COMPARING DRONE TECHNOLOGY TO TRADITIONAL GROUND COUNT METHOD AND THE EFFECTS OF NATURE MANAGEMENT ON BREEDING BLACK-HEADED GULL (*CHROICOCEPHALUS RIDIBUNDUS*) COLONY IN TARUP-DAVINDE

* Title of bachelor project: Nature management and age structure of breeding Black-headed Gull, Larus ridibundus, population in Tarup-Davinde

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Abstract

The Worlds populations of seabirds have been declining for the past decades due to human disturbance, degradation of habitats and overgrowth of breeding sites among others. In Denmark, the population of a common seabird, the Black-headed Gull, has been decreasing since the 1980'es with over 100.000 breeding pairs disappeared. In this study, the population of a Black-headed Gull colony in Tarup-Davinde was monitored by both drone and telescope. It was found that counting the population by telescope gave an underestimation of the actual population size, with only 45% of the gulls counted by telescope compared to the drone. In Tarup-Davinde the colony of breeding Black-headed Gulls was divided among three islands located in Birkum Lake and Langager Lake. Nature management that consisted of removing high vegetation was performed on the biggest of the three islands to see if it would positively affect the population, but no immediate effect was detected indicating a longer study period would be necessary. Tarup-Davinde and 10 other Danish Black-headed Gull colonies were also monitored to see if the breeding gulls seemed to favor a specific breeding site environment. The results showed that colonies with most gulls per square meter preferred a breeding site with a high density of ground vegetation in the island center with high vegetation at the edges surrounding the breeding site. Further analysis of the 11 colonies was made in the statistics software R, based on historical data obtained from a database of Danish bird observations and data from 2019. These results showed that fluctuations were detectable in all colonies, which signifies the importance of regular and accurate observations in the future, which could easily be provided by a drone.

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Introduction

For the past decades, seabirds have declined all over the world (Croxall *et al.* 2012). According to a study from 2015 (Paleczny *et al*, 2015) the global seabird population is assumed to have dropped 67.9% between 1950 and 2010. Human disturbance, degeneration of habitats, breeding sites that are overgrown by vegetation, commercial fishery, pollution and predation by invasive predators are thought to be the causes of the decline in seabird populations (Croxall *et al.* 2012; Lehikoinen *et al*. 2017).

In Denmark, the seabird the Black-headed Gull, *Larus ridibundus*, is a common breeding bird. It breeds in colonies near the coasts and wetlands, in lakes on small islands and in gravel pits and marshes (Bregnballe *et al.* 2015). Although common in Denmark, the Black-headed Gull populations have decreased since the mid 1980'es, with 100,000 breeding pairs lost in Denmark between 1988 and 1998 (Heldbjerg 2001), which left the Danish population on about 110,000 – 125,000 pairs in 2000 (Kjeldsen 2008). In 1997 it was put on the Danish Nature Agency's yellow list for species requiring special attention (Stoltze & Pihl 1998). In 2011 the Danish population was estimated to approximately 80,000 pairs (DOFbasen, *Hættemåger (Chroicocephalus ridibundus)*) The Black-headed Gull is considered a keystone species since it positively affects other breeding species, which include The Black-necked Grebe (*Podiceps nigricollis*), The Great Crested Grebe (*Podiceps cristatus*), The Little Gull (*Hydrocoloeus minutus*) and The Black Tern (*Chlidonias niger*) and various of waterfowl species (Kjeldsen 2008). These species nest in association with Black-headed Gull colonies to gain protection against predators, because Black-headed Gulls are an aggressive species that can protect both its own and other species' nests against predators (Viininen 2000).

A status report from 2017 regarding the Wadden Sea, an important area in the southeastern part of the North Sea for coastal breeding birds, also shows an ongoing decline in the population of Black-headed Gulls (Koffijberg *et al.* 2017). In this report, the authors argue that breeding failure usually delays signs of population decline by several years because the coastal breeding birds are long-lived species. Thus making it difficult to understand what is causing population decline in Black-headed Gulls not just in the Wadden Sea, but also in the rest of Denmark. Poor breeding success has proved to be one factor affecting population decline in seabirds and it was also found, that the Black-headed Gull colonies had low breeding success in most parts of the Wadden Sea. They also found that the annual survival of adult and subadult birds, meaning first-year survival, played a more important role for the Black-headed Gulls than breeding success in relation to population decline. Food resources seem to be a crucial limitation for annual survival (Koffijberg *et al.* 2017) and therefore it may also be an important driver for the decline in Black-headed Gull populations. Black-headed Gulls are versatile feeders and forage at a variety of habitats (Heldbjerg 2001) but in particular on fields and thus increased agricultural pressure could explain the lack of food available for the birds (Naturhistorisk Museum Århus; Koffijberg *et al.* 2017). Another study made in France (Péron *et al.* 2010) discovered that the colony size affected the survival of the chicks in the colony. They found a negative colony effect for chicks only a couple of days old, but as they grew older the proportion of surviving chicks increased with the colony size, meaning that if a chick survived the first days after hatching, it had a better chance at surviving if living in a big colony compared to living in smaller one. The same study (Péron *et al.* 2010) found that the larger colonies were more productive, compared to smaller ones and that the risk of complete colony failure increased as the colony size decreased. Besides that, the type and height of vegetation growing on the breeding site are thought to affect the breeding population of seabirds too (Lehikoinen *et al*. 2017). Since the overgrowth of vegetation on the breeding site can reduce the area accessible for breeding, it can lead the gulls to move to new breeding sites (Kjeldsen 2008). In Canada a study found, that bird populations had diminished due to the overgrowth of Common Reed (*Phragmites australis*) (Meyer *et al.* 2010). Another example was seen in Vejlerne, an important breeding area for birds by the Limfjord in Denmark, where Black-headed Gulls had trouble gaining access to their nests unhindered due to dense Reed beds (Kjeldsen 2008).

As stated above, several elements are affecting the population size and fluctuations of Black-headed Gulls. It is difficult to determine which ones are causing a decline in the populations since not enough research has been made on the subject (Heldbjerg 2001). Thus it is crucial to monitor the colonies to keep a watch on the fluctuations, and maybe also the environments they breed in since they can affect the breeding success (Arlt *et al.* 2008; Lehikoinen *et al*. 2017). In Denmark, Black-headed Gull colonies have been monitored regularly since the 1960'ies (DOFbasen) by binoculars or telescopes or by walking through the colony (Kjeldsen 2008; Holm & Bregnballe 2019). These types of observations (done by telescope or binoculars) are hereafter referred to as ground counts.

