Haulout patterns of harbour seal (*Phoca vitulina*) colonies in the Norwegian Skagerrak, as monitored through time-lapse camera surveys

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Abstract

Harbour seals (*Phoca vitulina*) are a part of the Norwegian coastal ecosystem and are distributed along the coastline, amongst the humans inhabiting and/or visiting these areas. We need to gain a better understanding of how to effectively manage and protect these seals. In this study, time-lapse camera surveys were employed to enhance our understanding of the haulout patterns of harbour seals in the Norwegian Skagerrak. I investigated how these patterns were influenced by environmental parameters, including wind speed, temperature, water level, time of day, and anthropogenic disturbances. Data was collected from cameras installed at the two locations: Lyngør and Østre-Bolærene, during 12 and 4 months, respectively. Temperature (p-value $< 0,001$) had a significant positive influence on haulout behaviour. Water level (p-value $< 0,001$) and wind speed (p-value $< 0,001$) had a negative effect on the number of seals on land. I observed that human presence had an impact on how the seals behaved. This may vary due to the layout of the area and if the area was highly populated by humans in the summer months. This study identified clear circadian patterns in the seals' haulout behaviour during autumn and early winter, with a preference for hauling out during late afternoon, night, and early morning. Previous studies have shown that seal haulout behaviour could be affected by various factors. This study's significant contribution lies in its successful demonstration of using time-lapse cameras to effectively monitor haulout patterns. Overall, this study provided valuable insights into the factors that influenced the haulout behaviour of harbour seals and emphasized the importance of considering environmental factors in understanding the behaviour of marine mammals. This in turn could give us a better understanding on how to correct seal count during the moulting season as well as give us a better understanding on their behaviour. We must take in account that there might be slight changes in the haulout behaviour during the moulting season.

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Acknowledgements

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– Elsa van Meurs

May 18th, 2023 Arendal

1. Introduction

Harbour seals (*Phoca vitulina*) are part of the semi-aquatic mammals called pinnipeds. These mammals have adapted to a diverse environment, making them able to live on land, ice and in water (Riedman, 1990). Harbour seals are relatively small seals with a variable fur coloration (Figure 1) and a compacted body (Wursig et al., 2018). They have a streamlined body shape, which reduces drag in the water and enables them to swim efficiently (Wursig et al., 2018). Weighing approximately 70 - 100 kilograms, females tend to weigh a little less than the males (Bjørge et al., 2010). These seals typically have a length of approximately 1,5 meters and can live up to 22 to 35 years (Bjørge et al., 2010). Harbour seals are generalists, making them able to live off a wide array of food (Blanchet et al., 2021). Due to their size, these seals primarily feed on smaller to medium-sized prey (Wursig et al., 2018).

Harbour seals become sexually mature from four to six years and give birth during the summer months (Kinze et al., 2002; Wursig et al., 2018). When born, the pups have already shed their first fur and are ready to enter the waters, but are dependent on good hiding spots due to predators (Wursig et al., 2018). This is the most critical period for harbour seals due to possible disturbances (Bjørge, 2014).

An adult harbour seal (age one and up) goes through a shedding period which is known as molting (Bjørge & Nilssen, 2021). In contrast to newborn pups, older individuals go through a yearly molting period where they replace their old fur with new fur (Paoli, 2020). The molting process takes place in late summer from August to September (Bjørge & Nilssen, 2021). Harbour seals also seem to have developed a behaviour that shortens the time used on molting due to an internal increase in skin temperature (Paterson et al., 2012). When the temperature rises in the summer months, harbour seals haulout more frequently, enabling them to shorten their molting period (Bjørge & Nilssen, 2021).. Additionally, they experience reduced heat loss on land compared to being in water. Increasing their body skin temperature also reduces foraging time (Bjørge & Nilssen, 2021).

Harbour seals are among the pinnipeds with the widest distribution, adapted to a huge variety of different habitats (Blanchet et al., 2021). They are a non-migratory species that lives in coastal areas and shows strong signs of site fidelity, making them more vulnerable to local disturbances (Bjørge et al., 2010). The most determining factor for the harbour seal habitat is the type of food, its distribution, and its abundance (Riedman, 1990). The habitat may vary due to the different seasons, providing them with different available nutrients. They typically inhabit coastal waters, estuaries, bays and may wander offshore to feed (Wursig et al., 2018). Some harbour seals can swim up freshwater rivers to forage (Riedman, 1990).

Figure 1. A group of harbour seals outside of Østre-Bolærene. Photo credit: Elsa van Meurs.

Harbour seals are dependent on patches of land or ice to rest, breed, moult, and raise young (Riedman, 1990). They prefer to haulout on rocky shores, skerries (see Figure 1), beaches, or man-made platforms (Blanchet et al., 2021). The term haulout refers to the act of leaving the water and crawling on dry areas (land or ice). Groups of seals inhabiting or hauling out on the same areas are called haulout groups (Härkönen & Harding, 2001). The amount of time spent on land varies depending on the season (Riedman, 1990). Many pinnipeds prefer more undisturbed areas, but harbour seals may inhabit areas near human presence (Riedman, 1990).

Information on haulout patterns during the moulting season is particularly important for aiding correction of population surveys (Lonergan et al., 2013). This is because harbour seals are counted during the moult, when they spend much time on land near their breeding sites (Riedman, 1990). The moulting season causes the seals to be stuck on land due to poor thermoregulation, but it is not the only event that keeps the seals on land (Riedman, 1990). Therefore, the eventual effects of diel and meteorological conditions on haulout behaviour during this season are particularly relevant.

External factors such as environmental parameters have a high influence on the haulout behaviour of harbour seals. Seasonality has an impact on the numbers of seals hauling out. A study by Granquist and Hauksson (2016) showed that the numbers of seals hauling out decreases during the winter months and increases during the summer months. They also observed the negative impact of wind speed and the positive effects of air temperature (Granquist & Hauksson, 2016). This was also shown in other studies where strong winds decreased the quality of the haulout sites (Mogren et al., 2010). The time of day was not found to affect the number of seals hauling out, possibly due to the correlation between time of day and tide height (Granquist & Hauksson, 2016). Other studies showed the opposite, where harbour seals preferred to haulout at night (Bringsdal, 2021; Grigg et al., 2002; Reder et al., 2003). The tide also affects the haulout behaviour due to the increase or decrease in areas to haulout on. Other studies have also shown that smaller boat traffic might have a temporary effect on the haulout behaviour of harbour seals (Henry & Hammill, 2001). They are also able to develop a tolerance for these smaller boats during the summer months, which may be a result of the moult (Henry & Hammill, 2001).

