Exploring the Effects of Cormorant Through the Use of Community Metabolism and Landscape Configurations

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Summary

During the last two decades, the growth of the cormorant population has increased almost exponentially in the Finnish archipelago. In consequence the input of nutrients from cormorants is causing landscape alterations to the breeding sites and conflicts between coastal inhabitants that see the Cormorant as a threat and conservationists who like to protect the bird. Since cormorants are nesting close to water, the nutrient runoff from the nesting sites may cause alterations in the aquatic community and could therefore contribute to eutrophication. The effects of eutrophication by cormorants on the subtidal hard bottoms community were analysed using a holistic approach which includes the estimation of oxygen fluctuation of the community. This method is known as community metabolism. I compared community metabolism estimations on islands with Cormorant nesting sites and islands without Cormorant nests. The research was executed at the Raseborg-Hanko region. Results showed that cormorants diminished community metabolism in the aquatic community on islands located in the inner archipelago. However, the communities located in the outer archipelago were not affected by the nutrient runoff from the cormorants. In conclusion, it seems to bet that the factor location of the islands is one of the factors that affect community metabolism.

Language: English

Key words: Cormorant, Landscape Configuration, Community Metabolism

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1 Introduction

1.1 Background

The Great Cormorant (*Phalacrocorax carbo sinensis)* hereafter just referred to as Cormorant, has in recent decades attracted a lot of attention in the Baltic Sea region. Notice was given to that species when the population declined dramatically in the breeding areas in Denmark, Germany, the Netherlands and Poland in the mid 20th century. Following the history into the past, the decline started already in the 19th century when the seabird was persecuted in the Baltic area. In 1960 the states around the Baltic Sea implemented the international law which protects the species by the provisions of the EU Bird Directive (79/409/EEC).

As a result of protection measures and the additional ban of DDT and PCB in the 1970s seemingly also helped to increase the number of breeding cormorant pairs besides the legal protection. The population recovered significantly in the 1980s and the cormorant started to expand its area towards the north-east Baltic Sea (Kohl, 2010).

After a period of approximately ten years, the cormorant settled on the Finnish coast and the first breeding nests were found in 1996. Starting with ten pairs in the same year, the population in Finland has increased almost exponentially until 2009 with approximately 16 000 breeding pairs. However, the exceptionally cold winter from 2009 to 2010 has shown that population growth has its limit and the numbers of new breeding pairs in 2010 were considerably lower. (Finnish Environment Institute (SYKE) 2009); (Herrmann, 2011)

According to the newest press releases of the Finnish Environmental Institute the population in 2011 has just grown by two new colonies and a total number of approximately 17 700 nesting pairs of cormorant which is comparatively little in relation to the 34 new colonies that evolved just one year ago ((SYKE), 08.09.2011).

1.2 The cormorant as a scapegoat

The increase of the cormorant species, however, generates a potential source of conflict between conservationists on the one hand, and anglers and fishermen on the other. This bird has in recent years become the target for many problems in the Baltic Sea and is probably already equally marked as the Grey Seal. However, whereas the Grey Seal is causing conflicts just with fishermen and anglers, the Cormorant is additionally causing landscape alterations, which are disliked by many coastal inhabitants.

1.2.1 Fish consumption

Cormorants are mainly piscivorous and need a daily nourishment of approximately half a kilogram of fish as an adult (SYKE, 2009) and even 900 g as a hatchling (Talala, 2008). Due to these quantities it is comprehensible that fishermen believe that Cormorant will cause a decrease in the fish population, which will reflect on the amount of fish caught as well as the income.

The REDCAFE report (Natural Environment Research Council, 2002) is a project funded by the European Union that aimed at reducing the conflict between cormorants and fishermen on a Pan-European scale. According to their final report, fishermen in Europe suffer from financial losses in their annual turnover, due to interference of Cormorant. Fishermen are complaining about an overall loss of 11 %, whereas recreational anglers are stating a loss of more than 50 % according to the 105 conflict cases recorded by the REDCAFE report in 2002.

According to the monitoring data of the Finnish Environmental Institution, SYKE, collected during five years in the archipelago around Tammisaari and Dragsfjärd, two thirds of the fish consumption of cormorant consists of roach and eelpout, and just one fifth of perch (SYKE, 2006). Fish that was economically important for fishermen, and eaten by the Cormorant, was merely the eel with just one percentage (SYKE, 2008). According to the newest research published in December 2011, cormorants do not contribute to the decline of valuable fish in Finland (Lehikoinen, 2011).

Studies on the feeding behaviour have shown that Cormorants eat mainly on juvenile fish which has a length between 10-20 cm (Leopold & van Damme, 2003). Fishermen and anglers, however, prefer fish with lengths above 20 cm, showing that the prey of the birds does not compete with the prey of fishermen or anglers.

The Finnish Game and Fisheries Research Institution, which has summarised three different studies concentrating on the diet of the cormorant in Finland, including observations from Tammisaari/Ekenäs from 2002-2009, shows that the feeding behaviour may be different from area to area and also from year to year (Lehikoinen, 2011; Salmi, 2009; Korhonen 2009). Therefore, attention should be paid to changing feeding behaviour with regard to year and area.

1.2.2 Landscape alterations

With a rising population growth of the cormorant a new interest group has been established in Finland. This interest group consists of coastal inhabitants and summer cottage owners that feel threatened by the presence of the seabird that nests close to their land. The main complaint of this interest group is the alteration of the landscape and the odour caused by the guano of the Cormorant (Vaasa´s local newspaper (Vasabladet) 2011, June 26).

Because cormorants are fish eaters they tend to nest in colonies close to a water body. For their nesting material they preferably use trees but also sea weeds, twigs and grasses, basically every plant that can be used for building nests. Due to that fact many nesting areas literally look grazed after dozens of cormorants have built their nests. But the alteration caused by the building of nests is not the only impact. The excess nutrient load deriving from the bird has an impact, too. The guano, which is very strong but rich in nutrients, is clearing away the residual leaves from the trees and bushes. In addition, it may also degrade grass roots and herbals in the central part of the colony. Because the vegetation on rocky islands is inherently little, the nesting site of the Cormorant can lead to a harsh impact on the existing vegetation.

Figure 1. Rönngrund island with Cormorant nesting site shows alterations in the centre of the nesting area. Just a bit outside that area, grass is growing with high density (photo taken by E. Diaz)

The vegetation just outside the colony, however, blooms because washed down nutrients improve the growth of the vegetation. As a result, herbals and grass roots that were present in the primary vegetation do not disappear from the island but grow just outside the nesting area. According to observations, the vegetation is able to totally recover after the colony has moved away from the nesting area. (SYKE, 2006)

By looking at the local newspaper of Vaasa ‘Vasabladet’ (see appendices), it can be seen that the Great Cormorant has been the topic of discussion during the whole summer of 2011. Just in the west of Finland already a couple of hundred of cormorant nests had been destroyed in the recent summer (FNB, 2011, Aug. 2). And approximately 800 observed nests had been damaged in the whole country by August 2011 (Erikson, 2011, Aug. 6).

During approximately two decades the interest of the impact caused by Cormorants increased due to the arising problems in fish stock decline and landscape alteration. Fortunately, the conflict between fishermen and conservationists recently came to an end, because a lot of research on the feeding behaviour of the cormorant has been done in Finland showing that the cormorant is not contributing to the decline of the fish population.

The issue of landscape alteration, however, seems to bring along another problem that does not only bother coastal inhabitants but could also have severe impacts on the nature.

Because landscape alterations at cormorant nesting sites have been detected over several years, it can be assumed that the properties of the soil have changed due to Cormorant impact. However, if Cormorants have the availability to change the properties of the soil on shore, then the possibility that nutrients that enter the water through runoff around the nesting site, change the properties of the aquatic community, too. The community that mainly consists of brown algae and benthic organisms, such as amphipoda, gastropods and crustaceans, could benefit from the nesting sites. However, as too much nutrient input can cause algal bloom and eutrophication, the Cormorant is also suspected to cause eutrophication. Because research on the impact of the cormorant on aquatic ecosystems has not been done in Finland, this work will concentrate on exploring the impacts of the Cormorant on the aquatic community system.

2 Previous research

2.1 Landscape configuration

2.1.1 On land

Research on different species that were suspected to cause changes in a community has been done in many places all over the world. The research of Breuning-Madsen *et* al. (2009) executed in Denmark, showed that Cormorant birds have significantly increased phosphorus, carbon and nitrogen contents in the soil which led to a change in the diversity of the vegetation and its landscape configuration. Previous research has also shown that high concentrations of nutrients, but also mineral salts and other elements were noted in the runoff of Cormorants (Klimaszyk et *al*, 2008).

2.1.2 Affects on the aquatic ecosystem

A study on Arctic sea birds executed in the coastal waters of Russia, showed that bird colonies can increase the potential of plankton in ice covered regions (Zelickman & Golovkin, 1972).

Piscivorous birds have shown to be a ‘very important intermediate link in some food webs and a factor which facilitates dislocation of matter between terrestrial and aquatic ecosystems’ (Klimaszyk, 2008). However, other so called ‘engineering species’ like the blue mussel, which is already present in certain ecosystems, can have similar effects and contribute to an enrichment of the biodiversity. As Bruno and Bertness (2001) detected in marine benthic systems, community structure and ecosystem functions are often dependent on particular species that modify and create highly diverse habitats.

