

The population of Black-headed gulls and species breeding in association with the Black-headed gulls\*

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## Abstract

The population of Black-headed gulls was studied in the Tarup-Davinde gravel pit to find out if the population size of breeding birds was increasing or decreasing. Nature management was made before the colony began to breed, to see if removing high vegetation would have any impact on the population size. The Black-headed gulls are said to provide protection to associating species and therefore the number of three other depending species were counted in the Tarup-Davinde gravel pit, to make a correlation. The number of breeding Black-headed gulls in 2019 is also been compared to other colonies in Denmark, to see if local migration is made between nearby colonies. The Black-headed gull colony in the Tarup-Davinde gravel pit is located in Birkum and Langager lake and scattered on three different islands. The data collected in 2019 in the Tarup-Davinde gravel pit was collected with both binoculars, telescope, and drone. R-studio was used to make statistical models on both the historical data and the data collected in 2019. The results showed that after a decline in population size, the breeding Black-headed gulls in the Tarup-Davinde gravel pit is increasing. Although, it might not have anything to do with the removal of the high vegetation. But the removal of the high vegetation into the water, creating floating bushes in the water, might have a positive impact on the associating species. The tendency of the correlation between the species who breed in association with the Black-headed gulls is, that the more Black-headed gulls there is breeding in the Tarup-Davinde gravel pit, the higher is the count for the associating species. Further research should be made to say if there are made local migration between the colonies, but there is shown a tendency when one colony is increasing another is declining. Out of the 11 colonies of breeding Black-headed gulls compared there were 6 colonies increasing, but the ones declining was halving there counts within the last years.

## Introduction

The number of Black-headed gulls, *Larus ridibundus*, is declining in Denmark. The Black-headed gull is on the yellow list of species in Denmark. The yellow list was made in 1997 and is a list of plants and animals which are to be taking special care for (Stolze and Pihl (red) 1998). When a species is on the yellow list it is about to enter the red list, which is when a species is gone extinct or are about to be. So, by making the yellow list and follow it, it might prevent some species from going extinct. In the 1960 the population of Black-headed gulls in Denmark where around 400,000 pairs and in 2011 that was decreased to around 80,000 pair. The Black-headed gull is already on the red list in Finland (Virkkala, 2016) and in 2016 there was made a study in Finland which showed that the population of Black-headed gulls was declining (Väänänen, et al. 2016).

All the colonies of Black-headed gulls in Denmark are being monitored and counted to estimate an increase, decrease or if the population is stabilized. All the data from the monitoring are entered into a database called Dansk Ornitologisk Forening (Dansk Ornitologisk Forening 2004). DOF manage an online website where ornithologists are recording their counts of birds in Denmark. The counts are registered in specific locations, so you can look up any location and know which bird species that live in specific areas and how many.

A colony of Black-headed gulls is breeding in the Tarup-Davinde gravel pit, which is a large gravel pit with lots of lakes. Some of the lakes in the gravel pit contains small island in the middle and these islands are ideal for the Black-headed gulls to breed on. When the Black-headed gulls breed on the islands, the islands provide protection for the birds because the predator must cross the water to enter the island. The only predator who preys on the gulls in Tarup-Davinde is bigger birds like the white-tailed eagle.

The Black-headed gull is a wader bird who lives in Europe, Asia, southeast Russia, and northeast China. Populations are also found on Greenland and Iceland. The Black-headed gull builds their nest near water and mostly in marshes (Hutchins, et al. 2002). They breed in colonies and always come back to the same colony and area to breed after winter (Péron, et al. 2010). A Black-headed gull colony can go from 100 individuals to around 25,000 individuals (Dansk Ornitologisk Forening 2011) and they stay in the same area to breed from Marts to August. In February and Marts, the birds assemble at the breeding area to choose partners. The Black-headed gull is monogamous (Hutchins, et al. 2002), which means they only breed with one partner. When the Black-headed gulls have parred up, they mate and start building their nest. The female incubates the eggs for 22 to 26 days and the juveniles are ready to fly after 32 to 35 days (Hutchins, et al. 2002).

Along with the Black-headed gulls, there is a lot of other species who breed on the islands. Generally, the islands are very utilized by a lot of species. The reason is mostly the protection of the nests but some of the species also use the Black-headed gulls as protection (Virkkala, R. 2016). The Black-headed gull is very aggressive towards predators when they breed, and some other species are taking advantage of that by breeding in association with the Black-headed gull colonies. When a predator approaches the colony the Black-headed gulls get startled and this will act as a warning for the other species. The other species will then have a bigger chance of escaping the predator. In that way, some species are depending on the Black-headed gull to breed, because of the protection they

provide. These depending species are amongst other the Black-necked grebe, the Common tern, and the Mediterranean gull.

The Mediterranean gull (*Larus melanocephalus*) is not an endangered species, but it is not a common species in Denmark and that is the reason for the low counts, it is just beginning to settle down in Denmark. The Mediterranean gull is breeding in colonies of Black-headed gulls or in colonies of the big Common gull. This is only for protection against predators (Dansk Ornitologisk Forening 2012). The Common tern (*Sterna hirundo*) is also not an endangered species but has been declining since 1900 and still is. The Common tern also breeds in association with the Black-headed gull (Dansk Ornitologisk Forening. 2018. Fjordterne). The Black-necked grebe (*Podiceps nigricollis*) is not an endangered species but is depending on the Black-headed gull colonies for breeding and for the protection of their eggs (Dansk Ornitologisk Forening. 2018. Sorthalset lappedykker). It is not that common for the Black-necked grebe to breed in Denmark (Dansk Ornitologisk Forening 2004).