The total population of harbour seals in Norway is about 10,000 individuals (Bjørge & Nilssen, 2021). These seals can be found from the southernmost tip of Norway to the west coast of Svalbard (Bjørge & Nilssen, 2021). The harbour seal population is managed through a Management Plan which ensures a viable population of harbour seals along the coast (Bjørge & Nilssen, 2021). Harbour seals living in the Skagerrak area haulout on rocky shores, skerries or smaller islands outside of an island chain (Härkönen & Harding, 2001). These seals may congregate in groups of up to a hundred individuals (Bjørge & Nilssen, 2021). Due to a high abundance of fisheries along the western coast of Norway, interactions between seals and fisheries may arise (Bjørge et al., 2002). This may be due to direct interactions where the seals get trapped in fishery equipment or by indirect interactions where they compete for the same recourses.

During the last decades, development of biotelemetry devices has allowed researchers to track individual seals and study haulout patterns at the individual level. Though these devices provide valuable individual information (for instance on haulout duration), data on few tracked individuals may be biased by individual traits, such as sex, maturity state and individual personality. Moreover, few telemetry studies cover the pupping and moulting seasons during the summer, as tags are usually glued to the seal fur after moulting and then fall off during the next moult, or most often before (Bringsdal, 2021). Harbour seals previously tagged in the Norwegian Skagerrak (18 individuals) have sent data between

September and March (Bringsdal, 2021), but little to no data has been published on how the haulout behaviour changes throughout an entire year. Therefor I believe that trail cameras, specifically time-lapse cameras, might be a better option in some cases.

Trail cameras are able to capture natural behaviour of the study species, but with limitations (Swann et al., 2011). There are different ways to set up a camera trap; a time-laps mode that takes a image during a set time frame, or motion mode that takes an image when something is moving. Time-lapse cameras are highly capable of detecting animal behaviour on a larger scale (Wearn & Glover-Kapfer, 2019). Time-lapse camera surveys are highly effective when studying animals in remote areas. These cameras are cost effective in a way that they collect large amounts of data compared to the visual surveys where a higher personal demand is needed as well as a higher chance of disturbing the wildlife. Using time-lapse camera surveys to monitor an animal or animals makes it possible to study animals over time and a more complete continuous image of its surroundings (Jones & Rees, 2022).

There are several studies using time-lapse cameras to observe animal behaviour. Studies on remotely located skinks (*Scincidae*) used trail cameras due to their remoteness and are able to monitor their behaviour and potential predator exposure (Bertoia et al., 2023). Researchers also used time-lapse cameras to study Bonelli's eagle (*Aquila fasciata*) behaviour during the nestling period where these animals don't want to be disturbed (López-López & Urios, 2010). There have also been studies on seals where they use surveys amongst time-lapse photography, as well as visual monitoring and aerial surveys to observe how grey seals (*Halichoerus grypus*) and harbour seals haulout behaviour is affected by the construction of a large Danish offshore wind farm (EDRen et al., 2010). Another study evaluates different survey techniques, amongst time-lapse photos, to provide a more accurate estimate of the populations size of the harbour seal (Thompson & Harwood, 1990).

This master project aimed to investigate the haulout patterns of harbour seal colonies in the Norwegian Skagerrak, using time-lapse camera surveys. The project has specifically investigated how the number of seals on land is affected by diel, seasonal, and environmental parameters, as well as by anthropogenic disturbance. The study lasted approximately a year in one location (17 February - 31st January 2023), and four months at the second location (29 September – 22 December.

2. Methods and materials

2.1 Study sites

To examine the haulout behaviour of harbour seals, Lyngør and Østre Bolærene (Figure 2) were selected as two distinct locations in the Skagerrak region. This decision was based on previous research and tagging efforts that had identified a noteworthy number of individuals in these two colonies, ultimately improving the reliability and accuracy of the results.

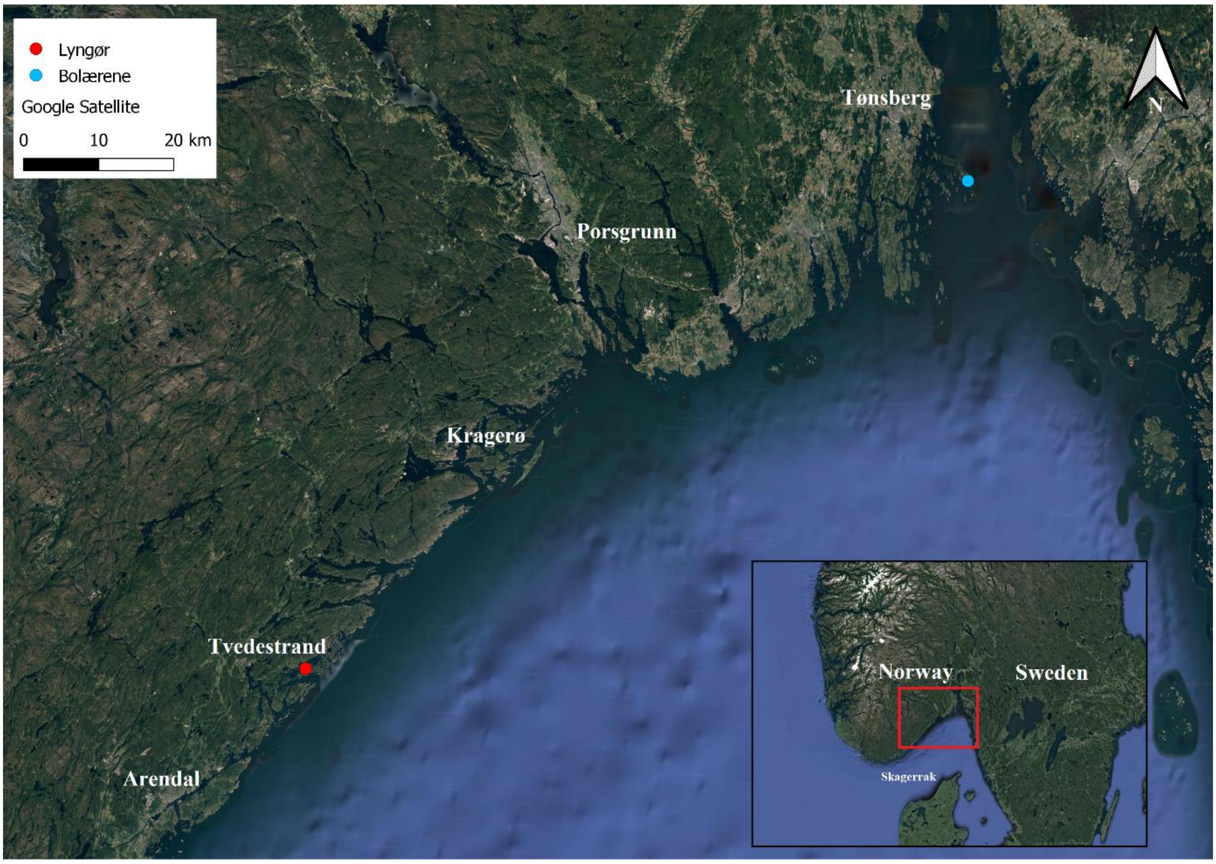

Figure 2. Skagerrak and the location of the two study sites. Location one is located nearby Lyngør. Location two is located on the exposed (Eastern) side of Bolærene (Østre Bolærene).

