The effects of recreation on the breeding behavior of Plovers nesting on Dutch sea dikes

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24-08-2021

Abstract

The world is currently experiencing a global decline in biodiversity and species are going extinct, often at increasing rates. Biodiversity is inherently connected to the functioning of ecosystems in many ways. As humans, we trust ecosystems to provide the resources and services we need to live, and thus the extinction of species can have a large impact on humanity. Researching specific conservation issues will provide the information that is necessary to make better informed management decisions in the protection of the species. Problems in animal protection can frequently be found in Plovers of the genus Charadrius. Many of the Plover species of this genus are in decline. Their habitats are threatened as a result of climate change, disturbance by people and predation. The Kentish Plover (*Charadrius alexandrinus*) and the Ringed Plover (*Charadrius hiaticula*) nest in the Netherlands. The trend of the breeding numbers of Ringed Plover is unstable and the number of Kentish Plovers is in rapid decline. In the Dutch Delta area these Plovers nest on sea dikes, in close proximity to an asphalted path with a lot of recreational activity. Before it can be decided what the best measures of protection are, it must first be investigated which stimuli have a negative effect on the Plovers. Thus, this study aimed to explain the type of disturbances that lead to the incubator temporarily leaving the nest. The duration of the absence, and the distance from the nest to the disturbance were also taken into account. Cyclists were the most common type of recreation, but pedestrians, dogs and birds of prey posed the largest threat. When more stimuli pass during a nest absence the Plovers take longer to return to the nest, leading to a higher risk of egg hypothermia or overheating. The distance to the disturbing factor was significantly smaller for the Ringed Plover compared to the Kentish Plover, suggesting that both species must be considered separately in conservation actions. Potential protective measures inspired by this study are the partial closure of paths on dikes, protection of the area around the nest with a barrier or anti-predator cages. For future research it is critical to investigate what causes nest loss, as seen during this study. The newfound knowledge on the effects of recreation on breeding behavior brings us one step closer to a better protection of Plovers nesting on Dutch sea dikes, and thus the Kentish Plover and Ringed Plover populations may have a bright future ahead.

Nederlandse samenvatting

Wereldwijd neemt de biodiversiteit af. Soorten sterven uit, vaak met toenemende snelheid. Het functioneren van ecosystemen is op veel manieren verbonden aan de biodiversiteit. Wij mensen vertrouwen op ecosystemen om ons te bieden wat wij nodig hebben, en het uitsterven van soorten kan een grote impact hebben en de mensheid. Soorten moeten dus beschermd worden, en dat kan het beste als er veel informatie is over de problemen die de soorten ondervinden. Het onderzoeken van specifieke problemen in natuurbehoud- en bescherming zal de informatie bieden die nodig is om goede beslissingen te nemen in beheer en beleid. Problemen in dierbescherming kunnen gevonden worden bij Plevieren van het geslacht Charadrius. Veel plevieren van het geslacht Charadrius nemen af in aantal. De habitats van deze soorten worden bedreigd door klimaatverandering, verstoring door mensen en predatie. De Strandplevier (*Charadrius alexandrinus)* en de Bontbekplevier (*Charadrius hiaticula*) broeden in Nederland. Het aantal Bontbekplevieren is onstabiel, en het aantal Strandplevieren neemt sterk af. Deze Plevieren broeden vaak op zeedijken in de Nederlandse Delta. Op deze zeedijken ligt een geasfalteerd pad waar veel recreatie plaatsvindt. De nesten van de Plevieren liggen op korte afstand tot dit pad, en het is aannemelijk dat de hoge recreatiedruk voor verstoring zorgt. Voordat bepaald kan worden hoe de nesten het beste beschermd kunnen worden, moet er eerst onderzocht worden welke stimuli een negatief effect hebben op de Plevieren. Daarom is het doel van deze studie om vast te stellen welke soorten verstoring ertoe leiden dat de broedende Plevier (de incubator) het nest verlaat. De duur van de afwezigheid en de afstand tot de verstoringsbron werden ook meegenomen, om een compleet beeld te krijgen van welke factoren de meest invloed hebben. Fietsers waren de meest voorkomende soort recreatie, maar voetgangers, honden en roofvogels vormden de grootste bedreiging voor de Plevieren. Wanneer er meer stimuli waren terwijl de Plevier het nest had verlaten, dan duurde het langer voordat de Plevier weer terugkeerde. Hoe langer het nest verlaten is, des te groter het risico op verhitting of onderkoeling van de eieren. De afstand tot de verstorende factor was significant kleiner voor de Bontbekplevier in vergelijking met de Strandplevier, dit resultaat suggereert dat beide soorten een aparte aanpak vergen in de bescherming. De resultaten van deze studie inspireren om Plevieren te beschermen door de algemene drukte te verlagen, het gebied rond de nesten te beschermen met barrières en te experimenteren met anti-predator kooien. Voor onderzoek in de toekomst is het essentieel dat onderzocht wordt waardoor nesten verdwijnen. De nieuwe kennis op het gebied van recreatie op dijken en het broedgedrag van plevieren brengt ons een stap dichterbij een betere bescherming van deze soorten, en zo neemt hopelijk het aantal Bontbekplevieren en Strandplevieren de komende jaren toe.

Introduction

The world is currently experiencing a global decline in biodiversity (Cardinale et al., 2012) and species are going extinct, often at increasing rates (Mace et al., 2012). Biodiversity is inherently connected to the functioning of ecosystems in many ways. As humans, we trust ecosystems to provide the resources and services we need to live, and thus the extinction of species can have a large impact on humanity. The increase of the human population size leads to a larger need for agricultural land, residential homes and infrastructure. Consequently, the loss of natural habitats is the biggest threat to biodiversity (Brooks et al., 2002; Hanski, 2011). Species decline due to a lack of natural environment or food, possibly leading to disturbances in the food web, which can lead to secondary extinctions (Sahasrabudhe & Motter, 2011). The only way to prevent this domino-effect and to ensure that ecosystems keep functioning, is to collect knowledge on the best ways to protect species.

As explained in a study by Soulé (1985), species conservation is complicated because of the many different aspects that influence the protection of an area. Interspecific relations must be taken into account, as well as the genetic diversity, the influence of humans in the management of a protected area and the economical side of animal protection. Conservation biology is important to investigate the multidisciplinary factors that influence the threatened species, and the resulting knowledge will aid in making informed decisions in the management of protected areas. The goal of conservation biology is to provide the theoretical basis and tools to keep the biological biodiversity (Soulé, 1985).

Numerous studies show that studying behavior is relevant in conservation biology, and that this knowledge can readily be applied to support management decisions (e.g. Moore et al., 2008; Shier, 2006; Wallace & Buchholz, 2001). Nevertheless, published studies focusing on wild animal behavior in relation to their protection generally focus on fundamental knowledge and evolutionary biology instead of its potential applicability in protection (Merrick & Koprowski, 2017). To bridge the large gap between behavioral research and applied protection, researchers should formulate research questions of which the answer could contribute to the recovery of the species. A scientific study can comply with this if the project is motivated by as specific issue in the protection of a species (inspired by Caro, 2016; Taylor et al., 2017).

Problems in animal protection can frequently be found in Plovers of the genus Charadrius (family *Charadriiae).* Plovers of this genus breed with the exception of Antarctica on all continents. Some species are highly threatened, and even the most common plover species are in decline. Most plover species occupy habitats that bring forth risks as a result of climate change, disturbance by people, habitat loss and predation (Colwell & Haig, 2019). The Little Ringed Plover (*Charadrius dubius*), Kentish Plover (*Charadrius alexandrines*) and the Ringed Plover (*Charadrius hiaticula*) nest in the Netherlands. Whereas the Little Ringed Plover showed a small, yet unsure increase in numbers in the last few years, the number of Ringed Plovers is very unstable and the number of Kentish Plovers is in rapid decline (Boele et al., 2021). It is a grim prospect, especially considering the Natura2000 conservation goals that are in place for both the Ringed Plover and Kentish Plover (Europees parlement, 2009). At this moment, both of these Plover species do not achieve the targets in all appointed areas in the Netherlands (Boele et al., 2021). Both species breed on sea dikes in the Netherlands. The asphalted roads on top of these dikes make the dikes attractive for recreational activity such as biking or walking. The Plovers that breed on these dikes could temporary leave the nest more often as a result of these disturbances (Arts & Meininger, 1997). In turn, this can result in hypothermia, overheating or predation of the eggs in the nest, which ultimately will affect the breeding success.

The relationship between the breeding of Plovers and recreational activity has been the subject of research before. In New York, it was found that the breeding success of the Piping plover (*Charadrius melodus*) was mainly dependent on natural predators, and not so much on human-induced disturbances (Doherty & Heath, 2011). In contrast, an Australian study showed that Hooded Plovers (*Thinornis cucullatus*) are disturbed by humans more often than by natural stimuli, and that the presence of humans at the nests leads to more temporary nest absences than any other type of disturbance (Weston & Elgar, 2007). In California, an increase of human recreation in the weekends and holidays led to an increase of Snowy Plover (*Charadrius nivosus*) chick deaths (Ruhlen et al., 2003). These examples indicate that the relationship between recreation and Plover breeding is species- and context-dependent. To date, no such research has taken place in the Netherlands, highlighting the knowledge gap and uncertainty of where to focus conservation efforts. Therefore, this study aims at determining the effect of recreational activity on the breeding behavior of the Ringed Plover and Kentish Plover on Dutch sea dikes.

The main goal is to determine which stimuli disturb the incubating Plovers, and to present the results in a manner that can aid in the protection of the populations. The total time from the nest abandonment until the return, as well as the distance from the disturbance to the nest was analyzed. The results of this study were used to formulate an advice for Plover protection, specific to their habitats on Dutch sea dikes. This advice can be used to make management decisions that help increase the success of these Plover populations in the future.