Colonial breeding birds, like the Black-headed Gull, breed close together. To avoid disturbance of the breeding birds, guidelines have been set for ground counts which request that the observer stays at a distance outside the colony when monitoring it (Holm & Bregnballe 2019). This makes it more difficult to obtain the real number and size of the colony because ground counts often are an underestimation of the real number (Blew 2003). Also, some colonies are too big or are breeding on islands too far away from land to be counted from a distance. In Denmark there are three examples of breeding sites lying far away, which are seen in Egå Engsø near Århus and in Filsø and Sneum Digesø near Esbjerg. Here only 45-60% of the true estimate of gulls was counted (Holm & Bregnballe 2019). With colonies like these, it would be necessary to visit the colony in order to be able to perform a ground count. The trouble with visiting a breeding colony is disturbing the birds, which can lead to lower breeding success (Carney & Sydeman 1999). It has been shown empirically in studies, that an observer's presence in study colonies is associated with negative impacts (Borrelle & Fletcher 2017). Black-headed Gulls are a long-lived species and they are found to be more vulnerable during breeding. Being more inclined to reduce parental effort if breeding conditions are unfavorable, they thus are particularly vulnerable to a disturbance caused by researchers (Blackmer *et al.* 2004). When an observer enters a breeding colony it may scare the birds of their nest allowing inter- or intraspecific predation or even abandonment or intraspecific aggression on the nests and thus loss of nests and chicks (Holm *et al.* 2018; Carney & Sydeman 1999). When conservation and monitoring activities reduce breeding success it increases the risk of a continuous decline in the population size, which in a worst-case scenario could lead to the extinction of vulnerable species (Borrelle & Fletcher 2017).

New technology to monitor seabirds and other wildlife has started to gain ground. It is the use of drones, also referred to as unmanned aerial vehicles (UAV), unmanned aerial systems (UAS) or remotely piloted aircraft (Hodgson 2018). Drones are gaining ground in ecological monitoring since they are a cost-effective way to monitor wildlife (Hodgson 2018) and are able to survey places that are normally hard to access (Hodgson et al. 2016). They are also useful in monitoring aggressive or sensitive species since they are remotely controlled (Chabot & Bird 2015). Drones have already been used in a variety of applications in wildlife science. This includes habitat research, wildlife telemetry tracking and monitoring of Sumatran Orangutan, marine mammals and elephants in South Africa (Chabot & Bird 2015; Wich *et al.*, 2016; Koski *et al.* 2010; Vermeulen *et al.*, 2013;). Drones seem to be a good alternative to ground count when monitoring waterbirds since these bird species are sensitive and tend to aggregate in small open areas. These areas are either used for breeding or foraging and are often hard to access but easily overflown by a drone (Chabot & Bird 2015).

Drones have also been found to be more precise in counting compared to the traditional ground count method (Hodgson *et al.* 2018; Hodgson *et al.* 2016). Hodgson *et al.* (2018) tested the accuracy of fake seabird colonies and found that drones were between 43% to 96% more accurate compared to ground count. The more accurate the counted numbers are the greater statistical power in finding sensitive population fluctuations is achieved. When detecting a trend in a population, the precision of the observations is highly important since it increases the statistical ability to find the trends. However, the precision does not guarantee greater estimate accuracy (Gerrodette 1987). Thus Hodgson *et al.* (2018) argue that a drone will provide greater statistical power for observing sensitive population fluctuations because of the increased accuracy and precision in the obtained data. And in addition, it may improve ecological management and outcomes hereof, since they are often dependent on the accuracy and timeline of the ecological data (Hodgson *et al.* 2018).

Besides increasing the statistical power, drones can also be timesaving. For example some bird species, like the Black-headed Gull, breed on the ground between vegetation making both birds and nests difficult to spot. But a drone would easily be able to spot them from the air. Also, some birds are breeding scattered around the country or even change breeding sites every year. In these situations, a drone could be a great help in locating the breeding site

(Holm & Bregnballe 2019). Other good qualities of using a drone to monitor a colony are, that it makes it possible to make quality assurance of the counting if the pictures or videos are saved by being able to count the birds again (Holm & Bregnballe 2019). Also still pictures introduce the opportunity of dividing the colony into multiple manageable subsets and thereby do the counting in multiple sittings (Hodgson 2016).

Although evidence on the extent of disturbance a drone inflicts on breeding birds during monitoring of the colony is limited, studies have shown that using drones reduce disturbance to colonial breeding birds compared to the traditional ground count method (Holm & Bregnballe 2019; Borrelle & Fletcher 2017). For some species, no behavioral changes were observed when monitored by drone. But some studies have also shown that some species are affected the same way when being monitored by drones as by the traditional ground count method (Borrelle & Fletcher 2017). And thus since drones as a method to monitor bird colonies are still new and evidence of its effect is limited, it is important to consider timing, duration, and frequency of data capture so that the disturbance is minimal. Although the use of drone in wildlife ecology is new, the drone technology is not, which offers great flexibility in size, color, flight profile, speed and also in sensor specification and data telemetry. This can help reduce the potential behavioral and physiological impacts on the colony, like the birds mistaking the drone for predation and thus fleeing the nest (Borrelle & Fletcher 2017.).

Although drones appear to somewhat reduce human disturbance of breeding seabirds (Holm & Bregnballe 2019; Borrelle & Fletcher 2017), other measures are needed to be taken into account to prevent future population declines. The habitat condition affects the birds since different breeding success is seen between different habitats (Arlt *et al.* 2008). Human actions have led to a reduction in breeding sites since the habitats preferred by the birds have either been degraded or overgrown by vegetation, which negatively affects the breeding success' and thus the population sizes (Croxall *et al.* 2012; Lehikoinen *et al*. 2017). A way to restore these habitats is through nature management also known as habitat management. Although little is known about the impacts of nature management, it has shown to have a positive effect on waterbird population sizes in wetlands (Lehikoinen *et al*. 2017). Management in the manner of vegetation removal by grazing, harrowing and cutting in wetlands has shown to correlate positively with an increase in bird numbers. Removal of vegetation by cutting increases the open area available for breeding, which can be favorable for many bird species. Also by removing vegetation as Common Reed, feeding opportunities are improved (Lehikoinen *et al*. 2017).

This project aims to investigate (1) whether the use of drones for monitoring breeding colonies provides more accurate and comparable data compared to the traditional ground count method. (2) Whether nature management on the breeding site could improve enough to show a positive effect on the breeding colony of the Black-headed gull.
(3) Whether there is a correlation between Danish Black-headed Gull population sizes and the environments they breed in.

