania Stenberg and Nyström (2009) showed that crested newts mainly reproduced in wetlands without fish. In accordance, in the Tullstorp catchment amphibian reproduction was found in only 1 out of 5 wetlands with predatory fish and in 4 out of 8 wetlands without fish. Noteworthy is a comparison of a number of examined ponds in the mentioned experiment and the correlative study, which were between 45 and 48. In this study, only 13 wetlands were analyzed and some of the wetlands without fish were very young and may not have been colonized by amphibians yet. In created wetlands without fish, age has a significant effect on the colonization probability of crested newts (Nyström & Stenberg, 2009).

According to macrophytes, which are important components for biodiversity in wetlands due to their nutrient treatment role (Ritchie, 2001), they were observed to be influenced, apart from the age of wetland, by a presence of crayfish. That was in wetland 8 where no points for vegetation were assigned and at the same time a Signal crayfish was found. Other studies have confirmed that this crayfish species has a strong negative impact on macrophytes (Nyström, Svensson, Lardner, Brönmark, & Graneli, 2001).

This study showed that the large wetland area together with positive landscape location and favorable surrounding conditions may cause good physical status of a wetland, and following from that, fauna and flora diversity. A complex shoreline may be of importance for macrophytes and birds as well as a presence of the island for these mentioned as second. All above-named features are accomplished in Sillesjö South wetland putting its environment in satisfying conditions. The poorest part of it, which needs to be improved, is morphometry as the wetland is completely covered with aquatic vegetation. However, abundance of macrophytes in wetlands may favour invertebrates, particularly in wetlands with fish, and in the case of wetland 6 no fish were found. It is worth to emphasize the animal abundance there despite of a lack of fish, which is most probably because of the fact, that many invertebrate and bird species have already adapted to live without fish (Nyström, 2011). In addition, the maximum depth of Sillesjö South is 1.5 m what suggests the varied water depths in wetland, and that in turns allows for the development of vegetation of diverse kinds, and following from that, wide range of birds and invertebrates for different purposes like spawning, nesting or feeding (France, 2003). The same source gives an idea of another possible reason for a high number of invertebrate and bird species in any wetland with high biodiversity. That is, animal abundance is closely correlated to number of wetlands in region, so wetland 11 Sillesjö North, which is situated very close to wetland 6, is likely to positively influence on its biological environment. Here comes the question, why then wetland 11 turned out to be significantly worse mainly in respect to its biological condition. Since both area and age of Sillesjö North are comparable to Sillesjö South's area and age, the only reasonable reason for lower number of birds and invertebrates may be the presence of predatory fish. Moreover, this study comprehends two wetlands that leave a great deal to be desired. Biodiversity of both Stora Markie and Sånarp is probably poor mainly due to their very young age (less than 4 months), whereas unsatisfactory biological conditions of Stora Markie may be additionally influenced by a little longer distance to other wetlands.

Essential for understanding how wetlands creation will affect the surrounding environment is the knowledge about how wetlands are predicted to be shaped, to be influenced by any factors, how water will be supplied to them, their climate and geomorphology are important features as well. Before constructing a new wetland that data acquisition is needed (France, 2003). Afterwards, there should be adopted a suitable method to assess the biodiversity status, and hence, value of the wetland to the community and the ecosystem. The Jönköping method was designed particularly for that issue and has turned out to fulfill its expectations regarding to facilities and reliable results. Personal observations in the field indicate a wide range of both physical and biological information about wetlands that are taken into account in the survey protocol. Results gained when using this method and survey protocol can be sufficient when testing hypothesis on factors affecting diversity in created wetlands. Moreover, the results illustrated by spiderweb graphs are certainly understandable and readable for landowners or any other people or organizations interested in a topic.

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Appendix I

Number for this study	ID	Name
1	36	Visningssträckan South
2	43	Sånarp
3	29	Jordeberga vid vindkraftverken East
4	28	Jordeberga vid vindkraftverken West
5	32	Visningssträckan North
6	19	Sillesjö South
7	49	Ådala
8	3	Stora Markie
9	27	Sotemosse
10	22	Hönsinge
11	18	Sillesjö North
12	13	Skönadal North
13	12	Skönadal West

Table 1 Thirteen wetlands with their numbers assigned for the purpose of this study, identification numbers and names