Methods

The study area consisted of three dikes in the province of Zeeland, the Netherlands. These dikes are located next to two estuaries, the Westerschelde (Ritthem 51°26'49.9"N 3°37'46.0"E, Kruiningen 51°25'52.1"N 4°02'47.6"E) and the Oosterschelde (Oostdijk 51°27'24.0"N 4°05'04.8"E). These locations are known to be breeding sites for the Kentish Plover and the Ringed Plover, and each has an asphalted path on top of the dike that can be used for recreation. The data were collected during the breeding season of 2021, the first observation taking place on the 7th of May, and the last taking place on the 27th of June.

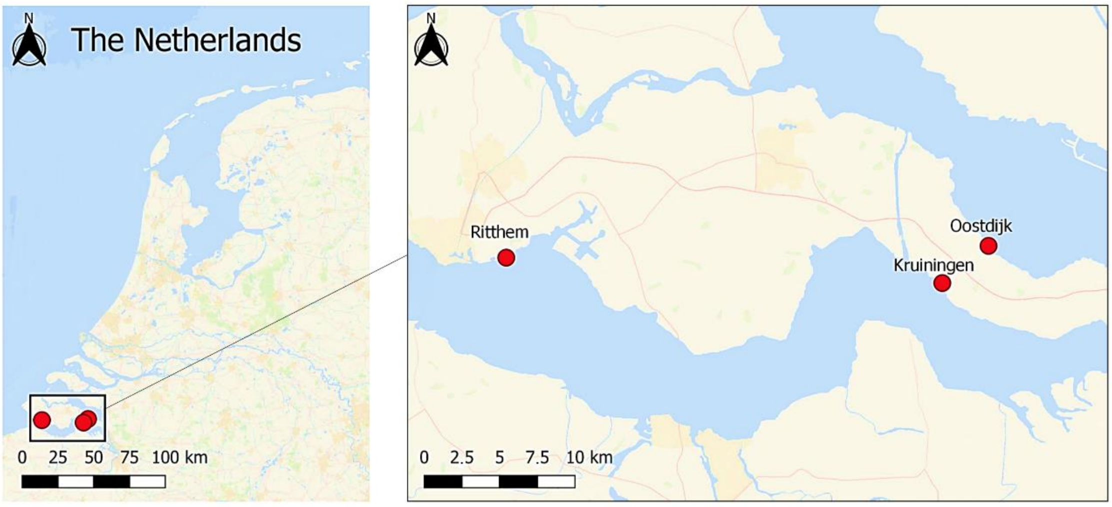

Figure 1: Breeding locations of the Kentish Plover and Ringed Plover nests that were included in this study.

Field procedures

Observations took place on non-rainy days with mild or warm weather (14 – 22°C; $\bar{x}$= 17.7°C) as recreational activity was expected on these days. The temperature and cloud cover was documented. Data were recorded with two trail camera's (Colorway CW-200W01). These cameras have a wide-angle lens, and so about 20 meters of the path was visible. When a nest was approached, the Plover left the nest. One camera was then placed 1.5 meter from the nest, and the other camera was placed aimed at the path from the grassy part of the dike. The observation officially started when the incubator returned to the nest, and was stopped one hour after. The cameras were set to film for 3 minutes when the motion sensors are triggered. Recreation on the path triggered the sensor of the dike camera, and the nest camera was triggered if the incubator left the nest or returned. To reduce disturbance caused by this project, a nest was observed only once a day and no more than two days in a week. A Dutch field protocol was added in appendix A. Pictures of the experimental set-up can be found in appendix B.

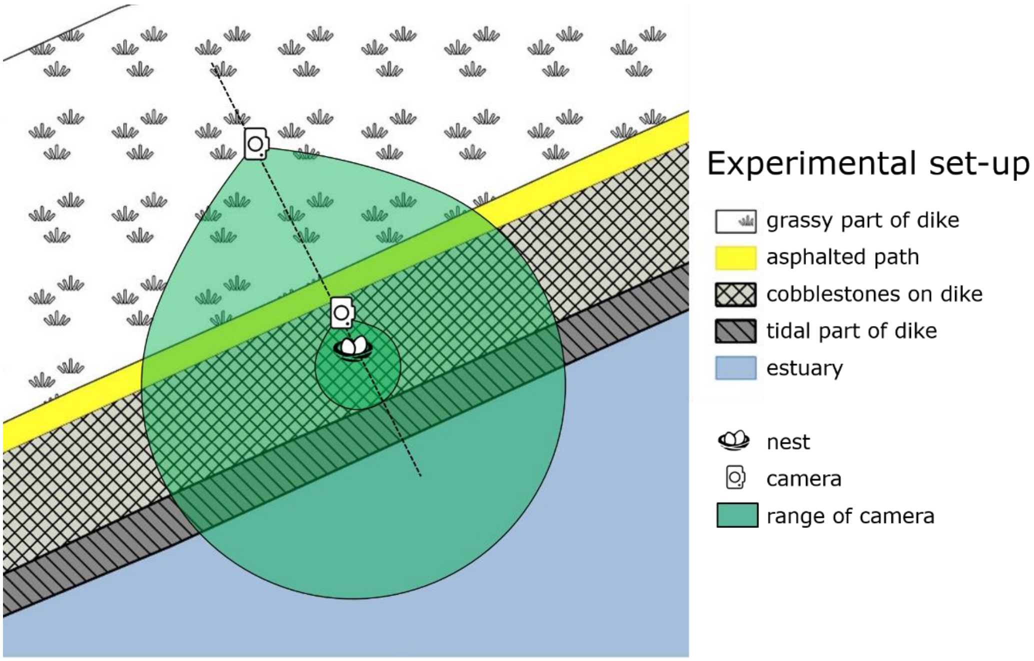

Figure 2: A schematic view of the experimental set-up in the field. One camera records passing recreation and other stimuli, the other records activity of the incubator on the nest.

Nests were observed in opportunistic fashion, sampling whenever the weather complied and at which location Plovers were breeding. The nests were far enough apart that the territories did not overlap. There was variety in how many nests were active at a given moment. In total 23 observations took place at 9 nests. Out of these observations, 16 took place at Kentish Plover nests and 7 at Ringed Plover nests. More information about the observations can be found in appendix E. In principle, each nest was observed at least once during the weekend and once during a weekday. The starting time for observations was varied, so that for every location an accurate estimate of the general recreation activity could be formed. Not all nests were observed an equal amount of time, due to nests disappearing or weather conditions (1 - 5 observations per nest, $\bar{x}$= 2.5). Out of the 14 Kentish Plover nests that were found at location Den Inkel, only 2 were successful. 11 failed nests disappeared completely, only in a single case egg shells were found. More information about the observations can be read in appendix E.

Video processing and data collection
The video footage from both cameras was combined in video editing software (Adobe Premiere Pro 2020, version 14.0.1), so that recreational activity and the behavior of the incubator could be observed at the same time. The resulting video was then watched and every activity was noted as a stimulus. If a stimulus led to the incubator leaving the nest, then the stimulus was considered a disturbance. In this case it was recorded for how many seconds the incubator left the nest in total. It was also recorded how many stimuli occurred during the time the incubator was not on the nest. The location of the disturbance at the time the incubator left the nest was estimated based on the video footage, and added as a point in QGIS (Version 3.16.7-Hannover). From this, the estimated distance from the disturbance to the nest was calculated. Sometimes the bird left the nest before the disturbance entered the range of the camera. In cases where the disturbance travelled at a continuous pace, the location at the time that the nest was abandoned was estimated by taking into account the speed of the disturbance.

Classification
As a next step, the raw data were further processed. With the help of the local weather forecast, The cloud cover was categorized into 'cloudy' and 'sunny'. People on any type of bicycle were classified as 'cyclists'. Joggers, people walking without a dog and a single swimmer that came out of the water to walk on the path were classified as 'pedestrians'. Any stimulus with a dog was classified as 'dog'. Birds were classified as 'birds'. Motorized vehicles such as mopeds, mobility scooters and a single motor crosser were classified as 'vehicles'. Sometimes the incubator left the nest to forage, to switch with the other parent, or for no reason detected. These instances were classified as 'incubator induced'. People skating, and a single horse were classified as 'other'. If stimuli occurred in groups, it was still considered one stimulus. Stimuli were considered a group if they were walking or cycling next to each other, or if they formed an obvious peloton. For every observation, the sum of stimuli of every category were calculated.

Statistical analysis
Summary statistics were presented as the mean ± one standard deviation. Statistical testing was executed in R (version R-3.6.0) (R Core Team, 2020) ran in the interface of the software RStudio (version 1.2.1335) (RStudio Team, 2020). The complete R script can be found in appendix C. For every comparative test, a suitable statistical test was chosen. A χ^2-test was used for comparing nominal data. A Welch t-test was used for continuous data. Multiple groups were compared with an Analysis of variance (ANOVA) test and a post-hoc Tukey test. Models were created when it was presumed that multiple factors had an effect on the response variable. Different models were created that incorporated different variables, details of which can be found in Appendix D. From these models the most suitable one was chosen by comparing the relative Akaike information criterion (AIC) values (Burnham & Anderson, 2004).

The differences in duration of nest absences were compared by creating a Linear mixed effects model. The model that showed the best fit included the category of disturbance, number of disturbances that occurred during the absence (abbreviated to 'NOD'), the species and ID of the nests as random effect variable.

$$Total\ time\ (s) \sim category + NOD + species + (1|Nest_{ID})$$

Model 1: Total time as an effect of category, number of disturbances (NOD) while the bird is gone, and the code of the nest as random effect variable.