The Black-necked grebe, the Common tern, and the Mediterranean gull are, together with the colony of Black-headed gulls, found in Birkum and Langager lake (Appendix 2, p. 19). They are scattered between the three islands but on the island, in Birkum lake the density of Black-headed gulls is the biggest. Even though the Black-headed gulls are scattered out on tree islands it will still be considered as one colony. The two islands in Langager lake is called the western island (Appendix 3, p. 20) and the eastern island (Appendix 4, p. 20).

The birdlife in the Tarup-Davinde gravel pit has been counted and monitored since 2010 by binoculars and telescope. In this project, the colony of Black-headed gulls will also be monitored with a drone. The colony in the Tarup-Davinde gravel pit have never been monitored with a drone before, so a test flying was made in Marts. This was done in cooperation with Henrik Kalckar Hansen, he is a nature guide in Tarup-Davinde gravel pit, and he have helped us through the project. The drone was flown across Birkum lake and over the island and the colony. Meanwhile, the colony was observed with a telescope to see the behavior and responses from the Black-headed gulls. In a study from the University of Aarhus they studied the responses on the use of drones in several bird colonies and among those birds who did not respond to the drone, was the Black-headed gull (Holm, et al. 2018; Holm, et al. 2019). The study also showed that when monitoring a breeding colony, and especially breeding Black-headed gulls, it would be best to do a transect with the drone (Holm, et al. 2018; Holm, et al. 2019).

Before the Black-headed gull began to breed in February there was made some nature management on the island in Birkum lake, where a lot of the high vegetation was removed and tossed into the lake. This was done to see if the removal of the high vegetation would have an impact on the colony of Black-headed gulls. I also wanted to see whether the changes in the colony of Black-headed gulls an impact have on the depending species. To figure that out I also must figure out if the colony in the Tarup-Davinde gravel pit has increased, decreased or is stabilized. Through the years the colony has both been decreasing and increasing. Some of the years have been bad for the Black-headed gull colony in Tarup-Davinde and therefore I address the following n hypotheses with this report: (1) Does the population of Black-headed gulls increase or decrease in the Tarup-

Davinde gravel pit; (2) Do the nature management have any impact on the population size of Black-headed gulls in the Tarup-Davinde gravel pit; (3) Have a decrease or an increase of Black-headed gulls in the Tarup-Davinde gravel pit any impact on the species who breed in association with them; (4) Does the Black-headed gulls make local migrations in search of better environment to breed in.

## Methods

At first, we found the historical data from 2010 to 2018 in both Tarup-Davinde and the other colonies in DOF, all the historical data is collected with binoculars and telescope. This was done in cooperation with Cathrine Thinggård Jacobsen, who also writes a bachelor project about Black-headed gulls in the Tarup-Davinde gravel pit. We use the historical data to make a comparison with that data from this year.

We made nature management in February on the island in Birkum lake, in cooperation with Henrik Kalckar Hansen. Here we removed some of the high vegetation and pushed it into the water in hope that it would sink to the bottom. We made calculations on the area that we removed vegetation on, and on the complete area on the island. The calculation on the area is done in Google Maps, with a measurement tool.

When the Black-headed gulls began to assembly and find partners in the Tarup-Davinde gravel pit, we began to visit the island with Per Rasmussen, the local ornithologist. He helped us count the birds with binoculars and telescope, and he has, among others, collected the historical data in DOF. We counted the Black-headed gulls from the side of the lake with a distance of almost 300 meters from the center of the island in Birkum lake to the shore. From shore and to the western islands in Langager lake there are respectively 130 and the eastern island 85 meters.

On the 29th April, we monitored the island with a drone, Dji phantom pro-drone. Before we went flying with the drone, we downloaded the app DroneDeploy, which we used to make a transect for the drone to follow. The drone flew 18 transects across and around the island at an altitude of 15 meters. When the drone flew in the transects it took pictures of the island. The pictures overlapped each other with 75% in the front and 70% on the sides. Thereby covering the whole island in approximately 14 minutes. Afterwards we uploaded the 345 pictures to the app, DroneDeploy, and the app assembled them to one whole picture of the island. The fact that the Black-headed gulls had started to breed made it possible to get a count of the whole colony by counting the numbers of individuals in the colony on the pictures (Appendix 5 and 6, p. 21), because not that many of the birds would be out foraging.

We also monitored the small islands in Langager lake with the drone, in April. Here the transect was not necessary because the island are that small. The drone could get a picture of the whole island in an altitude were the Black-headed gulls still could be counted. To count the birds on these pictures we put them into paint and counted them manually.

I used R studio to make the statistic models and graphs, and these are also made in cooperation with Cathrine Thinggård Jacobsen. We fitted the data on the Black-headed gulls, the species who breed in association with them and the data on the other colonies in R with either linear or quadratic

models. The graphs are made on real-life data, so we had to adjust the graphs and see which models got the best fit. We made models on the data to see if there are any correlation between the breeding Black-headed gulls and the years the population have been there. Also, to see if there are any correlation between the breeding Black-headed gulls and the species who breed in associations with them. And at last, to see if there are any tendency of the other colonies and the one in the Tarup-Davinde gravel pit, which seems to refer to a correlation between decreases and increases in the population breeding closely to each other.

## Results

When the Black-headed gulls began to breed in April 2019 we could begin to count the total number of breeding Black-headed gulls with the binoculars or telescope. We compared the number of breeding Black-headed gulls in 2019 to the number of breeding Black-headed gulls from 2010 to 2018 in figure 1.

