ASSESSING THE IMPACT OF COORDINATED MINK CULLING ON BIRD POPULATIONS ON COASTAL ISLANDS IN NORWAY

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ABSTRACT

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The introduction of the non-native American Mink *Neogale vison* (syn. *Neovison vison*), a predator of birds and their chicks and eggs, is one of many anthropogenic factors that may be driving the decline of seabird populations in areas where mink are prevalent. Previous studies have shown that ground-nesting birds utilising coastal ecosystems are especially vulnerable. In this study, we investigated changes in seabird and coastal-bound bird populations, focusing on ground-nesting species, and the potential effect from mink culling. Ten locations in the archipelago of Flatanger, a coastal municipality in central Norway, were surveyed, and bird counts from 1991, 2016, and 2023 were compared. A total of 247 mink were trapped and removed from 2015 to 2023 because of a bounty hunting program initiated by the government. The study found that the abundance of most avian species decreased from 1991 to 2016. However, from 2016 to 2023, diversity (Shannon diversity index, H') increased significantly, and a greater number of ground-nesting species were observed overall. Notably, numbers of terns, including the Common Tern *Sterna hirundo* and Arctic Tern *Sterna paradisaea*, decreased dramatically from 1991 to 2016 but showed the largest increase of any species between 2016 and 2023. Terns are particularly sensitive to mink predation. Our results suggest that incentivizing local hunters to trap mink may have contributed to an increase in local faunal diversity. However, further research and targeted management strategies are required to ensure long-term conservation, as the complexity of ecological drivers make it difficult to attribute population declines solely to mink predation. Nonetheless, early indications and the significant increase in H' following nine years of mink culling suggest culling may have contributed to positive ecological changes.

Key words: American Mink, predator control, seabirds, coastal Norway, biodiversity

INTRODUCTION

Globally, declines in the population sizes of many marine and coastal-bound species since the 1950s have been attributed to anthropogenic impacts on the marine ecosystem (Halpern et al., 2008; Paleczny et al., 2015). Similar negative trends have been documented in Norway and other parts of Europe (Croxall et al., 2012). Factors contributing to this decline include fisheries, climate change, human disturbances, hunting, pollution, disease, oil spills, environmental contamination, and the introduction of invasive species (Croxall et al., 2012). Alien species are organisms transported by human activities, intentionally or unintentionally, beyond their native ranges. Only a subset becomes invasive; that is, they establish self-sustaining populations, spread beyond their points of introduction, and cause measurable adverse impacts on native biodiversity or ecosystem processes (Dias et al., 2019). In many cases, alien species can alter natural habitats, occupy already stressed ecological niches, and displace local species (Croxall et al., 2012). Historically, the introduction of alien species has primarily occurred through deliberate release, farming, hybridisation, and escape from captivity into the wild. Additionally, travel, transportation, and shipping activities have served as major vectors facilitating their spread (Dias et al., 2019).

American Mink *Neogale vison* is a variant of wild mink that has been bred specifically for fur production. The species originates from North America, where wild mink was captured and selectively bred to enhance fur quality for the clothing industry. In Europe, including Norway, mink is considered a threat to seabirds and ground-nesting species in coastal areas (Bonesi & Palazon, 2007). Since its introduction in 1927, sporadic escape events have resulted in the spread and establishment of the American Mink along the entire Norwegian coastline (Bevanger, 2021; The Norwegian Directorate for Nature Management, 2011). Mink are highly skilled hunters and swimmers, posing a significant threat to local species that have historically been protected by nesting on islets and skerries (Burness & Morris, 1993; Craik, 1997). Mink culling campaigns have been implemented to mitigate losses of birds, but these efforts are time-intensive and require local knowledge. In some cases, professional hunting teams using trained dogs are needed to remove mink effectively from certain areas (The Norwegian Directorate for Nature Management, 2023).

In 2015, a government-funded bounty was introduced in Flatanger Municipality and other coastal municipalities. The program provided payment per mink collected, which increased culling efforts within the local community. Traps were supplied free of charge, and a local group was established to distribute and maintain the traps evenly along the coastline and islands in Flatanger. Access to annual counts of trapped mink, together with historical bird count data from the area, provided the opportunity to examine temporal trends and assess the potential effects of mink on seabird and shorebird populations.