Norling and Kautsky (2007) showed that the blue mussel strongly impacts community structure and ecosystem functioning, because increased bio deposition, i.e. the matter of mineral deposits, and nutrient regeneration supplying limiting resources and increasing the carrying capacity for other species. Therefore, the disturbance caused by the blue mussel might be positive because it increases the biodiversity of the ecosystem indicating an increase in the food chain (Power et *al*, 2011).

Previous studies have shown that certain species seem to have the ability to increase the amount of nitrogen and phosphorus in certain ecosystems. The input of nitrogen and phosphorus in terrestrial soils can be measured by taking samples and thereby determining if the components of N or P have increased. In aquatic ecosystems, however, we measure changes by using community metabolism, because it is a fast method which considers the whole community of flora and fauna. With community metabolism we can find significant differences in the aquatic ecosystem between cormorant nesting sites and islands without nests.

2.2 Community metabolism

The method of measuring community metabolism has become the most common method for monitoring metabolism of aquatic ecosystems (Köhler, 1998). The method was developed by Gaarder and Gran (1927) and is used for observing changes in the oxygen concentrations of the water. The concentrations are estimated from photosynthetic release as well as respiratory oxygen consumption.

In the study by Norling and Kautski (2007), in which the impacts of the engineering species *Mythilus edulis* have been analysed, the community metabolism has been monitored in order to see how the ecosystem reacts to changes. Analysing community metabolism has also shown to be a proper method to explore heterotrophy and autotrophy i.e. the dependency and independency respectively of food energy or nutrient resources within a community in aquatic systems can be measured (Bott, 1985). Whereas in autotrophic ecosystems the community can support itself i.e. primary producers get sufficient nutrient input and respiratory species enough oxygen and food, the community in heterotrophic ecosystems have to take organic substances from outside the community in order to maintain its health (Hopkinson & Smith, 2004).

Processes measured in community metabolism

- Oxygen produced by primary producers and consumed by benthos during light conditions is the net production (NP) of the community.
- Oxygen consumed by benthos and primary producers during dark conditions is the respiration (R).
- The sum of the net production (NP) and the respiration (R) data provided estimates of the gross production (GP) showing the amount of oxygen that is produced in total.
- The quotient of the magnitude of GP with the R data shows the dependency or independency of oxygen in the community in terms of heterotrophic or autotrophic levels respectively i.e. the GP/R ratio can be seen as insight into factors controlling pathways of carbon at a given location (Giblin et *al*, 1997).

3 Purpose of research

The presence of the cormorant in Finland is causing a lot of discussion since numbers of breeding pairs continuously increase. Previous research has shown that the Cormorant may be a potential 'engineering species' that could be able to change the ecosystem of the islands on where they nest. Therefore, Cormorant colonies may be a factor accelerating the eutrophication process (Klimaszyk et *al*; 2008).

However, the impact of the cormorant on the aquatic ecosystem has not been studied yet, the overall aim is to detect the impacts of eutrophication by cormorants on the subtidal benthic brackish-water community at local scales within the Gulf of Finland in order to contribute to a better understanding of the role of the Cormorant.

In this work the effects of nutrients released into the sea were analyzed, comparing islands where cormorant nest versus islands where they do not nest. This was replicated at three different locations. This allows us to test the effects of (1) the presence of the Cormorant where they nest and the ones at different (2) locations. Finally the (3) interaction of presence and location was assessed. For that reason three hypotheses have been formed of which one consists of H_0 and H_1.

(1) Presence:

- H_0: Cormorant nesting islands show no significant difference in community metabolism than islands without cormorant nesting site.
- H_1: Cormorant nesting islands are differing significantly in community metabolism compared to islands without Cormorant nesting site.

(2) Location:

- H_0: Cormorants are not causing significant changes to the community metabolism in the area Äggharuna, Lerharun and Rönngrund.
- H_1: Cormorant are causing significant changes in the community metabolism in the area Äggharuna, Lerharun and Rönngrund

(3) Interaction of presence and location:

- H_0: Cormorants are neither changing significantly the community metabolism within the location nor in the area.
- H_1: Cormorants are changing significantly the community metabolism within the location and also in the area.

As an addition, the relation between algae cover and community metabolism will be tested, for which the following hypotheses have been formed:

- H_0: Algal cover and community metabolism are not correlated to each other.
- H_1: Algal cover and community metabolism are correlated to each other.

3.1 Personal achievements

Because of personal interest, I added three aims that I would like to achieve with this work.

- The results gathered should help to find an answer to the role of the Cormorant within the Finnish archipelago.

- The results of this study should be accessible and understandable for local people who feel affected by the Cormorant. Because the impact of the Cormorant on the Finnish coast is hardly a controversial issue for local inhabitants, the results may contribute to a clearance of rumours.

- The Cormorant should be considered as part of the ecosystem and not as a threat to Finnish coastal inhabitants.

4 Material and method

The research on community metabolism and landscape configuration is a subproject of a larger study conducted by Dr. Eliecer Diaz and the Integrated Coastal Zone Team. The study on cormorants started already in 2010, when investigations on the settlement of cormorants in Finland and Sweden had been made. In November 2010, 36 regular stone bricks (30 x 30) were put at three meters beneath sea level close to the islands with and without a nesting site although measurements were planned to be taken first in early summer. The aims of the early disembarkation of the bricks were to compare spatial patterns, i.e. variability and heterogeneity, of opportunistic algae, mussels and bare space at the islands with and without cormorants and to estimate primary productivity.

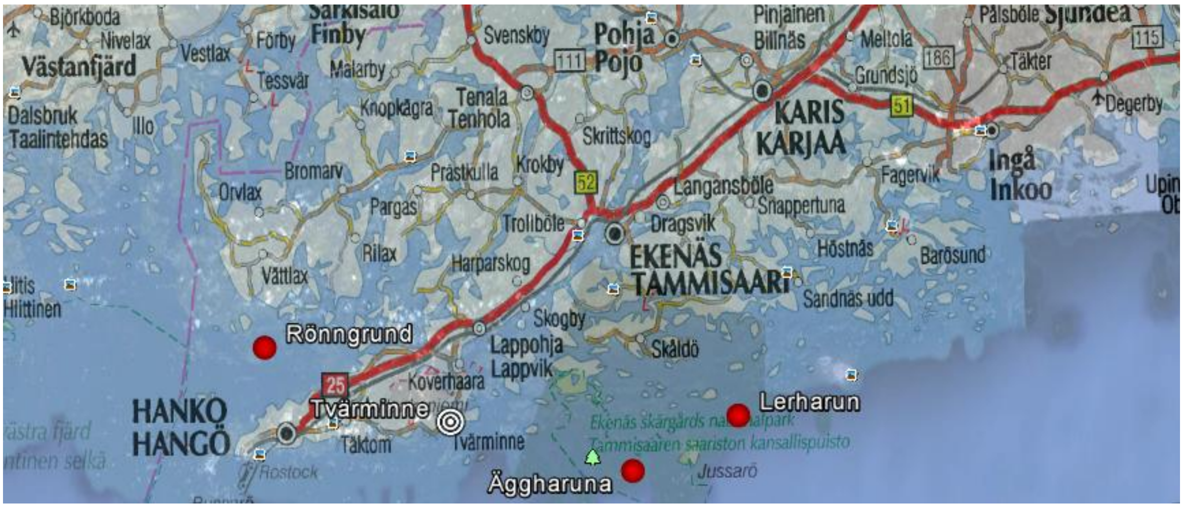

Figure 2: Map of Raseborg-Hanko area. Location where the research has been conducted is marked with red dots. The site of the lab at Tvärminne Station shown as double circle. (Source: Google Earth, Tiehallinto)

The work will be conducted at three pairs of islands where the density of cormorants is large, because the conditions for finding sensitive results are increased. (Kolb et *al*, 2010) Every pair of islands consists of one Cormorant nesting island and one non-nesting island which acts as a reference island (control). The distances of the islands within a pair are approximately 1-2 km. In Figure 2 one can see the area of Raseborg and Hanko from the south of Finland. Within the Ekenäs Archipelago National Park, which reaches from Lappohja as far as the island of Jussarö, lies the pair of islands called Äggharuna which was one out of three pair of islands tested in our research. Outside the National Park to the East the Lerharun pair of islands is situated. Lerharun did not have any settlement this year, due to unknown reasons. However, in previous years nesting populations had been documented on this island as the study has been conducted.

The last pair of islands is Rönngrund which is located at the North of Hanko. Rönngrund was exhibited to low wave exposure compared to the other pair. All three pairs of islands were chosen according to the data of the Finnish Environmental Institution that recorded the nesting sites of the Cormorant.

4.1 Hermetic boxes

As previous research has shown, the light and dark bottle method from Gaarder and Gran (1927) was a proper method to estimate community metabolism in aquatic ecosystems. Therefore, the method was applied to the research conducted in this study. Because no hermetic boxes of sufficient size were available, the development of 16 reliable hermetic boxes was of great importance.