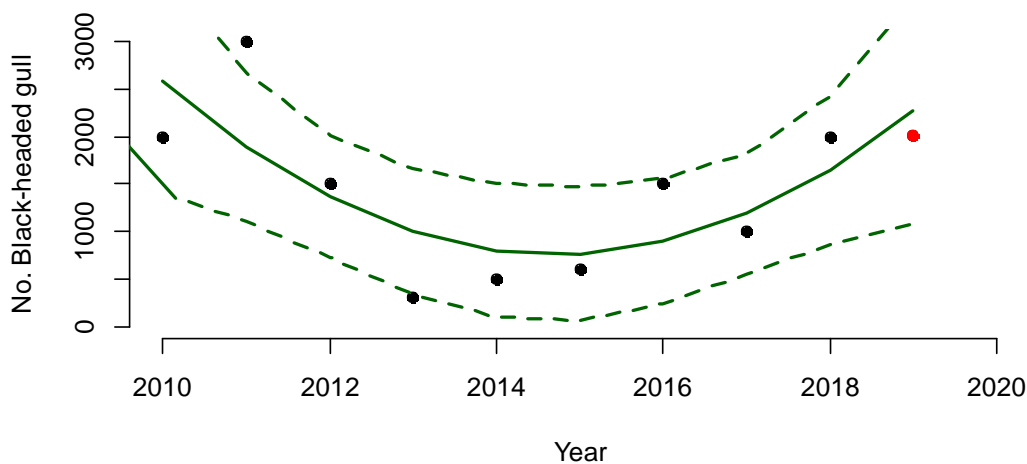


Figure 1: Number of breeding Black-headed gulls in Tarup-Davinde gravel pit, as a function of years.

We fitted a quadratic model on the data in figure 1 which have the form  $y=ax^2+bx+c$ , where  $y$  is the number of breeding Black-headed gulls and  $a$ ,  $b$  and  $c$  are coefficients made by fitting the model to the data. Our analysis on number of breeding Black-headed gulls and years, in R studio showed that  $a = 8.229e+01$ ,  $b = -3.316e+05$  and  $c = 3.340e+08$ . The model has a multiple R<sup>2</sup>-squared value on 0.57 and all the coefficients were statistically nonsignificant ( $p=0.053$ ). As shown in figure 1 the colony of Black-headed gulls in Tarup-Davinde is declining from 2010 to 2013 and here it increases until 2019. The dotted lines are a 95-percentage confidence interval, where it shows that almost all the spots lays inside that interval. The red spot is to highlight the counts for this year, 2019, and to show that it lays within the 95-percentage interval.

On the island in Birkum lake there was made nature management where some of the high vegetation was removed. A calculation has been made for the percentage removed vegetation, compared to how big the island is and how much vegetation there was before nature management. The island is 3360m<sup>2</sup> and before nature management the vegetation filled 3176m<sup>2</sup>, which is around 94% of the island. After nature management the vegetation filled 2837m<sup>2</sup>, 82% of the whole island,

which is a total removal of almost 10% of the island's vegetation. On figure 2 and 3 the difference before and after nature management is shown.



Figure 2: Island in Birkum lake before nature management.



Figure 3: Island in Birkum lake after nature management.

The reason for the difference in the pictures is that figure 1 is from Google Maps and figure 2 is taken by drone on the test flight in Marts, and that in Marts the vegetation has not begun to blossom. The nature management is done in the northern and eastern side of the island, which is shown in figure 2 and 3.

I compared the number of breeding Black-headed gulls in the Tarup-Davinde gravel pit with the number of breeding Common terns in the gravel pit.



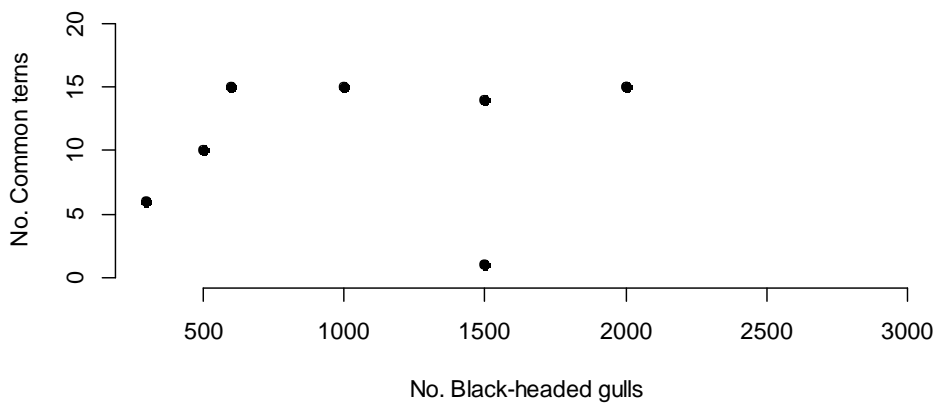


Figure 4: Number of breeding Common terns as a function of breeding Black-headed gulls in Tarup-Davinde gravel pit. Each point represents a yearly survey of the total number of breeding Common terns and breeding Black-headed gulls.

There is statistically significant correlation between the number of breeding Common terns and breeding Black-headed gulls in the Tarup-Davinde gravel pit ( $y=0.06x^2-0.001x+3.67$ ,  $R^2 = 0.97$ ,  $p\text{-value} = 9.993e-05$ ). The tendency of the graph is that it tends to increase until it reaches 15 breeding Common terns and here it levels off.

I compared the number of breeding Mediterranean gulls and the number of breeding Black-headed gulls in the Tarup-Davinde gravel pit in figure 5.