The aim of the study was to compare bird population counts from 10 coastal island locations in Flatanger, Norway, surveyed in 2023, with historical data collected in 1991 and 2016 at the same sites, in order to assess long-term changes associated with mink culling. We hypothesised that intensified mink culling, initiated in 2015, would have positive effects on coastal bird populations, reflected as higher bird counts and/or diversity in 2023 compared to baseline surveys conducted in 1991 and 2016.

STUDY AREA AND METHODS

Overview

Bird counts conducted in 1991 were carried out by personnel from the Norwegian Institute for Nature Research (NINA), whereas counts in 2016 and 2023 were conducted by Aqua Kompetanse AS and Akvaplan-niva AS, respectively. The seabird surveys in Flatanger municipality covered 10 locations distributed around Lyngværet (64°33′19.9″N, 10°46′20.8″E; WGS 84) (Fig. 1). Lyngværet is one of several areas in Norway designated to protect seabird and shorebird populations by providing critical breeding habitat with minimal human disturbance. Within Flatanger, Lyngværet is of particular importance because it supports the largest number and diversity of seabird species in the municipality, underscoring the need to maintain the area and its surroundings free of mink. In 1991, seabirds were surveyed at 18 locations.

To ensure reproducibility, the 2016 and 2023 survey focused on 10 locations that were closest to Lyngværet (Fig. 1). These locations ranged from Hamnarøya in the north (Location 1) to Buholman and Kvitholman in the south (Location 10). The area where mink culling was conducted covered approximately 200 km^2, and the 10 study locations were spread within this area. Fifty "Syningfella mink" traps (Syning, Norway), a Norwegian-produced kill trap specifically designed for mink, were deployed and checked at least once per week. The trap measures 19 × 19 × 16 cm and is fitted with a 20-cm entrance tunnel (8 cm in diameter) designed to prevent non-target species from entering. The trap is baited with food items (typically fish) placed at the back and is often combined with olfactory attractants. When triggered, it kills the mink instantly by delivering a blow to the neck. Each trap weighs 1.64 kg and is supplied with a setting device for the strike bar. Traps were placed along shorelines and on islets showing signs of mink activity (i.e., tracks, scats, or predation events), and they were relocated if subsequent inspections showed little or no evidence of mink presence. Trap density varied with site accessibility; however, efforts were made to maintain coverage across the coastal archipelago, resulting in approximately 200–250 trap-nights during the active season. In addition to trapping, hunting was carried out, including the use of dogs in 2015 and 2021. Approximately 20 local volunteers participated in the coordinated mink culling campaign between 2015 and 2023. In other studies, trapping efficiency is typically expressed as captures/trap-night (López et al., 2023); however, because trapping effort was not systematically recorded in Flatanger, this metric could not be calculated in the present study.

Data Collection

Bird counts were conducted during week 25 (mid-June) in 1991, 2016, and 2023. During each survey, all individual birds observed

