How Does Nest Predation Affect Common Eider (*Somateria mollissima*) Breeding?

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Swedish University of Agricultural Sciences, SLU
Department of Aquatic Resources (SLU Aqua)
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Abstract

The Common Eider (*Somateria mollissima*) population in the Baltic Sea has suffered from a huge decline during the last decades. Nest predation on eggs from Hooded Crow (*Corvus cornix*) and Herring Gull (*Larus argentatus*) has been proposed as one of the possible reasons for the decline. Other explanations are quality changes in the eiders' main food Blue Mussels (*Mytilus edulis*) and predation on adults and ducklings. There is a lack of studies examining nest predation in eider colonies in Swedish waters. Therefore, this study has investigated the early nest predation on eider nests at Stora Karlsö in the Baltic Sea. Possible factors contributing to egg predation has been examined, along with the consequences for the eider breeding. Camera surveillance was conducted between mid-April until mid-June 2024, monitoring a total of 17 eider nests. The predation pressure on eider eggs was high, with 42 % of the total clutch size being predated by Hooded Crow and Herring Gull, thus reducing the nest success to 65 %. One of the conclusions was that nest predation had more effect on the nest success than on the number of chicks per nest, possibly caused by female eiders in a poor body condition being more affected by egg predation and thus abandoning their nest. Furthermore, the risk of egg predation was highest in morning and mid-day during the egg laying days, explained by activity patterns of predators and egg guarding patterns of females. Another conclusion was therefore that there is a possible trade-off between foraging and egg guarding for eider females at Stora Karlsö, making eider females in a poor condition particularly vulnerable to early egg predation.

Keywords: Nest predation, Common Eider, Nest success, Predation pressure, Egg guarding, Activity patterns

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1. Introduction

Sea ducks in the northern hemisphere are suffering from a high predation pressure from various species (Götmark & Ahlund 1988; Holopainen et al. 2020; Mohring et al. 2024). Island breeders, such as the Common Eider (*Somateria mollissima)* try to avoid mammalian predation by choosing breeding sites without four-legged mammals (Ahlén & Andersson 1970; SLU Artdatabanken 2025). Still, the colonies of eider females in the Swedish coastline have suffered a population decline of about 50 % during the last ten years (SLU Artdatabanken 2025). Possible explanations are predation on adult females from White-tailed Eagle (*Haliaeetus albicilla*) (Mohring et al. 2024), warmer temperatures in the marine ecosystem causing decreased food quality (SLU Artdatabanken 2025), and nest predation of eggs from other bird species (Götmark & Ahlund 1988). The eider female is a capital breeder, meaning that they do not typically feed during breeding and that they lose a lot of weight to be able to spend almost 100 % of the time at the nest while incubating (Coulson 1999; Bottitta et al. 2003). However, during the first days of breeding the female is usually more absent from the nest (Ahlén & Andersson 1970), posing an increased risk of early nest predation (Öst et al. 2022). Öst et al. (2022) explained that females in a poor body condition might be particularly absent from the nest during the first days to gain more weight for the incubation period, thus lowering their nest success due to even more frequent nest predation. In this study, an analysis of the early nest predation on eider females is made to understand the factors contributing to egg predation and how it affects the female.

1.1 The Common Eider

The Common Eider is a long-lived sea duck that has a circumpolar breeding distribution, being found in coastal areas and on island groups (Chaulk 2005; SLU Artdatabanken 2025). In Swedish waters, the eider pairs fly from the wintering areas in the southern parts of the Baltic Sea in the early spring, arriving to the breeding areas on islands along the coast for the mating (SLU Artdatabanken 2025). There is no clear consensus in the literature regarding exactly how many days there are between mating and egg laying, but after mating the female searches a nest site between rocks and bushes on the island, and the male usually leaves when the female starts the incubation (SLU Artdatabanken 2025). During the first days the female is typically only present at the nest for laying the egg, which is done once per ~24h (Ahlén & Andersson 1970; Chaulk 2005). The reason is because the eider is a so called precocial breeder meaning that hatching occurs synchronously (Mohring et al. 2024). To prevent the eggs from hatching at different days, the female does not begin incubating the eggs until all or most of them are laid (Hanssen et al. 2002). For each egg laid, the female spends more time at the nest (Ahlén & Andersson 1970) until the incubation starts around five days after the first egg was laid (Olsson 2023). The most common clutch size is 4-5 eggs (Coulson 1999; Donehower & Bird 2008; Stien et al. 2010), and the egg production is strongly correlated to the fat reserves obtained in the wintering grounds (Kilpi & Lindström 1997; Mohring et al. 2024). The clutch size is often described as the reproductive investment, i.e. the total amount of eggs laid per female. The incubation period lasts about 24-28 days (Bottitta et al. 2003; SLU Artdatabanken 2025), and when the eggs have hatched the female leaves the nest with the chicks after around 24 hours (Mohring et al. 2024). From now on the female protects the ducklings from predators and leads them to areas where they can forage, which they can do immediately after leaving the nest (SLU Artdatabanken 2025).

Studies from different parts of the world reveal different information regarding the amount of time spent away from the nest during the incubation period, also called the amount of incubation intermissions. A study from Svalbard, Norway revealed that eider females could stay at their nest for several days after incubation had started (Ahlén & Andersson 1970). A study from the season of 2022 at Stora Karlsö, Sweden, using a video monitoring methodology, revealed that eider females left their nest for a short period almost once a day after incubation had started, but almost only during dark hours (Olsson 2023). However, there is a lack of information regarding the timing of incubation intermissions during the first egg laying days. What has been proven is that females that choose to leave their nest a lot during these days has a reduced nest survival probability due to nest predation, but with the advantage of more and larger eggs, possibly due to foraging during the incubation intermissions (Andersson & Waldeck 2006). This emphasizes that there for eider females might be a trade-off between foraging and egg guarding, and that these two parameters determine the final reproductive success. The reasons for the daily incubation intermissions are not well-studied, but as previously mentioned some suggestions are foraging of their main food, which is Blue Mussel (*Mytilus edulis*) (Bottitta et al. 2003; Chaulk 2005). A study of Waldeck and Larsson (2013) revealed that warmer winter temperatures in the Baltic Sea reduces the size and quality of Blue Mussels, which might explain why some females have not accumulated enough fat reserves during the weeks before incubation starts. This might explain why some eiders are particularly absent from the nest during the egg laying days and even during incubation, even though they are known as capital breeders.

1.2 Predation

The Common Eider is globally exposed to a high predation pressure from many diverse predators such as Arctic Fox (*Vulpes lagopus*), Polar Bear (*Ursus maritimus*), Glaucous Gull (*Larus hyperboreus*) and American Mink *(Neovison vison)* (Ahlén & Andersson 1970; Noel et al. 2005; Holopainen et al. 2020). Several studies also reveal that predation on ducklings is a big threat to the eider populations, meaning that populations having a high nest success not necessarily are stable (Swennen 1989; Donehower & Bird, 2008) For some eider colonies in Sweden, studies have revealed that the main predation is carried out by Hooded Crow (*Corvus cornix*) and Herring Gull (*Larus argentatus*) (Götmark & Ahlund 1988). These two predator species act as nest predators, taking eggs directly from the nest when the female eider is not present (Öst et. al 2022). Several studies suggest that this type of nest predation might reduce the number of hatched eggs or even the nest survival probability (Ahlén & Andersson 1970; Noel et al 2005; Stien et al. 2010).

At the island Stora Karlsö in the Baltic Sea in Sweden, Hooded Crow and Herring Gull are also known to be the main egg predators (Olsson 2023). The island does not have any four-legged animals like American Mink or Red Fox (Baltic Seabird Project 2024). Furthermore, the presence of White-tailed Eagle during the eider breeding period is very low due to human activity during the tourism period (Hentati-Sundberg et al 2021). Nest predation from this species is therefore considered negligible on the island. The most recent proper bird inventory on the island revealed that there are around 1000 breeding pairs of Common Eider (Könönen 2021). This is a relatively large colony in the Baltic Sea, possibly because of the absence of predators preying on adult eiders. However, the number of breeding eider pairs was only an estimation based on the number of individuals on the water, and the number is believed to have slightly decreased during the last years (Baltic Seabird Project 2024). The declining eider population on the island may itself be a threat to the population growth as the remaining individuals would be more vulnerable to predation pressure. The number of Herring Gull nests on the island was estimated to 169 in 2025 (Baltic Seabird Project 2025) and the number of breeding Hooded Crow pairs seven in 2021 (Könönen 2021), but the latter may have changed during the last four years.