The presence of cyclists and pedestrians were considered in more detail, because they were the most common stimuli to occur on the dikes. The occurrences were converted to an hourly rate per location. The hourly rates were compared with the use of a generalized linear model. The model with the best fit included the mode of transport (pedestrians or cyclists), the location of the nests (Ritthem, Oostdijk or Kruiningen), the interaction effect between location and transportation, and the weather (sunny or cloudy). Adding a variable to separate weekdays from workdays did not contribute to a better goodness of fit.

$$Hourly\ rate\ of\ impulses \sim transportation + location + transportation * location + weather$$

Model 2: The transportation, location and weather as a function of the hourly rate of cyclists and pedestrians.

Results

Observed stimuli

On average, the observed nests encountered 25.1 ± 25.1 stimuli per hour (n=23 observation sessions, 22 hours and 48 minutes of observation). Almost all stimuli were induced by human activity, such as biking, operating a vehicle, or walking a dog (24.6 ± 24.5 stimuli per hour). The only observed natural stimuli were other bird species, which only occurred during three observation sessions (n=3, 0.2 ± 0.7 stimuli per hour). Table 1 shows that out of all recorded stimuli, cyclists were the overwhelming majority, accounting for 84% of all stimuli (Chi square test: χ^2 = 421.36, df = 1, p-value = <0.001, n = 500).

Table 1: The relative frequency of encounters with stimuli at nests (n = 595).

Stimulus	**Recorded observations**	**Percentage Occurrence**
Cyclists	500	84
Pedestrians	40	7
Vehicle	37	6
Dog	8	1
Other	7	1
Birds	3	1

Nest absences

Out of the 69 nest-leaving events that were recorded, 40 were induced by the incubator. The incubator-induced absences can be classified into foraging behavior (72.50%, n=29), the incubator switching with the other parent (10.00%, n=4) and the times no reason could be determined (17.50%, n=7). Out of all nest absences, 16 were recorded for the Ringed Plover, and 53 were recorded for the Kentish Plover. Nest absences were observed at all 9 nests, but for 3 nests all absences were induced by the incubator.

A stimulus was considered a disturbance if the incubating bird left the nest as a result of its presence. Overall, 4.87% of all stimuli disturbed the incubator (n= 28). Vehicles and stimuli from the 'other' category never led to a nest-leaving event. Incubator-induced absences were not more common than disturbance-induced absences (Chi square test: χ^2 = 1.75, df = 1, p-value = 0.19, n = 69).

Notably, the incubating bird did not always show the same response to stimuli of the same category. Figure 2 displays how often the presence of a certain stimuli led to a nest absence, and the average duration of that absence. The presence of a bird that was not a parent of the nest always led to a nest absence (n=3). The presence of a dog led to a nest absence in 63% of the cases (n=8). Pedestrians led to nest absences in 35% of the cases (n=40) and cyclists led to nest absences only in 1.2% of the cases (n=500). The presence of vehicles never led to a nest absence (n=37). This category includes 29 scooters, 6 mopeds, 1 mobility scooter and 1 motorbike.

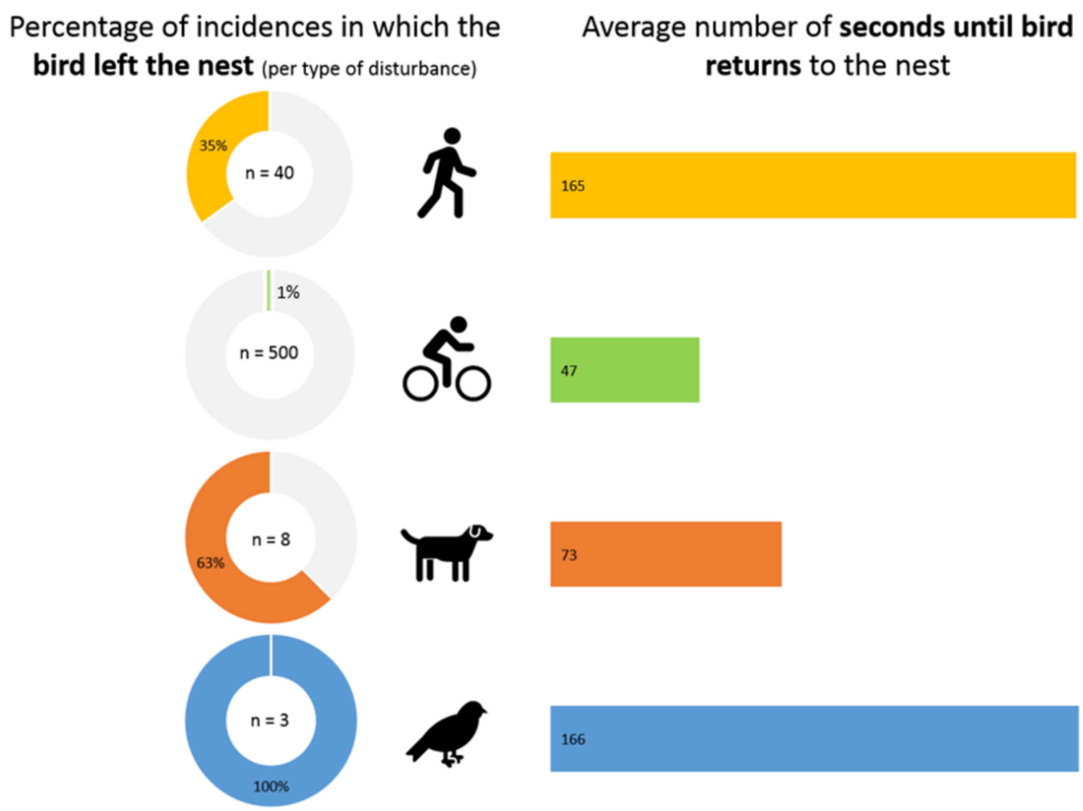

Figure 2: This figure shows how many times the different stimuli occurred, and what percentage of these occurrences led to a nest absence. The corresponding average number of seconds until the incubator returned is included for every category.

Absence duration

The mean duration of an absence was 101 ± 109 seconds for the Ringed Plover, whereas the mean for Kentish Plovers was 153 ± 200 seconds. This difference was not statistically significant (Welch t-test: t = -1.34, df = 46.85, p-value = 0.19, n = 69) and thus both species of Plover were analyzed together.

The 69 nest absences that were observed occurred at 9 different nests. In total, 35% of the variance in the absence duration was explained by the differences between these nests. The number of stimuli that occurred while the bird was responding to a disturbance had a significant effect on the total time (Anova: F-value=21.23, df = 59.58, p-value = 6.01e-07, model 1), suggesting that the presence of stimuli make the incubator more reluctant to return to the nest.

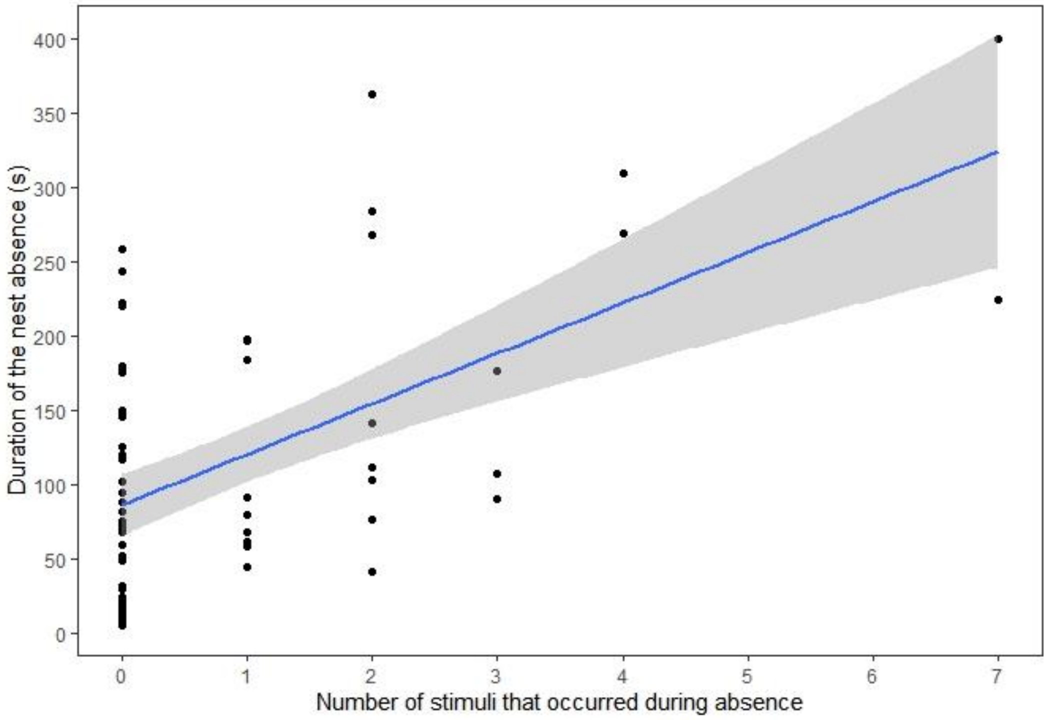

Figure 3: The Number of disturbances that occurred in the time the bird was away from the nest has a significant correlation with the duration of the absence. The regression line is displayed in blue and reveals that longer absences occur when there are more impulses. In grey the confidence area of the regression line is displayed.

The effect of different stimuli on absence duration

The type of disturbance did not have a significant effect on the duration of the absence (F-value = 1.17, df = 4, p-value = 0.33, model 1, Figure 4). Though not significant, the three pairs that were most different in comparison were pedestrians – incubator initiated, bird – incubator initiated and pedestrians – cyclists (Table 1, Figure 4).

Table 1: Results of the linear mixed model (model 1) testing the absence duration, with explanatory variables 'category' and 'number of stimuli that occurred during the absence'.