Methods and materials

Study species

The Black-headed Gull is a protected bird in Denmark which breeds scattered throughout the country and in Europe and Asia (Naturhistorisk Museum Århus). They breed in colonies which can contain thousands of birds and their breeding sites are found near the coasts and wetlands, on small islands in lakes and in gravel pits and marshes, where they are nesting on the ground (Bregnballe *et al.* 2015; DOFbasen, *Hættemåger (Chroicocephalus ridibundus)*).). The Black-headed gull is known for its characteristic brown hood covering its head, chin and throat, that appear during the breeding season and from which the name originates. Legs and beak are red and the adult plumage is a pale grey body with wings displaying white leading edges and black-tipped primary wing feathers (The Cornellab of Ornithology). Their plumage change in winter with loss of the brown hood and instead display a white head with a brown spot visible at their ear-coverts.

The breeding season starts in February-March with the development of the brown hood and the egg-laying period occurs in late April- first in May where 2-3 eggs are laid followed by a hatching period of approximately 23-36 days (Naturhistorisk Museum Århus; DOFbasen, *Hættemåger (Chroicocephalus ridibundus)*). They mature at age 2 and have a lifespan up to 30 years (Naturhistorisk Museum Århus). The juvenile-plumage has a mottled pattern of brownish spots on the back, a black-tipped tail and two smudgy spots on each side of the head, one above the eye and one behind the eye. Also the juvenile gulls appear to have thinner beaks with dark tips and darker legs (the Cornellab of Ornithology; Naturhistorisk Museum Århus).

Study areas

Tarup-Davinde

The breeding colony studied in this project is located in Tarup-Davinde on Funen in Denmark. The colony is divided between three islands located in two lakes located closely to each other, respectively Birkum Lake and Langager Lake. The biggest island containing the biggest portion of the colony, is called The Black-headed gull Island and is in Birkum Lake - in this report referred to as Island 1. The two other lakes are in Langager Lake and will be referred to as Island 2 and Island 3 respectively as seen on figure 1[1].

Island 1, which is the largest of the three islands with an area of 3360m^2, have for the last past years started to be overgrown by vegetation mainly by Red Twig Dogwood (*Cornus sericea*). Therefor Island 1 was exposed to nature management to detect whether a positive correlation was found between the breeding colony and nature management. The two other islands, Island 2 and Island 3, are both notably smaller than Island 1 with areas of 192m^2 and 161m^2 respectively. Neither of the two smaller islands was as overgrown by vegetation as Island 1 and had only a couple of small bushes growing.

[1] https://www.google.com/maps/

Figure 1: Depiction of the three breeding sites; Island 1, Island 2 and Island 3, for Black-headed gull colony in Tarup-Davinde

Beside the colony in Tarup-Davinde, 10 other Black-headed Gull colonies breeding at different sites in Denmark was surveyed. These colonies are located at:
Sneum Digesø, Egå engsø, Filsø Gåseholm, Filsø Hjortsholm, Gyldensteen Engsø, Bøjden Nor, Ølund (Odense fiord), Siø, Nørreballe Nor and Botofte skovmose.

Egå Engsø

Egå Engsø is a newly restored 100 hectares lake located north of Århus in Jutland in Denmark. Its two islands is a popular site for a number of both breeding and roosting birds (DOF, *Egå Engsø*).

Filsø Gåseholm

Filsø is a 95 hectares restored lake located on the western coast of Jutland between Ringkøbing Fiord and the Wadden Sea. The lake is a popular area for a number of both migratory and breeding birds. Filsø consists of three separate lakes respectively Søndersø, Mellemsø and Fiddesø (Aage V. Jensen Naturfond, *Filsø*). Gåseholm is one of the islands located in Mellemsø and is used by Black-headed Gulls as a breeding site.

Filsø Hjorteholm

Filsø is a 95 hectares restored lake located on the western coast of Jutland between Ringkøbing Fjord and the Wadden Sea. The lake is a popular area for a number of both migratory and breeding birds. Filsø consists of three separate lakes respectively Søndersø, Mellemsø and Fiddesø (Aage V. Jensen Naturfond, *Filsø*). Hjorteholm is one of the islands located in Søndersø and is used by Black-headed Gulls as a breeding site.

Gyldensteen Engsø

Gyldensteen Engsø is a freshwater lake located at Gyldensteen Strand, which is a restored area that also contains a saltwater fiord called the Costal Laguna on Nordfyn. Gyldensteen Strand is an important area for a number of waterbird because of the big wetland area. (DOF, *Gyldensteen Strand*) Engsøen contains several islands, but the Black-headed Gulls used only one as breeding site and thus only this one was studied. This island was located in the middle of the northern part of the lake.

Bøjden Nor

Bøjden Nor is a shallow Laguna located on the westcoast of Horneland-halvøen. This 118 hectares area is protected and one of Fuglefondens sanctuaries because of its importance for a number of breeding and roosting birds. The cove contains two landscaped islands designed for breeding sites for birds, including the Black-headed Gull (DOF, *Bøjden Nor*).

Ølund (Odense Fiord)

Ølund-Lammesøområdet is one of the greatest bird siting on Funen, located at Odense Fiord westcoat. The 158 hectares area was reestablished in 2009 and four landscaped islands were made for roosting and breeding birds (DOF, *Ølund-Lammesøområdet*). The island used by Black-headed Gulls as breeding site and thus studied in this project is located near the road Lammesøvej in the lake called Mellemstykket.

Siø

Siø is an island located between Tåsinge and Langeland. The breeding site studied in this project is an island located in a lake on the southeastern part of the island, south of highway 9.

Nørreballe Nor

Nørreballe Nor is located on Southern Langeland and is a part of a sanctuary owned by Fuglefonden which also include Tryggelev Nor and Salme Nor. Nørreballe Nor is a reestablished lake from 2004 and has become a popular siting for roosting and breeding birds (DOF, *Tryggelev Nor*). Nørreballe Nor contains four island designed for the birds but only the island located in the most northern end of the lakes was used by Black-headed Gulls and was thus studied in the project.

Botofte Skovmose

Botofte Skovmose is part of a low bottom area located on Langeland on the coast of the Great Belt. The lake attracts a number of bird species including the Black-headed Gull (Naturstyrelsen, *Vådeområdeprojekt: Botofte Skovmose*). The island studied for this project was located in a lake east of the town Botofte. This lake contained three islands but only the one located south of the lake hosted breeding Black-headed Gulls, and was thus studied in this project.

Sneum Digesø

Sneum Digesø is a 26 hectares artificial lake located south of Esbjerg in Jutland in Denmark. Every year it host thousands of breeding birds on its four islands including one of Denmark's largest breeding Black-headed Gull colonies (DOF, *Sneum Digesø*).

See appendix I for pictures of each of the studied islands at each location.

Ground count

A telescope was used to monitor the colony in Tarup-Davinde during the breeding season of 2019. The observer was standing on mainland approximately 280 meters from Island 1, approximately 90 meters from Island 2 and approximately 150 meters from Island 3. All the black-headed gulls present during the monitoring on the island were counted. This procedure was done once during the morning due to good light and visibility with assistance from experienced bird counter Per Rasmussen.