It is believed that the predation from Hooded Crow and Herring Gull is typically concentrated to the first days of breeding, since the female is more absent from the nest during this period. Females leaving their nest a lot during the first sensitive days of breeding may pose a bigger risk of having their eggs predated and therefore have a decreased reproductive success (Bottitta et al. 2003). Furthermore, a study of Öst et al. (2022) suggested that females that are in a poor body condition already in the beginning of their incubation are forced to leave the nest more often to forage as a preparation for the incubation, and that this behaviour can reduce the nest success. Botitta et al. (2003) even suggested that these females might abandon their nest since eiders are long-lived and will have several more chances to reproduce (Bottitta et al. 2003). The study of Olsson (2023) from the breeding season of 2022 at Stora Karlsö revealed that nest predation from Hooded Crow and Herring Gull was only occurring nine times during the whole breeding period. However, since the main focus in Olsson's (2023) study was not to examine nest predation but to analyze the breeding behaviour of the eider female, the methodology might have been different regarding study period and selection of observations. Furthermore, Olsson (2023) suggested that early nest predations might have been missed in her study since the camera surveillance was put up when some eider females had already started incubating. To cover this possible knowledge gap, the current study will focus on the early nest predation and compare results of nest success and basic breeding parameters with the study of Olsson (2023).

1.3 Aim of the study

To conclude, it is of importance to make a proper study on the early nest predation for the Common Eider since there is a lack of knowledge regarding the actual predation pressure on the island. Globally, few studies of nest predation on eiders include breeding attempts where only one or a few eggs were laid. Furthermore, the factors contributing to egg predation are not clear, more specifically the potential trade-off between foraging and egg guarding, the potential overlap of activity patterns of females and predators and the timing of egg laying vs. egg predation. Therefore, this study is needed to describe the actual nest predation pressure on the island. Also, it is needed to further investigate the correlation between egg guarding and predation risk as well as the activity patterns of females and predators, especially during the early breeding phase. With the results from this study, it will be possible to emphasize the most vulnerable stages of the breeding period as well as to create new ideas for future research. The following questions will be answered:

- **How much nest predation occurs?**
- **How does nest predation affect female Common Eider breeding?**
  Nest success, number of chicks, clutch size and expected number of eggs lost per female and breeding will be examined
- **What factors influence whether predation occurs or not?**
  Egg guarding vs. predation risk, activity patterns of females and predators, and timing of egg layings vs. egg predations will be examined.

2. Material and methods

2.1 Monitoring of breeding eiders on Stora Karlsö

The data for this study was collected at the island of Stora Karlsö, Gotland, Sweden (57°17'26"N 17°57'41.1"E). It is an island of 3 km^2 in the Baltic Sea, about 7 km west from the coast of Gotland and around 80 km east from the Swedish mainland. The island is unique in its rich bird life and the coastline is a protected bird area from the middle of March until September. Tourism is conducted from beginning of May until September with guided tours about birds, plants and cultural history. Research about the islands' great colonies of Guillemots (*Uria aalge*) and Razorbills (*Alca torda*) has been going on since the late 90's but studies of Common Eiders are more recent in this area. Video monitoring of breeding eiders was conducted in a small area at the northwest tip of the island (Figure 1). The area is known by sea bird researchers on the island for having several breeding eiders. The nests are typically found close to the beach in thick masses of dry leaves between rocks or bushes, with a moderate vegetation cover of trees. As seen in Figure 1, cameras for the video monitoring were put up in a line along the beach about 20 meters from the water.

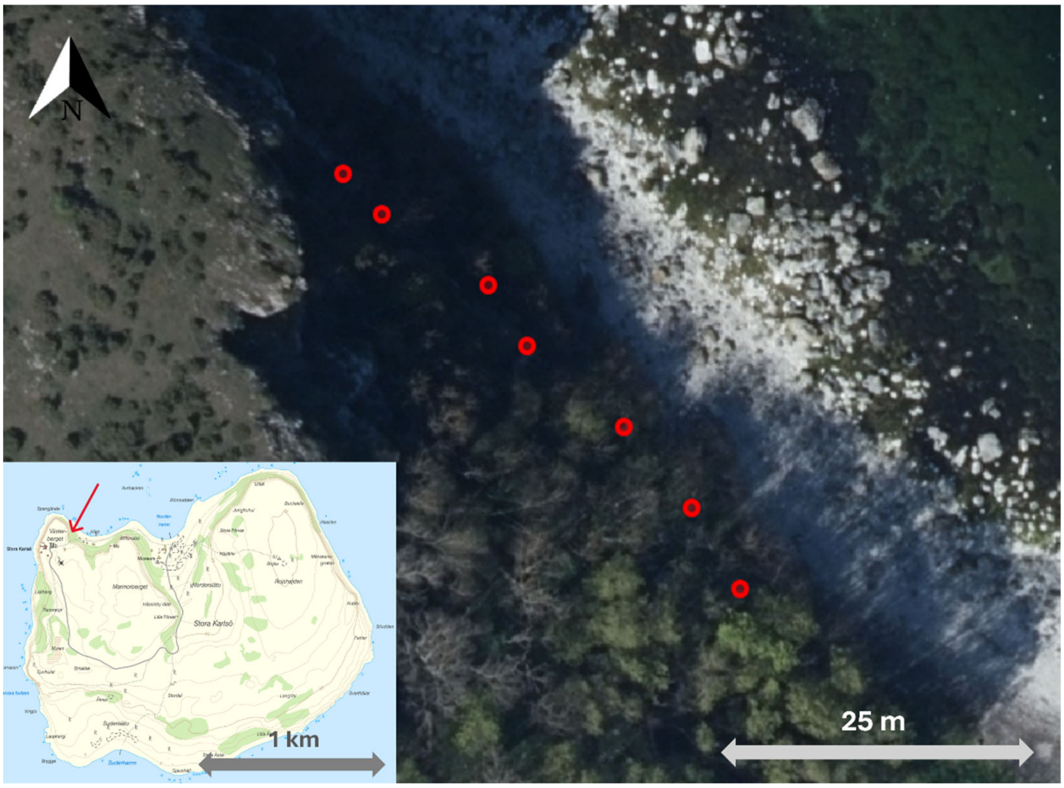


Figure 1. Placement of cameras in red dots. Zoom out of the island with arrow pointing at study area. (Flygbild, Karta (Min karta) © Lantmäteriet).

2.2 Filming setup

Data collection was made using eight IP-bullet cameras that recorded video during the whole eider breeding period on a Network Video Recorder (Provision). The cameras were put up in mid-April 2024 and put down in the beginning of June – beginning of July 2024. The cameras were set up before any eider female had started to lay any eggs and put down when the females seen in the camera view had completed incubation or left the nest. The cameras filmed day and night with an automated infrared radiation (IR) light during night. Video recordings were cut in shorter parts of one hour, thus giving a total of about 900 videos for each camera. One of the cameras never had any breeding female and was therefore not further studied. The placement of the cameras was determined with help of researchers at the island and their knowledge about the placement of nests from the previous year. The angle of the camera was adjusted when eider females arrived at the nest sites to cover as many females in one camera as possible. The aim was to get the best possible view of the females' egg layings, nest predations and incubation intermissions from the nest site.

2.3 Video analysis

To save time, an AI-model was trained to recognize the five categories of species that are most frequently in the study area. The training of the AI depended on a YOLOv11 nano object detection model that had been trained outside this project to identify five classes of objects: Eider female, Eider male, Herring gull, Hooded Crow and Razorbill (Herring Gull from now on called "gull" and Hooded Crow called "crow"). Razorbills were not the focus of this work but were included in the model as they would otherwise confuse the model and potentially generate false detections of the focus objects. In total 5852 images were used for training the model, split in 80 % training , 10 % validation and 10 % test data. After training for 100 epochs, the model achieved a F1 score of 0.95 at a 0.592 confidence level. A Python script was made making a plot of all the registrations of the different categories during the whole breeding period (Figure 2), one plot for each camera separately. Each plot was divided into five smaller plots for each category of species, with date of AI-registration shown on the x-axis. A zoom function made it possible to zoom in on specific days and thus gain a more detailed understanding of exactly when an AI registration was made; what hour, minute and second. The arrow in Figure 2 points at the successful AI registration of the eider female shown in Figure 3. The reason for the curve to go down to zero is either because the female was absent from the nest, loss of video material, difficult lighting conditions, or the female moving in a way that the AI did not recognize. The gull in Figure 3 is another example of a successful AI registration.

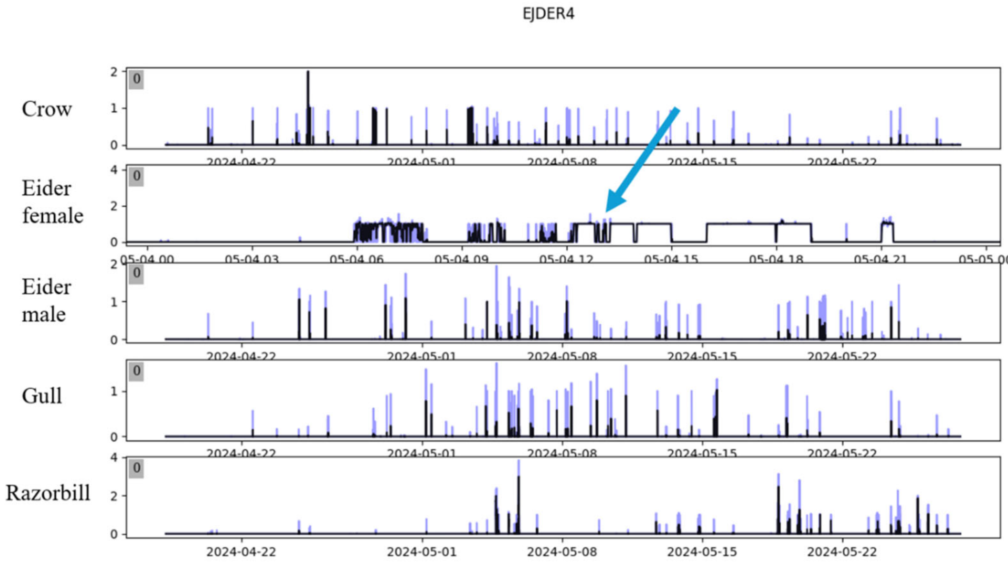


Figure 2. AI-registrations of the five categories of species at camera 4. Date (and time when zoomed in) on the x-axis and no. of individuals on the y-axis. The arrow points at the AI's registration of the eider female shown in Figure 3.