	Estimate	Std. Error	t-ratio	df	p-value
Pedestrians – incubator initiated	42.84	24.3	1.760	60.1	0.410
Bird – incubator initiated	53.44	42.8	1.249	58.2	0.720
Pedestrians – cyclists	-47.67	38.2	-1.248	60.6	0.720

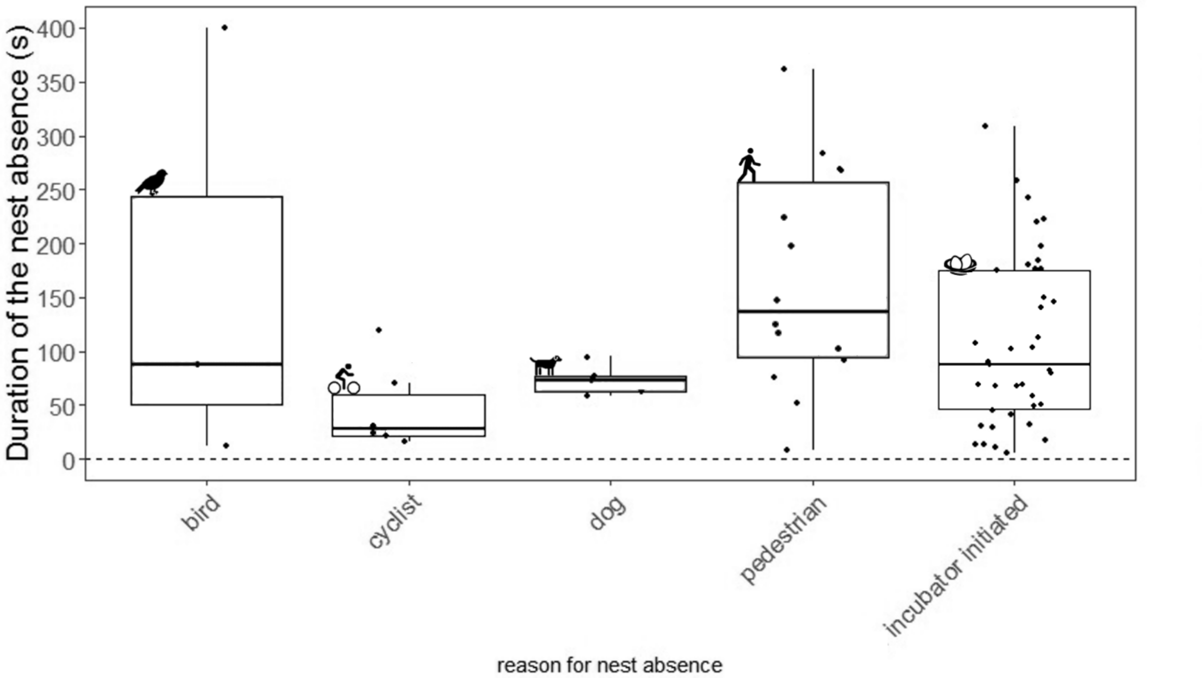

Figure 4: The duration in seconds of all nest absences. There were no significant differences.

Cyclists and pedestrians

Cyclist and pedestrians had the highest frequencies of occurrence of all impulses (84% of all impulses were cyclists, 7% were pedestrians). To gain more insight into these two categories, the average hourly rate of impulses was calculated for both categories in every observation session. The number of impulses differed between the two transportation modes ($P<0.001$) and between locations ($P<0.001$). Also the interaction between transportation and location was significant ($P<0.01$). This was explained by the hourly rate of cyclists at location Ritthem being significantly higher than cyclists in all other locations, and higher than the hourly rate of pedestrians in all three locations (Tukey test post-hoc test: p-values displayed in figure 5). Additionally, the hourly rate of pedestrians at location Oostdijk was significantly lower than the hourly rate of cyclists at location Den Inkel. The weather did not have a significant impact (table 2).

Table 2: Results of generalized linear model (model 2, Residual standard error: 10.58911) investigating the differences in hourly rate of pedestrians and cyclist at the different locations. The weather was included as explanatory variable.

	Sum sq.	**Mean sq.**	**F-value**	**df**	**p-value**
Transportation ***	4359	4359	38.88	1	<0.001
Location ***	2551	1276	11.38	2	<0.001
Transportation * Location **	1681	840	7.50	2	0.002
Weather .	343	343	3.06	1	0.088

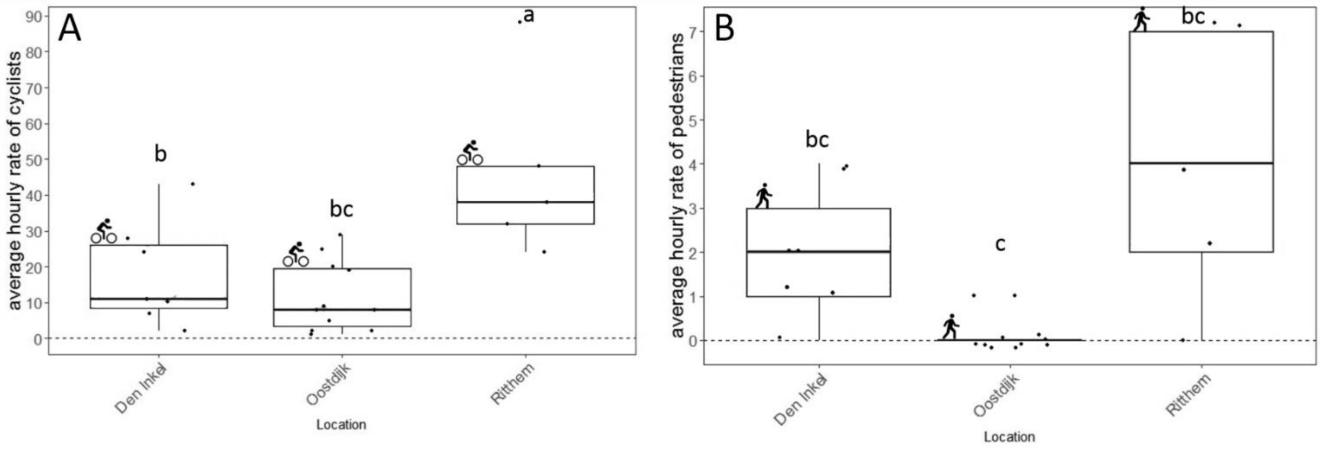

Figure 5: The hourly rates of cyclists and pedestrians at the different locations. The significance is displayed by the letters above the boxes. Mind the large difference of the scale of the y-axis.

Distance from the disturbance to the nest

The mean distance from the disturbance to the nest was 10.56 ± 6.82 meters for the Ringed Plover (n=12), and 24.28 ± 28.56 meters for the Kentish Plover (n=16). This difference was statistically significant (A Welch t-test: t = 3.0471, df = 24.658, p-value = 0.005, n = 28). This shows that Kentish Plovers will leave their nest sooner than Ringed Plovers. Because of this difference between the species, the disturbance that occurred at Ringed Plover nests will be analyzed separately from the disturbances that occurred at Kentish Plover nests.

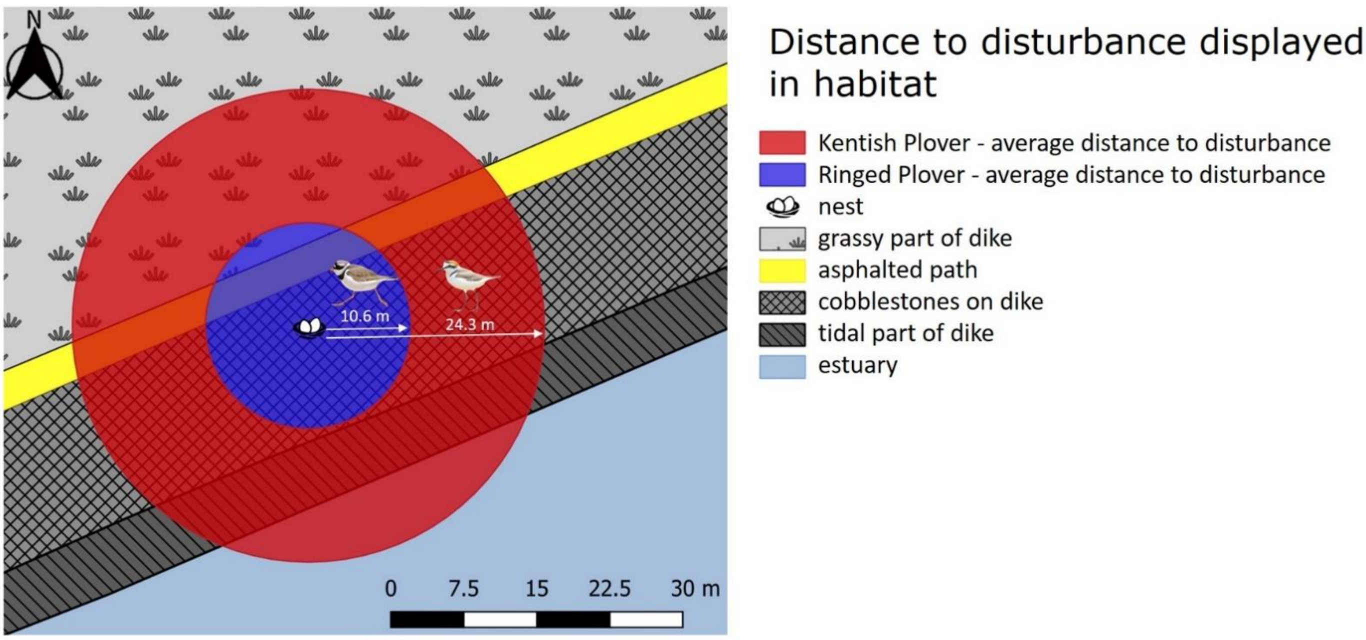

Figure 6: The average distances from the disturbance to the nest at the time the incubator left as a buffer around the nest. The average distance is significantly smaller for the Ringed Plover. The buffer overlaps with the path in both cases. Displayed is a real nest from the dataset (nest BB_Ritth1, Ringed Plover) in its actual habitat.