The air tightened boxes, developed by myself were the size of 50 x 44 x 25cm and were able to store each one algae covered brick inside its body. For the water sampling one small opening was drilled into the lid of the box which could be opened manually by the diver using a cork system. With the use of syringes, the water samples were removed from the boxes without any risk of water outside and inside the box being mixed. For better extraction of the water an additional hole with a similar cork system had been added in order to avoid a vacuum which would hamper the water extraction (as one can see in figure 3).

Figure 3. Dark and transparent boxes

Figure 4. Hermetic box with openings on the lid

Due to the fact that natural oxygen movements within the box are totally limited, the natural agitation of the oxygen had to be replaced by a manual mixing system activated from outside the box. For simulating the dark and light conditions eight dark boxes were darkened with duct tape, whereas the other eight boxes remained transparent.

4.2 Procedure

The field testing was carried out within three days in early June 2011: the 3rd, 5th and 9th. Each day one pair of islands was tested in the morning and evening with an approximated time difference of 7 hours. In total, during one day twelve hermetic boxes were used of which six were sunk by the mass of the stone bricks by the island with the Cormorant nesting site, and the other six by the Cormorant non-nesting island. The six boxes of each island were equally divided into dark and transparent chambers where the R or NP respectively was measured (n=3 dark and n=3 transparent respectively).

The water samples were extracted using syringes under water and were transported to the boat for further preparation. The water samples were filled into stoppered bottle brims, (100 ml) and manganese sulphate and an alkali-iodide-azide reagent were added. The estimations of oxygen consumption were assessed through the Winkler method (see appendices) at Tvärminne Zoological station (Norling & Kautzki, 2007).

The same oxygen sampling procedure was carried out after seven hours. Additionally photos of the stone bricks were taken in order to determine the type of community colonizing the bricks. To estimate the algae cover the computer image tool programme UTHSCSA was used. After gathering all data from both the Cormorant present and non-present islands, the boxes were collected and used for the next pair of islands.

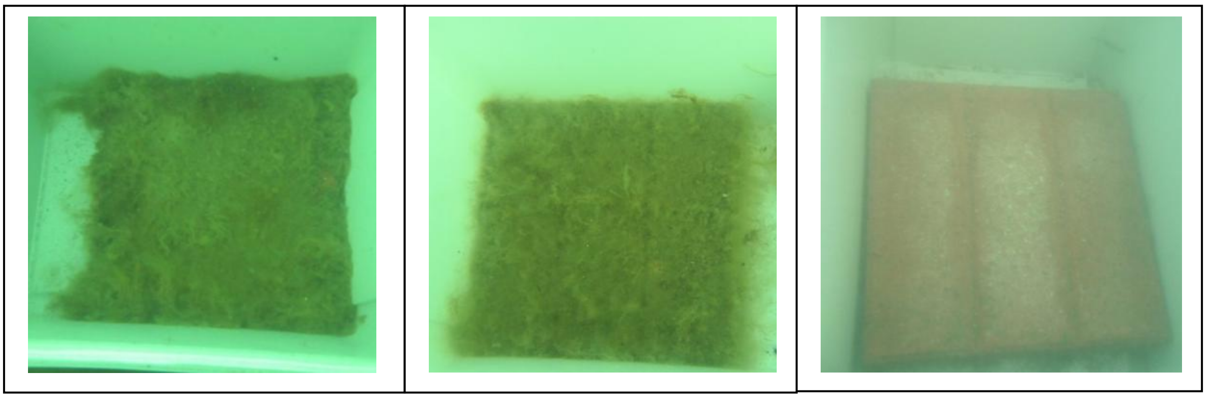

Figure 4: Bricks covered with algae. From left: Äggharuna, Lerharun, Rönngrund (all bricks are from islands with Cormorant nesting site and all three are in darkened boxes)

4.3 Statistical methods

For the statistical analysis, two statistical programmes, SPSS and STATISTICA, were applied. The Pearson correlation at the 0.05 significance level was used for looking at relations between community metabolism and algal cover on the brick. Because the data of the community metabolism processes known as NP, R, GP and GP/R were transformed and homocedastic, the Person correlation is trustworthy.

For the comparison of the community metabolism between the locations, the Cormorant nesting and non-nesting islands and the interaction of location and presence were tested using the 1-way-ANOVA. The testing at the 0.05 significance level was done for all three community metabolism processes (N, R, GP). For more specific information on pattern that were not categorized as *a priori* in the ANOVA test, the Post hoc test Newman-Keuls was used.

5 Results

5.1 *(*1) Presence

Table 1: Significance test with respect to the presence of Cormorant, tested on the processes of community metabolism (NP, R, GP) and the ratio GP/R.

Presence of Cormorant	**Type III Sum of squares**	**Mean Square**	**F**	**Sig.**
GP/R	**26.158**	**26.158**	**0.42**	**0.531**
GP	**0.075**	**0.075**	**0.223**	**0.647**
R	**2.200**	**2.200**	**0.843**	**0.378**
NP	**0.068**	**0.068**	**5.493**	**0.039**

Degrees of Freedom: 1

The different variables which comprise community metabolism have been tested separately on significant differences between subtidal communities from islands where cormorants' nests and islands with no nests. As it can be seen in table 1, the gross production/respiration ratio (GP/R), gross production (GP) and respiration (R) are not significantly different, whereas the net production (NP) has shown a significant value.

As the ANOVA test has shown (table 1), there are differences between communities in islands where Cormorant nest and islands without Cormorant nests in terms of net productivity, which leads to the rejection of the H_0 hypothesis. In Figure 6, it is possible to observe that the primary productivity mean value of the Cormorant nesting island is lower than the reference island without Cormorant.

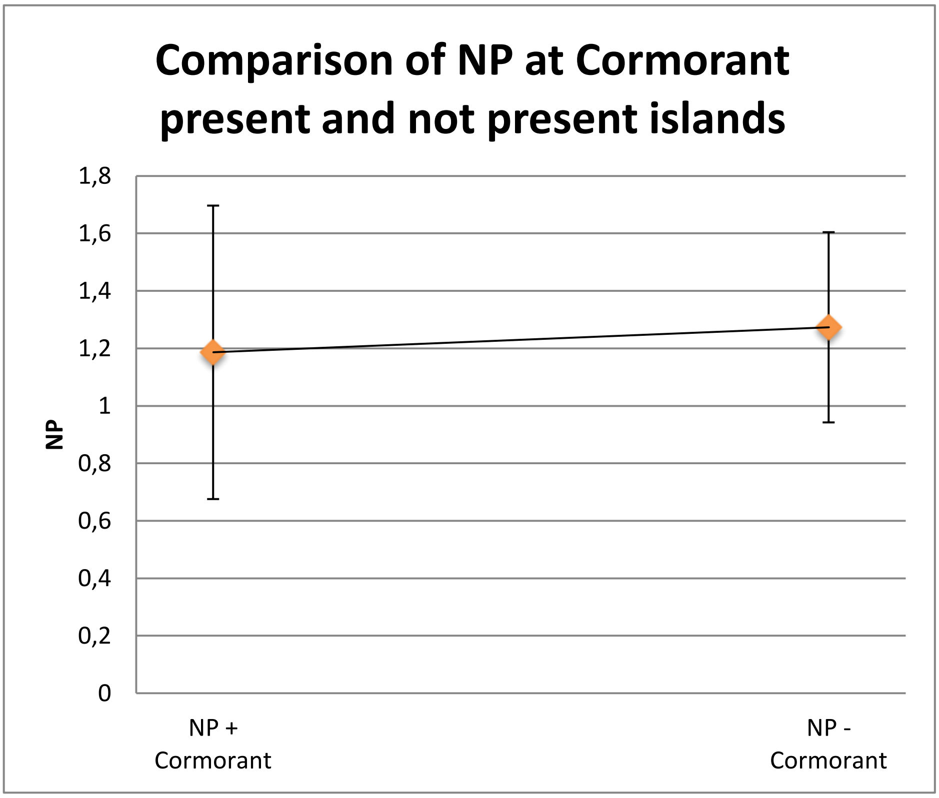

Figure 6: Significant differences in net production respectively to islands with nesting site and without. The Standard error (SE) estimated for cormorant nesting and non-nesting islands shows the estimated standard deviation of the mean value of the process. The range of the SE is higher at islands with cormorant nests.

5.2 (2) Location

As one can see in the column of the significant values (table 2), gross production (GP), respiration (R) and net production (NP) are significantly different. However, no significant difference in the total community metabolism ratio GP/R has been found. Because differences of three variables had been detected, three additional graphs for comparison are drawn in figure 7.

Table 2: Significance test respect to the three locations (n=3), showing significant differences in three out of four community processes.

Location	Type III Sum of squares	Mean Square	F	Sig.
GP/R	187.031	93.515	1.502	0.269
GP	8.372	4.186	12.423	0.002
R	61.604	30.802	11.801	0.002
NP	2.476	1.238	100.719	0.000

Degrees of Freedom : 2

The graphs of figure 7 show the mean values and the *SE* of the (a) net production, (b) respiration and (c) gross production. Comparing the net production (a) with the graph of the gross production (c) no significant differences can be observed. However, comparing the net production or gross production (c) with the respiration (b) they seem to differ.