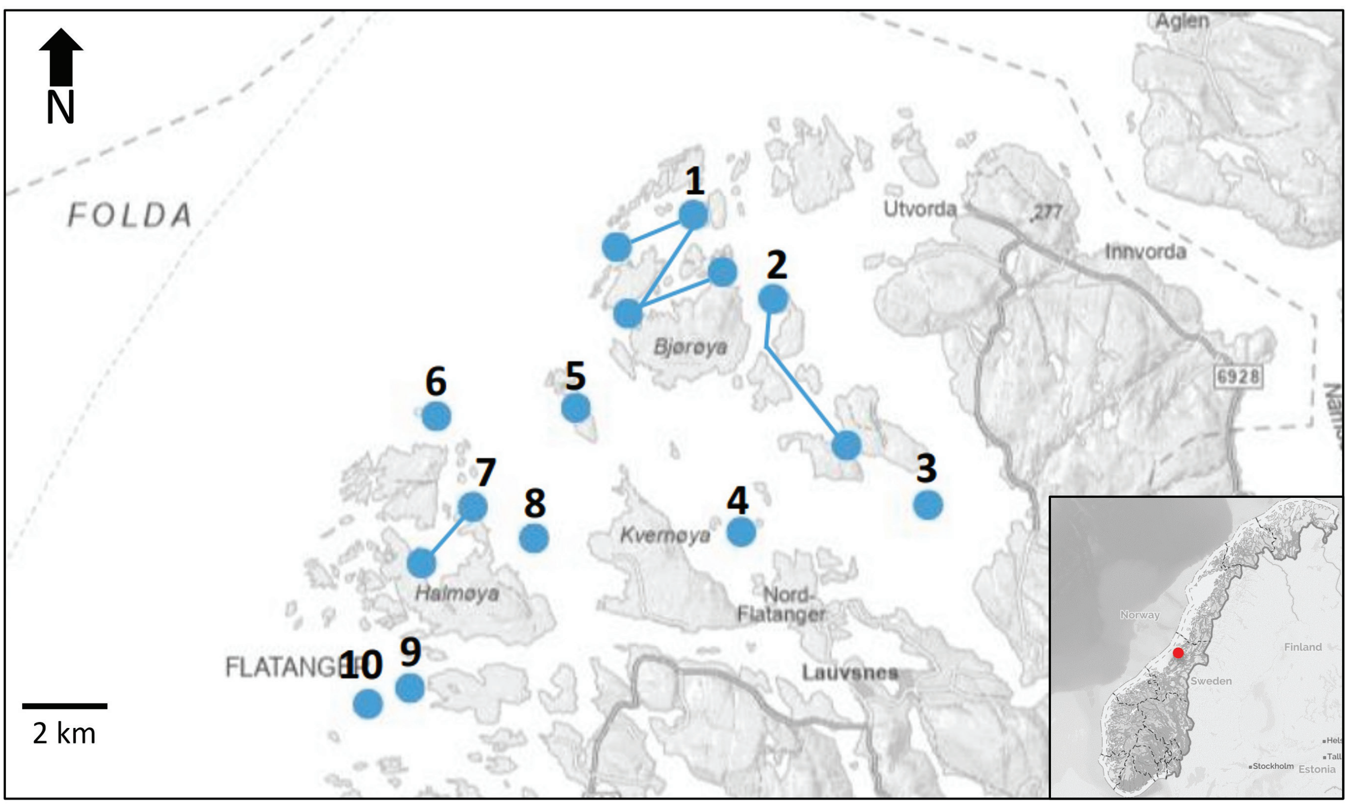

Figure 1. Bird monitoring locations in Flatanger, Trøndelag, Norway, marked with blue dots. Surveys were conducted during the nesting period (week 25) in 1991, 2016, and 2023. Lines between dots indicate survey routes conducted by boat. Locations were named after nearby islands or islets: (1) Ellingen – Hartvigøy, (2) Lindøya – Havstein, (3) Feøyholman – Sitterholman, (4) Lauvøyholman, (5) Lyngværet bird conservation area, (6) Måholman, (7) Seingsholman – Nygrunnen, (8) Floflesa, (9) Aspøyholman and (10) Buholman – Kvitholman.