The first location chosen in this study was Lyngør (in Tvedestrand municipality with the coordinates 58.617602 N, 9.074661 E). The skerry on which the seals were located, was surrounded by larger islands on all sides (Figure 3). This made it a more protected area from wind as well as waves. The location was covered with smaller islands and a few skerries, on which the seals could haulout. Lyngør was a popular vacation spot during the summer months and had high boat traffic as well as other water activities present (Arendal Turistkontor, 2023).

The study area laid next to Raet National Park. This national park had been protected since 2016, and 98% of this protected area laid in the marine environment (Raet national park, 2017). The area had become a sanctuary for the local lobster (*Homarus gammarus*) population (Kleiven & Agnalt, 2021; Raet national park, 2017). This in turn was a rich food source for the harbour seals residing in the area.

Figure 3. A view of the skerry located near Lyngør in Tvedestrand. The area is surrounded by bigger islands and the area is a high tourist attraction in the summer months. Photo credit: Elsa van Meurs.

Østre Bolærene (coordinates 59,192104 N, 10.583611 E) was located in outer Oslofjord in the Færder national park. The area had a rich animal life including harbour seals who were permanent residents (Færder, 2023). The location was covered with several smaller to mid-sized skerries (Figure 4). The skerry chosen for this study was very exposed to wind and waves. The tide also had a huge effect on which skerry the seals chose to lay on. The location laid next to the main boat route to Oslo.

Figure 4. A view of the skerries located outside of østre Bolærene. The group of Skerries in the front are the ones being watched during this study. Photo credit: Elsa van Meurs.

2.2 Time-lapse camera surveys

Three Bushwhacker Camo 4G time-lapse, each with a SE5200 solar power kit to keep the batteries charged (Figure 5), were installed at two known haulout sites for harbour seals in Norway (Lyngør and outer Oslofjord). The first camera was installed in February 2022 at Lyngør, and the second and third were installed in September 2022 at Østre Bolærene. The time-lapse cameras took one photo of the colony each hour, and only during daylight hours at Lyngør. The photos were sent via GSM to an FTP site at the Institute of Marine Research (IMR), and each photo automatically printed the date, time, air temperature, and moon phase. Additionally, the time-lapse cameras were equipped with an IR night vision feature that extended up to approximately 20 meters (maximum extend).

Figure 5. Time-lapse camera used in Lyngør. It consists of a solar panel placed on top and the camera with two antennas above the camera. The same setup is used at location two. Photo credit: Elsa van Meurs.

Placing the time-lapse cameras in the right spot was a crucial part of this research. The camera should be placed in a location where it could capture most of the smaller and larger skerries. In Lyngør, there was only one main skerry that the seals inhabited. Østre Bolærene was covered with several skerries, making it more difficult to place only one time-lapse camera. Therefore, two time-lapse cameras were placed, one facing south and another facing northwest, providing a full coverage of the haulout sites. However, the south camera failed after a few days and was therefore not used in the analysis. The northwest camera enabled me to capture images at night because the camera was less than 20 meters away from the observed animals. This camera was specifically used to test whether the number of seals varied significantly from day to night. The camera took one picture each hour during the whole period. This was to get a better understanding on how the number of seals changed during the day. Because the study generated an immense amount of data, I decided to select only one picture every hour for all the cameras. Additionally, considering that a single person was responsible for counting the images, it would have been overwhelming to handle multiple images per hour.

2.3 Environmental data

To look at the effect of environmental parameters on the number of seals coming ashore, data of air temperature, wind direction and wind speed were obtained for each hour from Norwegian Centre for Climate Services (NCCS) (https://seklima.met.no/). The weather station Lyngør Fyr was used for Lyngør and Færder Fyr was chosen for Østre Bolærene. Sea-water level could have a major impact on the haulout behaviour due to the possible loss of skerries to haulout on. Therefor the sea-water level was also noted each hour, from the Norwegian mapping authority (Kartverket) (https://www.kartverket.no/til-sjos/se-havniva).

2.4 Data analysis

The number of seals in each photo frame was manually counted and registered in excel. In cases of adverse weather conditions where the seals were less visible, but still reasonably distinguishable, population estimates were made. Otherwise, those photos were excluded from the results. Camera three at Østre Bolærene was able to capture the seals at night closest by laying on the rocks, not the individuals further away. This meant that to get the best results on daily variation on the seals hauling out, only the seals laying on the same rocks close by were counted during the night and day. Not the ones who I was able to see during the day who laid on rocks further away. Haulout behaviour, quantified by the number of seals on land, was examined in relation to time of day and environmental conditions to investigate their impact on resting patterns. Additionally, anthropogenic disturbances on haulout patterns was examined by comparing the number of seals on land on working days versus weekends and holidays. The summer holiday lasted from approximately 25th of June until 14th August, these dates were chosen due to school vacations. Statistical analyses were based on circular statistics and generalized linear models (GLMs), using R software (Dunn & Smyth, 2018). Data exploration was performed to locate eventual outliers in the seal counts and environmental variables. Due to the varying number of seals, these outliers needed to be traced back to their origin and double-checked.

To investigate the relationship between the different parameters and the number of seals, I employed a Generalized Linear Model (GLM) with a Poisson distribution and an appropriate link function. Instead of relying on scatter plots with a smoother and boxplots, the GLM with a Poisson distribution allowed me to model the count data accurately. I treated the number of seals as the response variable and the parameters as the predictor variables in the model. To establish the link between the linear predictor and the mean of the Poisson distribution, I used the log link function. This choice ensured that the predicted values remained positive and facilitated the modeling of the relationship between the parameters and the expected counts. Once the GLM with the Poisson distribution and log link function was fitted, I could interpret the estimated coefficients associated with the parameters. Positive coefficients indicated an increase in the expected number of seals for each unit increment in the corresponding parameter, while negative coefficients signified a decrease.

I used two different formulas due to two different localities. For Lyngør I used: log (number of seals) = β0 + β1 temperature + β2 water level + β3 wind + β4 day off. For Østre Bolærene I used: log (number of seals) = β0 + β1 temperature + β2 water level + β3 wind + β4 day or night

These formulas predicted the number of seals based on several predictor variables. Number of seals was the response variable, and the predictor variables were temperature, water level, wind, and day off for Lyngør and day or night for Østre Bolærene. β0 represented the number of seals when all the predictor variables were equal to zero. β1 temperature, β2 water level, β3 wind and β4 day or night represented the expected number in the log(number of seals) when each of the predictor variables increased with one unit respectively.

The model assumed a Poisson distribution for the response variable (number of seals) and used a significance level of 0,05. Afterwards the model needed to be validated by calculating the dispersion parameter. If the dispersion parameter was equal to 1, the model was not overdispersed (Loeloe & Madadizadeh, 2023). If the dispersion parameter was greater than 1, the model was overdispersed (Loeloe & Madadizadeh, 2023). This meant that the results gained from the Poisson test were invalid. A fitted negative binomial regression model could be used from the 'MASS' package in R (Ripley et al., 2013) if the Poisson test was overdispersed. This test analysed count data, categorized by whole number greater or equal to zero. The negative binominal regression could also handle greater range of variability, thus making it a possible better option for these parameters.