The type of disturbance causing an absence did not have an effect on the distance at which the Kentish Plover (one-way Anova, df = 2, F-value = 1.88, p-value = 0.195, Figure 7a), nor the Ringed Plover left the nest (one-way Anova, df = 2, F-value = 0.352, p-value = 0.712, Figure 7b). Table 3 shows how often the stimuli were observed on and off the asphalted path. Stimuli were only observed off-path seven times during this study, and these always led to a nest absence.

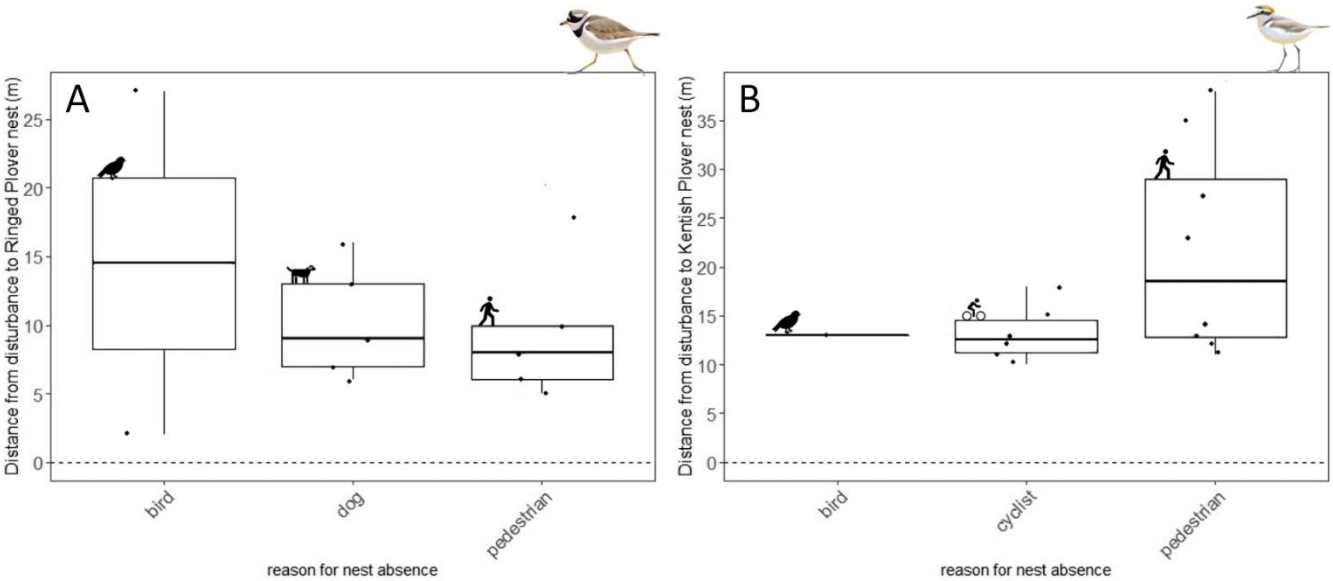

Figure 7: The distance from the stimulus causing disturbance to the nest of the affected incubator. The distance to the disturbing factor at the moment the nest is left is longer for Kentish Plover (panel B) than for the Ringed Plover (panel A). Mind the different range of the x-axes.

Table 3: the amount of disturbances that were seen on and off the asphalted path for the different categories.

	On path	Off path	Percentage off path
Bird	0	3	100
Pedestrian	10	3	23
Dog	4	1	20
Cyclist	6	0	0

Discussion

The main goal was to determine which stimuli disturb the Plovers that are nesting on Dutch sea dikes, and to present the results in a manner that can aid in the protection of the populations. The total time from the nest abandonment until the return, as well as the distance from the disturbance to the nest was analyzed. This study has shown that there are a lot of different stimuli near nests of the Ringed Plover and Kentish Plover on Dutch sea dikes. It is now clearer which stimuli cause disturbance, and thus the goal to gain more insight on the effect of recreational activity on Plovers nesting on Dutch dikes was reached.

Different causes of disturbance

The finding that Kentish and Ringed Plovers on Dutch sea dikes do not experience the most disturbance from cyclists is comforting, considering the high rate of occurrence. This result is in agreement with another Kentish Plover study that used a similar method on beaches in Spain (Gómez-Serrano, 2021). The study by Gómez-Serrano suggests that disturbance caused by static beach-users is greater than that of moving beach-users. Thus, the deduction that a stimulus spending more time in close proximity to the nest leads to more disturbance fits with the finding that pedestrians caused more disturbance than cyclists. However, studies comparing responses of birds to slowly moving humans and rapidly moving humans generally find that the increased speed leads to more disturbance (Joanna Burger, 1981; Yorio & Boersma, 1992), and so a more likely explanation of the lack of response to cyclists is habituation.

Habituation typically occurs in situations where the stimuli act in predictable fashion, and are not harmful to the birds (Platteeuw & Henkensj, 1997). It is assumed that the process of habituation is facilitated by having an almost constant supply of undifferentiated stimuli (Smit & Visser, 1993). Cyclists on Dutch sea dikes fit this description, they occur frequently and always on the asphalted path. Pedestrians and dogs move in a less predictable manner, and were occasionally seen walking off-path on the sea dikes where the nests lay. The unpredictability of the pedestrians is reflected by the duration of the pedestrian-induced absences, which show a large spread of values (results, figure 4). Within the group ‘pedestrians’ different types of recreation were observed, such as fishermen and people collecting shells. It was clear that these people did not see the nests, and there was an immense risk of the eggs being trampled.

Dogs were the highest human-induced disturbance to the incubating plovers, this finding is in line with previous research (Gómez-Serrano, 2021; Smit & Visser, 1993; Weston & Elgar, 2007). Like pedestrians, dogs were also seen wandering on the sea dikes off-leash and off-path. The response of the incubators to the dogs could be attributed to the unpredictable movement, as well as the actual risk they pose to the health of the Plovers. Whilst it was not seen in this study, dogs have been known to chase Hooded Plovers on beaches (Weston & Elgar, 2007). This study by Weston & Elgar suggests that the behavior rather than the presence of dogs determines the Plovers’ response , as unleashed dogs warranted a much larger response than leashed dogs.

Although birds of other species were not seen often, the largest percentage of incidences in which incubators left the nest belongs to this group, the occurrence of which always led to a nest absence. Two of these presences were birds of prey, and one of them was a swallow (*Delichon urbicum*) flying low over the sea dike. The swallow might be a coincidence, but the birds of prey that were seen during this study are interesting to consider, because it is still unknown what the predation pressure is on Dutch Plover nests. Other studies show similar results on beaches, where crows posed a specific threat because they can prey on eggs and chicks (Lafferty, 2001). Ravens and magpies are also mentioned as threatening natural sources of disturbance (Weston & Elgar, 2007). Other predators of

Plover species are small falcons (Melstrom & Horan, 2012) and large gulls (Ivan & Murphy, 2005). Presence of incubating Kentish Plover parents is suspected to enhance nest detectability to visual predators (Gómez-Serrano, 2021). Thus, the reaction to birds can be explained as predation-avoiding behavior.

The effect of multiple stimuli on nest absence

If stimuli occurred before the incubator went back to the nest, it prolonged the duration of the absence. Most likely, this is a tactic formed as to not reveal the location of the nest to new stimuli (Yalden & Yalden, 1990). This result is in line with previous research on Hooded Plovers (Weston & Elgar, 2007) where 17% of the observed potentially disturbing stimuli occurred while the incubator was already responding to another disturbance. These multiple disturbances prolonged the nest return time. In this study, all types of stimuli were incorporated in the analysis, and so a general 'busyness' can have an effect on the incubator, even if the separate stimuli would not be of great influence.

Distance from disturbance to nest

When a disturbance occurred, the Kentish Plovers left the nest sooner than the Ringed Plovers. On average, the ringed Plovers left the nest at 10.56 ± 6.82 meters and the Kentish Plovers at 24,28 ± 28,56 meters. These are short distances compared to other research. In the study of Plovers on Spanish beaches, an approach of less than 75 m was considered a 'nest disturbance event' (Gómez-Serrano, 2021). This sheds some light on the surprising choice of Plovers to nest on Dutch sea dikes, as they experience disturbance only if the stimulus is quite close. Birds are known to choose their habitats depending on the manner of which the structure of the habitat matches their tactics of escape (Götmark et al., 1995), and the Dutch sea dikes offer a predictable situation. The majority of the stimuli occurs only on the path, and the plovers have a good escape route towards the water. A study of Kentish Plovers nesting at a lake in Southern Spain found that plovers were killed by predators more often in nests covered by vegetation rather than exposed nests (Amat & Masero, 2004). This all suggests that the Dutch sea dikes are a reasonable choice as a nesting location for the Plovers, and that the protection of birds nesting in these habitats can have a positive effect on the nesting success.

The removal of outliers

In three cases, an outlier was removed for the analysis. One time, an incubator left the nest for a duration three times larger than the next biggest value in the dataset. There was no reason observed for this absence. There were more 'no reason' absences that had a much smaller duration, and so it was decided to remove this data point. Another outlier of duration of absence was induced by a motor crosser on the path. This data point is important to note, because it was the only time that a vehicle resulted in a nest absence. Presumably, the loud noise and the high speed that accompanied this disturbance scared the incubator more than other stimuli. Because a motor crosser was only seen once in the entire study period, it was decided to remove the data point for the analysis. The last outlier had an estimated distance 10 times larger than the next largest distance in the dataset. It was an absence caused by a swimmer in the water at location Den Inkel, who then crossed the dike and walked on the path. The large distance could be explained by the increased vision that the birds have to the waterside compared to the path. Also, the incubator probably did not expect a disturbance to occur on that side of the dike. As of now, the impact of swimmers and motor crossers remains unclear.