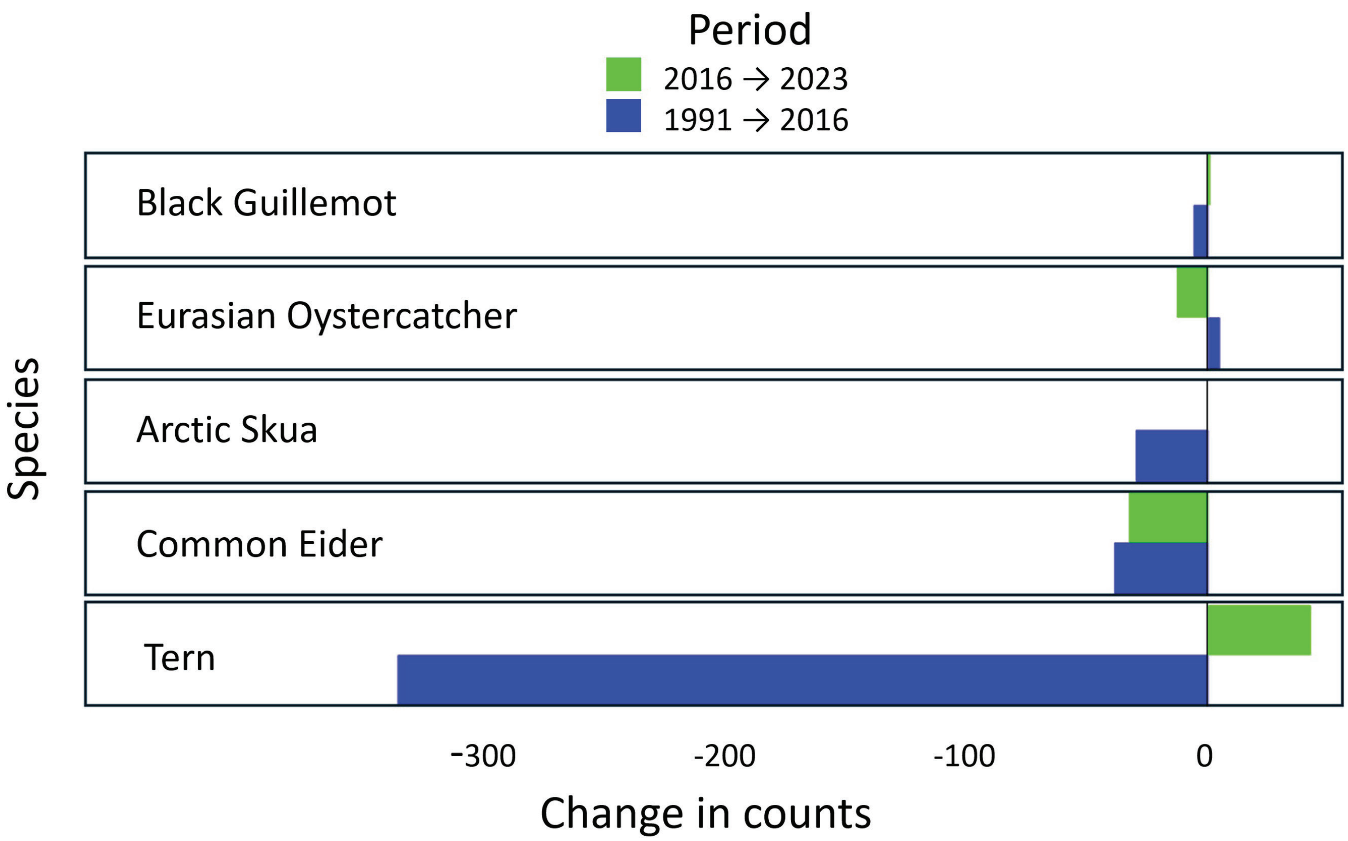

Figure 2. Change in seabird counts between 2016 and 2023 (green) and between 1991 and 2016 (blue), shown for each species (top to bottom).

were counted and identified to the lowest possible taxonomic level. These data provided total abundance per species and overall species richness at each site. Fieldwork was conducted on days with little to no wind (0–5 m/s), moderate temperatures (10–20 °C), and clear skies. Counts in 2016 and 2023 were conducted according to the method developed by Follestad & Lorentsen (2011) for seabirds along the Norwegian coast. Each survey was conducted by two observers trained in seabird identification, who compared and discussed counts to minimise counting errors. Nonetheless, the 1991 survey was conducted by different personnel than the 2016 and 2023 surveys. Although this could influence count precision, the number of species breeding in the area was low and the species present were well known. Tidal variation in the area ranged from 1–3 m and was not accounted for in the analyses. Nonetheless, field observations were spread across all stations during daytime, which reduced the potential bias introduced by both weather and tidal conditions.