3. Results

The time-lapse camera in Lyngør collected data for 12 months (17 February - 31st January 2023), except in the period 9-22 July, due to lack of battery. Data from 333 days in which the camera captured 8437 photos were collected. In this period the temperature ranged from -11 °C to 33°C, and had a mean temperature of 13,6 °C. Due to its wind protected placement (Figure 6) the wind speed ranged from 0 m/s to 16,5 m/s and had a mean wind speed of 4,6 m/s. The water level ranged from -3 cm to 127 cm, with an mean water level of 53,3 cm. The period had a maximum of 37 seals and a minimum of 0 seals, the average was around 9 seals per hour.

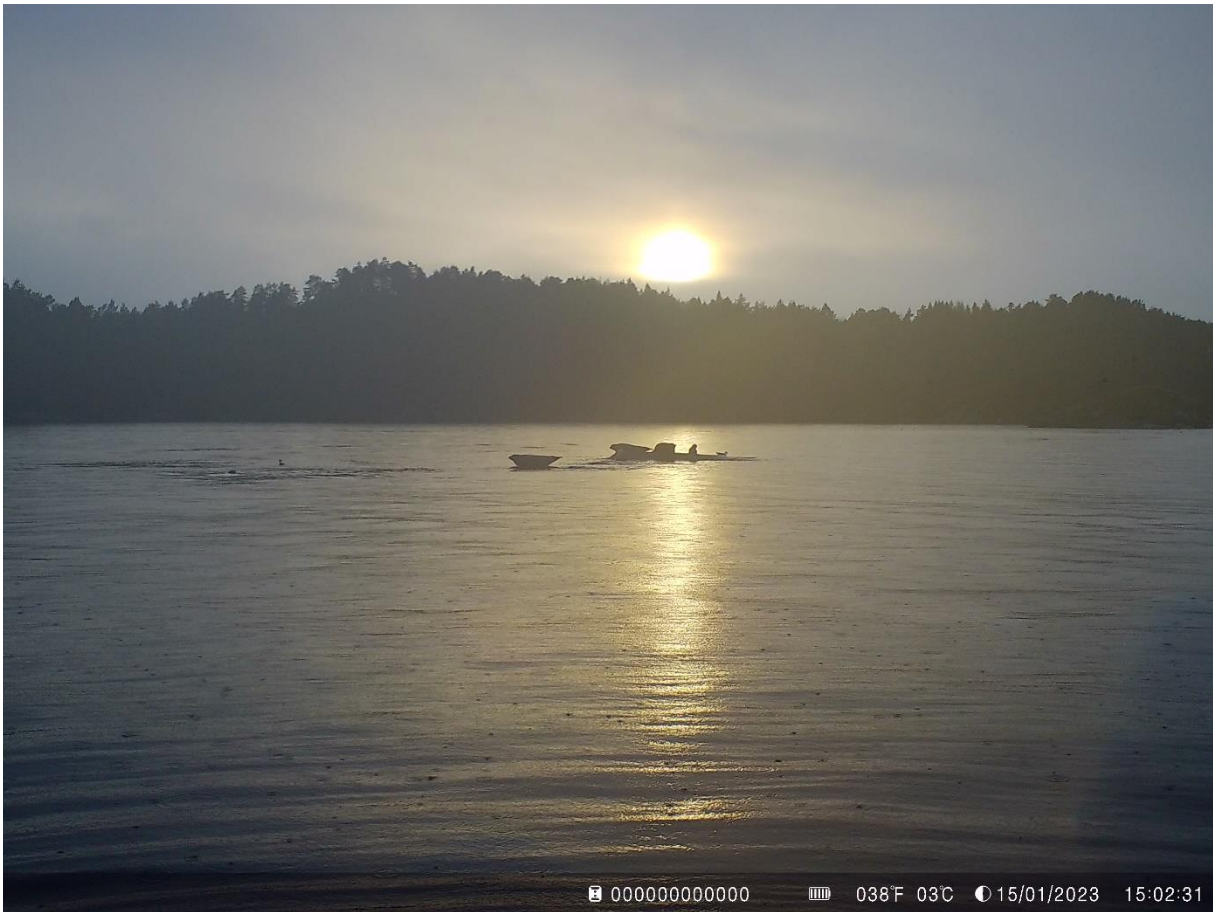

Figure 6. An image from the time-lapse camera placed at location one (Lyngør). An overview over some parameters are located at the bottom of the image.

Østre Bolærene collected data on 85 days in which the camera captured 2022 photos (29 September – 22 December). The temperature ranged from -4 °C to 26 °C, and had a mean temperature of 11,1 °C. The area had no form of wind protection and was exposed by both strong winds and waves (see figure 7 and 8). The wind speed ranged from 0,3 m/s to 18,8 m/s, and had a mean wind speed of 8,8 m/s. The water level ranged from 1 cm to 130 cm and had a mean of 60 cm. The period had a maximum of 18 seals and a minimum of 0 seals, the average was around 1 seal per hour.

Figure 7. An image from the time-lapse camera placed at Østre Bolærene, obtained during the day. An overview over some parameters are located at the bottom of the image.

Figure 8. A image from the time-lapse camera placed at Østre Bolærene, obtained during the night. An overview over some parameters are located at the bottom of the image.

Table 1

An overview over the different values and information gathered from the two locations studied in this study.

Location	N Images	Mean temperature (min – max)	Mean wind speed (min – max)	Mean water level (min – max)
Lyngør	8437	13,6 °C (-11 °C–33°C)	4,6 m/s (0 m/s – 16,5 m/s)	53,3 cm (-3 cm – 127 cm)
Østre Bolærene	2022	11,1 °C (-4 °C – 26 °C)	8,8 m/s (0,3 m/s – 18,8 m/s)	60 cm (1 cm – 130 cm)

3.1 How temperature affects the number of seals

How the haulout behaviour was affected by temperature was investigated at Lyngør during the period from 17.02.22 to 31.01.2023. The data showed a slight increase in the number of seals hauling out on the skerries as the temperature increased. The rate of increase was initially slow, but it accelerated after the temperature reached approximately 25°C (Figure 9).