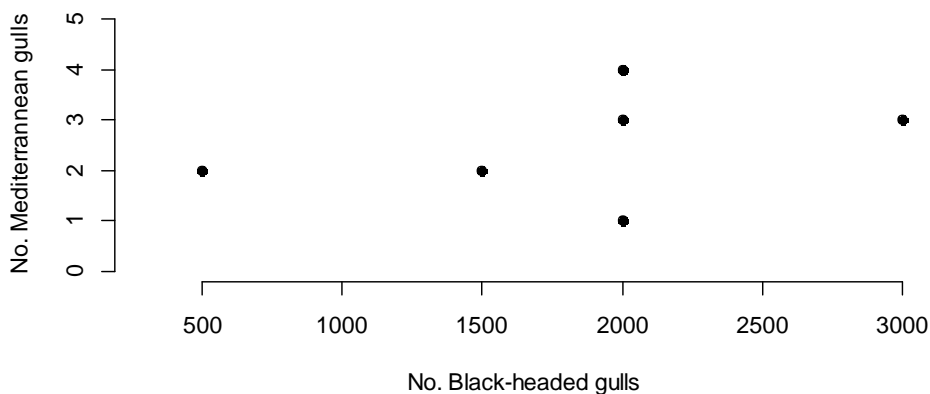


Figure 5: Number of breeding Mediterranean gulls as a function of breeding Black-headed gulls in Tarup-Davinde gravel pit. Each point represents a yearly survey of the total number of breeding Mediterranean gulls and breeding Black-headed gulls.

I fitted a linear model on the data in figure 5, which has the form  $y=ax+b$ , where  $a$  and  $b$  is coefficients from fitting the model to the data. My analysis shows that  $a = 0.0005$  and  $b = 1.67$ , and the model has a multiple R-squared value of 0.12. There is statistically no significant correlation between the number of breeding Mediterranean gulls and the number of breeding Black-headed gulls in Tarup-Davinde gravel pit ( $p\text{-value} = 0.5$ ). The tendency of the graph is an increase of breeding Mediterranean gulls the more breeding Black-headed gulls that is breeding in the Tarup-Davinde gravel pit.

I compared the number of Black-necked grebes and the number of breeding Black-headed gulls in Tarup-Davinde in figure 6.

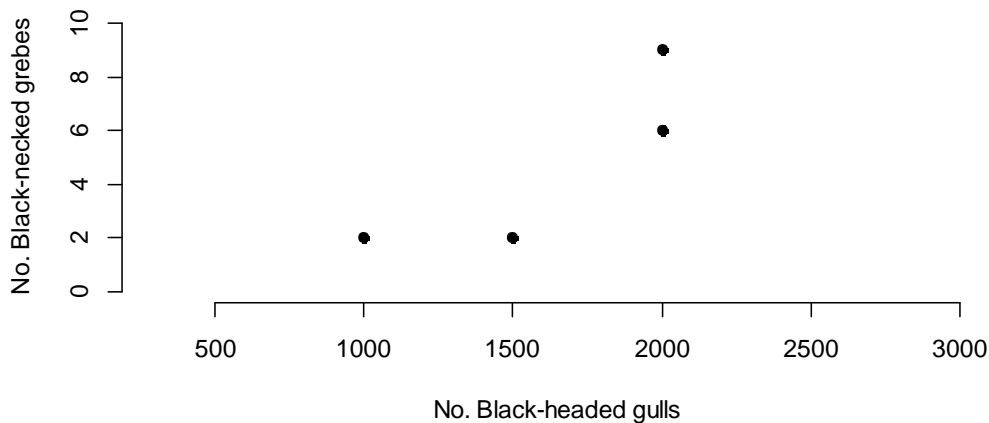


Figure 6: Number of Black-necked grebes in as a function of breeding Black-headed gulls in Tarup-Davinde gravel pit. Each point represents a yearly survey of the total number of Black-necked grebes and breeding Black-headed gulls.

There is statistically no significant correlation between the number of Black-necked grebes and the number of breeding Black-headed gulls ( $y=0.006x-5.0$ ,  $p$ -value = 0.15,  $R^2 = 0.72$ ). The tendency of the number of Black-necked grebes as a function of breeding Black-headed gulls is increasing. The more breeding Black-headed gulls there is in the Tarup-Davinde gravel pit, the more Black-necked grebes are there. Here is used Black-necked grebes and not breeding Black-necked, because the Black-necked grebe has not been breeding in Tarup-Davinde yet.

I compiled the historical data, from the other colonies and the Tarup-Davinde gravel pit, from Dansk Ornitologisk Forening and presented it in table 1.

Table 1: Number of breeding Black-headed gulls from 2010 to 2019 in Tarup-Davinde gravel pit and in other colonies.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>Tarup-Davinde</b>	2000	3000	1500	300	500	600	1500	1000	2000	2004
<b>Egå Engsø</b>	535	NA	2500	1500	500	1700	2000	2500	3000	2500
<b>Filsø, Hjorteholm</b>	NA	NA	NA	NA	NA	100	NA	1000	NA	480
<b>Filsø, Gåseholm</b>	NA	NA	NA	450	1380	600	2180	800	1100	77
<b>Sneum Digesø</b>	7386	8820	10000	9390	14300	18470	23180	14680	13260	12140
<b>Odense fjord, Ølund</b>	500	2580	NA	600	2	700	1000	NA	NA	200
<b>Gyldensteen Nor</b>	NA	NA	NA	NA	NA	NA	841	738	950	480
<b>Bøjden Nor</b>	NA	2	8	59	100	160	240	200	600	43
<b>Siø</b>	500	200	NA	NA	NA	NA	260	5	2600	965
<b>Nørreballe Nor</b>	50	30	200	325	500	400	300	40	100	50
<b>Botofte Skovmose</b>	12	120	220	300	200	1000	2000	1300	750	600

Some of the colonies is breeding in areas there has not been there always and some of the places has been restored or are new places created especially for wader birds, among others. Therefore, in table 1, when it says NA, it means that there is no observation of breeding Black-headed gulls in that place on that year. When we made the models in R with the data in table 1, we also used NA for no observation. If we have used zero instead of, it would have counted for 0 in the graphs as well. And we did not want to have points in our graphs with a zero count.