Limitations

The response that birds show to human disturbance is a very complex phenomenon, influenced by multiple different factors (Gómez-Serrano, 2021). It cannot be assumed that this study shows the complete pattern of behavior, as there are many factors involved that could not be taken into account. One of such factors is the sex roles. Between different Plover species there are differences in how incubation times are shared (Wallander, 2009) and it has been found that female Plovers are disturbed more often than males (Gómez-Serrano, 2021). Due to the small dataset, a distinction between males and females could not be made. The lack of data points due to disturbance leads to other risks as well. An example is that there are only three observations in the category 'birds'. If the nests were observed for a longer time, more birds may have been seen, and then the differences between locations may become clearer. And so, the way I would improve this research is to record for longer continuous observations. An investment in cameras with a larger storage capacity makes it possible to do observations for longer than an hour. Ideally, an observation session would span an entire day, so the data is not influenced by what time of day the observation took place. There were only a few Ringed Plover nests during the observation period. In the end it was decided to consider both species together for part of the analysis, because both experience the same recreational pressure and share the same habitat. The aim of this study was to get a general idea whether recreation had an effect on the breeding plovers, and for this goal it was beneficial to use as many of the field observations as possible. The consequence of this decision is that a difference between species in when they leave their nests may be overlooked. In the future it is advised to include the same amount of nests or both species, and ideally a larger sample size with an even spread over the different locations.

A factor that could be of influence but was not accounted for, was the stage of incubation that the nest was in. The time devoted to being alert and foraging can differ between the incubation stages of the Piping Plover (J. Burger, 1991). This may also be the case for the Plovers in this study. Towards the end of the incubation period, the Plovers may be willing to take more risks in incubation because of the energy already invested. As a result, their response to disturbances in early stages of incubation may differ from their response in late stages of incubation.

In seven cases, a reason for nest absence could not be determined. It is possible that the cause of the absence occurred outside of the recording range of the cameras, affecting the reliability of the found distance to the disturbances. The wide-angle cameras had a wide view in the direction of the nest and the estuary behind the dike, but the video footage lacks vision behind the camera in the sky above the dyke. It is also possible that in these cases the incubator was scared by a stimulus that turned around and went the other way, so it never crossed the motion sensors. The stimuli most likely to be missed on the video footage are birds. Specifically birds of prey could be the cause of nest absences at large distances. In the study of Hooded Plovers by Weston & Elgar (2007), a wider range of behavior was included, such as 'crouching over the nest'. An expansion of the recorded behaviors may lead to less cases of 'no reason' – absences, for example, the presence of a predatory bird might be indicated by the Plover looking up to the sky.

Although these factors somewhat limit the certainty that we have observed the complete range of stimuli and responses, the data is sufficient to attain the goal of this research project, which was to determine how big the effect of recreation is on the breeding behavior of the Ringed Plover and Kentish Plover, and to present the results in a manner that can aid in the protection of the populations. With this information it is more clear what appropriate management decisions are for the future.

Management implications

The Dutch sea dikes are in important nesting habitat for Plovers. Dutch coasts are under high recreation pressure, and beaches are no longer the quiet, natural habitats that they once were. The

Kentish Plover and Ringed Plover have found the Dutch sea dikes as a suitable alternative nesting habitat. This study has shown that a general busyness leads to longer nest absences. Lower nest attendance can have a negative effect on the thermoregulation of the eggs, and thus there will be a higher risk of failing (Amat et al., 2012; Wilson et al., 2017; Yasué & Dearden, 2006). The general presence of people also reduces Plover feeding rates (Lafferty, 2001; Weston & Elgar, 2005). Therefore, I suggest to reduce the amount of general human activity near nests. The current study found that most stimuli occur on the asphalted path, and so it would be best to find alternative paths on the other side of the sea dikes and close a small part of the path next to the nest. Whilst this may be an obvious solution for the Plovers, it is unsure what the reaction of locals might be to such a measure. For example, sea dikes without cyclists might be very attractive for dog walkers, even if it is prohibited. Therefore it is advised to take human sociology and available funds for management into account before taking any drastic measures.

Next, nests should be protected from people and dogs wandering on the sea dikes, to reduce the risk of trampled nests. A method inspired by Lafferty et al. (2006) is very promising, where a rope fence was installed to protect the nesting area of Snowy Plovers. This roped area was supplemented with signs and volunteers that suggested beach users to comply with the law to keep dogs leashed and stay out of the area. After this protection the Snowy Plover numbers increased every year, with a high success at fledging young. The sea dikes are narrow, and to protect an area as large as on American beaches in this study will probably not be possible (which started as a 265-m stretch of dry sand, and was later expanded). However, a barrier will encourage people to stay on the path with their dogs leashed. Even a barrier surrounding a smaller area can significantly reduce the disturbance by recreational activity such as fishing. The results of the current study suggest that the Ringed Plover requires a smaller protected area than the Kentish Plovers. The average distance to disturbance was 10,56 ± 6,82 meters for the Ringed Plover and 24,28 ± 28,56 meters for the Kentish Plover. And so, a protected area of about 30 meters will offer a lot of protection for both species. In most cases this area will overlap with the path, and so it will not be possible to place the barrier at the same distance on all sides. Thus even with a barrier in place, dogs walking the path most likely will still lead to nest absences, and a complete prohibition of dogs will provide the most protection (as seen in Lafferty, 2001).

Future research

During this breeding season, many nests disappeared. Out of the 14 Kentish Plover nests that were found at location Den Inkel, only 2 successfully hatched. 11 failed nests disappeared completely, only in a single case egg shells were found. Trampling, predation and weather conditions could all be plausible explanations for these failed nesting attempts. It is even possible that eggs were illegally taken from certain locations by egg collectors. To improve the protection of the nests at this promising location, it is important to investigate the causes of the nest disappearances. To gain more insight in these causes of failed nesting attempts, it would be best to observe some nests continuously as soon as they are found. This can be done by installing trail cameras that activate based on movement. An additional benefit to this sampling method is that the presence of predators at night will be recorded. When the cause of failed nesting attempts is clearer, then it can be decided if the best management options include direct protection such as exclosures and barriers, or indirect protection such as law enforcement (dog-leash laws) and informing the public.

This study found that birds of prey are a factor of disturbance for the Plovers nesting on sea dikes. Thus, predators could be an explanation for the disappearance of the nests. A predator exclosure may be a solution for this problem, however, results of using such exclosures has been contradicting. For Piping Plovers it was found that the exclosures significantly increased the hatching success of the nests, but it also brought forth the undesired effect of a higher nest abandonment rate, and a higher adult mortality (Barber et al., 2010). Just like the response to recreation, the effect of such exclosures may very well be site- and species-specific. The exclosures do not protect against weather conditions, and bring forth the added risk that the nest attracts more attention from all stimuli. Besides this, it may still be unclear which predators threaten the Plovers. And so to be certain that the use of exclosures will have more advantages than disadvantages, more research is required.

Conclusion

Plovers nesting on Dutch sea dikes are influenced by a lot of different stimuli; Pedestrians, dogs and birds pose the biggest threat. Whilst the results of this study are in line with previous research on the causes of Plover disturbance, the protection of the nesting area is difficult due to the unique habitat structure. This shines a light on how important it is to study the effects of recreation on Plovers in many contexts and locations. With enough research on this subject, eventually it will become more clear what Plovers look for in a breeding area. Then, areas can be found that are potential locations for breeding Plovers, and these areas can be managed so they do not have the high recreation pressure that the current locations have. The results of this study might also inspire more studies of birds species that nest in unique locations, and so conservation actions can be matched to the specific situations.

This study has shown that researching a specific conservation issue leads to a lot of information that not only helps determine what steps to take in protection, but also inspires future research. This study bridges the gap between animal behavior, which is usually fundamental, and applied conservation. Showing that the behavior of animals can give a lot of information about the situation that they are in.

Proposed measures for the situation on Dutch dikes are the partial closure of the asphalted paths, and protecting the nest against dogs and trampling with a roped barrier. Predator exclosures also protect against dogs and trampling, as well as other predators. However, implementing such a measure should be accompanied with research to ensure added effects such as higher adult mortality or nest abandonment rates do not decrease the breeding success instead of improving it. Observing some nests continuously will shed light on the causes of nests disappearing. All things considered, the results of this study clearly show what management actions to take and where more research is needed. This knowledge brings us one step closer to a better protection of Plovers nesting on Dutch sea dikes.

Acknowledgements

This work was supported by the organizations Rijkswaterstaat and Vogelbescherming Nederland. I gratefully acknowledge the funding received towards the research of Plovers by these organizations.

Throughout the writing of this report I have received a great deal of support and assistance.

I would first like to thank my supervisor, Floor Arts from Deltamilieu Projecten, for his guidance through each stage of the process. His dedication and keen interest, as well as his timely advice have helped to a great extend in accomplishing this task. I thank Floor for his patient support and opportunities I was given to execute this research.

I would also like to thank Marije Kuiper from Vogelbescherming Nederland for her kind help and co-operation. Her valuable comments and sharing of knowledge have helped a lot in my understanding of the situation on Dutch dikes. I also appreciate that she gave me the opportunity to attend meetings from the Vogelbescherming, from which I learned a lot.

I would like to acknowledge my colleagues from my internship at Deltamilieu projecten for their wonderful collaboration. I have learned a lot from our chats in the office and I want to thank them for giving me such a warm welcome in the company. I have enjoyed our stimulating discussions and their insightful feedback.

I offer my gratitude to my examiner Anouschka Hof for her patience and thorough proofreading of this work.

I am very thankful for my friend Dr. Katharina Hanika, whose great skill in planning and comforting words have provided the tools I needed to complete this research project.