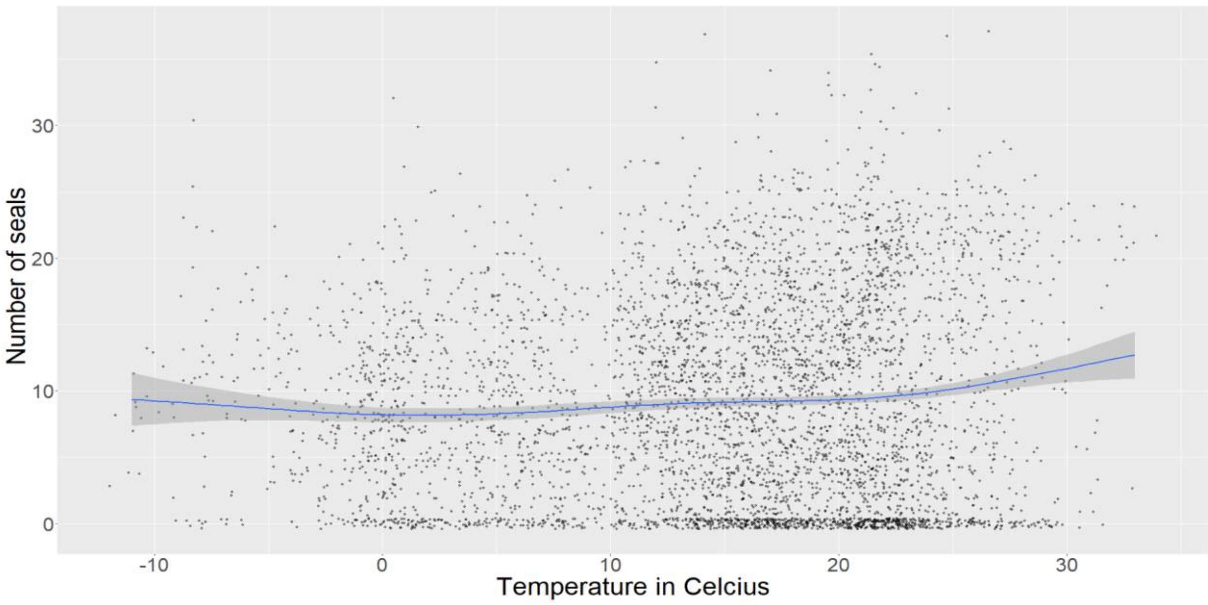

Figure 9. The relationship between the number of seals hauled out and the air temperature at Lyngør in the period from 17.02.22 to 31.01.2023.

3.2 How the water level affects the number of seals

How the rising water level had affected the haulout behaviour was investigated at Lyngør during the period from 17.02.22 to 31.01.2023. The data was recorded from a local weather station. The data showed a steady decrease in the number of seals hauling out on the skerries at Lyngør. A smooth line was added to see the pattern of the period. Starting with about 18 seals hauling out on skerries at 0 cm, reaching 0 seals hauling out at 125 cm (Figure 10).

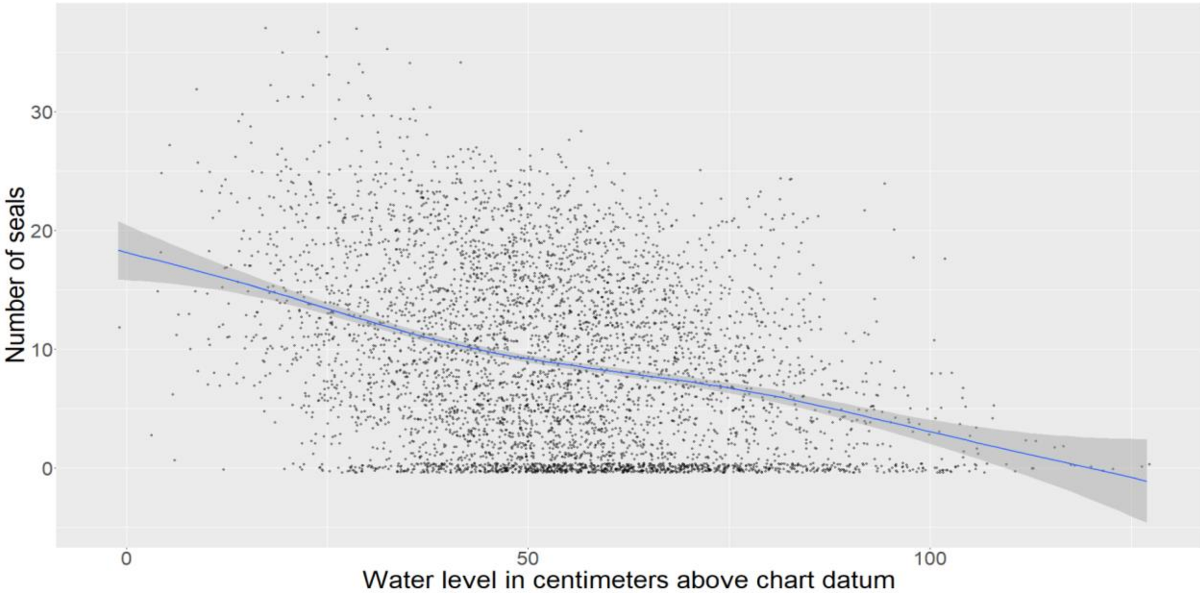

Figure 10. The graph displays the relationship between the number of seals hauled out and the fluctuating water level in the tidal cycle at Lyngør in the period from 17.02.22 to 31.01.2023.

3.3 How the wind speed affects the number of seals hauled out

How the increase in wind speed had affected the haulout behaviour was investigated at Lyngør during the period from 17.02.22 to 31.01.2023. The data was recorded from a local weather station. A smooth line was added to see the trend of the period. The graph showed a slight increase in the number of seals observed, peaking at around three to four meters per second. However, the number of seals steadily decreased thereafter, reaching zero at approximately 16,5 meters per second (Figure 11).

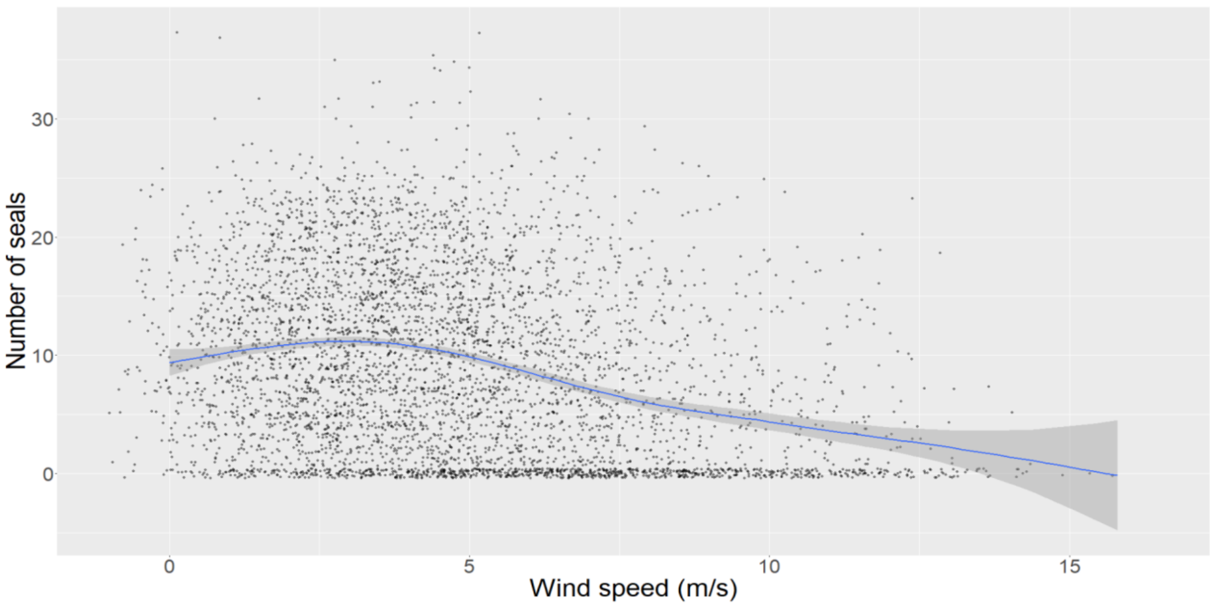

Figure 11. The graph displays the relationship between the number of seals hauled out and wind speed at Lyngør in the period from 17.02.22 to 31.01.2023.