As it can be seen from the graph of the (a) net production (NP) data, the location with the highest mean value is Äggharuna, followed by Lerharun and, with the lowest value, Rönngrund. When comparing the graph of the respiration (R) data (b) with the gross production one can see that the rank has changed. In the respiration (R) graph, the highest mean estimated are at the location of Lerharun, followed by Äggharun and last, Rönngrund. The gross production (GP) graph (c), however, is similar to the graph of the net production (NP). Furthermore, Rönngrund seems to differ from the locations Lerharun and Äggharuna, because of lower mean values detected in all three variables (NP, R, GP), showing that the hypothesis H_0 has to be rejected.

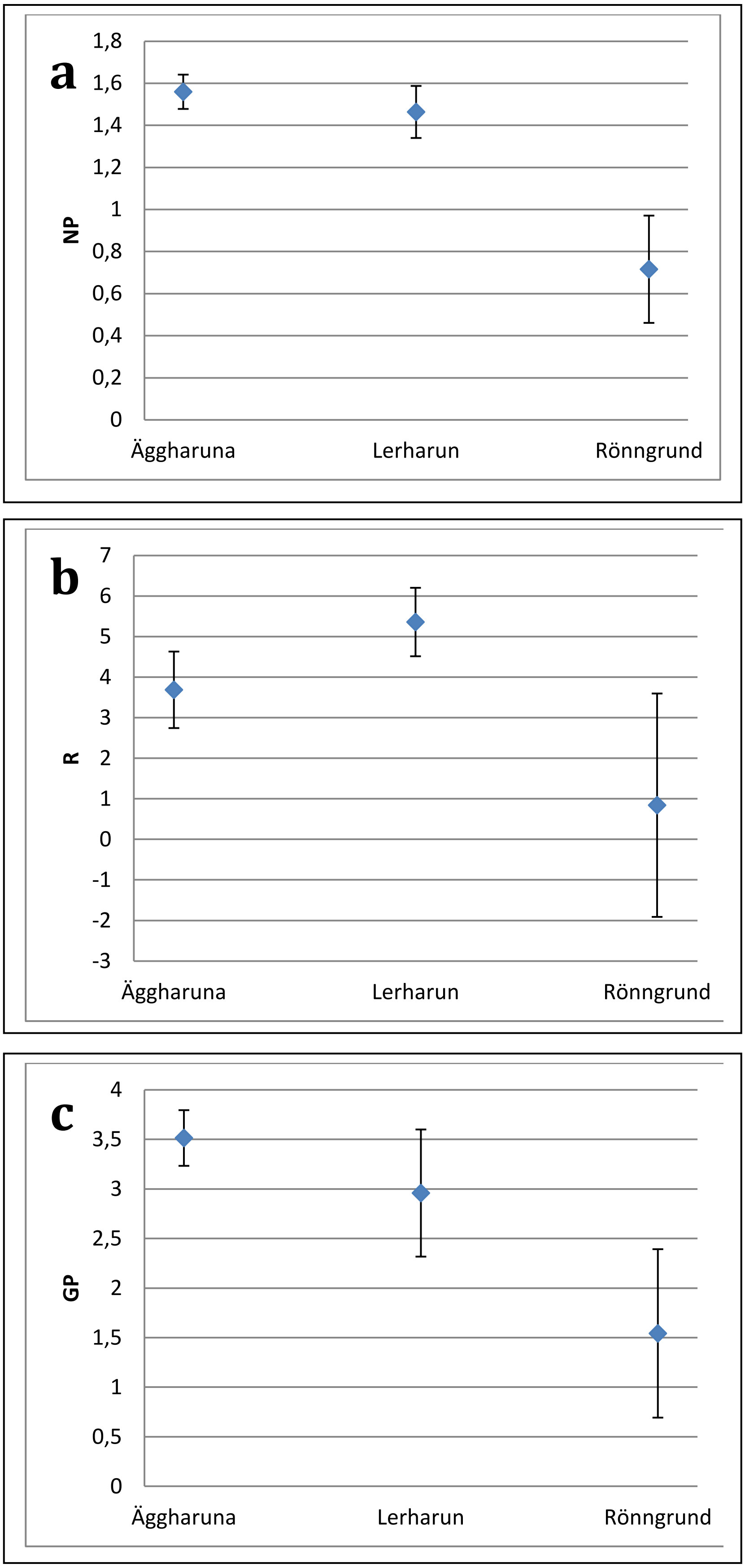

Figure 7. Significant differences in locations observed in (a) net production, (b) respiration and (c) gross production. Graph (b) showing that Lerharunhas a higher repiration value than Äggharun and Graphs (a,b,c) showing Rönngrund having least net production, respiration and gross production.

5.3 (3) Interaction of the factors presence and location

Although the differences between the islands with and without Cormorant population as well as the differences between the locations have been detected, the interest in testing the interaction between location and presence cormorants in the islands based on community metabolism analysis still exists.

Table 3: Summary of the interaction of the factors presence of Cormorant and location, showing significant differences in the net production (NP).

Interaction Presence and Location	Type III Sum of squares	Mean Square	F	Sig.
GP/R	259.363	129.682	2.083	0.175
GP	1.704	0.852	2.529	0.129
R	8.137	4.069	1.559	0.253
NP	0.225	0.112	9.143	0.005

Degrees of Freedom: 2

Significant difference in the net production can be observed in table 3, indicating that the H_0 can be rejected. Because the 1-way-ANOVA does not display which community metabolism differs from the other communities, three graphs of the net production (NP) have been drawn (figure 8).

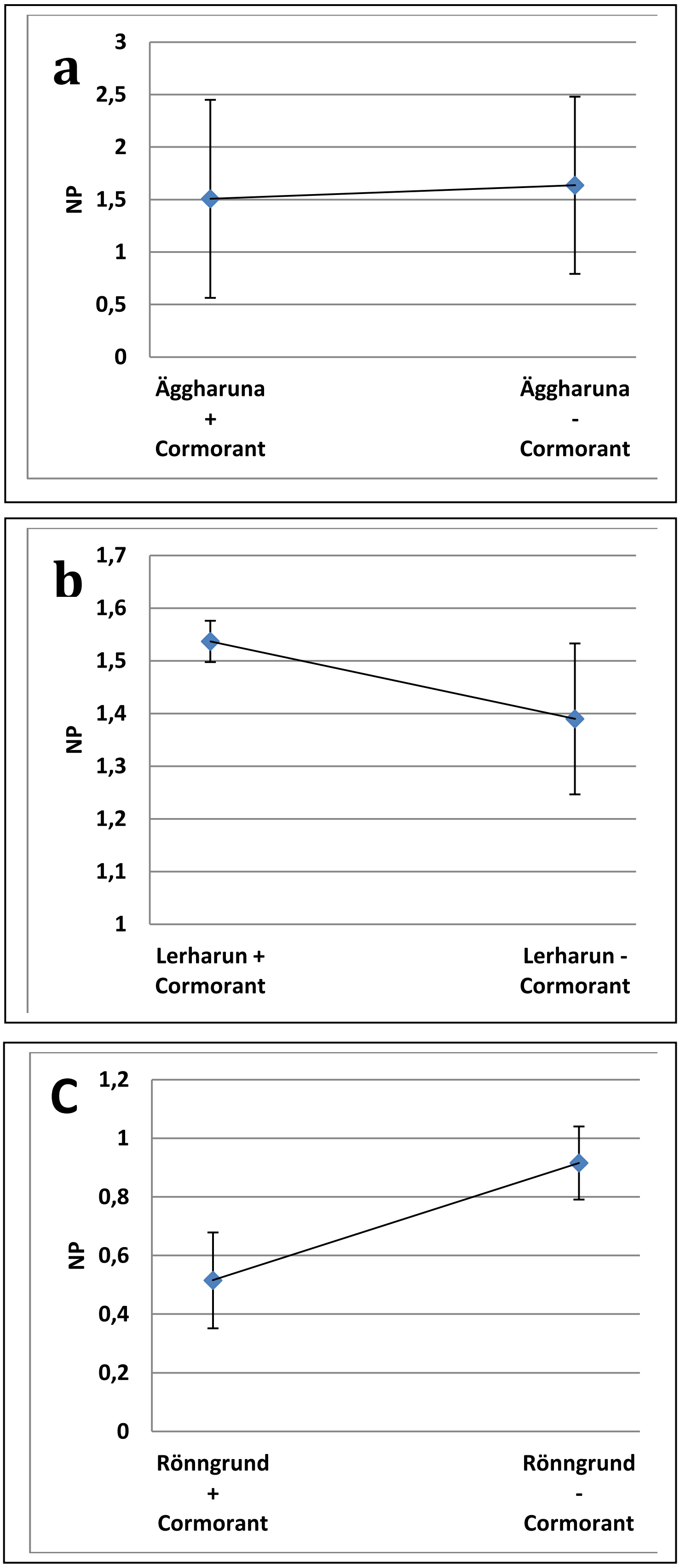

Figure 8. Significant differences in the net production tested on the comparison of location interacting with presence. The different locations (a)Äggharuna, (b) Lerharun and (c) Rönngrund. Within each graph a separation of Cormorant nesting islands and their reference islands has been done so that the mean and the SE can be seen for every island separately.