We presented the number of breeding Black-headed gulls from other colonies, as a function of years from 2010 to 2019, in figure 7 and 8. Figure 7 is only for Sneum Digesø because of the big difference to the other 10 colonies, which is shown in the bottom of figure 7.

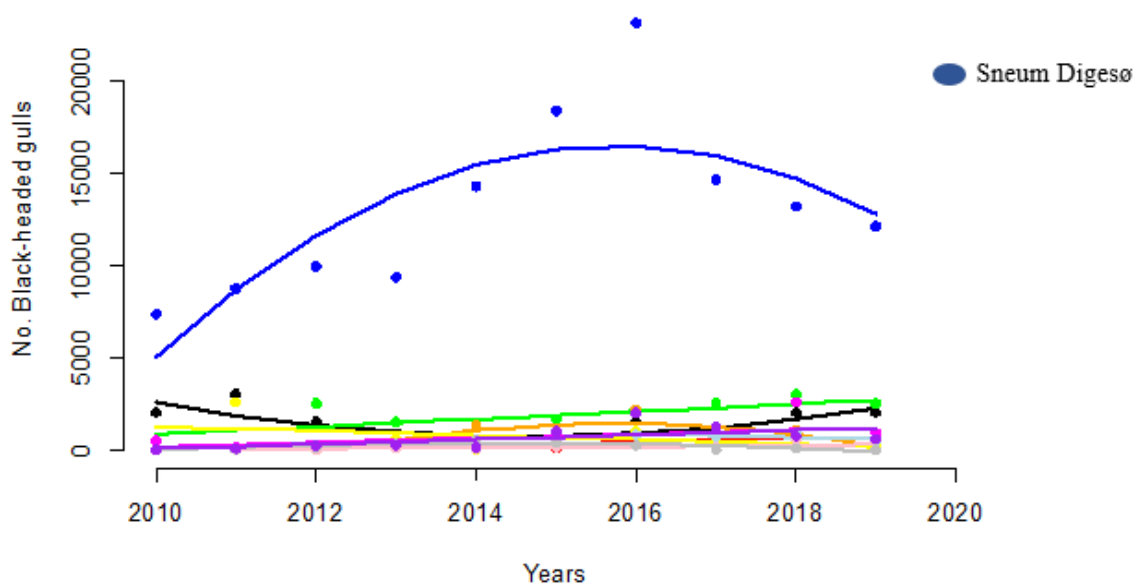


Figure 7: Number of breeding Black-headed gulls in other colonies as a function of years.

There is statistically significant correlation between breeding Black-headed gulls and years in Sneum Digesø ( $y = -3.491e+02x^2 + 1.407e+06x - 1.418e+09$ ,  $R^2 = 0.6$  and  $p\text{-value} = 0.04$ ). The tendency of the breeding Black-headed gulls in Sneum Digesø is an increase in the colony from 2010 to 2016 where it declines until 2019.

We removed the data from Sneum Digesø from the graph and made figure a, which gives a better picture of how the other colonies and models proceeds.

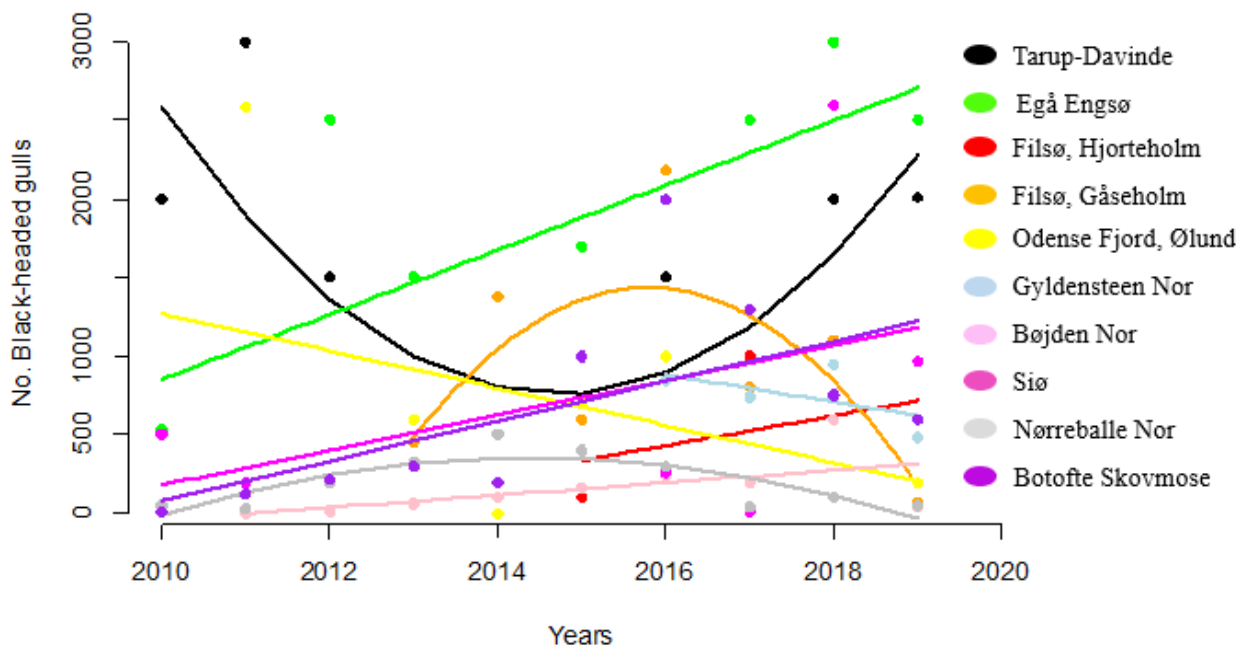


Figure 8: Number of breeding Black-headed gulls in Tarup-Davinde gravel pit and in other colonies as a function of years.