Bird species names		
Latin	English	Swedish
Podicipedidae	Grebes (not Great Crested Grebe)	Doppingar (ej skäggdopping)
Gallinula chloropus	Common Moorhen	Rörhöna
Anas clypeata	Northern Shoveler	Skedand
Anas querquedula	Garganey	Årta
Tringa ochropus	Green Sandpiper	Skogssnäppa
Chroicocephalus ridibundus	Black-headed Gull (Breeding colony)	Häckande skrattmåskoloni
Gallinago gallinago	Common Snipe	Enkelbeckasin
Tringa totanus	Common Redshank	Rödbena
Numenius arquata	Eurasian Curlew	Storspov
Motacilla flava	Yellow Wagtail	Gulärla
Larus minutus	Little Gull	Dvärgmås
Larus canus	Common Gull	Fiskmås
Mergus Merganser	Common Merganser	Storskrake
Haematopus ostrakgus	Eurasian Oystercatcher	Strandskata
Vanellus Vanellus	Northern Lapwing	Tofsvipa
Anas Platyrhynchos	Mallard	Gräsand
Actitis Hypoleucos	Common Sandpiper	Drillsviäppa
Charadrius Dubius	Little Ringed Plover	Mindre strandpipare
Fulica atra	Eurasian Coot	Sothöna
Anser Anser	Greylag Goose	Grågås
Podiceps grisegena	Red-necked Grebe	Grådhakedopping
Circus aeruginosus	Western Marsh Harrier	Brun Kärrhök
Tringa glareda	Wood sandpiper	Grönbena

Table 2 Table 3 Names of found bird species in Latin, English and Swedish

Appendix II

Visningssträckan South - wetland 1

Data	X/Y	6144203/1347796
	Date of construction	November 2009
Total sum of spiderweb points	Physical part	9
	Biological part	8
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Moderate

Figure 2 The picture of the wetland taken by Per Nyström on July 2011

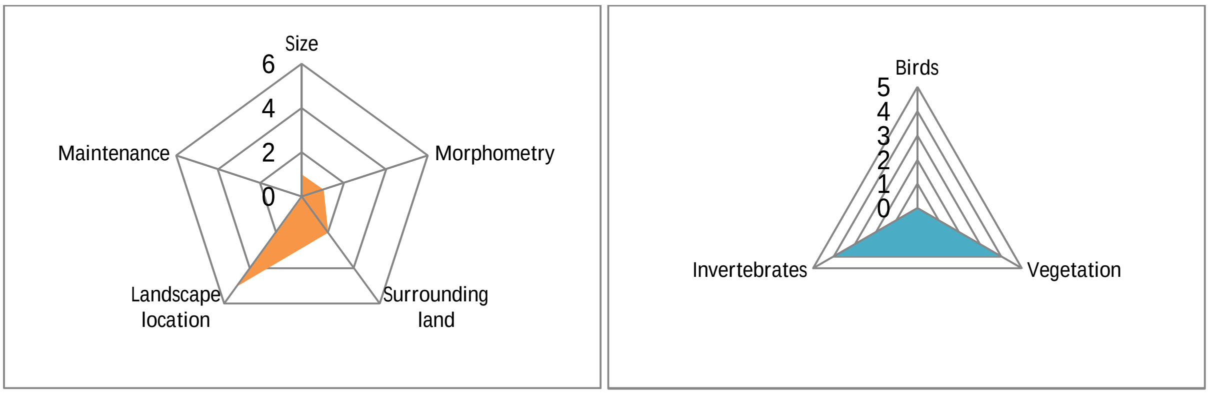


Figure 3 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Visningssträckan South

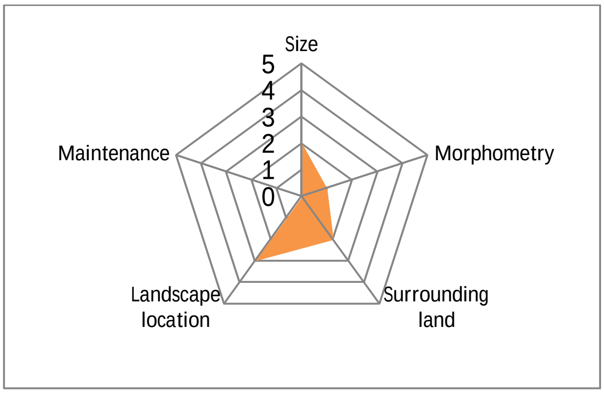
Notes: no birds, no predatory fish, amphibian reproduction

Appendix II

Sånarp – wetland 2

Data	X/Y	6141744/1350104
	Date of construction	March 2011
Total sum of spiderweb points	Physical part	8
	Biological part	2
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Poor

Figure 3 The picture of the wetland taken by Per Nyström on July 2011



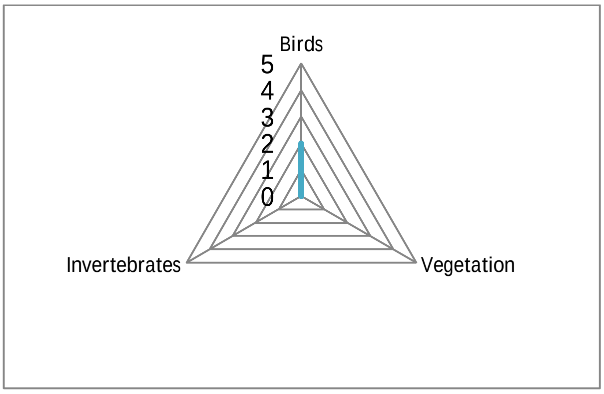


Figure 4 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Sånarp

Notes: no predatory fish, no amphibian reproduction

Appendix II

Jordeberga vid vindkraftverken East- wetland 3

Data	X/Y	6146747/1348341
	Date of construction	July 2009
Total sum of spiderweb points	Physical part	7
	Biological part	7
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Moderate