'Äggharuna' displayed in figure 8 (a) seems to have remarkably small mean difference between both islands compared to Lerharun (b) and Rönngrund (c). Also the variation represented as *SE* of both islands within the location is remarkably high. Comparing graph (a) 'Äggharuna' with graph (b) 'Lerharun' and (c), it can be seen that (a) Äggharuna and (b) Lerharun have similar mean values in contrast to (c) Rönngrund. The range of mean values in (a) Äggharuna and (b) Lerharun are approximately between 1.4 - 1.7 NP units.

However, when looking at the graph of (c) Rönngrund, the mean values at Cormorant nesting islands are three times lower than at (a) Äggharuna and (b) Lerharun. But also the mean value of the islands without Cormorant at (c) Rönngrund is almost twice as low as (a) Äggharuna and (b) Lerharun. The *SE* at (c) Rönngrund, however, is seemingly lower compared to (a) Äggharuna and (b) Lerharun.

The outcome that had been tested so far with the 1-way-ANOVA, however, does merely displays that significant differences occurred. The 1-way-ANOVA test generalises data in the way that it only shows, e.g. that significant differences regarding the net production exist but not which island's net production is different from the others. From the graphs displayed in figure 8 it can be seen that Rönngrund might differ from the other two locations, because of lower mean values compared to the other locations. In order to test the significance between the different islands the SNK test was used.

5.3.1 SNK test

In the SNK test, each one of the six islands were tested separately from all other islands with regard to the variables of location and presence. The data sheet (appendix) therefore contains 6 x 6 relevant numbers that show if significant differences have been detected between the islands. Examining all 36 results showed that the islands what are significantly different to all other islands were Rönngrund with Cormorant nests and Rönngrund without nests.

5.4 Algal cover and community metabolism

The data of algal cover estimated from the bricks was used to correlate to the variables of community metabolism (NP, R, GP and GP/R). As table 4 shows, the Pearson correlation between algae cover and community metabolism has detected significant differences for NP, R and GP but no significant difference for the GP/R (see also figures in the appendix). Therefore, the hypothesis $3H_0$ can be rejected for the net production, respiration and gross production.

The Pearson correlation shows that no relation between the GP/R data and the algae cover exists, i.e. the GP/R production is not dependent on algae growth. As an example, the brick picture from Rönngrund (figure 5) may have a GP/R ratio similar to Äggharuna or Lerharun, although the algae cover significantly differs.

Table 4. Correlations between algae cover and the variables of community metabolism, showing significant differences in net production (NP), respiration (R) and gross production (GP).

Correlations		
		sig. (2-tailed)
Algae cover vs	**GP/R**	**0.845**
	NP	**0.000**
	R	**0.001**
	GP	**0.007**

6 Interpretation and discussion

6.1 Interpretation

One of the main interests has been on finding significant differences in community metabolism between islands where Cormorant nest and islands without nesting. According to previous research, nutrient input of the guano of piscivorous birds has shown to have significant effects on the environment (Breuning-Matsen (2009); Klimaszyk (2008)). Therefore, it is likely to think that the community metabolism of the islands with nesting sites will differ from the three islands without Cormorant nesting sites.

The results gathered during the research show that the six target communities are differently affected by cormorants. Through the oxygen measuring method within communities, information that has been gathered shows that community metabolism has altered differently at certain locations and that there are effects of Cormorant on community metabolism.

With the Pearson correlation executed on algal cover and community metabolism it has been detected that the growth of algal cover increases some values of the community metabolism. This means that the bigger the area of algal cover becomes, the higher is the value for net production (NP), respiration (R) and gross production (GP). Since recent research has shown that Cormorants can contribute to eutrophication (Klimaszyk, 2008), the algae cover is expected to be higher at Cormorant nesting sites. Therefore the hypothesis (H_1) that states that algae cover and community metabolism are correlated to each other should be applied. Furthermore, this would mean that the animals living in the community might be correlated to algal cover as well, because they are an important part of the community metabolism that has the availability to alter the ecosystem.

At the location of Rönngrund, only small amounts of algae cover were found at both islands. Observations made during the research could explain why the algae cover has been so limited in that area. The significant low algae cover and the therewith connected low value of net production at the Rönngrund islands may be resultant due to decreased water mobility, i.e. currents and wave action detected at this location. Because algae naturally spread through spores that are transported either by air or water, currents are needed to carry the spores in all directions (Eddy, 1927). But because less water mobility had been observed at Rönngrund, the distribution of the algae may not have been as successful as at Äggharuna and Lerharun. Therefore it is assumed in this work that both islands at the Rönngrund location have been affected by decreased water mobility and algae were not able to spread as much as the algae at other locations. But also the harsh winter in 2010 could have had an impact on the algal cover. The cold winter could have created a layer of ice extending until 3m in depth which could have delayed the settlement of algae during winter-spring, while in more exposed sites, the effects of the ice are less strong.

Furthermore, as it can be seen from the map, referenced as figure 2, Äggharuna and Lerharun are, compared to Rönngrund, closer to each other. The exposure towards the open sea is higher at Äggharuna and Lerharun than it is at Rönngrund, because the formation of the Hanko peninsula seems to protect the location. When taking the position of the three different locations into account, one might expect to see differences. The test 1-way-ANOVA on location but also the SNK test of the interaction on presence and location have shown to confirm the assumption that location Rönngrund is significantly different than the other two locations.

In addition, the SNK test has shown that in location Rönngrund, the island with Cormorant nesting sites and the island without cormorants have been significantly different from each other. This explains the significant difference in the comparison of Cormorant effected community metabolism and not affected community metabolism i.e. Cormorants have effected community metabolism at location Rönngrund. However, if it can be assumed that the external factor ‘location’ has a high impact on the community composition and can therefore be expressed in differences in oxygen fluctuations, the different conditions of wave action between the locations, should be taken into account.

6.2 Conclusion

As a conclusion, Cormorant birds do not seem to affect the community metabolism significantly at two out of three locations tested in this research. However, Rönngrund have shown significant differences in the net production at the island with Cormorant nesting site and the island without nests where the net production was increased at the islands without Cormorant nests. This indicates that there is more biotic activity at islands without cormorant nests i.e. the community at the island without Cormorants has to be more active in order to maintain the community structure than the community with cormorants. However, since the GP/R ratio has never been detected as significantly different, indicating that no pattern in heterotrophy or autotrophy has been found, the community of Cormorant nesting sites nor the island without cormorant nest is depending on substances from outside the community. That indicates that Cormorants do not contribute to an alteration in the community structure.

Fluctuations within the community metabolism could be rather explained by different conditions in the locations, e.g. different intensity of wave action, and species that live in the community (Tamminen, 1998). When oxygen value used by macro and meiofauna, bacteria and benthos are higher than the value of net production, the community might consist of an increased amount of oxygen using species and a decreased number of primary producers like micro- and macroalgae that produce oxygen out of photosynthesis. In the present experiment, the differences between Äggharuna, Lerharun and Rönngrund can be explained by different community structures. Therefore, it can be assumed that at location Lerharun (figure 7) the oxygen needed of respiratory species, i.e. bacteria and benthos, is higher than the amount of oxygen produced from meiofauna and macrofauna.

But also different species of primary producers can cause fluctuations in oxygen production. As Burris (1977) reported that certain kinds of algae produce different amounts of oxygen. Therefore, it might be possible that different net production values could be explained by different species. In the present study, however, mainly one species of brown algae had been found indicating that fluctuations from different algae species are rather unlikely.

However, because no intense determination of species has been done in this thesis, I have to assume that the significant differences detected at Rönngrund are explained by the decreased water mobility that had been observed.

6.3 Risks and recommendations

After carrying out the research, it has become clear that certain risks and weaknesses have made the process more difficult; starting from the equipment, measuring methods to the forces of nature. The hermetic boxes which were made of plastic were very vulnerable and broke very easily. Unfortunately, data had to be rejected once because one transparent box broke during the process at Äggharuna Islands. Fortunately, the weakness of the transparent boxes was detected at a very early stage so that further incidents could be avoided. Because the darkened boxes were additionally darkened with duct tape, they were much more stable.

The second difficulty in the research was the measuring of oxygen using the Winkler Method. Although the Winkler Method is known for giving very precise values, the use of the method is more complicated in comparison with using an oxygen measuring device. The conservation of the oxygen, for example, has to be done directly after the samples have been taken. The difficulty of the whole process was to insert the two reagents without adding oxygen in a swinging boat. Furthermore, the samples had to be stored in cold temperature water until the following processes of the method could be executed in the lab. With varying temperatures from seven to twenty degrees Celsius and a very strong sun radiation in the late afternoons, this condition was sometimes hard to achieve. Because the Winkler Method consists of several steps and processes, we had to be very accurate in order to achieve results that were trustworthy.