Drone

A Dji Phantom Pro Drone was used to monitor the colony on the three isles. This drone was selected based on another study, which showed that when monitored, the breeding Black-headed Gulls did not react on the drone, and was thus not disturbed (Holm & Bregnballe 2019). Two apps were used as tool, respectively Dji Go and DroneDeploy, which were both downloaded from Google Play. The Dji Go app is developed by Dji and was used to control the drone manually from a handheld android device and used to take a full picture shot of each of the three islands. The DroneDeploy app is developed by DroneDeploy and was used to both map the area of Island 1 and collect the images taken during the flight time.
The drone was set to fly at an altitude of 50 feet since this gave the best quality of picture (Holm 2018) and with a 75% front overlap and 70% side overlap of pictures that ensured the pictures could be stitched together. Based on altitude and overlap the app automatically calculated the number of transects to 18 transects. The flight time lasted around 14 minutes and 282 pictures were taken.

The pictures were then uploaded to the DroneDeploy server[2], which subsequently stitched the pictures together to an orthomosaic of the whole island. All of the Black-headed Gulls present on the pictures were then counted manually in the DroneDeploy app.

Island 2 and 3 were small enough, so only a single image of each of the island was necessary. The gulls on these two islands were also counted manually.

While the drone flew over the islands, the birds were observed through a telescope to see if they were disturbed by the presence of the drone.

[2] https://www.dronedeploy.com

In order to fly with a drone in Denmark, it is regulatory to have a drone certificate. This was required from a Danish website associated with the Agency of Traffic, Construction and Residence[3].

Nature management

The nature management was performed on Island 1 on the 5th and 12th of February 2019, before the Black-headed Gulls started to nest and breed. The nature management consisted of removal of small bushes and trees, mainly Red Twig Dogwood, *Cornus sericea*. This was done in collaboration with Henrik Kalckar Hansen, ranger in Tarup-Davinde. A motor driven boat was used to get to the island and a chain saw was used to cut down bushes and trees.

Collection of historical data

Data of the Tarup-Davinde colony's population size from the years 2010 to 2018 was collected from a database of bird observations called DOFbasen[4]. DOFbasen is a database containing bird observations collected for thousands of bird species in Denmark by volunteering and experienced bird counters. Counts were made several times each year but in this project the highest number of breeding Black-headed Gulls registered from each year was used. The data registered in DOFbasen for the colony in Tarup-Davinde had all been obtained by the ground count method as described above, but by multiple bird counters through the years.

The population numbers from the 10 Danish colonies from years 2010 to 2019 were also collected from DOFbasen. In this project the highest number of birds registered from each year was used. This data had been collected and entered by different experienced bird counters. They either used telescope or binoculars. Data was not available for every year due to no monitoring these years.

Area and coverage

The area covered by vegetation on Island 1 in Tarup-Davinde before nature management was calculated with help from Google Maps[5], which contain a function that calculate the area of a selected region. Firstly Island 1 was found in Google Maps and then the function "measure distance" was used by clicking right on the computer mouse and the encircling the desired area, in this case Island 1, with the computer mouse. The Google Maps server then automatically calculated the total area. Then the area of Island 1 covered by vegetation was calculated the same way and the percentage was calculated (see appendix II). The area of vegetation on Island 1 after nature management on Island 1 was calculated on the DroneDeploy website[6] which have a similar function able to automatically calculate the area

[3] http://dronetegn.dk
[4] https://dofbasen.dk/search/index.php
[5] https://google.dk/maps
[6] https://www.dronedeploy.com

by encircling the desired area. The percentage of vegetation removal was then calculated manually (Appendix II)

The total area for each of the 11 breeding sites were also calculated by Google Maps. The total area was used to find the number of Black-headed Gulls per square meter for each of the 11 breeding sites to see at which environment the density of gulls were highest.

The percentage of vegetation coverage was also estimated by looking at satellite photos from Google Maps of each of the breeding sites (appendix I). This percentage is a rough estimate of how much vegetation was covering each breeding site and was performed in spring 2019

All of the 11 Danish colonies were visited at least once in spring 2019 to observe the type and height of vegetation present on the breeding sites through binoculars.
Based on the density and height of vegetation present each island was divided into four categories of environment:
1: Low vegetation and low vegetation density (<50 %)
2: Low vegetation and high vegetation density (> 60 %)
3: Both low and high vegetation and low vegetation density (<50 %)
4: Both low and high vegetation and high vegetation density (>60 %)
Low vegetation refers to plants and grass covering the ground while high vegetation refers to shrubs, trees and reed.

Statistics

In this project all analysis of statistics was performed in the software, R, for statistical computing and graphics. One of two types of regression models was fitted to the data depending on which was statistically the best fit. This was determined by looking at the p-value to see which model showed most statistical significance. These two models were a quadratic model ($y = x \cdot a^2 + b \cdot x + c$) and a linear model ($y = x \cdot a + b$) and the coefficients a, b and c was estimated from fitting the data to the model. Also in most cases a regression line was fitted to the data too.

Level of statistical significance in this report is set to $p < 0.05$.

Counts were not available from every year on DOFbasen for some of the 11 colonies. These years with missing data was entered in the software, R, as y = NA.

Results

1430 breeding Black-headed gulls were counted on Island 1, 294 Black-headed gulls on Island 2 and 280 Black-headed gulls on Island 3 resulting in a total count of 2004 gulls counted by telescope in Tarup-Davinde.

The number of gulls on Island 2 was taken from a previous count because vegetation had gotten to high. The number of gulls counted for Island 2 was 147 pairs of breeding Black-headed Gulls, which was multiplied by 2 to get an estimate of the total number.

By drone 3620 Black-headed Gulls were counted on Island 1 (fig. 2), 301 Black-headed gulls on Island 2 (fig. 3) and 466 Black-headed gulls on Island (fig. 4). Thus resulting in a total count of 4411 breeding Black-headed Gulls counted by drone in Tarup-Davinde.
The birds were easily spotted and counted on the images from the drone and were not seemingly disturbed by the drones presence (fig. 2).

Comparing the two methods show that approximately 45 % of the gulls were counted by telescope if the total count by drone is viewed as the true number of breeding Black-headed Gulls. On Island 1 the ground count method counted 40 % of the gulls, on island 2 98 % of the gulls were counted by telescope and on Island 3 60% of the gulls were counted by telescope.