Each defined location (1–10) was observed either from boat or from land. Observation and photographic documentation were conducted using binoculars (Swarovski 10 × 42 EL; Swarovski®, Austria), a DSLR camera (Canon 6D; Canon®, Japan) equipped with a 500 mm telephoto lens (Sigma 500 mm, f/5.6; Sigma®, Japan), and a telescope (Meopta Meostar 82 mm; Meopta®, Czech Republic). In areas with dense Gull aggregations, photographs were archived and subsequently analysed to optimize count accuracy. Counts were based on individual birds rather than nests or eggs. All species were included in analyses, including non-seabird species such as shorebirds and ground-nesting birds breeding in coastal habitats. All observations were also registered in the national species database, available at www.Artsobservasjoner.no.

Data Preparation

Although field counts included all bird species observed, our analyses were restricted to species assumed to nest at the study sites and therefore be susceptible to mink predation. Species recorded only as foraging in the study area were excluded from the analyses, as they were considered unlikely to be directly impacted by mink predation. Excluded species were Red-throated Loon *Gavia stellata*, Black-throated Loon *Gavia arctica*, Great Cormorant *Phalacrocorax carbo*, Rock Pipit *Anthus petrosus*, Northern Wheatear *Oenanthe oenanthe*, and Hooded Crow *Corvus cornix*. In 1991, observations did not distinguish between Arctic Tern *Sterna paradisaea* and Common Tern *Sterna hirundo*, whereas the two species were recorded separately in 2016 and 2023. To ensure comparability among survey years, all tern observations were pooled and analysed as a single category ("tern").

Data Analysis

Statistical analyses were conducted and figures produced using RStudio (RStudio, 2024). To assess species population trends over time, data from all 10 locations were pooled and expressed as positive or negative changes in the total number of individuals. The Shannon diversity index (H') was calculated. This index is particularly useful for monitoring populations over time, as it considers species richness (the number of different species) and their relative abundance. For example, if a colony contains many different species but one species dominates in terms of individual numbers, H' will be lower compared to a scenario