The number of breeding Black-headed gulls in Tarup-Davinde gravel pit and in other colonies as a function of years is shown in figure 8, and if some of the spots is difficult to see, the data is presented in table 1. The explanation for the colors is in the right side of figure 8. The black model is for Tarup-Davinde and here, as I said before, there is no significant correlation between breeding Black-headed gulls and years ( $y=8.229e+01x^2-3.316e+05x+3.340e+08$ ,  $R^2 = 0.57$  and  $p\text{-value} = 0.053$ ).

There is a significant correlation between breeding Black-headed gulls and years in Egå Engsø, the green model ( $y=206x-413012.7$ ,  $R^2 = 0.46$  and  $p\text{-value} = 0.044$ ). The tendency of the model is that the number of breeding Black-headed gulls in Egå Engsø is increasing linearly from 2010 to 2019.

The observation in Filsø, Hjorteholm, is very few and here there is no significant correlation between breeding Black-headed gulls and years, the red model ( $y=95x-191088$ ,  $R^2 = 0.18$  and  $p\text{-value} = 0.72$ ). The tendency of the breeding Black-headed gulls in Filsø, Hjorteholm, is that it is increasing from 2015 to 2019.

There is also statistically no significant correlation between breeding Black-headed gulls and years in Filsø, Gåseholm, the orange model ( $y=-1.224e+02x^2+4.936e+05x-4.975e+08$ ,  $R^2 = 0.47$  and  $p\text{-value} = 0.27$ ). The tendency of numbers of breeding Black-headed gulls in Filsø, Gåseholm, is that it is increasing from 2013 to 2016 and afterwards it is declining to 2019.

In Odense Fjord, Ølund, there is statistically no significant correlation between breeding Black-headed gulls and years, the yellow model ( $y=-118.6x+239600$ ,  $R^2 = 0.18$  and  $p\text{-value} = 0.34$ ). The tendency of the breeding Black-headed gulls in Ølund is that it is declining from 2010 to 2019.

The light blue model is Gyldensteen Nor, which has no significant correlation between breeding Black-headed gulls and years ( $y=-87.10x+176476.5$ ,  $R^2 = 0.31$  and  $p\text{-value} = 0.44$ ). The tendency of the number of breeding Black-headed gulls in Gyldensteen Nor, is that it is declining from 2016 to 2019.

There is also statistically no significant correlation between breeding Black-headed gulls and years in Bøjden Nor, the pink model ( $y=39.37x-79166.94$ ,  $R^2 = 0.34$  and  $p\text{-value} = 0.10$ ). The tendency of the slope is an increase from 2011 to 2019.

The magenta colored model is Siø and here is also statistically no significant correlation between the breeding Black-headed gulls and years ( $y=111.2x-223284$ ,  $R^2 = 0.19$  and  $p\text{-value} = 0.39$ ). The tendency of the graph is an increase of breeding Black-headed gulls on Siø from 2010 to 2019.

There is a significant correlation between breeding Black-headed gulls and years in Nørreballe Nor, the grey model ( $y=-1.839e+01x^2+7.409e+04x-7.462e+07$ ,  $R^2 = 0.68$  and  $p\text{-value} = 0.019$ ). The tendency of the model is an increase from 2010 to 2014 and here it declines towards 2019.

There is no significant correlation between breeding Black-headed gulls and years in Botofte Skovmose, purple model ( $y=127.28x-255765.13$ ,  $R^2 = 0.37$  and  $p\text{-value} = 0.06$ ). The tendency of the graph is an increase in breeding Black-headed gulls in Botofte Skovmose from 2010 to 2019.

The breeding Black-headed gulls in the Tarup-Davinde gravel pit is collected with both binoculars/telescope and drone on 2019. I presented the collected data in table 2 along with the percentage difference between the two methods.

Table 2: Breeding Black-headed gulls in Tarup-Davinde. Counted with binoculars and with drone, and the deviation of those two methods.

	Island in Birkum lake	Island west in Langager lake	Island east in Langager lake	Total number
<b>Binoculars</b>	1430	294	280	2004
<b>Drone</b>	3698	325	466	4489
<b>% difference</b>	61%	10%	40%	55%

Since 2010 the Black-headed gulls have been monitored with binoculars and telescope. In table 2 it is shown that, by counting the Black-headed gulls with drone gives the number of breeding individuals that is more than twice the number counted by binoculars and telescope. The percentage difference on the small islands in Langager lake is not that large as the difference on the big island in Birkum lake.

## Discussion

Our analysis of population counts of Black-headed gulls at the Tarup-Davinde gravel pit shows some clear and interesting trends. The population of Black-headed gulls at the Tarup-Davinde gravel pit has existed since 2010 and the number of breeding Black-headed gulls in the population has been through both a decline and increase in number. On figure 1 it is shown that the number of

breeding Black-headed gulls were declining from 2010 to 2013 and that it is increasing from 2013 to 2019. The quadratic model shows statistically a nonsignificant correlation although the p-value is 0.053, which is not that far from 0.05 and the tendency do follow the model. The multiple R-squared value is 0.57 which is also an acceptable value. So, despite the statistically nonsignificant it could be discussed that there is a correlation between the number of breeding Black-headed gulls and years in the Tarup-Davinde gravel pit. The data is built on real-life data and will therefore not be a perfect fitted plot. Figure 1 shows a 95-percentage confidence interval where two spots are outside of that confidence interval. These are two extreme values where the population has been at its highest, 3000 breeding birds, and on its lowest, 300 breeding birds. The fact that the population is declining that much can be explained by a fox who figured out how to cross the water and prey on the population on the big island in Birkum lake. Henrik Kalckar Hansen told that when he and Per Rasmussen observed that the population of the Black-headed gulls had declined a lot that year, they sailed to the island and as they approached the island a fox jumped in the water and swam towards its cubs on the shore. The colony almost vanished after that. This was in 2012/2013 and can explain the extremely low number of Black-headed gulls breeding in 2013. The extremely high number of breeding Black-headed gulls in 2011 could have been a good year for the colony but can also be explained by a source of errors.