Figure 5 The picture of the wetland taken by Per Nyström on July 2011

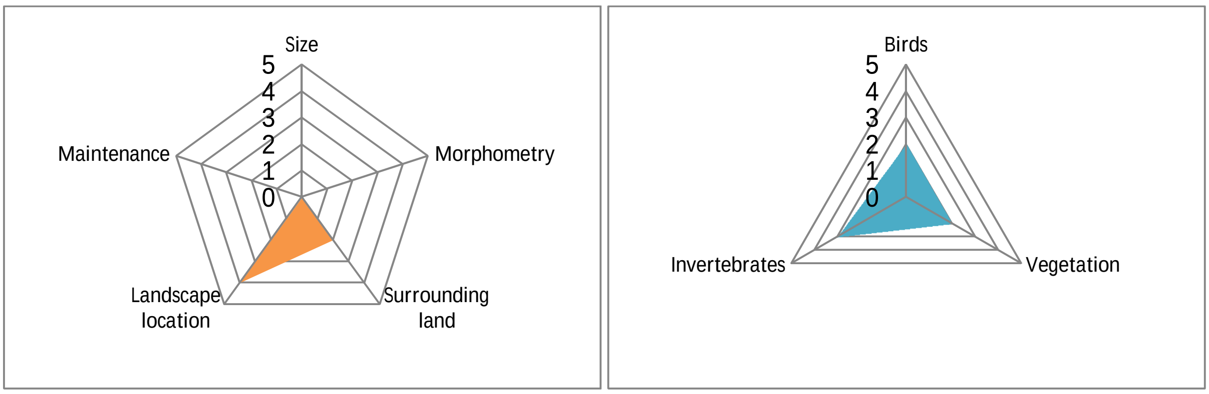


Figure 6 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Jordeberga vid vindkraftverken East

Notes: no predatory fish, amphibian reproduction (Smooth Newt)

Appendix II

Jordeberga vid vindkraftverken West – wetland 4

Data	X/Y	6146822/1348336
	Date of construction	July 2009
Total sum of spiderweb points	Physical part	8
	Biological part	3
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Poor

Figure 7 The picture of the wetland taken by Per Nyström on July 2011

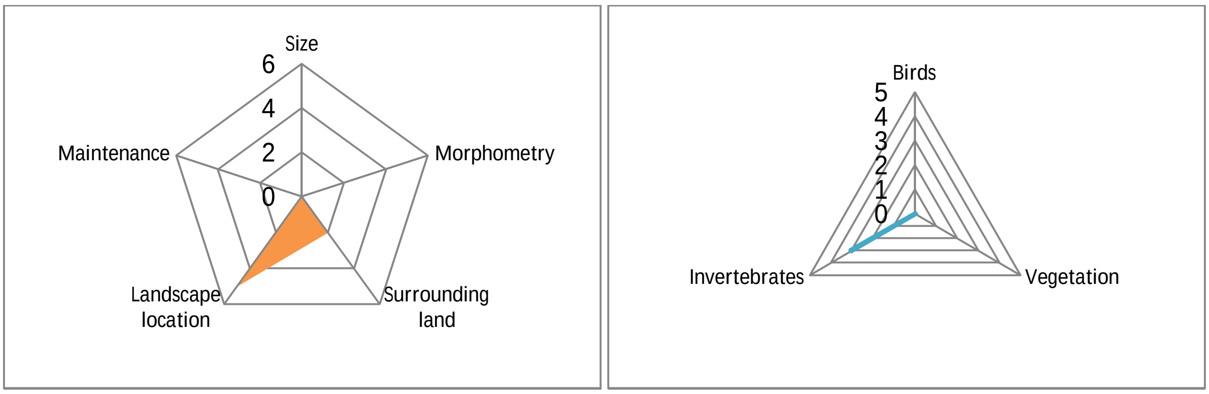


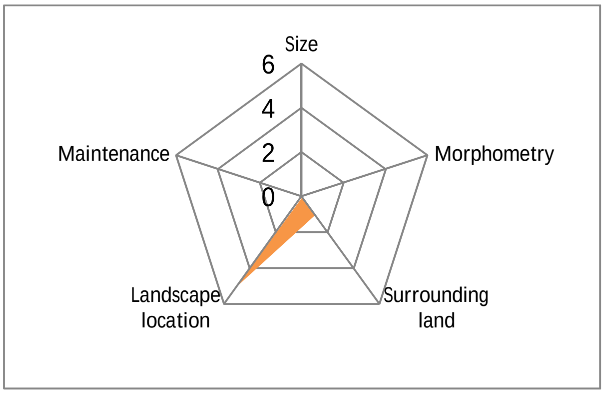
Figure 8 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Jordeberga vid vindkraftverken West