The third obstacle that has to be taken into account is the weather. Because the research was originally planned to be executed twice, once in the early summer and once in the late summer, the time of carrying out the research was limited. Due to the reason that the winter was exceptionally cold that year, the birds came back later to their nesting areas. Furthermore, the three dates needed for the testing should be no longer apart than one week from each other, because fast increasing temperatures in early June could influence the result too much. As a matter of fact, the two pairs of islands, Äggharuna and Lerharun, were due to their exposure to the open sea, hard to reach by wind coming from the south. Fortunately, after several windy days the wind settled for a few days and the testing phase started.

6.4 Improvements

The original idea of this research was to execute two testing phases in the early and late summer. The data gathered in early June should have been compared to the data gathered in late August. Unfortunately, the work load was too intense for this study. However, an expansion of the research would probably have given more variation due to different algae and plants that grow in summer.

In addition, the analysis of the species living within the community could have given a broader picture and probably given a broader insight into how community metabolism is affected. Another improvement for further research on this issue would be the expansion of the whole project to more than three pairs of islands with additional focus on the effects on exposed islands and protected islands. But the fishermen disturbed almost all islands which were not located within national parks.

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8. Appendices

Vasabladet articles published in 2011

Vasabladet 15.08.2011

FOTO: ARKIV/LISEN JULIN

Fiskelag får vänta på besked om skarvjakt

Kring midsommar lämnade fiskelagen i Munsala och Oravais in en ansökan till Närings-, trafik- och miljöcentralen. Ansökan gällde tillstånd för att få jaga skarv.

Ännu har inget besked kommit i ärendet och tålamodet hos fiskelagen håller på att ta slut.

– Om man blir nonchalerad tillräckligt länge slutar det med att man tar saken i egna händer, säger Kaj Wik, ordförande för fiskelaget i Munsala.

Fiskelagen hade hoppats på att kunna inleda jakten tidigare än i fjol. Då fick de börja jaga från och med den 20 augusti men då hade största delen av skarvarna redan hunnit bege sig söderut.

– Nu ser det ut som om det inte blir någon jakt alls i år, säger Wik.

På NTM-centralen uppger man att det är semestrar som orsakat fördröjningen och att beslutet kommer nästa vecka.

Wik är förargad på hela systemet och förstår inte hur det kan ta så länge.

– Om jag har semester en månad så ser jag till att det finns någon annan som sköter mina uppgifter under den tiden.

Han säger att myndigheterna inte bryr sig om hur landsbygdsbefolkningen har det.

– I Sverige är situationen en helt annan. Där får man till och med jaga skarv året om på vissa platser.

MICHAELA ROSENBACK

I KORTHET Vasabladet 02.08.2011

Flera hundra storskarvsbon har blivit förstörda

Flera hundra storskarvsbon har återigen förstörts i Västra Finland. Under de senaste dagarna har ungefär 700 förstörda storskarvsbon hittats på tre olika områden, uppger Egentliga Finlands Närings-, trafik- och miljöcentral, NTM. I varje bo fanns i medeltal 3–4 ägg, av vilka en del redan börjat kläckas. Brotten har redan anmälts till polisen.

Redan förra veckan hittades förstörda bon på ön Turvasaari i Satakunta. Nya observationer har gjorts på Stengrundet i Väståboland och på en klippa i Gustavs. Enligt NTM-centralen har det inte utfärdats några tillstånd för att störa storskarvarnas häckning i områdena.

Att störa storskarven är förbjudet utan tillstånd från myndigheterna. FNB

6th August 2011 Vasabladet

Storskarvarnas bon blir fler och det ser ut som om fågelarten är hä[r] för att stanna.

FOTO: ARKIV/LISEN JULIN

Skarvstammen i Kvarken blir allt större

Antalet storskarvbon i Kvarken har blivit 300 fler sedan förra året. Nationellt sett har antalet bon ökat med nästan en fjärdedel.

VASA/KORSHOLM

Storskarvstammen breder ut sig i hela Finland. Ökningen har ändå mattats av de senaste åren hävdar forskaren Pekka Rusanen på Finlands miljöcentral.

– I början av 2000-talet var ökningen i medeltal runt 70 procent, men de senaste fyra åren har den sjunkit till 27 procent.

En möjlig orsak till det här att skarven blivit en mycket omdebatterad fågelart och många ser gärna att den försvinner från den finländska faunan. Vissa irriterar sig så mycket på skarvarna att de tar saken i egna händer och ser det som sin uppgift att stoppa tillväxten genom att förstöra skarvbon.

Runt 800 skarvbon har nämligen förstörts i hela landet under sommaren. Det är en stor ökning från i fjol.

– Det här är olagligt. Jag tycker att det är mycket tråkigt att folk känner att de måste ta till sådana här åtgärder, säger Rusanen.

Han hävdar att förstöringen av skarvbon ställer till problem också för andra fågelarter då folk går i land på kobbar och skär under häckningstiden.

– Det enda förstöringen lede[r] till är att skarven flyttar till någo[t] annat område i närheten. D[e] slutar inte försöka bygga bo[n] bara för att ett förstörs.

Den första kolonin med häckande skarvar påträffades i Finland 1996. Rusanen hävdar at[t] fågelarten fortfarande försöke[r] hitta sin plats och befinner si[g] endast i sprindningsfasen.

Anser du att det är ett problem att skarvstammen växer?

– Det beror på hur man ser p[å] saken. Storskarven började var[a] en så naturlig del av skärgården. De stör inte andra fåglar och äte[r] i regel mest småfisk.

IDA ERIKSO[N]

Skarvar i Finland

- Under sommaren 2011 räknades skarvbon i den finländska skärgården. Det totala antalet bon var 17 700. Det är 3 300 flera än förra sommaren.
- I Kvarkenområdet hittades 1 087 bon. Förra sommaren var de 719.
- Mest skarvar häckar i Bottenhavet och den största skarvkolonin finns i Raumo.

Har forskarna rätt är skarven den enda fågel i världen med medfödd förmåga att skilja mellan skräpfisk och värdefisk.

Vasabladet 26.06.11

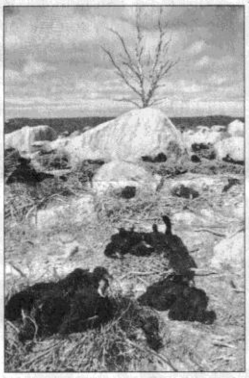
Stoppa skarven innan den tar över hela skärgården!

För många kustbor är skärgården med dess rena natur och artrika fiskevatten en ovärderlig resurs.

Men medan glesbygds- och stugfolket omfattas av allt strängare miljöbestämmelser då det gäller avloppsvatten och avträde tillåts de förhållandevis nyinflyttade skarvarna att förpesta holme efter holme i sin explosiva förökning. Av Fjärdsgrundet i Monåfjärden, en gång reserverat som rekreationsområde, återstår i dag i praktiken bara en hög vit, stinkande spillning. (Vbl 24.6)

Sju häckande par år 2001 har förbytts i 650 häckande par år 2011. Alla med matematiskt sinne kan bilda sig en uppfattning hur siffran ser ut om ytterligare tio år och hur många skär som har intagits vid det laget.

Det här gäller alldeles speciellt som försöken att decimera stammen har stött på patrull i Vasa förvaltningsdomstol. Förvaltningsdomstolen har stöd i Finlands miljöcentrals forskning, enligt vilken skarven huvudsakligen livnär sig på mört och tånglake. Även biologen Hans Hästbacka bedömer att skarven gillar skräpfisk som mört, björkna och spigg.



Skarvarna i Monåfjärden har nu också erövrat Lillgrundet. FOTO: LISEN JULIN

måste stoppas innan det är för sent?

Enligt Olburs ska felet sökas hos Europeiska kommissionen som 1979 förde upp den ena skarvarten på en lista över fåglar med behov av skydd. Han anser att vi borde få samma kommission att vidta mått och steg för att undanröja de formella hindren för skyddsjakt året runt.

Har de rätt är skarven förmodligen den enda fågel i världen som förmår skilja skräpfisk från värdefisk. Det sunda bondförnuftet säger att skarven knappast har den intelligensnivån och att forskningen i detta fall måste vara behäftad med brister.

Det tror också biologen Christer Olburs som gjorde ett tappert försök att räta ut en del frågetecken i en Vbl-debattartikel i går. Olburs hävdar att lax och öring är i riskzonen och att också en hotad art som harren kan vara i fara.

Eftersom harren har varit så gott som utrotad på våra breddgrader borde vi förstå att värna om de få exemplar som eventuellt ännu förekommer i våra vatten. Men som lagstiftarna nu verkar vilja ha det ska också harren bli föda för den spökfågel till dödgrävare som har blivit en allt vanligare syn längs våra kuster.

Vad göra? Vad kan yrkesfiskarna och en allt mer desperat kustbefolkning företa sig för att få beslutsfattarna att förstå att skarvens framfart

MED ANDRA ORD:
En inflyttad fågel borde inte ha större rätt till skärgården än dess urinvånare.

Å andra sidan har representanter för EU intygat att skarvproblemet är en nationell angelägenhet och att unionen inte lägger sig i om Finland vill följa Sveriges väg och förhindra skarvarnas utbredning. Men det vill vi tydligen inte – förvaltningsdomstolens färska nej till skyddsjakt visar att det sunda förnuftet saknas på den här sidan av Bottenviken.