Different source of errors is a possibility and can lead to uncertainty in the results. The counting by binoculars and telescope is done manually, which is different and individually from person to person how they count the birds. Therefore, there could easily be a counting mistake when dealing with a population of 500 individuals, or larger. There is also variation in how the counting of breeding birds is done. Some are counting all birds that lay down and multiply by two, to get the number of breeding birds. This is done by Per Rasmussen in the Tarup-Davinde gravel pit. Some are counting all the birds and multiplying with 0.7 to get the number of breeding birds (Holm, (red.) et al. 2019). Counting a population of Black-headed gulls can take around one hour and in that timescale some birds would have moved and could, therefore, be counted two times. Counting the population by drone and by transect takes around 15 minutes, according to the size of the island. This gives the birds lesser time to move around, and they will even be pictured so they will be still when counting. Of course, some of the birds could be counted twice if they are photographed twice. With the drone there is also a difference in how the birds are counted. When the drone flies the transect it not only takes pictures of the island, but also the water. In the water there is also birds, and some counts them too, but some do not. So, it really depends on who is counting the birds as much as it depends on what method there is used. At last, despite we removed some of the high vegetation, which gave a good view from the shore, there is still a lot of bushes and small trees. And this remaining high vegetation is preventing the drone from getting pictures of the birds breeding underneath the vegetation. So, that is also a source of error to keep in mind when judging the results.

Studying the breeding Black-headed gulls in the Tarup-Davinde gravel pit shows that the nature management might not have an impact on the population size. The colony in the Tarup-Davinde gravel pit has since 2013 increased in breeding individuals and is in 2019 around the same amount of breeding individuals as in 2010. The red spot in figure 1 is the number of breeding Black-headed

gulls in 2019 and the fact that it does stay inside the 95-percentage confidence interval shows that the nature management might not have had an impact on the colony. The nature management I am referring to here is the removal of the high vegetation on the island in Birkum lake. If the nature management should have an impact on the population the number of breeding Black-headed gulls should at least have been a lot bigger in 2019 than in 2018. The difference between those two years is only 4 birds more in 2019, which is not a big difference in the population. Also, we removed around 10% of the high vegetation on the island, we might should have removed even more to see a difference.

It is interesting to compare the trends in the Black-headed gulls to those other associating species. The fact that there is statistically correlation between the breeding Common terns and the breeding Black-headed gulls in the Tarup-Davinde gravel pit, supports the state that the Black-headed gulls are an aggressive breeding species who provides protection to the associated breeding species. On figure 4 the tendency of the breeding Common terns is presented, and it seems that the population has a maximum. The graph levels of at 15 breeding Common terns, which have been the total number of breeding Common terns the last three years (Appendix 1, p. 19). The correlation could be a coincidence, or it could be the amount of breeding Common terns the Tarup-Davinde gravel pit can withhold. The Black-necked grebe and the breeding Mediterranean gulls do not have a statistic correlation with the Black-headed gulls. Although, the model fitted on the Black-necked grebes data showed a p-value on 0.15, which could be acceptable. The multiple R-squared values for the Black-necked grebe model is 0.72, which is an acceptable value. Looking at figure 6 the tendency of the data also shows that the bigger number of breeding Black-headed gulls, the bigger number of Black-necked grebes. So, promising numbers for the Black-necked grebes in the Tarup-Davinde gravel pit. The Black-necked grebes have not been breeding in the Tarup-Davinde gravel pit yet, but they like to breed in bushes in the water like the ones around the big island in Birkum lake. These were created while doing nature management and as a failure attempt to let the lake absorb the branches. This is shown in figure 3. So, it might not be long before seeing the Black-necked grebes breeding in the Tarup-Davinde gravel pit. All in all, there is a tendency that shows, that the more numbers of breeding Black-headed gulls the bigger is the number of the associating species breeding along with them.

Our comparison of the trends in the Tarup-Davinde gravel pit with breeding Black-headed gull colonies in other locations is informative. The data from Sneum Digesø interrupted the visual picture of all the colonies in figure 7, so a second graph was made, so the other colonies were shown, figure 8. If we compare the 11 colonies, including the one in Tarup-Davinde, there are five colonies there increases linear and two colonies decline linear. Some of the colonies are fitted with a quadratic model and three of them have a tendency where it increases in the beginning and declines at the end. Only the colony in Tarup-Davinde is declining in the beginning and increasing at the end. Not all the colonies have a significant correlation so they will be turned down as nonsignificant, but some of them can be discussed. The colony in Bøjden Nor has a p-value on 0.10 which could be acceptable and on figure 8 you can see that the spots have a fair placement. But the multiple R-squared is 0.34 and indicate a bad fit for the model on the data points. The model on the data from Botofte Skovmose has not been accepted as a significant correlation between the two

variables but the p-value on 0.06 could be acceptable as significant. Although, the multiple R-squared value is on 0.37, which is not acceptable and looking at figure 8 confirms it. The spots vary a lot from the purple line. The tendency of the data from Botofte Skovmose do show an increase in numbers of breeding Black-headed gulls so there might be a correlation. Overall there is more increasing colonies than there are declining colonies in this project, which could communicate that the population of Black-headed gulls in Denmark is increasing.