Notes: no birds, no predatory fish, no amphibian reproduction, wetland almost dry

Visningssträckan North – wetland 5

Data	X/Y	6145088/1347913
	Date of construction	November 2009
Total sum of spiderweb points	Physical part	7
	Biological part	8
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Moderate

Figure 9 The picture of the wetland taken by Per Nyström on July 2011



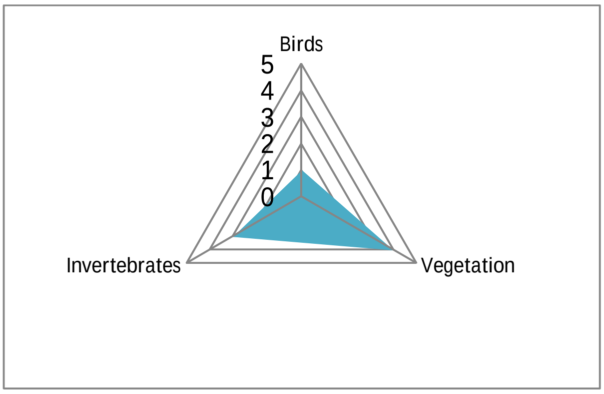


Figure 10 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Visningssträckan North

Notes: Red-listed birds (Yellow Wagtail), no predatory fish, amphibian reproduction (Great Crested Newt, Smooth Newt)

Appendix II

Sillesjö South wetland 6

Data	X/Y	6149221/1347218
	Date of construction	November 2009
Total sum of spiderweb points	Physical part	17
	Biological part	14
Biodiversity status	Physical part	Good
	Biological part	High

Figure 11 The picture of the wetland taken by Per Nyström on July 2011

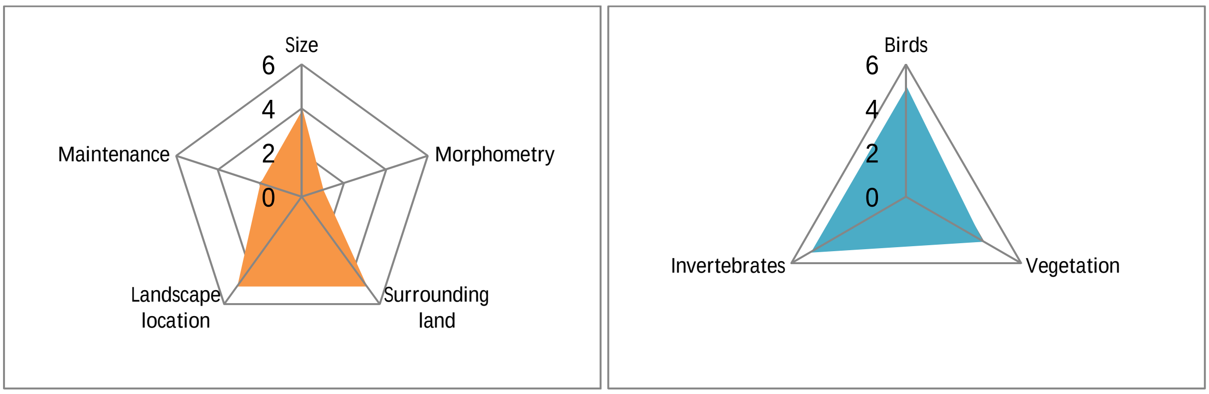


Figure 12 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Sillesjö South

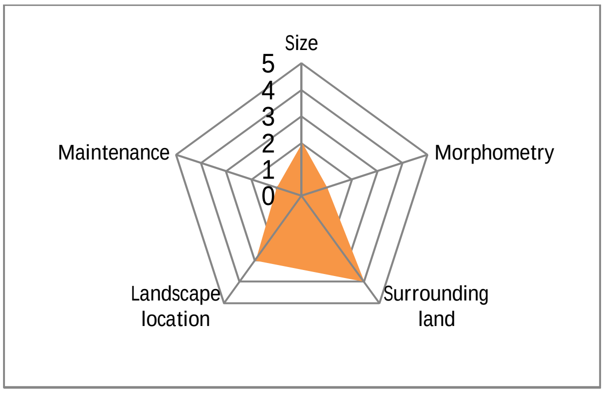
Notes: Red-listed birds (Red-necked Grebe, Western Marsh Harrier, Wood Sandpiper), no predatory fish, amphibian reproduction

Appendix II

Ådala – wetland 7

Data	X/Y	6147817/1347994
	Date of construction	May 2010
Total sum of spiderweb points	Physical part	11
	Biological part	4
Biodiversity status	Physical part	Moderate
	Biological part	Unsatisfactory