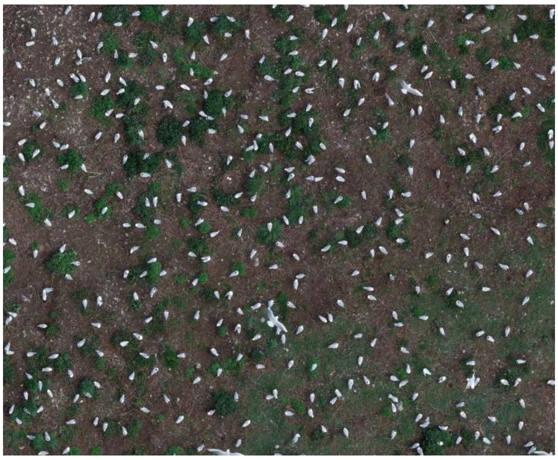

Figure 2: A section from Island 1 taken by drone from the DroneDeploy server. The picture shows no response from the Black-headed Gulls towards the drone.

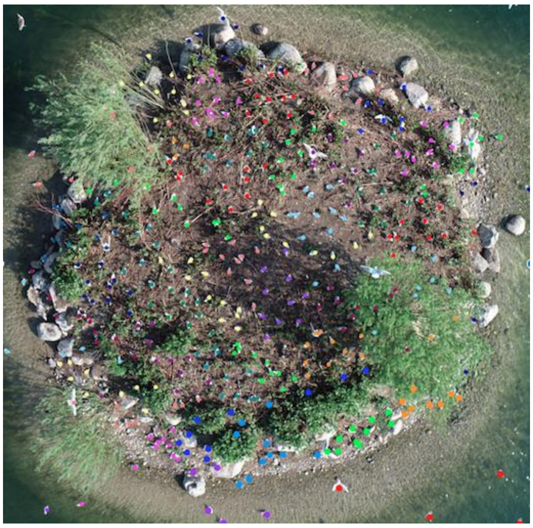

Figure 3: Picture of Island 2 taken by drone. The colored dots represents counted Black-headed Gulls

Figure 4: Picture of Island 3 taken by drone. The colored dots represents counted Black-headed Gulls

The regression model fitted to the data of the Tarup-Davinde colony from 2010-2019 had the form of a quadratic model ($y = x \cdot a^2 + b \cdot x + c$) where y is the number of birds, and the estimated coefficients from this analysis were a = 8.23e+01, b= -3.32e+05 and c = 3.34e+08 (fig. 5). The model had a multiple R^2 value of 0.57 and p value of 0.054, which is just above the level of significance meaning the coefficients, did not show statistical significance. The population decreased from 2010 to 2015 but subsequently increased from 2016 to 2019. The grey dotted lines show the 95% confidence interval, which in this analysis contained all observations except two extreme points from 2011 and 2013, also referred to as outliers. The green marker displays the observation done after nature management and lies inside the confidence interval and thus nature management did not seemingly affect the population size in 2019.

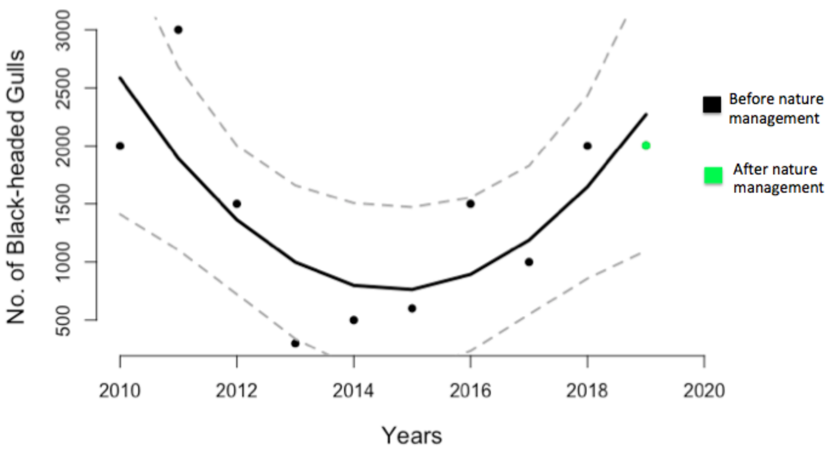

Figure 5: The population size of the Black-headed Gull colony in Tarup-Davinde from 2010 to 2019 with 95% confidence interval. The green marker represents the population size of the Black-headed Gull colony after performed nature management.

Before nature management 75% of Island 1 was covered by vegetation. After nature management 20 % of the vegetation had been removed, leaving 60% of Island 1 to be covered by vegetation (appendix II).

Population size at year 2019, type of vegetation, island areas and vegetation coverage for each breeding site at the 11 colonies was estimated (table 1).

Table 1: Area (m^2), vegetation coverage estimation (%), population size in 2019, density of breeding Black-headed Gulls and environment type at the breeding site for the 11 Danish colonies

	Area (m^2)	Vegetation coverage estimate (%)	Population size 2019 (no. of Black-headed gulls)	Density of breeding Black-headed gulls	Environment type
Tarup-Davinde	3713 m^2	60 %	2004 gulls	0.54 $\frac{gulls}{m2}$	**4**
Egå Engsø	7138 m^2	85 %	2500 gulls	0.35 $\frac{gulls}{m2}$	**2**
Filsø Gåseholm	1895 m^2	95 %	77 gulls	0.041 $\frac{gulls}{m2}$	**2**
Filsø Hjorteholm	3531 m^2	75 %	480 gulls	0.14 $\frac{gulls}{m2}$	**2**
Gyldensteen Engsø	4965 m^2	30 %	480 gulls	0.097 $\frac{gulls}{m2}$	**1**
Bøjden Nor	874 m^2	30 %	43 gulls	0.050 $\frac{gulls}{m2}$	**1**
Ølund (Odense Fiord)	641 m^2	90 %	200 gulls	0.31 $\frac{gulls}{m2}$	**4**
Siø	2836 m^2	30 %	965 gulls	0.34 $\frac{gulls}{m2}$	**3**
Nørreballe Nor	1594 m^2	15 %	50 gulls	0.031 $\frac{gulls}{m2}$	**1**
Botofte Skovmose	2062 m^2	95 %	600 gulls	0.29 $\frac{gulls}{m2}$	**4**
Sneum Digesø	38713 m^2	75 %	12140 gulls	0.31 $\frac{gulls}{m2}$	**4**

The highest densities of Black-headed Gulls per square meter are seen at the environment categories 2, 3 and 4 (figure 6 and table 1). The highest densities observed range between 0.29 and 0.54 and four of them are found at type 4. These four colonies are Tarup-Davinde, which has the highest density at 0.54 gulls per square meter, Ølund (Odense Fiord), Botofte Skovmose and Sneum Digesø. The two other colonies with a high density are Egå Engsø and Siø, which are found at type 2 and 3 respectively. The last 5 colonies have densities ranging from 0.03 to 0.14 and are found at environment type 1 or 2. The regression model fitted to fig. 6 had the form of a linear model ($y = x \cdot a + b$) where y is number of birds per square meter and the estimated coefficients from this analysis were a = 0.10 and b= -0.031. The model had a multiple R^2 value of 0.63 and the estimated coefficients were statistically significant since the p value was 0.0034 and thus below the level of statistical significance.