The state of local migration can maybe be explained by the historical data from the other colonies of Black-headed gulls, breeding in other locations. Looking at table 1 and comparing the colony in Tarup-Davinde with the more closely placed colony, Odense Fjord, Ølund, it shows that both colonies had an increase from 2010 to 2011 and both a roughly decline from 2011 to 2013. Then again, an increase from 2013 to 2016 in both colonies, after here only the colony in Tarup-Davinde keeps increasing and the colony in Odense Fjord, Ølund again declines in number to 2019. In 2016 was Odense Fjord, Ølund start declining again another colony nearby starts growing. Gyldensteen Nor is established around 2016 and this might have something to do with the fact that the colony in Odense Fjord, Ølund is declining. Some of the Black-headed gulls could have started breeding in Gyldensteen Nor instead of Odense Fjord when they returned from their migration. But the fact that Tarup-Davinde also increases could also explain it, with the bird flying to the Tarup-Davinde gravel pit to breed instead. The same tendency of shifting colonies is seen on South Funen with the three closely placed colonies Siø, Nørreballe Nor and Botofte Skovmose. In figure 8 it shows clearly that the colony on Siø and in Botofte Skovmose follows the same tendency with a linear increase and then the colony in Nørreballe Nor is declining. As the colony in Nørreballe Nor is declining the two other colonies increase every year. It is difficult to define a reliable reason for the decline and the increase in the closely placed colonies and especially with the data collected in this project. But the fact that the nearby colonies show different trends indicate that there might be a correlation between the colonies close to each other.

My comparison of the two methods used to estimate bird numbers (binoculars/telescope and drone) shows that drone-based counting might be more accurate. In table 2 the two methods of counting Black-headed gulls are compared, and we could quickly conclude that the method with the drone is the best, because we get the best and more accurate result. But we must remember the fact that monitoring with drones still is a new method and is still being studied. If we were after a precise result it would be best to collect the data with the drone but the people monitoring in the Tarup-Davinde gravel pit have not had access to a drone. So, to continue the tendency of the colony from the last ten years it would be best to collect the data with binoculars and telescope. Although, a monitoring with the drone along with the binoculars and the telescope, could be good to see the accurate number of birds in the colony. If the number of breeding Black-headed gulls collected with the drone was used and compared with the other nine years it would be out of the 95-percentage confidence interval. Just look at the year 2011 were they counted 3000 breeding Black-headed gulls in Tarup-Davinde, that spot is already an extreme spot, so would 4489 breeding Black-headed gulls also be. If the collected data from the drone would be used in a comparison, there would have to be more years of collecting with the drone. The data collected in Tarup-Davinde since 2010 have given a good picture of the tendency of the colony and its breeding potential. So, using binoculars and



telescope is not wrong but not that accurate and there is a lot of source of errors. You could say, that if there has been a difference of 55 percent all the years, there will have been more birds in the colony, which is not a bad thing. And in that case the colony in the Tarup-Davinde gravel pit would be one of the largest in Denmark.

Looking at the Black-headed population in Denmark and all the colonies compared in this project, it generally looks good. We have looked at 11 colonies and 6 of them are increasing. One of the bad news is that the biggest colony in Denmark, Sneum Digesø, has declined since 2016 from 23180 breeding Black-headed gulls to 12140 in 2019. Almost a halving of that colony and that is the tendency there is shown in all the colonies there are declining in figure 8. Some of the colonies even decline more than with a halving.

## **Conclusion**

The population of Black-headed gulls in Tarup-Davinde has both decreased and increased in the last ten years, and in the last year, it has been increasing in breeding individuals. Therefore, it can be concluded that the colony of Black-headed gulls in the Tarup-Davinde gravel pit is increasing. The nature management would not have anything to do with the increase in population size but might have another positive effect on some of the other species who are breeding in association with the Black-headed gulls. It can also be concluded that the size of the Black-headed gull population has an impact on the species that breed in association with them, although the statistic model did not show a significant correlation for all three species. To conclude that the Black-headed gulls are making local migrations between colonies when one colony is declining would be unreliable. But despite the increase of breeding Black-headed gulls we have seen in this project it can be concluded that the population of Black-headed gulls is declining in Denmark. Nevertheless, more research is needed to find out more about the mechanisms underlying the trends we can see in our data.

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## Appendix

Appendix 1: Number of Black-headed gulls, Common terns, Mediterranean gulls and Black-necked grebes in the Tarup-Davinde gravel pit, from 2010 to 2019.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>Black-headed gull</b>	2000	3000	1500	300	500	600	1500	1000	2000	2004
<b>Common tern</b>	0	0	1	6	10	15	14	15	15	15
<b>Mediterranean gull</b>	1	3	2	0	2	0	0	0	4	3
<b>Black-necked grebe</b>	0	0	2	0	0	0	0	2	6	9

Appendix 2: A map over Birkum and Langager lake in the Tarup-Davinde gravel pit. Number 1 is the big island in Birkum lake, 2 is the western island in Langager lake, and 3 is the eastern island in Langager lake.



Appendix 3: A drone picture of the western island in Langager lake.



Appendix 4: A drone picture of the eastern island in Langager lake.



Appendix 5: A picture of the island in Birkum lake in the app DroneDeploy, after counting the Black-headed gulls using the counting tool.



Appendix 6: A closeup of the counting of the Black-headed gulls in the app DroneDeploy.