Lastly, I thank my family for their continuous support and understanding. Peter Hoek, Hella Hoek and Dennis Hoek, thank you for providing what I needed to be able to do this project in Zeeland and for your wise counsel and sympathetic ear.

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Appendix A: Dutch field protocol

Project 'verstoring van de strandplevier en de bontbekplevier op dijken'
Sabine Hoek
Protocol veldwerk + data verzameling
Nederlandse samenvatting

Materialen

2 camera's: Colorway CW-200W01
Statief
Hesje
SD-kaarten
batterijen
eventueel stoeltje
Notitieboek en pen
Telefoon met internet voor nestkaart en temperatuurwaarneming

software:
QGIS (open source) (alternatief: ArcGIS)
VLC (open source)
Adobe Premiere Pro (of een ander programma voor videobewerking)
R en Rstudio (open source)

Methode

<u>Voorbereiding checklist</u>

- Beide camera's hebben een lege SD-kaart
- Beide camera's hebben volle batterijen
- Het regent niet
- Nestinformatie is bekend
- Camera-instellingen controleren

<u>Camera-instellingen</u>
mode: video
video resolution: 1280x720p
video length: 3 minutes
audio recording: off
Sensitivity motion sensors: high

<u>In het veld:</u>
Noteer de volgende gegevens:

1. Hoeveel seconden loopt de recreatiecamera achter op de nestcamera?
2. Datum
3. Nestcode (correspondeert met nestcode in nestkaart.nl)
4. Temperatuur
5. Bewolkt/zonnig/gedeeltelijk bewolkt/overwegend zonnig
6. Observatie starttijd
7. Observatie eindtijd

Proefopstelling

De nestcamera wordt op ongeveer anderhalve meter van het nest geplaatst en is van het pad af gericht. Op deze manier wordt voorkomen dat er bij iedere recreatie een filmpje wordt gemaakt. De nestcamera heeft een korte pin die tussen de stenen wordt geplaatst. De camera kan verstevigd worden met enkele stenen aan de basis. Belangrijk is dat de bewegingssensoren vrij zijn.

De recreatiecamera wordt op een statief geplaatst en kijkt naar de recreatie en het nest. In praktijk is dit zo'n 5-10 meter van het nest vandaan. Het is belangrijk dat deze camera zoveel mogelijk van het pad filmt, maar niet zo ver weg staat dat de beweging sensoren niet aan gaan. Op het statief wordt een hesje gehangen met 'vogelwacht erop'. Dit voorkomt in de meeste gevallen dat mensen het niet prettig vinden om gefilmd te worden.

Na het opzetten van de camera's neemt de observator plaats, het liefst op een niet-invasieve manier (dit kan zijn tussen de begroeiing op de dijk, of een stuk verderop naast het pad). Er wordt gekeken naar het nest en er wordt opgeschreven op welke tijd de vogel weer op het nest gaat zitten. Zodra de vogel weer zit gaat het uur van observatie in. In sommige gevallen zijn de vogels te bang om op het nest te gaan zitten met een camera ernaast, in dat geval wordt de poging na een half uur afgebroken. De volgende dag kan het opnieuw geprobeerd worden.

Na een uur worden de camera's weer opgehaald. Een nest wordt voor maximaal 1 observatie per dag gebruikt om verstoring door dit onderzoek te minimaliseren. Na een observatie worden gegevens in nestkaart ingevoerd.

Data verwerking

De data die nu verzameld is zijn losse filmpjes van 3 minuten, die starten bij beweging van de vogel (nestcamera) of de aanwezigheid van recreatie (recreatiecamera). Voor analyse worden deze losse clips gemonteerd, zodat voor iedere observatie 1 film bestaat waarop beide camera's tegelijk zichtbaar zijn.

Alle clips worden ingeladen in Adobe Premiere Pro 2020 CC. Er wordt gekeken naar de timestamps. De Scale en positie van de nestcamera wordt zo aangepast dat deze klein in een hoek te zien is. In de tijdlijn worden de clipjes zo neergezet dat ze in echte tijd tegelijk afspelen, er moet dus een correctie uitgevoerd worden voor de afwijkende tijd die genoteerd is aan het begin van het veldwerk. Als alle clips in de tijdlijn staan kan de film geëxporteerd worden.

Na deze stap van processing kunnen de films geanalyseerd worden. De film wordt geopend in VLC, hierin is het mogelijk de afspeelsnelheid aan te passen. Zo wordt een uur observatie versneld bekeken en gepauzeerd als er recreatie langskomt of de vogel om een andere reden zijn nest verlaat. Iedere vorm van recreatie of verstoring wordt genoteerd. In het geval dat de vogel zijn nest verlaat wordt dit in een apart excel sheet uitgebreider genoteerd (o.a. totale tijd van nest geweest). De locatie van de verstoring op het moment dat de vogel van zijn nest af gaat wordt als punt op de kaart in QGIS genoteerd.

In QGIS zal vervolgens de lineaire afstand tussen nest en verstoring berekend worden in meter. Deze afstanden worden gebruikt in de data analyse.

Appendix B: Pictures of experimental setup

Data collection

After editing the videos the activity on the path and the nest were observed at the same time