Figure 3. Eider female at the nest (Camera 4, 2024-05-04 13:07) and Herring Gull taking an egg from another nest (Camera 6, 2024-05-07 16:38). Both photo sequencies were captured by the AI and plotted in the AI registration plot.

The video material was studied one camera at the time using the AI registrations of females, males, crows and gulls. Firstly, registrations of females and males were checked to find all possible nest sites in the camera view. Exact time stamp for arrival to the nest was observed from the plot (Figure 2), and the video material was entered to verify the registration with a human eye. Nests that were too far away or covered by bushes were not studied. The nests were given an ID with the first number corresponding to the camera name and the second to the nest site in chronological order from when the females arrived. Secondly, egg layings were studied by observing the video material from the first week of breeding, since the AI-registrations could not be used for this. When it was not possible to find egg laying events, the first observed egg was noted.

To understand the factors contributing to egg predation, the video material was studied in more detail for those egg layings that could be given an exact time stamp ±1 hour (n = 33). Firstly, timing of egg layings and eventual predation was noted. Secondly, all incubation intermissions from the egg laying until the morning/mid-day (depending on when the female returned to the nest) the day after were noted to receive the number of hours when eggs were unattended. For example, if the female laid an egg at 15:00, left the nest at 21:00 and returned at 04:18 the day after, six hours was noted as the time spent at the nest and an incubation intermission of seven hours and 18 minutes was noted. This was converted into number of hours when eggs were unattended using:

No. of hours when eggs were unattended = $h + \frac{m}{60}$ (1),

where h = no. of whole hours of unattendance, m = no. of minutes of unattendance for those observations where the egg was unattended for a part of the hour. If the egg was predated before the female had returned to the nest, the egg was seen as unattended until the predator took the egg. Lastly, the time for return was noted for all the females that laid eggs that were not predated.

At last, predation events were studied using all the AI registrations of crow and gull. Sometimes the AI registered a razorbill or an eider female as a crow, and sometimes an eider male was registered as a gull. In these cases, a human eye verified the actual species and only correct registrations were further studied. Predator events were divided into four categories for crow and gull, separately:

1. Predator took an egg from the nest and ate it or carried it away.
2. Predator ate an already predated egg directly from or besides the nest.
3. Predator root around in the nest without finding any egg.
4. Predator passed by close to the nest and appeared to be searching for eggs.

Observations from category 1 were the most used in the analyses of this study. Observations from categories 2, 3 and 4 were only used in the analysis of activity patterns of predators on different hours of the day. Observations from category 3 were additionally used in the analysis of search effort for predators. A predator passing by far back in the camera view or gathering nest material was not counted into any category. Lastly, the time for leaving the nest and number of chicks was registered. A breeding attempt was defined as when a female laid at least one egg at a nest site well seen. A successful breeding/successful nest was defined as when the female left the nest with at least one chick. An unsuccessful nest was thus defined as a breeding attempt where no chick was hatched. For one nest site, it was impossible to count the number of chicks due to vegetation cover and the number of chicks was therefore an estimation based on the last number of eggs seen. For some nest sites it was difficult to decide for example whether four or five chicks left the nest. In these cases, the minimum number of chicks was chosen.

Some nest sites that were too far away from the camera view or covered by vegetation were excluded from the final results due to lack of information about the breeding events at these sites. Some egg predations from unknown nests were observed. These were not counted in the results since it was impossible to associate them with any nest or egg laying. A few eggs were disappearing from the nest without it being possible to associate them to any predation. These eggs were not counted in the results, since it was unclear if predation had occurred or if the eggs had rolled out of the nest. Data was gathered and analysed in Excel.

2.4 Statistical analysis & calculations

Statistical analysis was made in Excel with the addition of the Excel solver package. Chi-square test was made using the CHISQ.DIST.RT function. Standard deviation was calculated with the STDEV.P function. Equations from a study in Svalbard, Norway (Ahlén & Andersson 1970:93, 96) were used to calculate mean egg loss per successful nest and nest survival probability. Mean egg loss per successful nest during breeding could be calculated with:

$$\textit{Mean egg loss} = \frac{p}{t} \times b \qquad (2),$$

where p = total no. of predated eggs, t = total no. of days of exposure and b = mean breeding period. Only successful nests were included in this calculation. Total number of days of exposure was calculated as the sum of the days between first egg laying and date of leaving nest with chicks, for all successful nests (see Appendix B for raw data). Mean breeding period was calculated based on the mean date for egg laying and date of leaving nest for all successful nests. Nest survival probability during breeding could be calculated with:

$$\textit{P(nest survival)} = (1 - \frac{u}{t})^b \qquad (3),$$

where u = total no. of unsuccessful nests, t = total no. of days of exposure and b = mean breeding period. All nests were included in this calculation. The total number of days of exposure was calculated in two different ways for successful and unsuccessful nests respectively. For successful nests, the days of exposure were defined as the sum of the number of days between first egg laying and date of leaving the nest with chick, for all successful nests together. For unsuccessful nests, the days of exposure were defined as the number of days between egg laying and egg predation, for all unsuccessful nests (see Appendix B for raw data). For those cases where all eggs were predated and the female was absent from the nest for several days before laying a new egg, only days when eggs were laying in the nest were counted as days of exposure. The value used for the mean breeding period was the same as when making the calculations from equation (2).

A logistic regression was made for the observations of time spent at the nest after egg laying and whether the egg was predated or not (see Appendix C). Using Excel Solver, an estimated intercept and slope was retrieved. The std. error and p-value was calculated using R version 4.4.2. To calculate the probability of predation depending on the number of hours spent at the nest after egg laying, the following equation was used:

$$P(egg\ predated) = \frac{1}{1+e^{(-(i\ +xh))}} \quad (4),$$

Where i = intercept, x = slope and h = no. of hours spent at nest.

3. Results

3.1 Nest success, predation pressure and breeding parameters

A total of 17 nest sites with a breeding attempt were observed, of which six were abandoned after egg predation and never got any chicks. This results in 11 successful breeding attempts and a total nest success of 65 % (Table 1). The clutch size varied between one and nine eggs, with a mean value of 4.59 eggs (Standard deviation = SD = 1.91 eggs) based on 17 females (Table 1). The number of chicks per nest varied between zero to five chicks with a mean value of 2.65 (SD = 2.03 chicks) based on 17 females (Table 1). 71 % of all the nests had at least one egg predated by a crow or gull. Out of these, 50 % abandoned their nest and never got any chicks, and 50 % ended as a successful breeding attempt. 29 % were not predated at all (Figure 4). The predation factor ranging from 0 to 1 in Figure 4 represents a numeric value of the ratio of predated eggs per nest. The number of eggs predated per nest varied between zero and six eggs, with a mean value of 1.94 eggs (SD = 1.95 eggs) (Figure 4). The predators' total search effort, including successful search attempts when an egg was found and eaten for the first time (category 1, see section 2.3), as well as unsuccessful search attempts when no egg was found (category 3), are presented in Figure 5. A total of 33 egg predations were observed, corresponding to 42% of the total clutch size being predated (Table 1). 36 % of predations were made by crow and 64 % by gull (Figure 5). Crows had a ratio of 36% successful search attempts and 64 % unsuccessful, and gulls 40% successful and 60 % unsuccessful (Figure 5). No predations on adult females were observed (see Appendix A for raw data on all predation events). All egg predations occurred when the female was absent from the nest, except one when a female was scared away from the nest by a gull.

Mean dates for different breeding events are presented in Table 2. The mean date of first arrival to nest was 30 April, based on all nest sites (n = 17). The mean date of first egg laying was 1 May, based on nests where egg laying either could be set an exact time stamp or be estimated within ±36 hours based on observations of first arrival and first egg seen (n = 15). Mean date of first egg laying for successful nests (n = 11) was also calculated to be able to decide mean breeding period in equation (2), and the date was 1 May once more. The mean date for leaving the nest with chicks was 2 June based on nests with successful breeding (n = 11). To calculate the mean egg loss per nest during breeding (Table 3), only successful nests were studied (n = 11) since the aim was to calculate in the same way as in a study from Norway (Ahlén & Andersson 1970) to compare results. Mean breeding period was calculated to 32 days based on results from Table 2.