Samtidigt ska vi ju också se skarvinvasionen som en skrällande väckarklocka ifråga om havets tillstånd och den övergödning som pågår. Hade vi bara i tid förstått att värna om naturen och minskat den diffusa belastningen skulle vi knappast ens ha fått något problem med skarvar.

Som man bäddar får man ligga, säger ordspråket.

VAD TYCKER DU?
Kommentera ledaren på www.vasabladet.fi

By looking at the local newspaper of Vaasa ‘Vasabladet’ the Great Cormorant has been in the middle of discussion during the whole summer 2011. Just in the west of Finland already a couple of hundred of cormorant nests had been destroyed in the recent summer (02.08.2011). And approximately 800 observed nests have been damaged this year in the whole country by August 2011 (Vasabladet, 06.08.2011).

Table of oxygen saturation

levels before and after treatment, including the heterotrophic levels calculated for every pair of dark and transparent boxes (labelled as d or t in the end of the first column of every pair of island). The group of measurements belonging to the top belong to the Cormorant present islands and the measurements below the one of the islands without Cormorant (labelled as t or c in the second character).

Äggharuna

			heterotrophic		GP	GP/R
At1d	101,27	96,81	-4,46	R	26,62	-6,0
At1t	98,94	130,02	31,08	NP		
At2t	102,50	134,55	32,05	NP	26,28	-4,6
At2d	103,40	97,63	-5,77	R		
At3d	101,75	97,50	-4,25	R	26,15	-6,2
At3t	103,60	134,00	30,40	NP		
					average:	-5,6
					SD	0,874466

					GP	GP/R
Bc1d	105,80	103,46	-2,34	R	45,96	-19,6
Bc1t	103,26	151,56	48,30	NP		
Bc2t	105,32	113,00	7,68	NP	5,69	2,9
Bc2d	104,08	102,09	-1,99	R		
Bc3d	98,94	105,18	6,24	R	43,29	6,9
Bc3t	105,25	142,30	37,05	NP		
					average:	-6,4
					SD	18,79386

Lerharun

					GP	GP/R
LAt1d	110,79	116,91	6,12	R	39,78	6,5
LAt1t	110,49	144,15	33,66	NP		
LAt2t	110,94	141,28	30,34	NP	21,89	-2,6
LAt2d	110,64	102,19	-8,45	R		
LAt3d	110,49	101,06	-9,43	R	27,09	-2,9
LAt3t	109,74	146,26	36,52	NP		
					average:	0,3
					SD	5,331757

					GP	GP/R
LBc1d	108,75	91,55	-17,20	R	7,41	-0,4
LBc1t	107,62	132,23	24,61	NP		
LBc2t	108,23	124,53	16,30	NP	11,02	-2,1
LBc2d	107,17	101,89	-5,28	R		
LBc3d	107,77	96,98	-10,79	R	21,52	-2,0
LBc3t	107,09	139,40	32,31	NP		
					average:	-1,5
					SD	0,930669

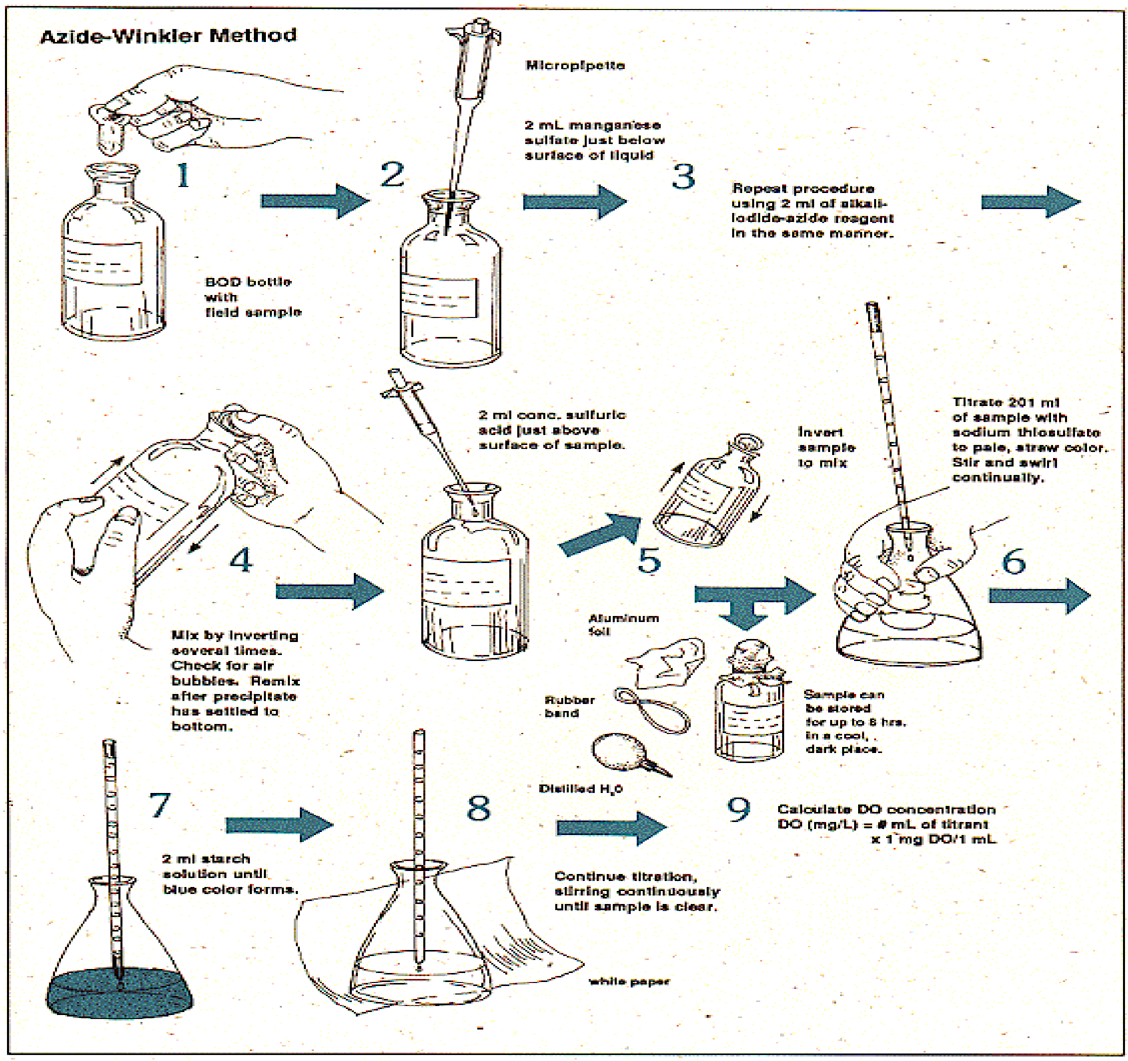
Rönngrund

					GP	GP/R
HAt1d	101,88	99,81	-2,08	R	1,12	-0,5
HAt1t	101,10	104,30	3,20	NP		
HAt2t	102,75	105,69	2,94	NP	2,85	-33,0
HAt2d	102,66	102,57	-0,09	R		
HAt3d	x	x				
HAt3t	102,83	103,96	1,12	NP		
					average:	-16,8
					SD	22,95151

					GP	GP/R
HBc1d	104,74	101,97	-2,77	R	7,35	-2,7
HBc1t	105,34	115,46	10,12	NP		
HBc2t	106,46	113,47	7,01	NP	5,79	-4,8
HBc2d	103,52	102,31	-1,21	R		
HBc3d	104,74	103,61	-1,12	R	4,15	-3,7
HBc3t	104,56	109,84	5,28	NP		
					average:	-3,7
					SD	1,064861

Azide-Winkler Method (taken from the Department of Ecology)

1. Fill a 300-mL glass stoppered BOD bottle with sample water. Remember – no bubbles!
2. Immediately add 2mL of manganese sulfate to the collection bottle by inserting the calibrated pipette just below the surface of the liquid. (If the reagent is added above the sample surface, you will introduce oxygen into the sample.) Squeeze the pipette slowly so no bubbles are introduced via the pipette.



3. Add 2 mL of alkali-iodide-azide reagent in the same manner.
4. Stopper the bottle with care to be sure no air is introduced. Mix the sample by inverting several times. Check for air bubbles; discard the sample and start over if any are seen. If oxygen is present, a brownish-orange cloud of precipitate or floc will appear. When this floc has settle to the bottom, mix the sample by turning it upside down several times and let it settle again.
5. Add 2 mL of concentrated sulfuric acid via a pipette held just above the surface of the sample. Carefully stopper and invert several times to dissolve the floc. At this point, the sample is "fixed" and can be stored for up to 8 hours if kept in a cool, dark place. As an added precaution, squirt distilled water along the stopper, and cap the bottle with aluminum foil and a rubber band during the storage period.

6. In a glass flask, titrate 201 mL of the sample with sodium thiosulfate to a pale straw color. Titrate by slowly dropping titrant solution from a calibrated pipette into the flask and continually stirring or swirling the sample water.
7. Add 2 mL of starch solution so a blue color forms.
8. Continue slowly titrating until the sample turns clear. As this experiment reaches the endpoint, it will take only one drop of the tritrant to eliminate the blue color. Be especially careful that each drop is fully mixed into the sample before adding the next. It is sometimes helpful to hold the flask up to a white sheet of paper to check for absence of the blue color.
9. The concentration of dissolved oxygen in the sample is equivalent to the number of milliliters of titrant used. Each milliliter of sodium thiosulfate added in steps 6 and 8 equals 1 mg/L dissolved oxygen.