3.4 How holidays and weekends affect the number of seals

Looking at how the haulout behaviour of the harbour seals was affected by holidays, weekends and days off was done by making two boxplots for each month for days off (holidays and weekends) and normal weekdays (Figure 12). The different months showed different results. January, February, March September, and November showed signs that the seals hauled out more during holidays, weekends and days off. While the other months showed signs for the opposite. Increasing human activity was not looked at in these boxplots.

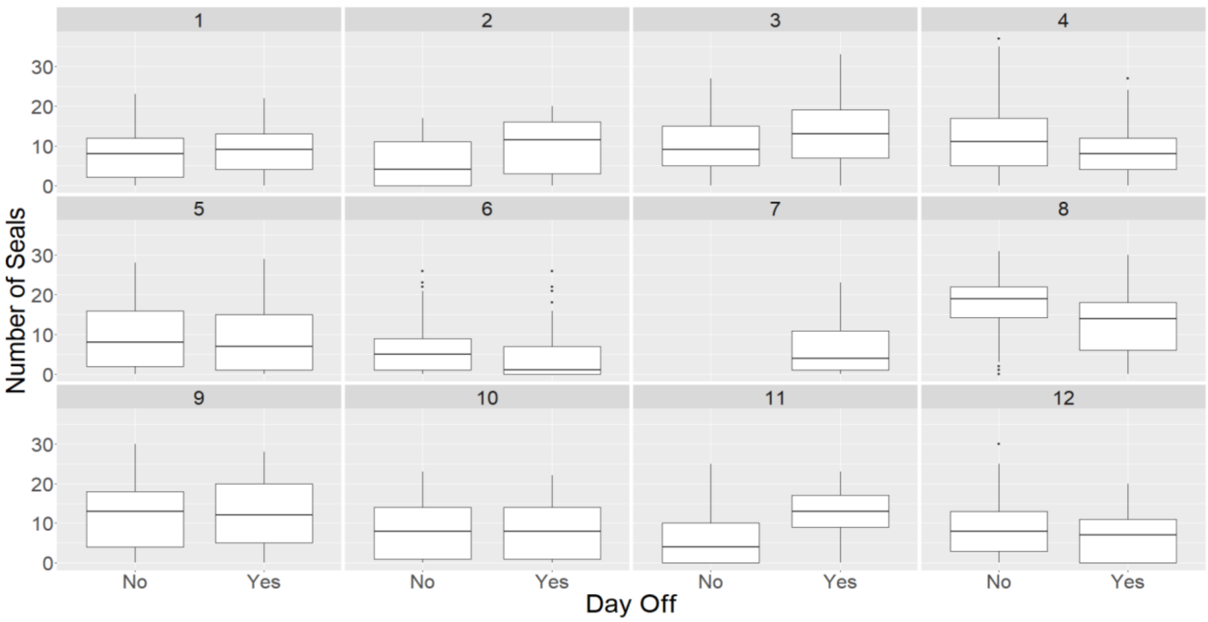

Figure 12. The effect of holidays and weekends on the haulout behaviour of harbour seal populations during the different months. The months are from 1 to 12 (January to December) starting at the top left panel. The data was collected at Lyngør in the period from 17.02.22 to 31.01.2023.

3.5 How the number of seals varied during the time of day

Looking at the daily activity on location two, there was a slight trend of increasing numbers of seals during the early day and late in the night. In the period from 07.00 to 14.00 the number of seals decreased towards the point that there almost were no seals to be spotted near the camera. From 15.00 to 19.00 the numbers of seals increased and reached its highest point from 20.00 to 01.00. During this period most of the seals were spotted. The numbers decreased from 01.00 to 06.00 before reaching an all low at 07.00 again (Figure 13).

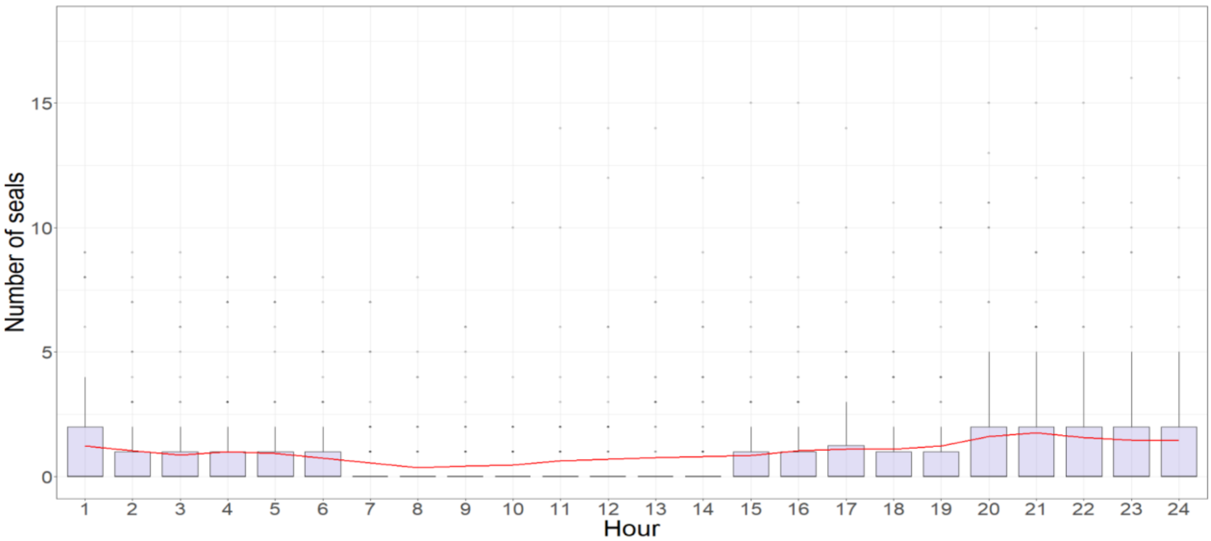

Figure 13. The graph displays the haulout behaviour of the harbour seals at Østre Bolærene during an entire day. The data was collected from 29 September to 22 Desember.