Equation (2) was then used and mean egg loss per successful nest during breeding was calculated to 1.14. Unsuccessful nests were handled in the calculation of nest survival probability during breeding with equation (3), along with all successful nests (total n = 17) (Table 4). Nest survival probability during breeding was 0.61. It is important to note that these calculations were made with the assumption that the predation risk is constant during the whole breeding period.

*Table 1. Clutch size for all nest sites studied in the area (n = 17). The first number of the nest site refers to the camera number and the second to the nest in chronological order from when the females arrived. Ratio of predated eggs and chicks is presented for each nest site. + = Minimum no. of chicks seen. * = Estimation based on last no. of eggs observed.*

Nest	Clutch size	Predated eggs	Chicks
1.1	9	5	4+
2.1	4	0	4*
2.2	1	1	0
2.3	6	6	0
2.4	1	1	0
3.1	7	3	4
4.1	3	0	3
4.2	3	3	0
5.1	5	0	5
5.2	5	2	3
6.1	5	1	4
6.2	5	1	4
6.3	5	5	0
6.4	5	0	5+
7.1	6	1	5
7.2	4	0	4+
7.3	4	4	0
Total	**78**	**33**	**45**

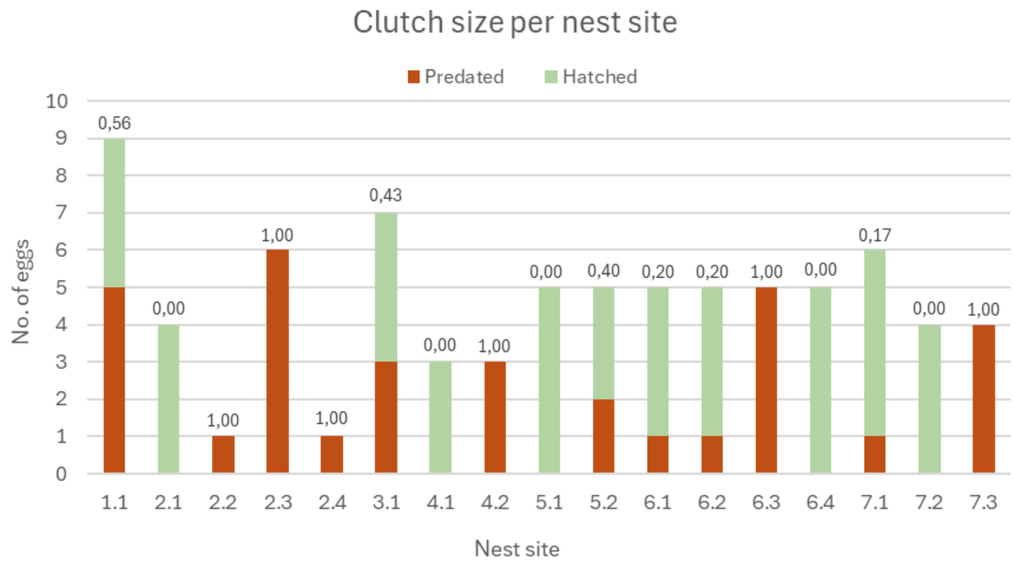
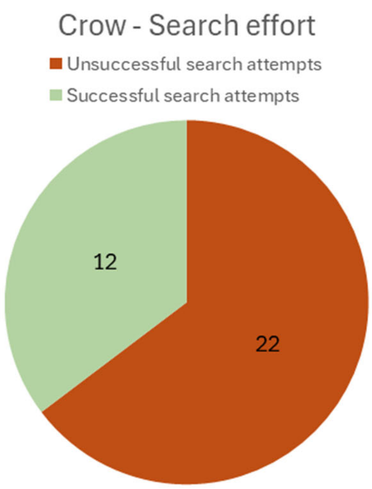


Figure 4. Total clutch size per nest site (no. of nests = 17) (no. of eggs = 78) defined as the sum of predated eggs (red bars) and hatched eggs (green bars). Predation factor per nest site presented on top of each bar, expressed as a ratio between number of eggs predated vs. clutch size where 0 = No egg predated, 1 = All eggs predated.



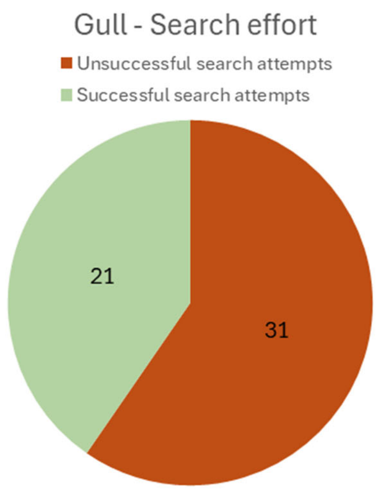


Figure 5. Total search effort for crow and gull expressed as the proportion of unsuccessful and successful search attempts. The numbers in the circle represent the total number of unsuccessful vs. successful search attempts during the whole breeding period.

Table 2. Mean date and time for different breeding events, where SD is the standard deviation and n is the number of nests included in the calculation.

Breeding event	First arrival	First egg laying	First egg laying successful nests	Leaves nest
Mean date	2024-04-30 16:36	2024-05-01 23:06	2024-05-01 19:04	2024-06-02 19:12
SD	3 d 4 h 5 min	5 d 9 h 22 min	6 d 6 h 29 min	5 d 6 h 14 min
n	17	15	11	11

Table 3. Values that were used when calculating mean egg loss per successful nest during breeding using equation (2). Only successful nests were included (n = 11). Mean egg loss per successful nest is presented in bold.

n	No. of eggs predated	Total no. of days of exposure	Mean breeding period in days	**Mean egg loss per nest**
11	13	365	32	1.14

Table 4. Values that were used when calculating nest survival probability using equation (3). All nests were included in the calculation (n = 17). Nest survival probability during breeding is presented in bold.

n	No. of unsuccessful nests	No. of days of exposure	Mean breeding period in days	**Nest survival probability**
17	6	396	32	0.61

3.2 Timing of predation events & egg layings

Dates for egg layings are presented in Figure 6 (number of observations of egg layings = 33), and dates for egg predations in Figure 7 (number of observations of egg predations = 33). Only egg layings that could be given an exact time stamp ±1 hour are included. Egg layings mainly occurred between 24 April and 9 May, except for two egg layings on 16 May and 17 May. The mean date of egg laying was 2 May (SD = 4 d 0 h 10 min). Egg predations mainly occurred between 24 April and 8 May, except for one predation event on 19 May. The mean date of egg predation was 3 May (SD = 4 d 12 h 0 min) (see Appendix A for raw data). Hour of the day when egg predations and egg layings occurred are presented in Figure 8. A chi-square test revealed that egg predations significantly occurred during light hours between 04:00 – 20:59 and not at other times of the day, $\chi^2(1, N = 33) = 14$, $p = 0.0002$. 52% of all predations occurred between 04:00 – 08:59 (Figure 8). The mean hour for egg predation was 10:03 (SD = 5 h 6 min) (see Appendix A for raw data). 76% of all egg layings (± 1 hour) (n = 33) occurred between 12:00 – 22:59 (Figure 8). The mean hour for egg laying was

13:34 (SD = 5 h 59 min). Active presence of predators is presented in Figure 9, defined as all predator observations from category 1, 2, 3 and 4 (see section 2.3) during the whole breeding season, each hour separately. Predators were only active during the light hours of the day and gulls were particularly active between 04:00 – 04:59. The mean time of day for predation presence was 10:31 (SD = 5 h 34 min).

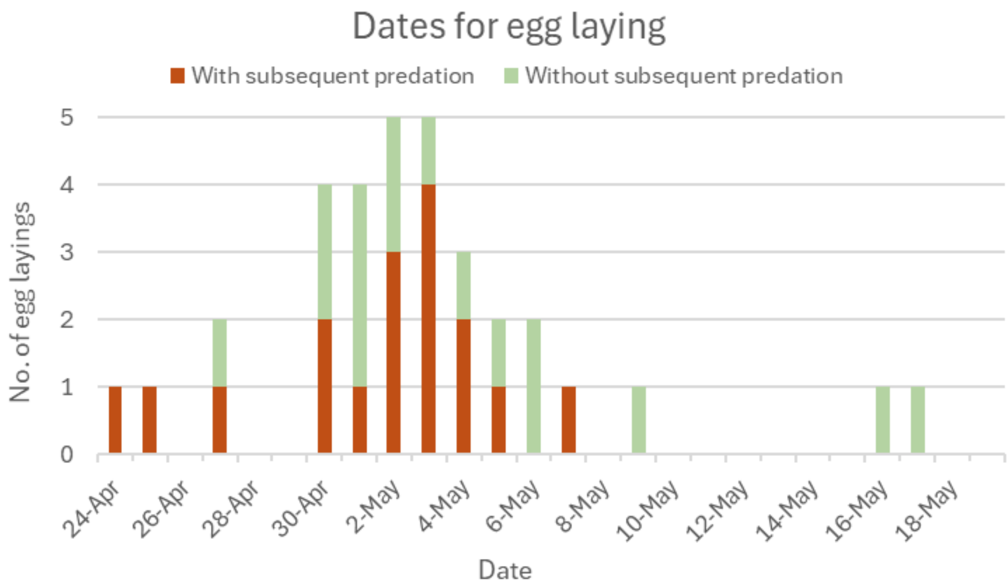


Figure 6. Total number of egg layings on different dates. Only egg layings that could be set a time stamp within ±1 hour are included (n = 33), therefore not corresponding to the actual number of eggs laid. Red colour represents eggs that ended up predated, and green colour eggs that ended up hatched.