Figure 14 The picture of the wetland taken by Per Nyström on July 2011



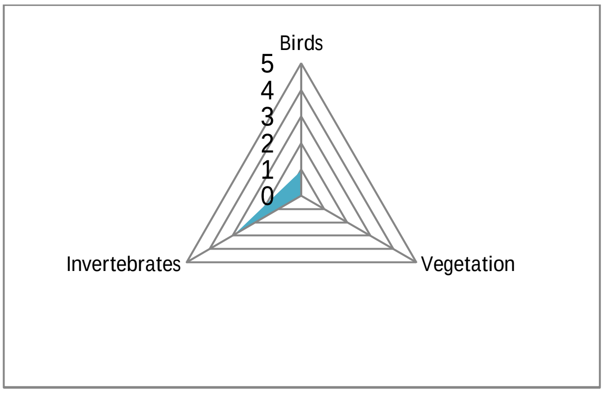


Figure 15 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Ådala

Notes: no predatory fish, amphibian reproduction (Great Crested Newt)

Appendix II

Stora Markie - wetland 8

Data	X/Y	6149835/1341451
	Date of construction	April 2011
Total sum of spiderweb points	Physical part	5
	Biological part	5
Biodiversity status	Physical part	Poor
	Biological part	Unsatisfactory

Figure 16 The picture of the wetland taken by Per Nyström on July 2011

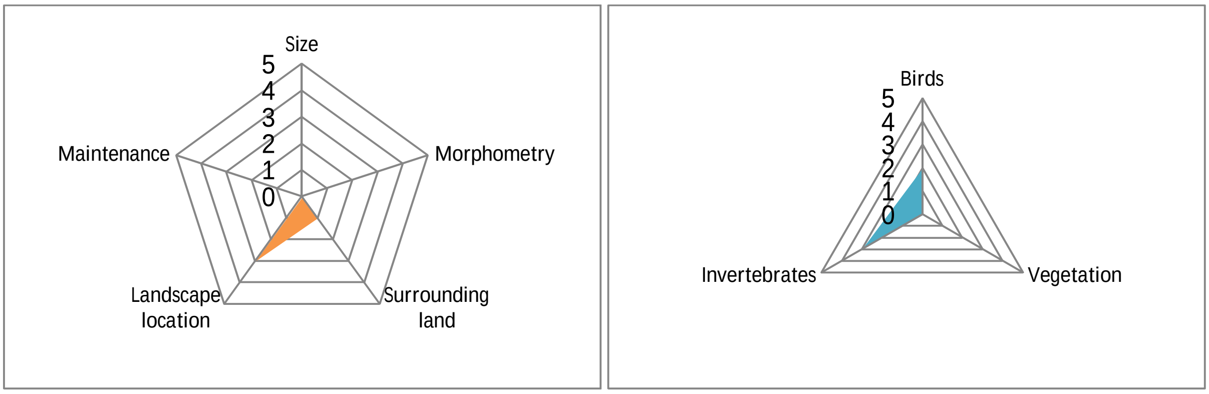


Figure 17 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Stora Markie

Notes: no predatory fish, no amphibian reproduction, Signal crayfish, wetland connected to a small stream

Appendix II

Sotemosse – wetland 9

Data	X/Y	6147362/1348946
	Date of construction	June 2010
Total sum of spiderweb points	Physical part	8
	Biological part	10
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Good

Figure 18 The picture of the wetland taken by Per Nyström on July 2011

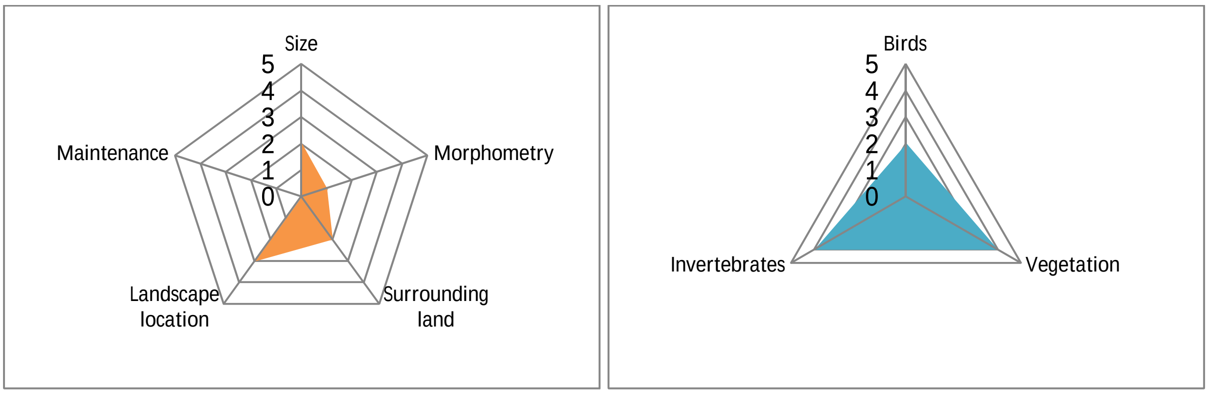


Figure 19 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Sotemosse

Notes: predatory fish (Common Roach), no amphibian reproduction, wetland connected to an old wetland