3.6 Model estimates

Starting with Lyngør, the estimated intercept was 3,294667 with a standard error of 0,055367. The z-value of 59,506 indicated a highly significant effect (p-value < 0,001) (Table 2).

For the wind speed parameter, the estimated coefficient was -0,099257 with a standard error of 0,005473. The z-value of -18,136 indicated a highly significant effect (p-value < 0,001). A decrease in the wind speed was associated with a decrease in the expected value of the response variable (number of seals).

The coefficient of the parameter temperature had an estimate of 0,009326 with a standard error of 0,001764. The z-value of 5,285 indicated a highly significant effect (p-value < 0,001). Therefore, an increase in temperature was associated with an increase in the expected value of the response variable (number of seals). This suggested that higher temperatures lead to an increase in the number of observed seals in Lyngør, according to the model.

Similarly, the estimated coefficient for the water level was -0,014767 with a standard error of 0,000808. The z-value of -18,276 indicated a highly significant effect (p-value < 0,001). A decrease in the water level was associated with a decrease in the expected value of the response variable (number of seals). Hence, lower water levels were linked to a decrease in the observed number of seals.

Regarding the "Day off" predictor (Yes), the estimated coefficient was -0,081804 with a standard error of 0,030371. The z-value of -2,693 indicated a significant effect (p-value = 0,007). Being a day off, such as holidays, weekends, and vacations, had a negative impact on the expected value of the response variable (number of seals). This implied that during days off, there was likely to be a decrease in the observed number of seals.

Table 2

An overview over the estimates, standard error, z-value and p-value of the Lyngør GLM model. Intercept represents the expected value of the response variable (number of seals) when all other predictors (wind speed, temperature, water level and day off (yes)) are zero.

LYNGØR	ESTIMATE	STD. ERROR	Z-VALUE	P-VALUE
(INTERCEPT)	3,294667	0,055367	59,506	< 0,001
WIND SPEED	-0,099257	0,005473	-18,136	< 0,001
TEMPERATURE	0,009326	0,001764	5,285	< 0,001
WATER LEVEL	-0,014767	0,000808	-18,276	< 0,001
DAY OFF (YES)	-0,081804	0,030371	-2,693	0,007

For Østre Bolærene, the estimated intercept was 2,58985 with a standard error of 0,20812. The z-value of 12,444 indicated a highly significant effect (p-value < 0,001).

For the wind speed parameter, the estimated coefficient was -0,08407 with a standard error of 0,01487. The z-value of -5,654 indicated a highly significant effect (p-value < 0,001). A decrease in the wind speed was associated with a decrease in the expected value of the response variable (number of seals) (Table 3).

The coefficient of the parameter temperature had an estimate of 0,03997 with a standard error of 0,01116. The z-value of 3,581 indicated a highly significant effect (p-value < 0,001). Therefore, an increase in temperature was associated with an increase in the expected value of the response variable (number of seals). This suggested that higher temperatures lead to an increase in the number of observed seals in Lyngør, according to the model.

Similarly, the estimated coefficient for the water level was -0,05564 with a standard error of 0,00310. The z-value of -17,946 indicated a highly significant effect (p-value < 0,001). A decrease in the water level was associated with a decrease in the expected value of the response variable (number of seals).

Lastly, the estimated coefficient for the "nday2_Night" predictor was 0,83995 with a standard error of 0,11969. The z-value of 7,018 indicated a highly significant effect (p-value < 0,001). This suggested that when the "nday2_Night" condition was present, the expected value of the response variable (number of seals) increased.

Table 3

An overview over the estimates, standard error, z-value and p-value of the Østre Bolærene GLM model. Intercept represents the expected value of the response variable (number of seals) when all other predictors (wind speed, temperature, water level and nday2_night) are zero.

ØSTRE BOLÆRENE	ESTIMATE	STD. ERROR	Z-VALUE	P-VALUE
(INTERCEPT)	2,58985	0,20812	12,444	< 0,001
WIND SPEED	-0,08407	0,01487	-5,654	< 0,001
TEMPERATURE	0,03997	0,01116	3,581	< 0,001
WATER LEVEL	-0,05564	0,00310	-17,946	< 0,001
NDAY2_NIGHT	0,83995	0,11969	7,018	< 0,001

4. Discussion

The research conducted in this study relies on data captured by time-lapse cameras positioned at two distinct locations within the Skagerrak region. A total of 8437 images from Lyngør and 2022 images from Østre Bolærene were carefully examined to determine the number of seals present. Environmental parameters such as water level, wind speed have a negative effect on the haulout behaviour, while temperature has a positive effect. Moreover, the time of day and the occurrence of weekends or holidays displayed differing effects on how the seals engage in haulout behaviour. These findings have the potential to contribute to a deeper comprehension of the harbour seal's haulout behaviour in the Skagerrak region.

4.1 Temperature and haulout behaviour

When examining the temperature parameter, one can observe a significant increase in the number of seals as the temperature rises. This can be explained by their thermoregulation and the benefits of coming ashore during warmer temperatures (Grellier et al., 1996). Being endothermic, these seals need to maintain a constant body temperature. They are able to regulate their heat loss (Wursig et al., 2018). However, the relationship between temperature and haulout behaviour seems to be influenced by the distance to the foraging site. In earlier studies where seals had longer foraging trips and could be at sea for several days, haulout behaviour was less affected by temperature and more by the distance to the foraging site (Allen-Miller, 1988; Thompson et al., 1989). In some cases, such as this study, temperature may have a stronger influence on haulout behaviour due to the shorter distance to the foraging site. Seals in this population may not rely on resting as much as populations that travel many kilometres. Warmer temperatures generally promote haulout behaviour, but age and sex also influences skerry preference (Reder et al., 2003).

4.2 Tidal influence on haulout behaviour

Rising water levels decrease the dry areas available for seals to haulout on, thereby decreasing the number of seals hauling out. Some studies suggest a more direct connection between tidal level and haulout behaviour, hauling out more at the lowest tides (Patterson & Acevedo-Gutiérrez, 2008). However, there is variation in the influence of tides in different areas, with sites experiencing higher tidal influence being more impacted than those with lower tidal influence (Mogren et al., 2010). The timing of the tides also has an influence on haulout behaviour (Boveng et al., 2003).

4.3 Wind speed and haulout behaviour

In this study, the wind speed had a negative effect on the number of seals hauling out. Increasing wind speed decreased the number of seals hauling out. Sea spray and waves due to strong wind (exposure) is also known to impact the haulout sites and decrease their quality for the seals (Mogren et al., 2010). Some studies performed on Weddell seals (*Leptonychotes weddellii*) have shown that seals tend to haulout less when the wind is strong, which therefore has a significant effect on the number of seals (Lake et al., 1997; Siniff et al., 1971; Smith, 1965). Calm, as well as warmer weather, promotes haulout behaviour (Reder et al., 2003).