NOTE: Be very careful when doing DO analyses. The reagents are corrosive, so keep them away from your skin and clothes. Wear safety goggles and wash your hands when you are done.

Probe and Meter Method

1. Calibrate the probe according to the manufacturer's suggestions.
2. Collect the water sample into any appropriate sample container, being careful to avoid aerating the sample as describe above.
3. Place the probe in the sample, allow the meter to equilibrate, and read the DO concentration directly off the scale. NOTE: The probe may need to be gently stirred to aid water movement across the membrane.

Field DO probes are easily ruined through deterioration of the membrane, trapping of air bubbles under the membrane, and contamination of the sensing element. It often is difficult to assess whether or not a probe is functioning properly. Because of this, the meter must be calibrated before and after each series of measurements. When you calibrate the instrument, you compare DO concentrations measured by the probe to those measured using the Azide-Winkler method described above and then correct all samples for any measurement error. The meter manufacturer's calibration procedure should be followed exactly. If the error is high or erratic, all sample results should be discarded.

QA/QC Considerations

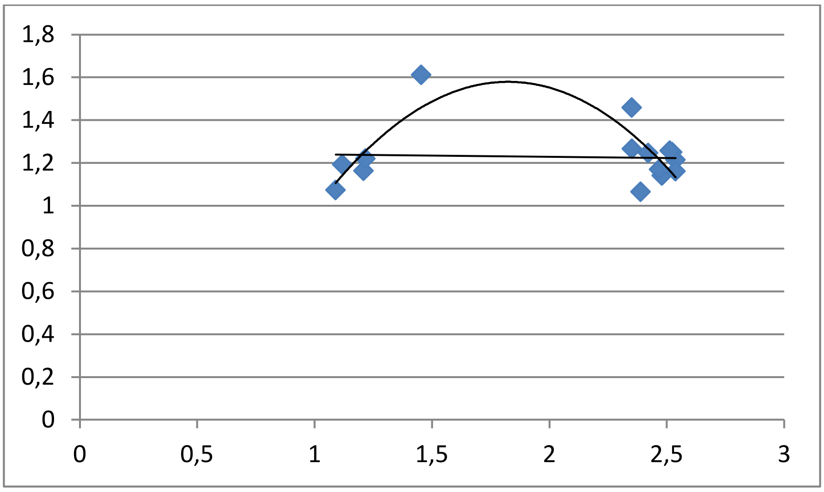
Even though the Winkler dissolved oxygen method is the method against which the others are calibrated, there are still tests that can be made to ensure that the Winklers themselves are accurate. To test the method, you need to have samples with a known oxygen concentration so you can compare your results to what you know is the real answer. These are called calibration samples or standards. A 100 percent saturation solution can be prepared by bubbling air into distilled water. If low DOs are expected, a zero DO solution can be made by adding excess sodium sulfite and a trace of cobalt chloride to a sample. In a professional lab, a calibration standard would be analyzed with each bath of samples run.

Randomly select 5 to 10 percent of the samples for duplicate laboratory analysis. If you are interested in field variability, select 5 to 10 percent of the samples for field duplication (e.g., collect two samples from the same station).

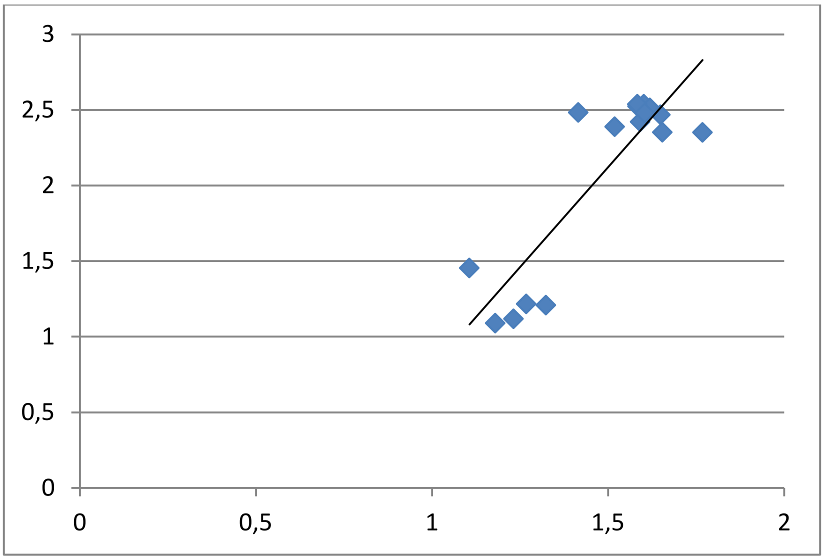
If you are using a probe and meter or field kit for measurement, 5 to 10 percent of your samples should be checked against the Winkler DO method.

Figures of Cover versus community metabolism

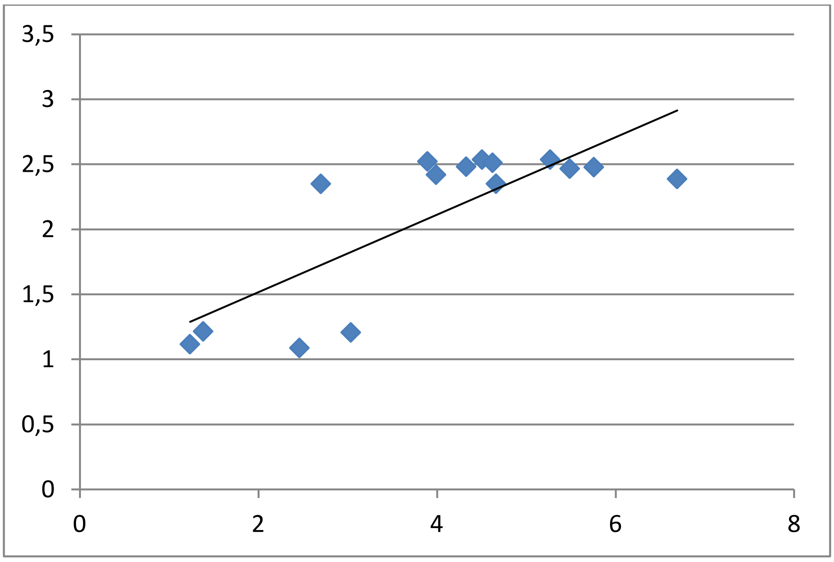
GP/R vs cover (no correlation)



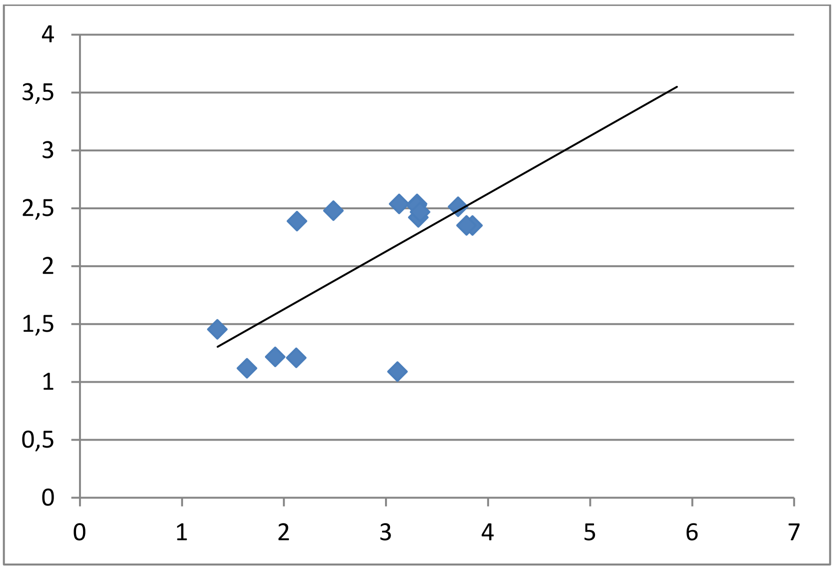
NP vs cover (correlated)



R vs cover (correlated)



GP vs cover (correlated)



SNK test results

Newman-Keuls test; variable logNP (Spreadsheet1) Approximate Probabilities for Post Hoc Tests Error: Between MS = ,01229, df = 11,000

	Cormorant	location	{1} - 1,5074	{2} - 1,5367	{3} - ,51534	{4} - 1,6366	{5} - 1,3897	{6} - ,91570
1	present	Äggharuna		0,761888	0,000196	0,388488	0,237373	0,000336
2	present	Lerharun	0,761888		0,000167	0,311979	0,302322	0,000362
3	present	Rönngrund	0,000196	0,000167		0,000173	0,000199	0,001501
4	control	Äggharuna	0,388488	0,311979	0,000173		0,094784	0,000219
5	control	Lerharun	0,237373	0,302322	0,000199	0,094784		0,000528
6	control	Rönngrund	0,000336	0,000362	0,001501	0,000219	0,000528	