Hönsinge – wetland 10

Data	X/Y	6147729/1347013
	Date of construction	April 2009
Total sum of spiderweb points	Physical part	12
	Biological part	7
Biodiversity status	Physical part	Moderate
	Biological part	Moderate

Figure 110 The picture of the wetland taken by Per Nyström on July 2011

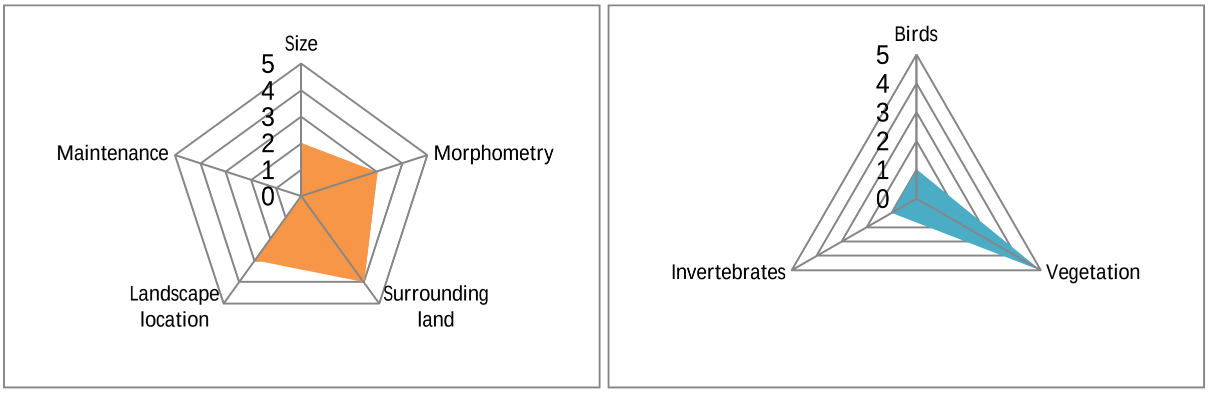


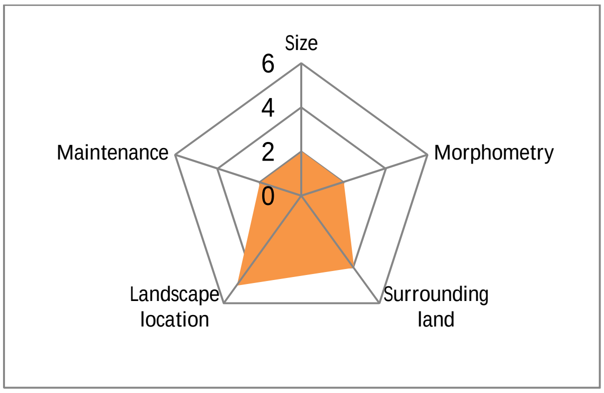
Figure 11 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Hönsinge

Notes: predatory fish (Northern pike), amphibian reproduction

Sillesjö North – wetland 11

Data	X/Y	6149383/1347121
	Date of construction	March 2009
Total sum of spiderweb points	Physical part	15
	Biological part	6
Biodiversity status	Physical part	Moderate
	Biological part	Unsatisfactory

Figure 12 The picture of the wetland taken by Per Nyström on July 2011



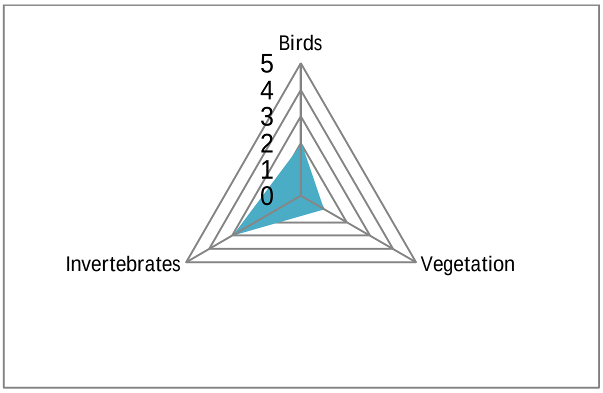


Figure 13 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Sillesjö North

Notes: predatory fish (Northern pike, Common Roach), no amphibian reproduction

Appendix II

Skönadal North – wetland 12

Data	X/Y	6150525/1345121
	Date of construction	April 2010
Total sum of spiderweb points	Physical part	7
	Biological part	7
Biodiversity status	Physical part	Unsatisfactory
	Biological part	Moderate