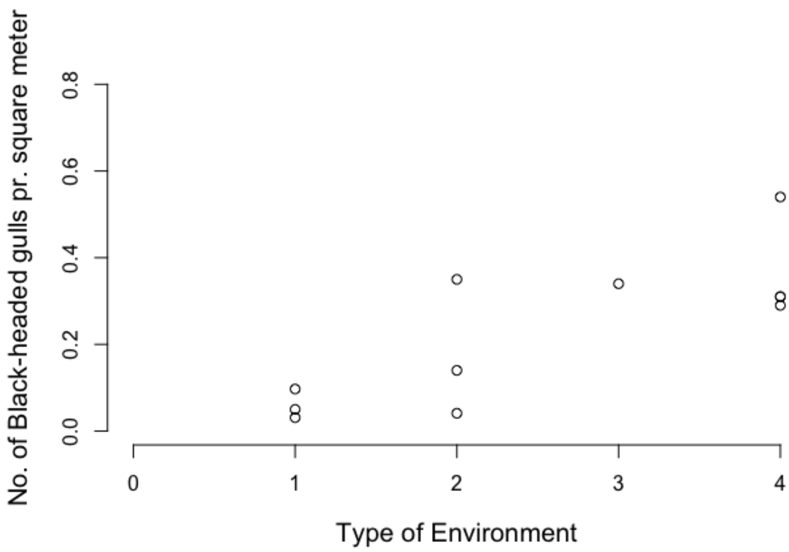

Figure 6: The density (gulls pr. square meter) of the Black-headed Gull colony in Tarup-Davinde and the 10 other Danish colonies from 2019 in relation to the type and density of vegetation present on the breeding site.

All of the 11 colonies population sizes from 2010 to 2019 is depicted in fig. 7 and fig. 8. The colony from Sneum Digesø was put in a separate graph (fig. 8) because of its high population size. Since 2010, 6 of the colonies had generally increased in populations size, 4 of the colonies had decreased while one ended up at the same population size in 2019. However fluctuations in the population sizes was detected in all 11 colonies.

The regression model fitted to the population of Egå Engsø (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = 205.90 and b= -413012.68. The model had a multiple R^2 value of 0.46 and a standard error at 83.8. The estimated coefficients were statistically significant since the p value was 0.044 and thus below the level of statistical significance. The population showed an increase from 2010 to 2019.

The regression model fitted to the population of Filsø Gåseholm (fig. 7) had the form of a quadratic model ($y = x \cdot a^2 + b \cdot x + c$) where y is number of birds and the estimated coefficients from this analysis were a = -1.22e+02, b= 4.96e+05 and c = -4.98e+08. The model had a multiple R^2 value of 0.46 and a standard error at 6.77e+01. The estimated coefficients were not statistically significant since the p value was 0.29 and thus above the level of statistical significance. The population showed a curved course with an increase from 2013 to 2016 followed by a decrease from 2016 to 2019. No registrations were made from 2010-2012.

The regression model fitted to the population of Filsø Hjorteholm (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = 95 and b= -191,088. The model had a multiple R^2 value of 0.18 and a standard error of 205. The estimated coefficients were not statistically significant since the p value was 0.72 and thus above the level of statistical significance. The population showed a general increase but with fluctuations. No registrations were made from 2010 to 2014 and in 2016 and 2018.

The regression model fitted to the population of Gyldensteen Engsø (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = -87.10 and b= 176,476.50. The model had a multiple R^2 value of 0.31 and a standard error of 91.31. The estimated coefficients were not statistically significant since the p value was 0.44 and thus above the level of statistical significance. The population showed a general decrease but with fluctuations. No registrations were made from 2010-2015.

The regression model fitted to the population of Ølund (Odense Fiord) (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = -118.6 and b= 239,600.3. The model had a multiple R^2 value of 0.18 and a standard error of 112.7. The estimated coefficients were not statistically significant since the p value was 0.30 and thus above the level of statistical significance. The population showed a general decrease but with fluctuations and an extreme outlier in 2011 at 2580 gulls. No registrations were made in 2012, 2017 and 2018.

The regression model fitted to the population of Bøjden Nor (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = 39.37 and b= -79,116.94. The model had a multiple R^2 value of 0.34 and a standard error of 20.94. The estimated coefficients were not statistically significant since the p value was 0.10 and thus above the level of statistical significance. The population showed a general increase but two outliers in 2018 and 2019 of 600 gulls and 43 gulls respectively. No registrations were made in 2010.

The regression model fitted to the population of Siø (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = 111.2 and b= -223,284.1. The model had a multiple R^2 value of 0.19 and a standard error of 115.1. The estimated coefficients were not statistically significant since the p value was 0.39 and thus above the level of statistical significance. The population showed a general increase with two outliers in 2018 and 2019 of 2600 gulls and 965 gulls respectively. No registrations were made from 2013 to 2015.

The regression model fitted to the population of Botofte Skovmose (fig. 7) had the form of a linear model ($y = x \cdot a + b$) where y is number of birds and the estimated coefficients from this analysis were a = 127.28 and b= -2,255,765.13. The model had a multiple R^2 value of 0.37 and a standard error of 58.27. The estimated coefficients were not statistically significant since the p value was 0.060 and thus above the level of statistical significance. The population showed a general increase but with one outlier in 2016 on 2000 gulls.

The regression model fitted to the population of Nørreballe Nor (fig. 7) had the form of a quadratic model ($y = x \cdot a^2 + b \cdot x + c$) where y is number of birds and the estimated coefficients from this analysis were a = -1.84e+01, b= 7409e+04 and c = -7462e+07. The model had a multiple R^2 value of 0.68 and a standard error at 4.82e+00. The estimated coefficients were statistically significant since the p value was 0.019 and thus below the level of statistical significance. The population showed a curved course with an increase from 2010 to 2014 followed by a decrease from 2015 to 2019.