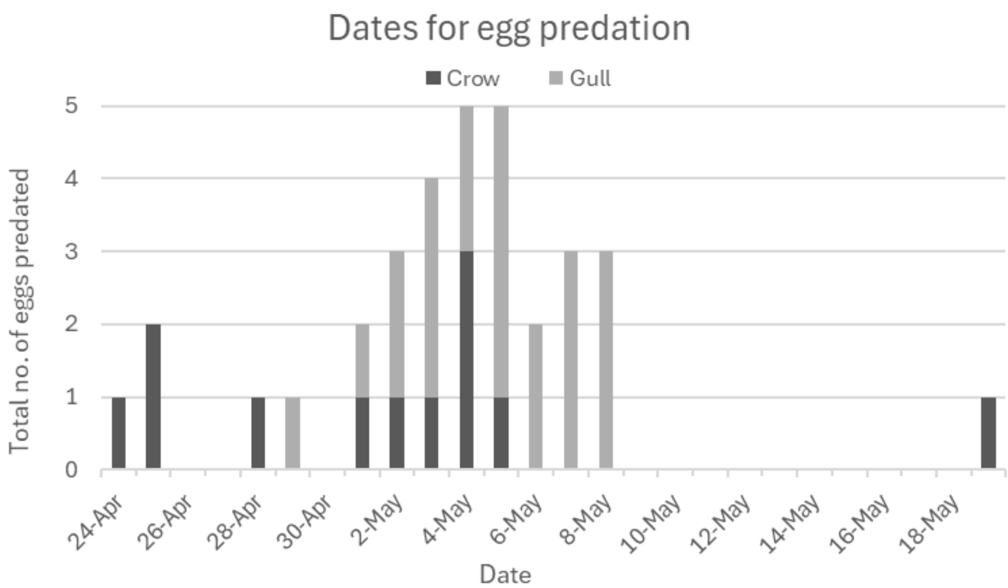


Figure 7. Total number of egg predations by crow vs. gull on different dates (n = 33).

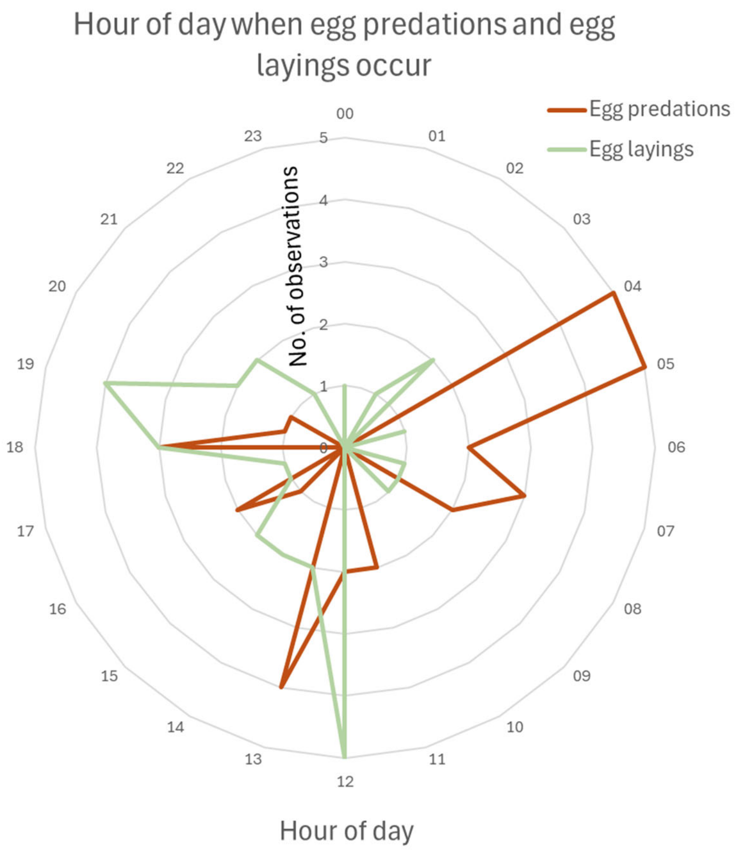


Figure 8. Timing of egg layings (n = 33) and egg predations (n = 33). Only egg layings where a time stamp within ±1 hour could be set are included. The radius of the circle corresponds to the number of observations and the circumference the hour of the day, where 00 equals time 00:00 – 00:59.

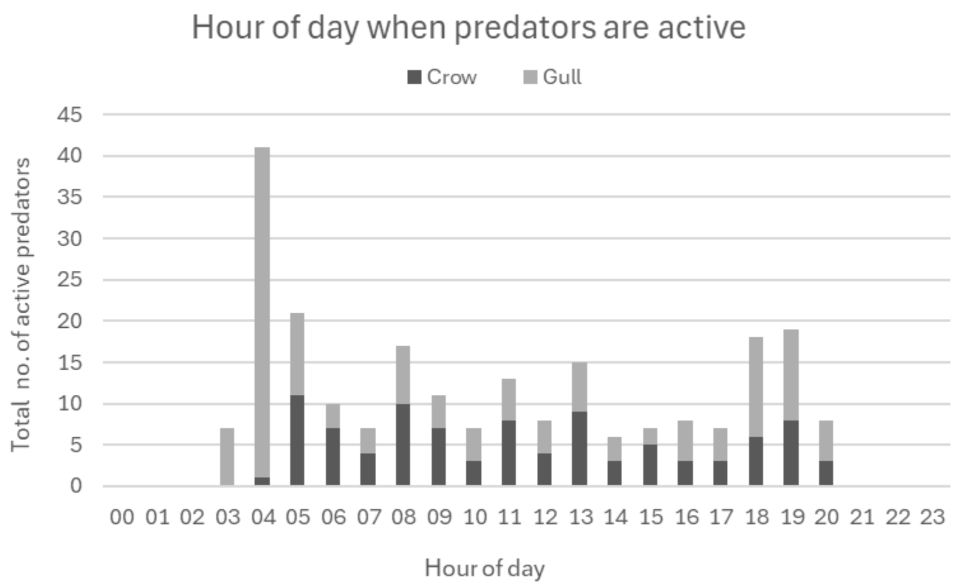


Figure 9. Total number of active predators on different hours of the day, where 00 equals 00:00 – 00:59. Crows in dark grey and gulls in light grey.

To understand the factors contributing to egg predation, incubation intermissions during the first day after egg laying were studied in detail for the 33 egg layings where a time stamp (± 1 hour) could be set. Raw data for this detailed analysis, including a calculation of the predation risk during different hours of the day is presented in Table C1 in Appendix C. Unattended eggs were observed during all hours of the day, but particularly many between 21:00 – 04:00 (Figure 10). 17 of the eggs were predated, and all of them were taken either the same day or the day after the egg laying. 16 eggs were not predated (See Appendix C). Predation risk during different hours of the day the first day after egg laying is presented in Figure 11, based on 33 egg layings. The predation risk was highest during the morning between 04:00 – 07:59 and during mid-day between 11:00 – 13:59.

The time spent at the nest after egg laying is presented in Figure 12. All females that laid an egg that was predated were staying at their nest for less than two hours. All females that stayed at their nest for a longer period (ranging from 2-13 hours) laid eggs that were not predated. A logistic regression was made for the data in Figure 12, and calculations for the probability of predation were made using equation (4). A probability curve is presented in Figure 13, showing that there was a significant correlation between probability for predation and time spent at the nest after egg laying ($p = 0.0247$) (see Appendix D for regression statistics). In other words; females staying at their nest for a longer period had a reduced risk of egg predation at the 5 % significance level. The hour for returning to the nest the day after egg laying is presented in Figure 14 for those females laying an egg that was not predated ($n = 16$). All females returned to the nest the day after egg laying, 81 % between 01:00 – 05:59.