4.4 How holidays and weekends affect the number of seals hauling out

Some locations are more popular tourist spots than others, making these areas highly populated by humans during weekends and vacations. This, in turn, influences the local harbour seals residing in the area. During pupping season, which has regional differences, the effect of human presence has a higher impact on the haulout behaviour of the seals as well as changing and impacting the pups (Osinga et al., 2012; Temte et al., 1991). Therefore, it is highly important to find out where the pups are and protect them from unnecessary human impact. Lyngør is, as mentioned, a highly attractive tourist location and has a high boat traffic during the summer months. There are some boat tours in Østre Bolærene that try to locate the seals for tourists visiting the isles. However, due to little information about the haulout behaviour in July because of a camera failure, I am not able to confirm if the results shown in figure 12 are correct. It may also be the case that the local seals are used to the human presence and are therefore not as shy, and they might ignore the humans more than populations in non-tourist locations. As a result, this factor may influence our findings, potentially leading to an increased inclination for seals to haulout as temperatures rise.

4.5 Varying haulout behaviour during the day

There is a clear circadian pattern in the haulout behaviour of harbour seals, with a preference for afternoons, nights, and early mornings, and avoidance of midday haulout. This preference was also observed in earlier studies, where seals preferred hauling out during the afternoon and evening (Reder et al., 2003). However, differences were noted between age, sex, and seasonal changes (Reder et al., 2003). Other studies have also shown that harbour seals prefer to haulout at night and less during the day (Bringsdal, 2021). The reason why these harbour seals haulout during the darker hours might be because of several factor. By hauling out during the night they can avoid predators when resting. They might also prefer to stay in the water when the sun is up due to human disturbance (London et al., 2012). Their response to human presence depends on the location of the locality. In highly popular tourist areas, seals may be more tolerant of human presence and less likely to flee. Though some have seen that there is a difference in when they haulout depending on time of the year (London et al., 2012). Therefor our result might only be valid for the time of year the data was collected (29 September to 22 December), and therefore be different during the moulting period.

4.6 Sources of error

The study was conducted at two locations, and it was necessary to find two weather stations that had similar environmental factors. For location one, Lyngør fyr was chosen as the closest area that measured all the required parameters. However, Lyngør fyr is more exposed than the actual study area, which may have caused some faulty wind results. Unfortunately, no other location was closer regarding the other environmental results. Nevertheless, the water level was the same at both the weather station and the study site, because of its short distance from one another, and thus had no incorrect effects on the results. Temperature results were obtained from the time-lapse camera on cite, which is more accurate than what might have been collected from the weather station. This is because the seals were directly exposed to sunlight, as was the time-lapse camera, making the temperature measurements more precise.

Location two was more challenging because only the water level was measured nearby, and the wind speed was measured from the mainland, making it less reliable. To obtain accurate results that more likely matched the study location, I selected a weather station with a similar environment. Færder fyr, which is about 20 kilometres south of Østre Bolærene, was chosen as it had a similar environment. Although it was slightly further from our study location, the environment was very similar, making it a suitable option.

This project encountered several issues due to its nature. Firstly, the results were highly impacted by human error, as no artificial intelligence was used to count the seals, resulting in a manual count that might have a few mistakes. Distinguishing between seals and rocks was also challenging, particularly during times of poor visibility or bad weather conditions, which sometimes made it impossible to count the seals.

The project involved taking one image per hour, which provided sufficient information during certain periods. However, it is important to note that during the summer months when human activity is higher, this method may yield incomplete information as it only captures specific moments and may not capture all human activities in the area. This limitation could potentially result in misleading or incomplete data. Battery life was another issue, with AA batteries lasting longer during ample sunlight but draining quickly during cloudy periods. This caused data loss during the summer holidays, during which the camera was inaccessible for approximately 10 to 11 days.

4.7 Further suggestions

Ideally, the same observatory study should be conducted at multiple sites along the Norwegian coast, with each study taking place for approximately one year. This would provide a better understanding of how environmental parameters affect haulout behaviour at different locations and provide more accurate population estimates for each site. This method would be preferable to counting seals on land during the moulting season, as seals may forage or inhabit other skerries. This may give us a better count estimate of the entire harbour seal population.

An Artificial Intelligence (AI) system could potentially provide better results without human error. An AI works faster and therefor also enables to process data from a larger number of time-lapse cameras.

It would also be valuable to investigate how lunar stages affect haulout behaviour. While camera three did not capture enough data to yield significant results, a larger dataset would provide more insight into this relationship.

The placement of the time-lapse cameras is a crucial part of the study and for the Lyngør location the camera was placed outside of the night vision range and was not able to observe the colony at night causing me to not get any data of the seals during the darker hours. The number of time-lapse cameras placed at one colony is dependable on the colony size. Larger colonies may inhabit more skerries than smaller ones and might therefor not be able to be detected using only one time-lapse camera. The haulout site might also be large and not observable from one time-lapse cameras.

This study can give us a good insight on how the seals differ in haulout behaviour due to different parameters. This in turn gives us a better understanding on how to correct the seal count performed during the moulting season. It is however important to note that the haulout behaviour can differ in this time of year. The technique used in this study might be suitable for the purpose of learning more of their behaviour during the moulting season which might give an even better understanding on how to correct the seal count.

5. Conclusion

Harbour seals are an important part of the Norwegian coastal ecosystem, and their populations are regulated. This research provides valuable information on how to monitor these populations using trail cameras, specifically time-lapse cameras, and how they can give valuable information on types of behaviour. Given the regional differences between harbour seal populations, it is crucial to understand their haulout preferences in different localities. At the two localities chosen in this study, Lyngør and Østre Bolærene, I found that the haulout behaviour was affected differently by different parameters.

This study shows how trail cameras, specifically time-lapse cameras, can be used to get a better understanding on a specific behaviour of an animal. In this case I got a closer look on what parameters affected the haulout behaviour of the harbour seal

The number of seals hauling out increases when temperatures rise, as they benefit from coming ashore in warmer weather. However, this behaviour varies depending on the proximity of their foraging site. Seals with foraging sites nearby may not rely on resting when returning to their haulout site, while those with more distant foraging sites must rest more often and are therefore less selective in their choice of haulout site. Rising water levels due to changing tides reduce the number of spots available for seals to rest on, which in turn decreases their haulout behaviour. Increasing wind speed also has negative effects on haulout behaviour, as strong winds and sea sprays make haulout sites less comfortable for the seals.

Harbour seals exhibit a clear circadian pattern, preferring to haulout during the night and early morning and avoiding midday in our study period which was from 29 September to 22 December. This might be different in other localities and other seasons.

Though this study scratches the surface of how time-lapse cameras can give more information on how to calculate when to count seals and how the haulout behaviour of the harbour seal is affected, more data is needed. Specifically during the moulting season, due to possible changes in haulout behaviour it might cause. Though this study gives an overall insight on how different parameters influence the haulout behaviour and shows how important it is to consider how different environmental parameters affect the behaviour of marine mammals.

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