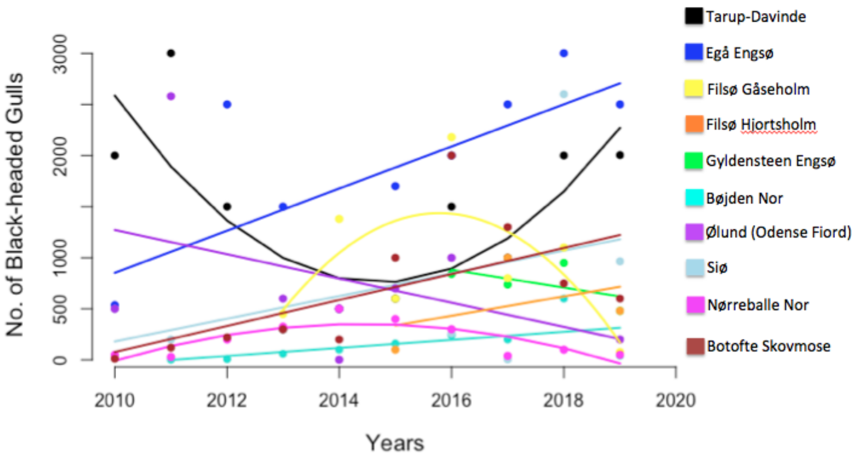

Figure 7: The population size of the Black-headed Gull colonies in Tarup-Davinde and the 10 other Danish colonies from 2010 to 2019.

The regression model fitted to the population of Sneum Digesø (fig. 8) had the form of a quadratic model ($y = x \cdot a^2 + b \cdot x + c$) where y is number of birds and the estimated coefficients from this analysis were a = -3.49e+02, b= 1.41e+06 and c = -1.42e+09. The model had a multiple R^2 value of 0.60 and a standard error at 1.50e+02. The estimated coefficients were statistically significant since the p value was 0.040 and thus below the level of statistical significance. The population showed a curved course with an increase from 2010 to 2016 followed by a decrease from 2017 to 2019 but with one outlier in 2016 on 23,180 gulls.

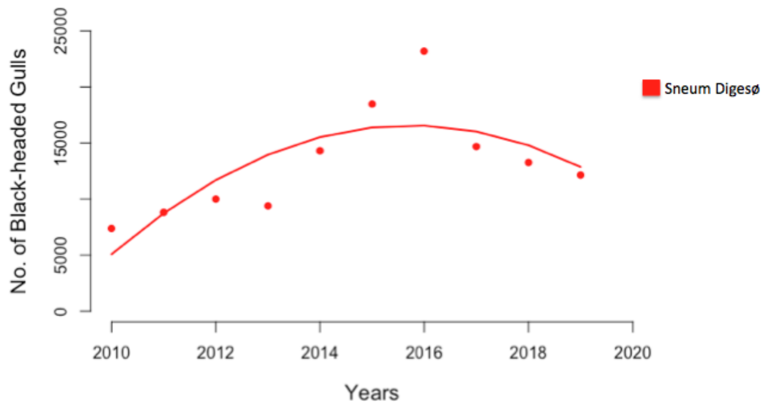

Figure 8: The population size of the Black-headed gull colonies in Sneum Digesø from 2010 to 2019.

Discussion

The breeding Black-headed Gull colony in Tarup-Davinde was in the spring of 2019 monitored by both telescope and drone. The total count by telescope was 2004 gulls while the total count by drone was more than two times as big at 4411 gulls, meaning that the colony in Tarup-Davinde was twice as big as expected. If the total count by drone is viewed as the true population size, then the traditional ground count method by telescope only counted 45% of the gulls. This result is similar to those found in Holm & Bregnballe (2019) study. They found that 45% to 60% of gulls were counted by telescope compared to the drone.

The deviation between the two monitoring methods was biggest at Island 1 and Island 3, where only 40% and 60% gulls were counted by the ground count method. On Island 2 the deviation was too little to be of significance since 98% of the gulls were counted by telescope. Evidently, the deviation between the counts was biggest for Island 1 (40%), which also is the biggest island, meaning that comparing ground counts between islands with different sizes can be deceptive.

The big deviation between Island 2 (98%) and Island 3 (60%) was also worth noting since these two islands had almost the same size. The difference between these two islands during ground count was the distance between observer and island. The observer stood 90m^2 from Island 2 and 150m^2 from island 3 meaning that distance may also affect the quality of the ground count results since the shorter distance to Island 2 could make it easier for the observer to see and count the gulls, and separate them from other breeding species like terns. Thus comparing ground counts between islands made at different distances from the breeding site can be deceptive. These results implicate that it would be more important to monitor the bigger islands or the islands located at a far distance from an observing point with a drone.

However, if only some colonies are monitored by drone, the comparison of population sizes of different colonies that are not all monitored by drone, would be deceptive. Thus it is necessary to understand how data derived from drones compare with those from ground counts. Hodgson *et al.* (2016) created a ratio of drone counts and ground counts to help make interpretations between the two monitoring methods. They discovered that when creating 15 duplicate counts a drone counts and ground counts ration with an accuracy of +/- 10% could be made (Hodgson *et al.* 2016). Creating a ratio of the two monitoring methods could be a beneficial way to interpret and compare data derived from the two methods, and to compare historical data with new data derived from drone counts (Hodgson *et al.* 2016).

Besides being a more precise counting method, the drone has been found to be less disturbing for the breeding colony (Holm & Bregnballe 2019; Borrelle & Fletcher 2017). The Dji Phantom Pro drone, which was used in this study, had already been tested as a monitoring device on breeding Black-headed Gull colonies, showing no respond from the gulls (Holm & Bregnballe 2019). During the monitoring for this study, the gulls showed no response toward the drone either as seen in figure 2. Also as a precaution, while the drone flew over the islands collecting data, the colony was observed through a telescope to check the gulls' reaction. Through this observation, it was also noted that the drone did not seemingly disturb the breeding Black-headed Gulls (fig. 2). Monitoring the colony in Tarup-Davinde by telescope did not disturb the colony either since the observing point was at an appropriate distance from the breeding site. The amount of disturbance is an important aspect when comparing and evaluating the two methods to each other. This is because the ground count method that was used in the past did not cause any disturbance (DOF, *Tilgængelige optællingsvejledninger til ynglefugle*) and thus it was crucial that the drone did not as well, in order to be accepted as a superior monitoring method.

Although monitoring by drone has shown to be a more precise counting method (Hodgson *et al.* 2018; Hodgson *et al.* 2016) the result can still vary depending on the observer's skills and experience (Holm & Bregnballe 2019). Thus a source of error when counting specific species on drone images is not being able or experienced enough to distinguish between species. In this study, it was difficult to distinguish between breeding Black-headed Gulls, the Mediterranean Gull (*Ichthyaetus Melanocephalus*) and Terns (*Sternidae*) since they have similar looks and the two latter are often found breeding close to the Black-headed Gull colony (Holm & Bregnballe 2019; DOFbasen, *Observationer ved Birkum*). The number of Mediterranean Gulls and Common Terns breeding close the Black-headed Gull colony in Tarup-Davinde is, however, too small (DOFbasen, *Observationer ved Birkum*) to be of significance for the total count of the population size of the Black-headed Gulls. An improvement could be flying at a lower altitude, as long as it does not increase disturbance. In this project, the altitude was set to 20 meters. In the study of Holm & Bregnballe from 2019, the altitude was in some transect flights set to 10-15 meters and did not show any disturbance. Transect images taking at an altitude of 10-15 metes would possibly make it easier to distinguish between different species especially for inexperienced counters. It may also make it easier to count the gulls if they are hiding under high vegetation.