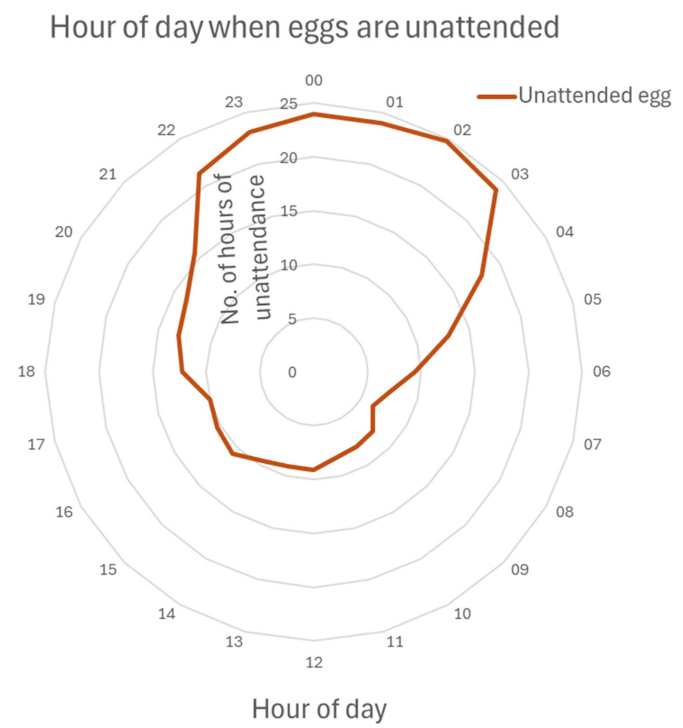


Figure 10. Number of hours where eggs were observed unattended on different hours of the day during the first day after egg laying (no. of egg layings = 33) (total no. of hours of unattendance = 333). The radius of the circle corresponds to the number of hours of unattendance and the circumference the hour of day, where 00 equals time 00:00 – 00:59

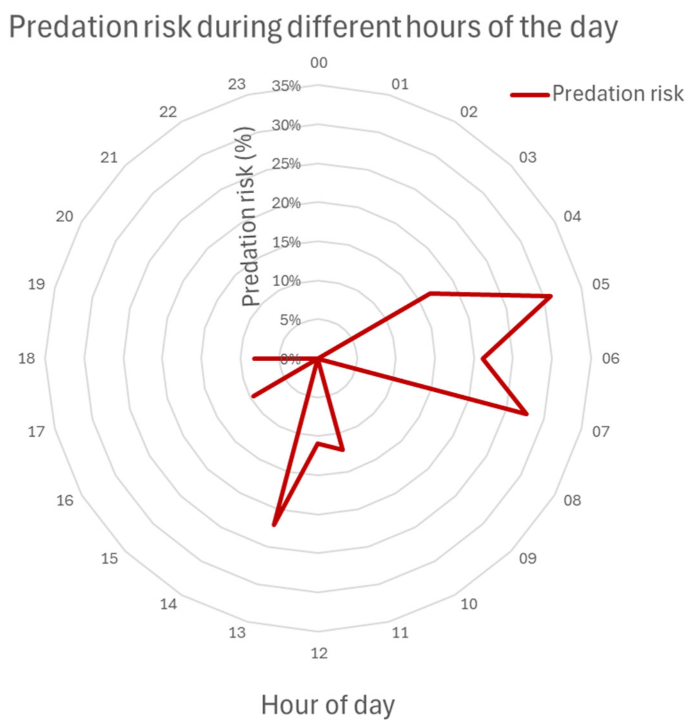


Figure 11. Predation risk during different hours of the day, based on the ratio between number of egg predations and number of observations of unattended eggs.

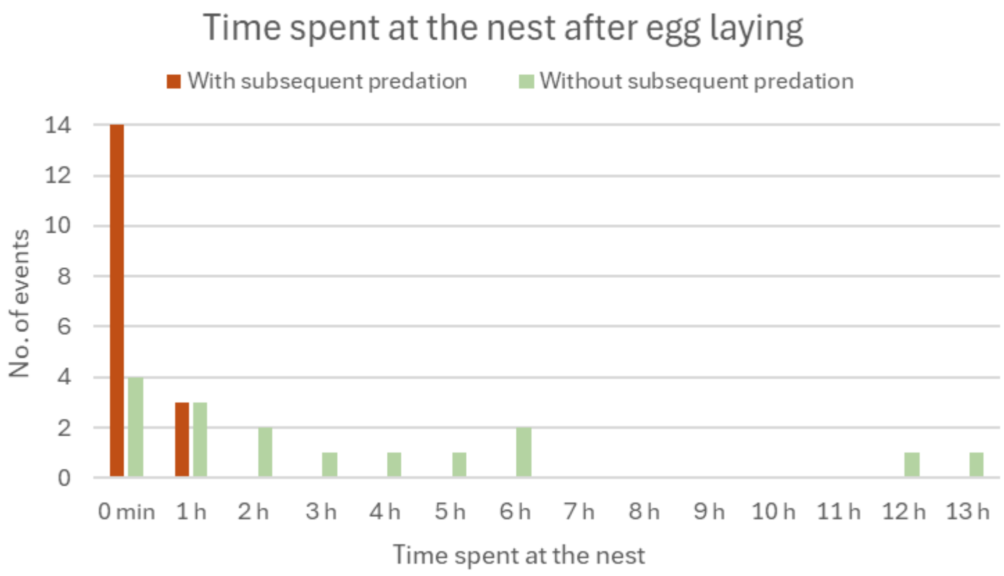


Figure 12. Time spent at the nest after egg laying for eggs that were predated (red bars) (n = 17) and eggs that were not predated (green bars) (n =16). 0 min equals 0 min – 60 min.

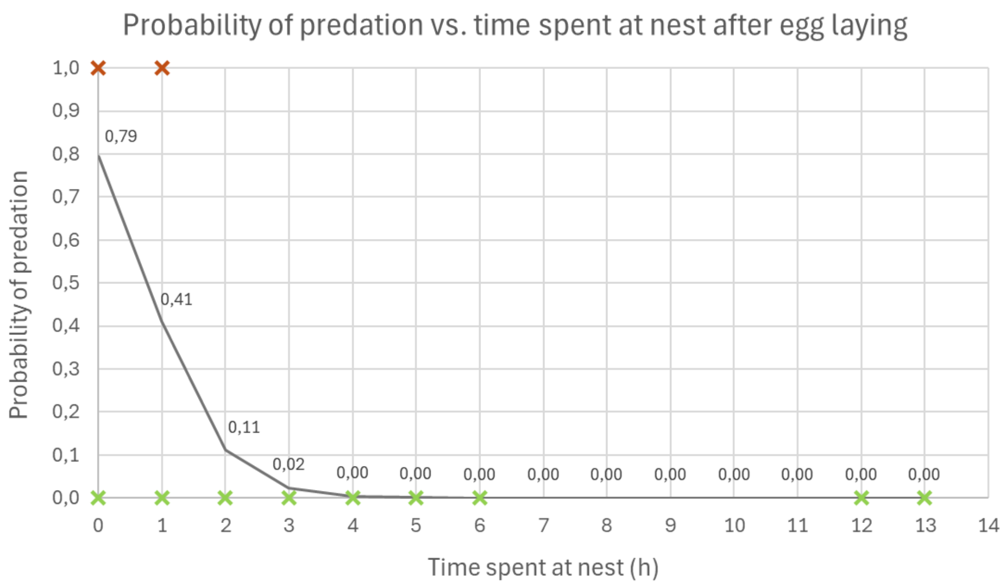


Figure 13. Probability of predation in relation to time spent at the nest after egg laying, where 0 equals 0 min – 59 min. The graph is based on a logistic regression model with a p-value of 0.0247 and a total of 34 observations. Red crosses represent the time spent at the nest for eggs that were predated (n = 17) and green crosses eggs that were not predated (n = 17). Several observations overlap explaining why only eleven crosses are seen in the graph. Probability of predation for each hour is presented next to the graph line.

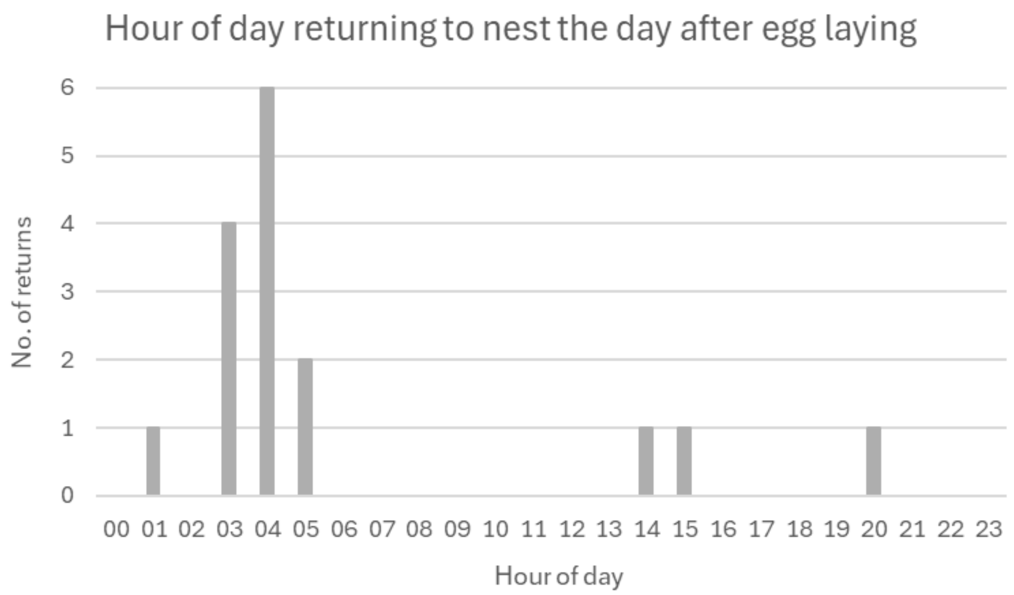


Figure 14. Hour of day when returning to nest the day after egg laying, where 00 equals 00:00 – 00:59. Only returns from females laying non-predated eggs are presented.