Appendix C: R script

```
## getting ready ##

{

setwd("G:/stage/R_files")
library(ggplot2)
library(ggpubr)
library(multcompView)
library(multcomp)
library(emmeans)
library(lme4)
library(ggplot2)
library(lmerTest)
library(rtools)
library(tidyverse)
library(broom)
library(AICcmodavg)
library(nlme)

tt <- read.csv("tt.csv",sep=",")
tt$Total_time <- as.numeric(tt$Total_time)
distance <- read.csv("distance2.csv",sep=",")

}

##creating models for absence duration ##

{

a <- lmer(Total_time ~ (1|Nest_ID) + aod, data = tt)
b <- lmer(Total_time ~ (1|Nest_ID) + aod + category, data = tt)
c <- lmer(Total_time ~ (1|Nest_ID) + aod + category + Species, data = tt)

model.set <- list(a, b, c)
model.names <- c("a", "b", "c")
aictab(model.set, modnames = model.names) # model c best fit

anova(c)
rand(c)
c
summary(c)

}

## creating models for hourly rates of cyclists and pedestrians ##

{

ar <- read.csv("footbiker.csv",sep=",")
View(ar)
ar$ar <- as.numeric(ar$ar)



arm1 <- glm(average_rate ~ trans, data = ar)
arm2 <- glm(average_rate ~ trans + Location, data = ar)
arm3 <- glm(average_rate ~ trans + Location + trans*Location, data = ar)
arm4 <- glm(average_rate ~ trans + Location + trans*Location + Weather, data = ar)
```

```
arm5 <- glm(average_rate ~ trans + Location + trans*Location + Daytype, data = ar)
arm6 <- glm(average_rate ~ trans + Location + trans*Location + Daytype + Weather, data = ar)

summary(arm1)
summary(arm2)
summary(arm3)
summary(arm4)
summary(arm5)
summary(arm6)

arm4

model.set <- list(arm1, arm2, arm3, arm4, arm5, arm6 )
model.names <- c("arm1", "arm2", "arm3", "arm4", "arm5", "arm6")
aictab(model.set, modnames = model.names) # model arm4 best fit

tukey.arm4<-TukeyHSD(arm4)
tukey.arm4

}



## analysis of hourly rates pedestrians and cyclists ##

{

box <- read.csv("footbikeBOX.csv",sep=",")
foot <- read.csv("footsavg.csv",sep=";")
bike <- read.csv("bikesrateavg.csv",sep=";")

View(bike)
View(box)
View(foot)

bike$avg <- as.numeric(bike$avg)
foot$avg <- as.numeric(foot$avg)

}

## boxplot that includes pedestrians and cyclists, not included in rapport ##

{

c <- ggplot(data=box, aes(x=transport, y=average_rate))+ geom_boxplot(outlier.shape = NA, colour="black") +
theme_bw() + theme_bw()


plot <- c + geom_point(size=1, position=position_jitter(h=0.2,w=0.2),aes()) +

  geom_hline(yintercept=0, linetype="dashed", color = "black", size=0.5)+

  xlab("categories") + ylab ("average hourly rate")+

  theme(panel.border = element_rect(),

        panel.grid.major = element_blank(),

        panel.grid.minor = element_blank(),

        axis.title.y=element_text(size=16),

        axis.text.x=element_text(size=13, angle = 45, hjust = 1),
```

```
        axis.text.y=element_text(size=13),
        strip.text.x = element_text(size = 13),
        strip.background = element_rect(
          color="black", fill="black"))+
  scale_y_continuous(breaks = seq(0, 100, by = 10))
plot
}
## boxplot of hourly rates of bikes ##
{
c <- ggplot(data=bike, aes(x=Location, y=avg))+
  geom_boxplot(outlier.shape = NA, colour="black") + theme_bw() +
  theme_bw()

plot <- c + geom_point(size=1, position=position_jitter(h=0.2,w=0.2),aes()) +
  geom_hline(yintercept=0, linetype="dashed", color = "black", size=0.5)+
  xlab("Location") + ylab ("average hourly rate of cyclists")+
  theme(panel.border = element_rect(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.title.y=element_text(size=13),
        axis.text.x=element_text(size=13, angle = 45, hjust = 1),
        axis.text.y=element_text(size=13),
        strip.text.x = element_text(size = 13),
        strip.background = element_rect(
          color="black", fill="black"))+
  scale_y_continuous(breaks = seq(0, 100, by = 10))

plot
}

## boxplot of hourly rates of pedestrians ##
{
c <- ggplot(data=foot, aes(x=Location, y=avg))+
  geom_boxplot(outlier.shape = NA, colour="black") + theme_bw() +
  theme_bw()
```

```
plot <- c + geom_point(size=1, position=position_jitter(h=0.2,w=0.2),aes()) +
  geom_hline(yintercept=0, linetype="dashed", color = "black", size=0.5)+
  xlab("Location") + ylab ("average hourly rate of pedestrians")+
  theme(panel.border = element_rect(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.title.y=element_text(size=16),
        axis.text.x=element_text(size=13, angle = 45, hjust = 1),
        axis.text.y=element_text(size=13),
        strip.text.x = element_text(size = 13),
        strip.background = element_rect(
          color="black", fill="black"))+
  scale_y_continuous(breaks = seq(0, 10, by = 1))
plot
}


## checking differences between species for absence duration ##
stt <- read.csv("species_TT.csv",sep=",")
test_stt <- t.test(stt$Total_time~stt$Species)
test_stt


## checking differences between species for distance ##

disp <- read.csv("disp.csv",sep=";")
View(disp)
disp$Dist <- as.numeric(disp$Dist)
test_disp <- t.test(disp$Dist~disp$Species)
test_disp

SPdist <- read.csv("SPdist.csv",sep=";")
BBdist <- read.csv("BBdist.csv",sep=";")
SPdist$Dist2 <- as.numeric(SPdist$Dist2)
BBdist$Dist2 <- as.numeric(BBdist$Dist2)


## ANOVA for categories affecting distance, Kentish Plover ##

View(SPdist)
SPdistaov <- aov(Dist2 ~ category, data = SPdist)
tukey.SPdistaov<-TukeyHSD(SPdistaov)
summary(SPdistaov)
summary(tukey.SPdistaov)
tukey.SPdistaov
```

```
cld <- multcompLetters4(SPdistaov,tukey.SPdistaov)
print(cld)


## ANOVA for categories affecting distance, Ringed Plover ##

View(BBdist)
BBdistaov <- aov(Dist2 ~ category, data = BBdist)
tukey.BBdistaov<-TukeyHSD(BBdistaov)
summary(BBdistaov)
summary(tukey.BBdistaov)
tukey.BBdistaov
cld <- multcompLetters4(BBdistaov,tukey.BBdistaov)
print(cld)

## boxplot for Ringed Plover, distance, categories ##

{

a <- ggplot(data=BBdist, aes(x=category, y=Dist2))+

  geom_boxplot(outlier.shape = NA, colour="black") + theme_bw() +

  theme_bw()

plot <- a + geom_point(size=1, position=position_jitter(h=0.2,w=0.2),aes()) +

  geom_hline(yintercept=0, linetype="dashed", color = "black", size=0.5)+

  xlab("reason for nest absence") + ylab ("Distance from disturbance to Ringed Plover nest (m)")+

  theme(panel.border = element_rect(),

        panel.grid.major = element_blank(),

        panel.grid.minor = element_blank(),

        axis.title.y=element_text(size=12),

        axis.text.x=element_text(size=13, angle = 45, hjust = 1),

        axis.text.y=element_text(size=13),

        strip.text.x = element_text(size = 13),

        strip.background = element_rect(

          color="black", fill="black"))+

  scale_y_continuous(breaks = seq(0, 45, by = 5))


plot

}


## boxplot for Kentish Plover, distance, categories ##

{

a <- ggplot(data=SPdist, aes(x=category, y=Dist2))+

  geom_boxplot(outlier.shape = NA, colour="black") + theme_bw() +
```

```
  theme_bw()
plot <- a + geom_point(size=1, position=position_jitter(h=0.2,w=0.2),aes()) +
  geom_hline(yintercept=0, linetype="dashed", color = "black", size=0.5)+
  xlab("reason for nest absence") + ylab ("Distance from disturbance to Kentish Plover nest (m)")+
  theme(panel.border = element_rect(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.title.y=element_text(size=12),
        axis.text.x=element_text(size=13, angle = 45, hjust = 1),
        axis.text.y=element_text(size=13),
        strip.text.x = element_text(size = 13),
        strip.background = element_rect(
          color="black", fill="black"))+
  scale_y_continuous(breaks = seq(0, 45, by = 5))
plot
}
## creating plot for number of disturbances while incubator off nest ##
{
plot(tt$aod~tt$Total_time)
ggplot(tt$aod~tt$Total_time)
PLOTJE <- (prelim_plot <- ggplot(tt, aes(x = aod, y = Total_time)) +
         geom_point() +
geom_smooth(method = "lm"))

plot <- PLOTJE + geom_point(size=1, position=position_jitter(h=0.2,w=0.2),aes()) +
  geom_hline(yintercept=0, linetype="dashed", color = "gray30", size=0.5)+
  xlab("categories") + ylab ("average rate")+
  theme(panel.border = element_rect(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.title.y=element_text(size=16),
        axis.text.x=element_text(size=13, angle = 45, hjust = 1),
        axis.text.y=element_text(size=13),
        strip.text.x = element_text(size = 13),
        strip.background = element_rect(
```

```
        color="black", fill="gray90"))

plot

PLOTJE + theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank())

PLOTJE <- (prelim_plot <- ggplot(tt, aes(x = aod, y = Total_time)) +

          geom_point() +

          geom_smooth(method = "lm") + theme_bw() +

          theme_bw())

PLOTJE + xlab("Number of stimuli that occurred during absence") + ylab ("Duration of the nest absence (s)") +
scale_x_continuous(breaks = seq(0, 7, by = 1)) + scale_y_continuous(breaks = seq(0, 400, by = 50)) +
theme(panel.grid.major.x = element_blank()) + theme(panel.grid.major.y = element_blank()) +
theme(panel.grid.minor.x = element_blank()) + theme(panel.grid.minor.y = element_blank())

}
```

Appendix D: details of model selection

Model selection for absence duration

Models:

a <- lmer(Total_time ~ (1|Nest_ID) + aod, data = tt)
b <- lmer(Total_time ~ (1|Nest_ID) + aod + category, data = tt)
c <- lmer(Total_time ~ (1|Nest_ID) + aod + category + Species, data = tt)

Model selection based on AICc:

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	Res.LL
c	9	714.62	0.00	0.99	0.99	-346.73
b	8	724.19	9.58	0.01	1.00	-352.86
a	4	754.13	39.51	0.00	1.00	-372.74

model c was the best fit.

Model selection for rates of cyclists and pedestrians

Models:

arm1 <- glm(average_rate ~ trans, data = ar)
arm2 <- glm(average_rate ~ trans + Location, data = ar)
arm3 <- glm(average_rate ~ trans + Location + trans*Location, data = ar)
arm4 <- glm(average_rate ~ trans + Location + trans*Location + Weather, data = ar)
arm5 <- glm(average_rate ~ trans + Location + trans*Location + Daytype, data = ar)
arm6 <- glm(average_rate ~ trans + Location + trans*Location + Daytype + Weather, data = ar)

Model selection based on AICc:

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
arm4	8	359.94	0.00	0.28	0.28	-170.03
arm7	8	359.94	0.00	0.28	0.55	-170.03
arm3	7	360.47	0.53	0.21	0.77	-171.76
arm5	8	361.51	1.56	0.13	0.89	-170.81
arm6	9	361.92	1.98	0.10	1.00	-169.46
arm2	5	369.05	9.10	0.00	1.00	-178.77
arm1	3	379.56	19.61	0.00	1.00	-186.49

model arm4 was the best fit.

Appendix E: information about observation sessions

Sessioncode	Location	Nest ID	Species	Weather	Daytype	Session
A	Ritthem	BB_Ritth1	Ringed Plover	sunny	Weekend	13:47 - 15:19
B	Ritthem	BB_Ritth1	Ringed Plover	sunny	Weekend	15:40 - 16:00
C	Ritthem	BB_Ritth1	Ringed Plover	sunny	Workday	14:21 - 15:05
D	Ritthem	BB_Ritth1	Ringed Plover	sunny	Workday	15:00 - 16:33
E	Ritthem	BB_Ritth1	Ringed Plover	cloudy	Workday	10:57 - 12:00
F	Oostdijk	SPMH2103	Kentish Plover	cloudy	Workday	10:29 - 11:29
G	Oostdijk	SPMH2103	Kentish Plover	cloudy	Workday	16:06 - 17:13
H	Oostdijk	SPMH2103	Kentish Plover	sunny	Weekend	13:08 - 13:54
I	Oostdijk	BBMH2109	Ringed Plover	sunny	Weekend	15:38 - 16:40
J	Oostdijk	BBMH2109	Ringed Plover	sunny	Workday	14:03 - 14:54
K	Oostdijk	SPMH2104	Kentish Plover	sunny	Weekend	13:40 - 14:46
L	Oostdijk	SPMH2104	Kentish Plover	sunny	Workday	11:42 - 12:42
M	Oostdijk	SPMH2103	Kentish Plover	sunny	Weekend	15:25 - 16:22
N	Oostdijk	SPMH2104	Kentish Plover	sunny	Weekend	11:33 - 12:37
O	Oostdijk	SPFA2101	Kentish Plover	sunny	Workday	14:02 - 15:04
P	Oostdijk	SPFA2101	Kentish Plover	sunny	Weekend	13:06 - 14:05
Q	Den Inkel	SPWJ2111	Kentish Plover	sunny	Workday	13:52 - 14:47
R	Den Inkel	SPWJ2111	Kentish Plover	sunny	Weekend	11:18 - 11:56
S	Den Inkel	SPWJ2112	Kentish Plover	sunny	Weekend	15:54 - 17:30
T	Den Inkel	SPWJ2112	Kentish Plover	cloudy	Weekend	10:13 - 10:41
U	Den Inkel	SPWJ2112	Kentish Plover	sunny	Workday	15:46 - 16:54
V	Den Inkel	SPFA2102	Kentish Plover	sunny	Weekend	11:08 - 12:11
W	Den Inkel	SPPW15	Kentish Plover	cloudy	Weekend	12:44 - 13:44