Figure 14 The picture of the wetland taken by Per Nyström on July 2011

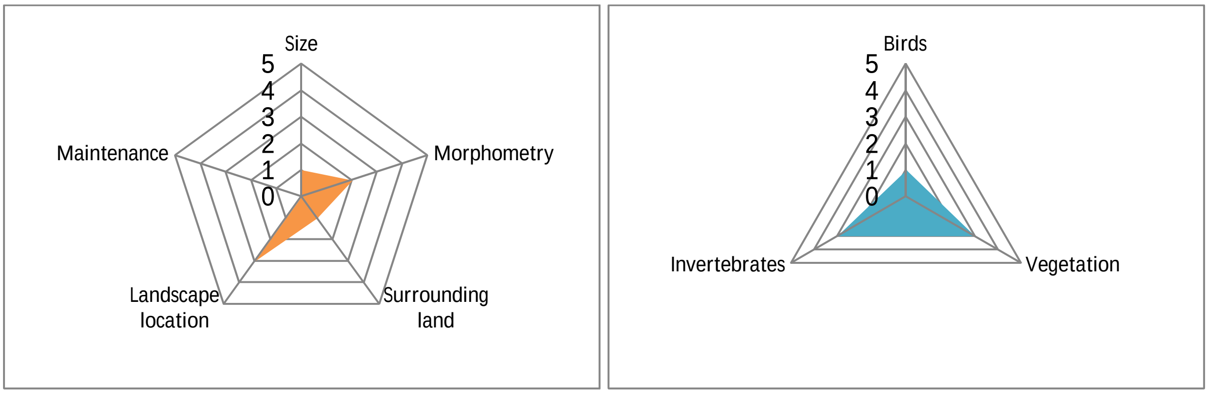


Figure 15 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Skönadal North

Notes: Red-listed birds (Western Marsh Harrier), predatory fish, no amphibian reproduction

Appendix I

Skönadal West – wetland 13

Data	X/Y	6150556/1344927
	Date of construction	April 2010
Total sum of spiderweb points	Physical part	11
	Biological part	8
Biodiversity status	Physical part	Moderate
	Biological part	Moderate

Figure 16 The picture of the wetland taken by Per Nyström on July 2011

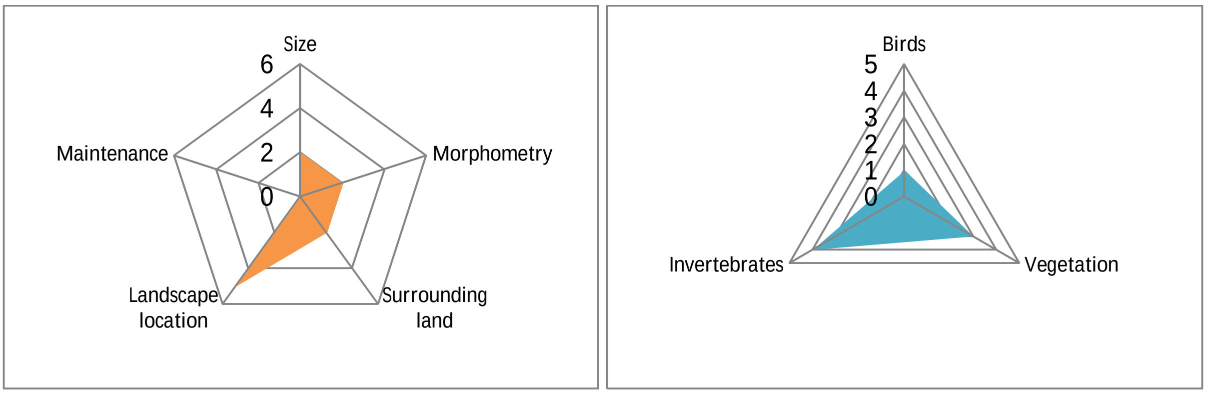


Figure 17 Spider webs of physical (left) and biological (right) parts showing biodiversity conditions for Skönadal West

Notes: predatory fish (Northern pike), no amphibian reproduction, wetland connected to Tullstorpsån

Survey protocol for biodiversity in wetlands

Office | Field data | Advanced level

Object information

Name | Date

County | Surveyed by

Municipality | Water body-ID

Name of property | Downstreams lake

Main river basin | Any form of protection

Block-ID | Contructed | Restored | Year of final inspection | Costs

Purpose Nutrient retention | Biodiversity | Cultural environment | Recreation

Former land use | Photographs, general picture | Sketch available

Type of inlet: Natural | Artificial fall incl. height | Riser structure /pump | Fish screen /eel trunk

Leak in inlet | Photo inlet

Type of outlet: Natural | Artificial fall incl height | Riser structure /pump | Fish screen /eel trunk