4. Discussion

4.1 How much nest predation occurs and how does it affect the female Common Eider breeding?

Two of the questions to be answered in this study was how much nest predation occurs and how it affects the female Common Eider breeding. To answer this, a discussion about nest success, predation pressure, number of chicks and egg loss will be made. To begin with, the total nest success was 65 % (n=17), which can be compared with the 79 % (n = 14) shown in Olsson's (2023) study on eider females at Stora Karlsö from the breeding season of 2022. One likely explanation to the decreased nest success is that the percentage of predated eggs increased from 13 % in 2022 (Olsson 2023) compared to 42 % in 2024. More evidence of the high predation pressure is found when comparing the nest successes from Stora Karlsö with two other studies of nest predation of Common Eider colonies. Firstly, a study in Maine, USA (Donehower & Bird 2008) revealed that a nest success of 84 % can be expected when almost no nest predation occurs, which is a value very close to the value of year 2022 at Stora Karlsö. A study from northern Norway (Stien et al. 2010) revealed that for one of the two studied islands a nest success of 61 % can be expected with moderate to high predation pressure, which is a value very close to the value of year 2024 at Stora Karlsö. It is therefore once more possible to conclude that the lower nest success at Stora Karlsö compared to year 2022 could be explained by higher predation pressure.

Both predator species of this study had around the same ratio of successful search attempts vs. unsuccessful and could therefore be regarded as equally effective predators. However, gulls accounted for 64 % of the predation and crows for 36 %. The higher predation pressure from gulls could be explained by the most recent inventories of breeding bird species at Stora Karlsö from 2021, where the estimated amount of breeding Hooded Crow pairs was seven (Könönen 2021), and the number of Herring Gull nests 169 (Baltic Seabird Project 2025). However, it is important to mention that the current study has not shown the number of individuals of predators, meaning that there is a possibility that there was only one or a few pairs of gulls acting as predators. Still, the results could indicate that gulls may pose a greater threat to the eider nest success at Stora Karlsö than crows.

It is not possible to make any firm conclusions regarding why the predation pressure increased from year 2022 to 2024. One speculation was that the video recording, that started around 12 days later year 2022 (Olsson 2023), would have missed the earliest breeding attempts and thus also the earliest predation events.

However, when calculating the mean arrival date of unsuccessful nests in year 2024 it appeared to be two days later than for all nests, indicating that females with unsuccessful nests do not necessarily arrive before females with successful nests. They should therefore have been recorded in year 2022 even though the cameras were put up later. Another explanation could be that Olsson's (2023) study had another methodology where predation was not in the focus, which could have made that some egg predations were missed in the video analysis. The last possible explanation could be that there has been a decreasing trend of the Common Eider population at Stora Karlsö (Baltic Seabird Project 2024) since the last big bird inventory by Könönen (2021), and that this smaller population would suffer from the so called Allee-effect. The Allee-effect means that when a prey population decreases in number, their reproductive success will be affected to a greater extent by predator pressure, even though the predator population is the same size as before (Oro et al. 2006). Oro et al. (2006) showed in a study from Spain that the Allee-effect occurred for a predator-prey colony of two species of gulls, where one of the species acted as nest predator on the other species. The study showed that smaller populations of prey were suffering from a decreased reproductive success and breeding success caused by the higher nest predation pressure. Even though the predator and prey species were not the same as in the current study, the results of Oro et al. (2006) still emphasize the importance of considering the Allee-effect as a possible explanation for higher predation pressure.

The number of chicks per nest site varied between zero to five with a mean value of 2.65 chicks. These results are very similar to those of year 2022, ranging from zero to six with an average of 2.60 (Olsson 2023:7). This indicates that nests that were successful managed to produce relatively many chicks even though they were suffering from a high predation pressure. In other words, the predation pressure seems to have more effect on the nest success than on the number of hatched eggs for the studied eiders. One possible explanation could be that eider females in a poor body condition are more affected by heavy nest predation since eider females' egg production is strongly correlated with their body condition during egg-laying (Kilpi & Lindström 1997; Mohring et al. 2024). Females in a poor body condition might then choose to abandon their nest after egg predation; a common behaviour in long-lived birds since they will have several more years to reproduce (Bottitta et al. 2003). Females in a good body condition might be less affected by the predation pressure since they have a greater capacity of producing many eggs (Mohring et al. 2024). One important bias should be mentioned in this reasoning; females might have abandoned their nest just to make a new one that were unknown to predators outside of the camera view, and these nests were not part of the results in this study. It is therefore possible that the actual nest success was higher than 65 %. Also, further studies about how the changes in the quality of the eiders main food blue mussels affect the egg production are needed to draw any firm conclusions about the body condition changes of the Common Eider population at Stora Karlsö.

The clutch size per nest site varied between one and nine eggs, in contrast to three to nine eggs in the year 2022 (Olsson 2023). This could be explained by the fact that three more nests were studied in 2024. The mean clutch size was 4.59 which is slightly lower than in year 2022 at Stora Karlsö (mean = 4.90) (Olsson 2023). It is normal for eider colonies to have some variation in clutch size from year to year (Coulson 1999). The mean clutch size is also still very close to other studies of Common Eiders at islands with crows or gulls as main nest predators: 4.65 eggs in Maine, USA (Donehower & Bird 2008), 4.25 eggs in northern Norway (Stien et al. 2010), 4.19 – 4.34 eggs in Great Britain (Coulson 1999), and 4.62 eggs in southwestern Finland (Öst et al. 2022). The conclusion is made that the slight decline in clutch size from two years ago is a part of the annual changes in clutch size and is therefore not necessarily related to the increased predation pressure.

Mean egg loss per successful nest during breeding was 1.14 eggs and the nest survival probability was 0.61. The mean egg loss can be compared with the results of Ahlén and Andersson (1970) which varied between 0.16 – 0.90 eggs in eider colonies with different intensities of nest predation pressure. Their conclusion was that even a loss of 0.49 eggs was considered a high predation rate, meaning that an egg loss of 1.14 eggs can be regarded as having a big impact on the eider breeding biology, since the eider females need to have enough fat reserves to produce one additional egg in order to get the same number of chicks. The nest survival probability is relatively low when comparing with the study of Ahlén and Andersson (1970), indicating that eiders at Stora Karlsö have a moderate chance of having their nest survived during the whole breeding period. However, the clear conclusion that can be made is that even though the nest survives, the female needs to have enough fat reserves to be able to lay in average one additional egg to maintain the same number of hatched eggs as if no predation occurred. It is therefore once more possible to speculate whether predation pressure might have a bigger influence on females in a poor body condition. Additionally, it is important to mention that even though the nest survived and the eggs hatched, several studies have shown that predation on ducklings during the first weeks have a great impact on the actual reproductive success (Swennen 1989; Donehower & Bird, 2008). In this study, all nests were regarded as successful if the female left the nest with at least one chick, but it was not possible to study the duckling survival, and this is an important bias.

4.2 What factors influence whether predation occurs or not?

The third question to be answered in this study was what factors influence whether predation occurs or not. To answer this, a discussion about egg guarding vs. predation risk, activity patterns, and timing of egg layings vs. egg predations will be made. To begin with, the mean date for egg predation was 3 May and mean date for egg laying 2 May. It is therefore clear that egg predation is synchronized with the main period of egg laying, indicating that the risk of egg predation is higher during the early breeding period. The most frequent hours for egg predation and egg layings also showed a pattern; egg predations were mainly occurring in the morning with a few predations during mid-day and evening, while egg layings were mainly occurring after mid-day. Active presence of predators was also only concentrated to the light hours of the day, gulls particularly often in the early morning. One could therefore speculate whether the female eiders have gradually adapted the timing of their egg laying to the activity patterns of predators, or vice versa. However, there is a lack of knowledge in the literature about the physiology behind egg laying as well as to what extent the timing of egg laying is correlated with the mating period, and this knowledge gap needs to be filled to be able to draw any firm conclusions.

Furthermore, we can conclude that the incubation intermissions the day after egg laying are concentrated to the night, meaning that females to a greater extent try to be present at the nest during the light hours when predators are active. However, unattended eggs are still observed during light hours, posing an increased risk of predation especially during morning and mid-day. These results can be compared with those of Olsson (2023), where incubation intermissions counted from the first day of incubation (around five days after the first egg) were studied. The results from that study showed that females very seldom left their eggs unattended during light hours when incubation had started. It is therefore possible to conclude that eider females more often leave their eggs unattended during light hours during egg laying days compared to during incubation. It is already known that the eider female is a precocial breeder meaning that they do not start to incubate the eggs until most or all of them are laid. But one question is then why they do not stay at the nest to guard the eggs during light hours without incubating them? One explanation could be that they leave their nests to forage to maximize their fat reserves for the incubation and to be able to produce more eggs, and that this foraging is easier during light hours. One could then ask the question “Why don’t the eider females maximize their fat reserves before starting to lay eggs?” It is not possible to further discuss this based on the results from this study, but studies from different domains in ecology such as changes in the marine food web, duck egg laying physiology and global changes in timing of mating period might give answers.