The breeding Black-headed Gull colony in Tarup-Davinde showed a decrease from 2010 to 2015 (fig. 5). Especially from 2012 to 2013 a drastic drop from 1500 gulls to 300 gulls was observed supposedly because of predation on Island 1. In 2013 a fox had been observed swimming away from the island by ranger Henrik Kalckar Hansen. According to him most of the breeding gulls were breeding on Islands 2 and 3 that year but also in 2014 and 2015. Predation could explain why the population size dropped so drastically in just one year and why it stayed low for another two years. Another explanation, which could also be applied for the other outlier observed in the year 2011 (3000 gulls), is that different bird counters collect the data obtained from the DOFbase. Thus the quality of the data may vary from year to year depending on the bird counters experience (Holm & Bregnballe 2019).
From 2015 the colony's population size started increasing and ended at roughly the same size as in 2010 (2000 gulls) implying that the colony had recovered from the predation and the following bad years.

Nature management did not seemingly affect the colony in neither a positive nor a negative way since the population size was the same in both 2018 and 2019. It may, however, be to soon to interpret, since the last count was done the same year as the nature management. It may be that the effects are not detectable yet but will be visible on a future population since nature management has been found to improve the number of water birds after three years of management (Lehikoinen *et al.* 2017).
It could also be, that the full carrying capacity of the breeding Black-headed gulls is reached in Tarup-Davinde. When compared to the other 10 colonies (table 10) the colony in Tarup-Davinde showed to have the highest density of gull per square meter. This shows that even though it is not the biggest colony in Denmark it contains many gulls compared to the area of the breeding site.

When comparing the density of breeding Black-headed gulls per square meter to the type of environment, it seems they prefer high vegetation to low vegetation. Out of the 11 colonies, five of those with the highest density of gulls per square meter were found in environments with high vegetation (fig. 6). This high vegetation was in most cases either shrub, trees or reed growing on the island edges except in Tarup-Davinde, where the shrubs had started to grow towards the center of Island 1. The breeding gulls may prefer breeding sites with high vegetation at the edges surrounding the islands and dense ground vegetation, because it reduces disturbance from unwanted visitors and offers them cover from predators. If the high vegetation, however, starts to overgrow the entire breeding site, it will evidently cause the

breeding birds to move (Kjeldsen 2008; Meyer 2010) and thus nature management in Tarup-Davinde was necessary to keep the colony from diminishing.
Since the data was based on visiting and monitoring each breeding site by binoculars from a distance, it is somewhat subjective. To improve these results and increase their objectivity it is recommended to monitor each breeding site more carefully, e.g. with a drone.

The model fitted to the data of both the breeding Black-headed Gull colony in Tarup-Davinde and Botofte Skovmose had p-values above the level of significance, respectively 0.054 and 0.060. These p-values are however very close to the level of significance at 0.05 and thus these two colonies are considered to exhibit statistical significance.

Counts of population size were not registered in the database every year for all of the colonies. This could be the reason for the lack of statistical significance for some of the colonies. From the 11 colonies, under half showed statistical significance and they all lacked observations for at least one year. A consequence of the missing data is that only strong tendencies are found in the colonies because the weak are not detectable.

When looking at all of the colonies (fig. 7 and fig. 8), all showed fluctuations both big and small. It is difficult to explain the reasons behind the big fluctuations and dynamics seen in the 11 colonies. Explanations could be predation like in Tarup-Davinde with the fox or maybe because of the weather. However, some fluctuations like those seen in Ølund (Odense Fiord) were the population size drops from 2580 gulls to 2 gulls seem to be too big to be caused by natural reason. An important source of error is the data itself since it is obtained from the DOFbase and since it is collected and registered by multiple birds counters. These bird counters are volunteers and thus have not been trained in collecting the data in the same way or with the same equipment. Also, they vary in experience. The quality of the data also depends on the locations, since some of the breeding sites are located far from land and are thus hard to monitor precisely.
There is also a possibility that some of the registered counts are of breeding pairs instead of the total count of the colony. This could explain why a colony sometimes seems to increase with the double or decrease to the half from one year to the next.

Drones used as a method for monitoring seabirds were revealed to give a more accurate result of the population size of Black-headed Gulls without disturbing the breeding birds. Drones are thus a seemingly favorable monitoring method for breeding Black-headed Gulls colonies, and if used exclusively would provide more accurate data, which enables smaller population fluctuations to be detected. Drones could also be of great use in nature management to help survey the environment on breeding sites since it would make it easier to detect overgrowth of vegetation, which then could be removed. Nature management did not seem to have an immediate effect on the breeding colony of Black-headed gulls in Tarup-Davinde but the effects of these actions are expected to be detectable in future populations.

The use of drones in both bird monitoring and conservation could both reduce human disturbance at breeding sites and provide more accurate results of population dynamics resulting in better and more effective management, which all in all could stop the many seabird populations from decreasing.

Conclusion

Drones as a monitoring technology appeared to be a more accurate method to monitor Black-headed Gulls compared to the traditional ground count method. The gulls were easily counted on the drone images and the birds were seemingly not disturbed by the drone's presence, which is highly preferable since human disturbance is known to negatively affect bird population sizes (Croxall *et al.* 2012). The ground count method only counted 45% of the gulls in the colony of Tarup-Davinde compared to the drone, and thus the colony in Tarup-Davinde was much bigger than anticipated. It was also found by comparing data collected over a period of 11 years the Tarup-Davinde colony's population seemed to be increasing again after a couple of bad years caused by predation. Nature management was also performed in Tarup-Davinde on the biggest island but results showed no immediate impact on the colony, but these effects are possibly detectable on future populations. By comparing data collected over a period of 11 years the Tarup-Davinde colony's population seemed to be increasing again after a couple of bad years caused by predation. This study also found that Black-headed Gulls in 11 different Danish colonies seemed to favor breeding sites with high vegetation at the edges surrounding the site and dense ground vegetation, which may offer protection. All 11 colony populations were also analyzed on the basis of 11 years of data that showed fluctuations among all of the colonies. These results signify the importance of regular and accurate monitoring of the population dynamics so that more effective management decisions can be made an effort to prevent the decline of seabirds.

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