Leak in outlet | Overgrown outlet | Dammed | Photo outlet

Motorable zone around the dam | Motorable dam bank | Outlet co-ordinates

Remark

Physical parts

Size (figures alternatively Yes/No) | Certainty

Size

Circumference (m) | Wetland area (ha) | Waypointnummer

Shores (% of the shoreline; 0 = 0%, 1 = < 5%, 2 = 5-50%, 3 = >50%, alternatively number of hectares)

Flat (slope more than 1:6) | Flood plain area (ha)

Depth (% of the area; 0 = 0%, 1 = < 5%, 2 = 5-50%, 3 = >50%, alternatively meters or Yes/No)

Area shallower than 0.5 m | Maximum depth (m)

Remark

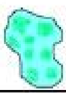
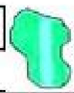
Morphometry

Certainty

Islands

Number

Mosaic-like appearance, vegetation (mark the figure that best describes the reality)

1. 
2. 
3. 
4. 
5. 
6. 

"Blue border"

Presence | Length

Remark

Surrounding land

Certainty

% of the shoreline; 0 = 0%, 1 = <5%, 2 = 5-50%, 3 = >50%

Land type	0-20 m	20-100 m
Dry land, not wooded		
Moist land, not wooded		
Swamp		
Younder deciduous forest		
Older deciduous forest (>50 y)		
Mixed forest		
Coniferous forestry		
Other		
Farming methods		
Pasture		
Haying, the material is removed		
Arable land with annual crop		
Fertilization		
Other		

Presence of (Yes/No)

	0-20 m	20-100 m
Stone wall		
Clearence cairn		
Open ditch		
Paved road (with trafic)		
Buildings		
Farm with livestock/barn		
Lookout post for birds of prey/crows		
Organic production		
Other kind of impact		

Remark

Landscape location in the catchment area

Certainty

Wetland located at site of a former natural wetland

Distance to closest wetland (m)

Distance to closest water body (m)

Size of catchment area (ha)

Ratio of the catchment area/wetland area

Water supply to the wetland (tick the appropriate box, also specify the width of any ditch or stream)

Spring-fed | Shallow soil water | Natural stream | Surface runoff

Surface water | Field drainage | Open ditch | Other

Water from the wetland (specify where the wetland falls into by ticking the appropriate box)

Open ditch | Natural stream | Lake | Other

Water quality (figures alternatively Yes in the appropriate box)

Secchi depth Large | Medium | Small | Not estimated

pH | Time of measurment | Not estimated

Remark

Maintenence (% of shoreline; 0 = 0%, 1 = < 5%, 2 = 5-50%, 3 = >50%, alternatively Yes/No)

Certainty

Maintenence occurs | No maintenence

Haying Occasional | Regularly | Material removed | Haying out in the water

Pasture Grazing occurs | Grazing out in the water

Grazed by: Beef | Horses | Sheep/goats | Deer

Used as irrigation dam

Remark

Biological part

Birds

Certainty

Indicator species

	Observed	Nesting	External source		Observed	Nesting	Ext. source
Grebes (not Great Crested Grebe)				Common Snipe			
Common Moorhen				Common Redshank			
Northern Shoveler				Eurasian Curlew			
Gargany				Yellow Wagtail			
Green Sandpiper				Little Gull			
Breeding colony of Black-headed Gull							

Other species

Total number of species found

Feeding occurs

Total number of nesting species

Number of red-listed or N2000-species

Remark

Vegetation (0 = no vegetation, 1 = <5%, 2 = 5 - 50%, 3 = >50%)

Certainty

Total vegetation in the wetland

Vegetation absent

Dominant species

Emersed vegetation

Floating leaf vegetation

Pondweed

Submersed vegetation

Remark

Invertebrates Benthic fauna, visual inspection + netting

Certainty

Taxa found (presence is indicated with a "Yes"), indicator species .in bold

Flatworms		Oligochaets		Medicinal leech		Glossiphoniids (leeches)	
Other leeches		Mussles		Pulmonate snails (no operculum, not flattened sp.)			
Planorbidae snails (flattened, no operculum)				Prosobranch snails (with an operculum)			
Freshwater isopods		Freshwater amphipods		Spiders		Freshwater mites	
Alderflies		Butterfly larvae		Free-living caddiesflies		Case-building caddiesflies	
Dragonflies		Damselflies		Mayflies		Stoneflies	
Saucer bug		Backswimmer		Water boatmen		Water scorpion	
Water stick-insect		Pond skater		Phantom midge l.		Chironomids	
Biting midges		Black flies		Crane flies/ fly larvae		Large diving beetles (≥ 1 cm)	
		Small diving beetles (< 1 cm)				Other water beetles	

Number of red-listed or N2000-species

Remark

Amphibians and reptiles

Remark

Fish and crayfish (Yes or No)

Certainty

Fish present

Fish absent

Fish presence unsure

No migration barrier downstream

No migration barrier upstream

Remark

Information about other values

Positive

Negative

Wetland arranged for visitors

Other:

Sketch of the wetland, show the north arrow