With the probability curve from Figure 14 it is clear that the risk of predation is significantly dependent on the time spent at the nest after egg laying. We can therefore conclude that eggs that are quickly left unattended (regardless of the time of day for egg laying) will pose a greater risk of predation since most egg layings occur during light hours. If the female leaves the nest within two hours from the egg laying there is a big risk that the sun is still up and that the eggs are left unattended during the active hours of the predators. Furthermore, 77 % of the females laying an egg that was not predated returned early in the morning, thus once more indicating that the females that lay eggs that hatch tend to return at the same time as the predators become active to reduce the risk of predation. These results, indicating that early nest attendance have a big impact on the egg survival probability is strengthened by the results of a study in Hudson Bay, Canada. In that study, females that chose to guard their nest instead of potentially foraging increased the nest survival probability with 20-35 % (Andersson & Waldeck 2006). However, it is important to note that even though the clutch survival probability is increased, the clutch size and the size of the eggs might be reduced as a consequence of the female spending more time guarding the nest instead of potentially foraging.

To conclude, the results prove that egg guarding from the eider female is a clear important factor for egg survival, something that is in accordance with earlier studies (Andersson & Waldeck 2006; Donehower & Bird 2008; Stien et al. 2010; Öst et al. 2022). The results from this study indicates that eider females have a trade-off between potential foraging during the light hours of the day and guarding their eggs, and that this trade-off is particularly important during the egg laying days. This study has also shown that it is during the light hours of the day that the predation risk is highest. A good egg laying strategy for a female eider, optimizing the trade-off between potential foraging and egg guarding, would therefore be as follows: The egg is laid in the afternoon, the female stays at the nest and leaves it around 19:00 when the predation risk is lower than during morning and mid-day, and while there is still light. The female then returns early in the morning around 03:00 before the predation risk increases. This egg laying strategy would make it possible for females to potentially forage during light hours at the same time as minimizing the risk of egg predation.

4.3 Conclusion and future research

This study has showed that the local population of Common Eider at Stora Karlsö suffers from a relatively high predation pressure on eggs, and the biggest threat might be from Herring Gulls since they take the most eggs. These results are important for future studies of nest predation or eventual conservation efforts for the Common Eider colony at Stora Karlsö. The predation pressure has increased a lot since two years ago, and one possible explanation is the Allee-effect caused by a decline in the eider population size. Furthermore, the predation pressure on eggs seems to have a greater impact on the nest success rather than on the number of chicks per successful nest. One possible explanation is that eider females in a poor body condition are more affected by heavy egg predation, since they have a reduced egg laying capacity and therefore chooses to abandon their nest. The poor body condition has in other studies been shown to be correlated with warmer winter temperatures reducing the quality of blue mussels. Warmer temperatures during winter might therefore be an indirect explanation for the early abandonment of eider nests.

This study has also shown that even though a nest site is successful, the high predation pressure means that female eiders must produce on average more than one extra egg per breeding season if they want to have the same average number of chicks per female as if no predation occurred. Lastly, it was possible to conclude that the risk of egg predation is highest during the egg laying days, especially during early morning and mid-day, explained by the activity patterns of the predators and the fact that the females to a greater extent are absent from the nest during light hours during the egg laying days. It seems like eider females at Stora Karlsö have a trade-off between potential foraging and egg guarding, and that the best strategy would be to do foraging during evening when the predation risk is lower, or to start laying eggs when almost all fat reserves are accumulated.

A future study aiming to gain a more detailed understanding of how nest predation affects individual females would be interesting. One of the most important biases of this study was that we did not know if it was the same female individuals laying all the eggs at the nest. ID-marking of females and camouflaged scales in the study area measuring the females' weight, combined with the current video monitoring, would make it possible to see if there is a correlation between female body condition and nest success under high predation pressure on eggs. It would also be possible to further understand the reasons for why certain females leave their nest a lot more than others during the first days of breeding, since it is believed that they forage during this time. ID-marking of Hooded Crows and Herring Gulls would also improve the study because it would provide information on the number of predator individuals responsible for nest predation, which would provide more detailed information about the background to the increased predation pressure. Furthermore, it would provide an understanding of the predators’ egg searching behaviour regarding to what extent they can remember old eider nest sites, which would be valuable information for eventual future conservation efforts for the Common Eider population at Stora Karlsö.

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Appendix A

Table A1 presents all predation events in chronological order along with date, time, nest site where predation occurred, predator species and prey.

Table A1. Predation events presented in chronological order with date and time for when predation occurred, nest site from which the egg was taken, predator species and prey.

Date	Time	Nest site	Species	Prey
2024-04-24	12:43	1.1	Crow	Egg
2024-04-25	07:29	3.1	Crow	Egg
2024-04-25	16:24	1.1	Crow	Egg
2024-04-28	13:12	3.1	Crow	Egg
2024-04-29	19:32	1.1	Gull	Egg
2024-05-01	05:25	6.1	Gull	Egg
2024-05-01	11:53	7.1	Crow	Egg
2024-05-02	07:45	6.2	Gull	Egg
2024-05-02	08:54	2.2	Crow	Egg
2024-05-02	18:25 - 19:00	4.2	Gull	Egg
2024-05-03	04:10	1.1	Gull	Egg
2024-05-03	04:18	1.1	Gull	Egg
2024-05-03	05:12	6.3	Gull	Egg
2024-05-03	06:57	3.1	Crow	Egg
2024-05-04	04:58	7.3	Gull	Egg
2024-05-04	06:30	6.3	Crow	Egg
2024-05-04	08:36	6.3	Crow	Egg
2024-05-04	12:31	5.2	Crow	Egg
2024-05-04	13:18	4.2	Gull	Egg
2024-05-05	04:34	7.3	Gull	Egg
2024-05-05	05:45	6.3	Crow	Egg
2024-05-05	05:45	6.3	Gull	Egg
2024-05-05	05:55	5.2	Gull	Egg
2024-05-05	15:11	7.3	Gull	Egg
2024-05-06	13:12	2.4	Gull	Egg
2024-05-06	13:16	2.3	Gull	Egg
2024-05-07	16:38	4.2	Gull	Egg
2024-05-07	18:21	2.3	Gull	Egg
2024-05-07	18:23	2.3	Gull	Egg
2024-05-08	04:50	7.3	Gull	Egg
2024-05-08	07:04	2.3	Gull	Egg
2024-05-08	11:26	2.3	Gull	Egg
2024-05-19	20:12	2.3	Crow	Egg

Appendix B

Table B1 presents number of days of exposure for successful and unsuccessful nests respectively, where days of exposure means the number of days where eggs laid in the nest and were exposed to a risk of predation. The total number of days of exposure is presented for both successful and unsuccessful nests respectively, and the grand total number of days of exposure is presented in bold.

Table B1. No. of days of exposure for successful nests = Days between first egg laying (±24 hours) and date of leaving nest with chicks. No. of days of exposure for unsuccessful nests = Days between egg laying (±24 hours) and date of predation. Total number of days of exposure presented in bold.

Successful nests	No. of days of exposure	Unsuccessful nests	No. of days of exposure
1.1	44	2.2	2
2.1	30	2.3	9
3.1	40	2.4	3
4.1	30	4.2	4
5.1	30	6.3	6
5.2	32	7.3	7
6.1	30	Total	31
6.2	36		
6.4	31		
7.1	32		
7.2	30		
Total	365		
Grand Total	**396**		

Appendix C

The 33 egg layings that could be given an exact time stamp (±1 hour) were further studied as explained in the methodology section. Table C1 presents number of egg layings, number of predations and number of hours when eggs were unattended (calculated with equation (1)) during different hours of the day. Predation risk is presented as a ratio between number of predations and number of observations of unattended eggs, for each hour of the day separately.

Table C1. Number of egg layings, eventual egg predations and observations of unattended eggs during different hours of the day during the first day and night after egg laying (no. of egg layings = 33). Predation risk is presented as a ratio between no. of predations and no. of hours when eggs were unattended.

Hour	No. of egg layings	No. of predations	No. of hours when eggs were unattended	Predation risk
00	1	0	24	0%
01	0	0	24	0%
02	1	0	25	0%
03	2	0	24	0%
04	0	3	18	17%
05	1	4	13	31%
06	0	2	9	21%
07	1	2	7	28%
08	1	0	6	0%
09	1	0	8	0%
10	0	0	8	0%
11	0	1	8	12%
12	5	1	9	11%
13	2	2	9	22%
14	2	0	10	0%
15	2	0	11	0%
16	1	1	10	10%
17	1	0	10	0%
18	3	1	12	8%
19	4	0	13	0%
20	2	0	14	0%
21	2	0	16	0%
22	1	0	21	0%
23	0	0	23	0%
Total	33	17	333	

Appendix D

Values retrieved from the logistic regression for the number of hours spent at the nest after egg laying and whether the egg was predated or not are presented in Table D1. The p-value of 0.0247 was < 0.05 showing that there was a significant correlation between time spent at nest and predation risk. Number of observed nests where eggs were predated = 17. Number of observed nests where eggs were not predated = 17.

Table D1. Estimated intercept value and slope retrieved from the logistic regression. Std. error presented along with P-value in bold.

	Estimate	Std. error	P-value
Intercept	1.3470	0.5636	0.0169
Slope	-1.7088	0.7607	**0.0247**