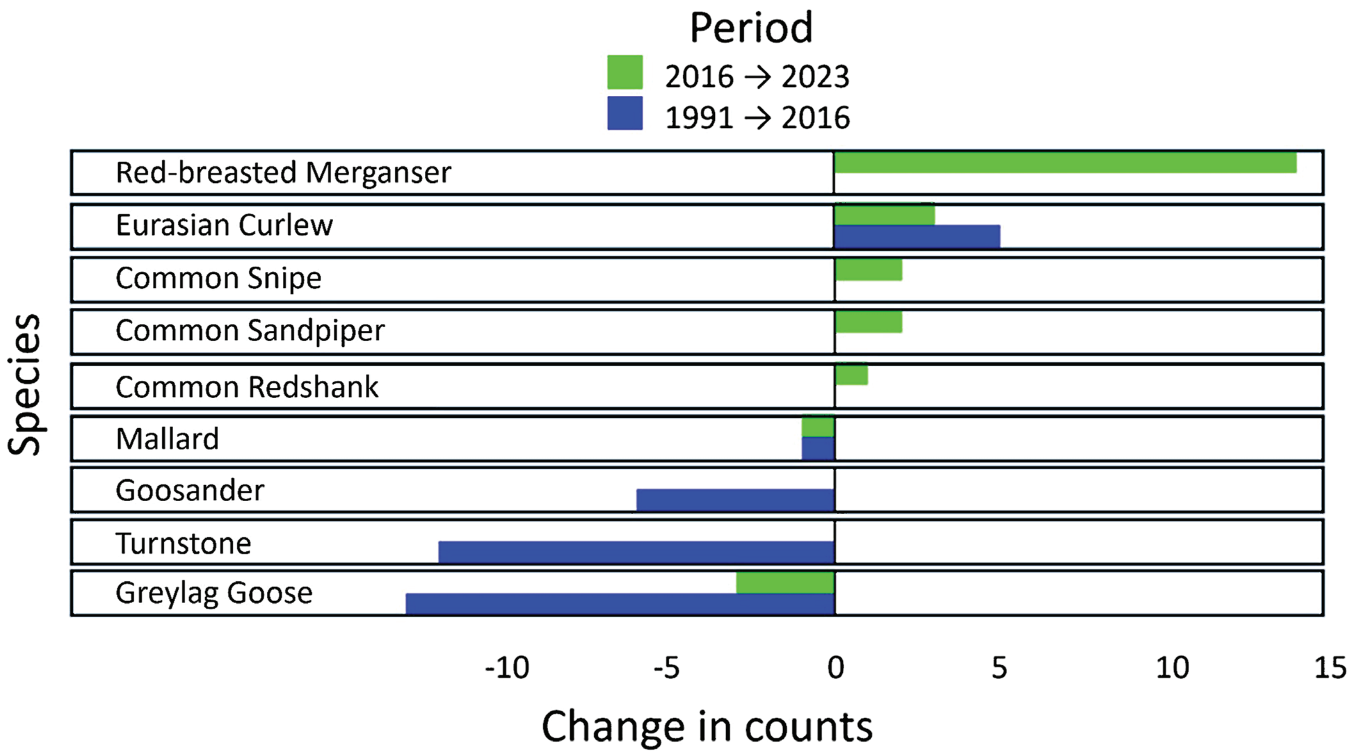

Figure 3. Changes in counts of other bird groups, including shorebirds, waders, and ducks and geese, between 2016 and 2023 (green) and between 1991 and 2016 (blue), shown for each species (top to bottom).

where individuals are more evenly distributed across species. A decrease in H' indicates that the colony is becoming less diverse, whereas an increase in H' suggests greater diversity, which may indicate a healthier and more resilient ecosystem. It is important to note that H' provides only a general measure of diversity, and further investigation may be needed to understand the underlying causes of any observed changes (Ortiz-Burgos, 2016).

Diversity indices were calculated per colony but were pooled in the results to allow tractable comparisons across years and taxa. However, site-specific trends are discussed when relevant. The calculations presented are based on mean H' values with 95% confidence intervals (CI) from the 10 locations. To analyse the differences in mean H' between 1991, 2016, and 2023, a repeated-measures analysis of variance (ANOVA) was used. This test assessed overall differences among years, and Tukey's Honestly Significant Difference (HSD) was used to identify which specific years differed significantly. The repeated-measures ANOVA was appropriate because the data included measurements from the same stations across three years. To compare H' between different years, a post-hoc analysis was conducted using Tukey's HSD test. Assumptions of normality were assessed using the Shapiro-Wilk test, and Levene's test indicated homogeneity of variance among years.

To assess changes in key species (including terns), a Friedman test for repeated measures was used, with location as the blocking factor (10 locations × 3 years). Post hoc pairwise comparisons between years were conducted using Wilcoxon signed-rank tests. This approach was chosen because the dataset included repeated measurements across the same locations, with non-normally distributed counts and a small sample size.

RESULTS

Overview

The total number of nesting bird species observed was 13 in 1991, 14 in 2016, and 16 in 2023. Across all years, a total of 18 species were recorded. The species count included non-passerines and excluded some seabirds and shorebirds that do not normally breed in the area. The total number of individuals recorded was 1,339 in 1991, 2,040 in 2016, and 1,108 in 2023. Six species increased in abundance during the period of intensified mink culling between 2016 and 2023, while 10 species decreased and three remained unchanged. The species that increased in abundance were terns (+43), Red-breasted Merganser *Mergus serrator* (+14), Eurasian Curlew *Numenius arquata* (+3), Common Sandpiper *Actitis hypoleucos* (+2), Common Snipe *Gallinago gallinago* (+2), and Common Redshank *Tringa totanus* (+1). Gulls accounted for the largest observed decline in abundance between 2016 and 2023, including European Herring Gull *Larus argentatus* (-488), Great Black-backed Gull *Larus marinus* (-322), and Common Gull *Larus canus* (-135) (Figs. 4, 6). Species that showed a consistent negative population trend from 1991 to 2023 were Common Eider *Somateria mollissima*, Mallard *Anas platyrhynchos*, and Greylag Goose *Anser anser*. Common Merganser *Mergus merganser* showed a negative population trend from 1991 to 2016, but no change from 2016 to 2023. The population of Ruddy Turnstone Arenaria interpres disappeared after 1991, and no individuals were observed at the locations surveyed in 2016 or 2023.

Mink Culling

From 2015 to 2023, a total of 247 mink were removed in Flatanger Municipality through trapping and hunting. Most

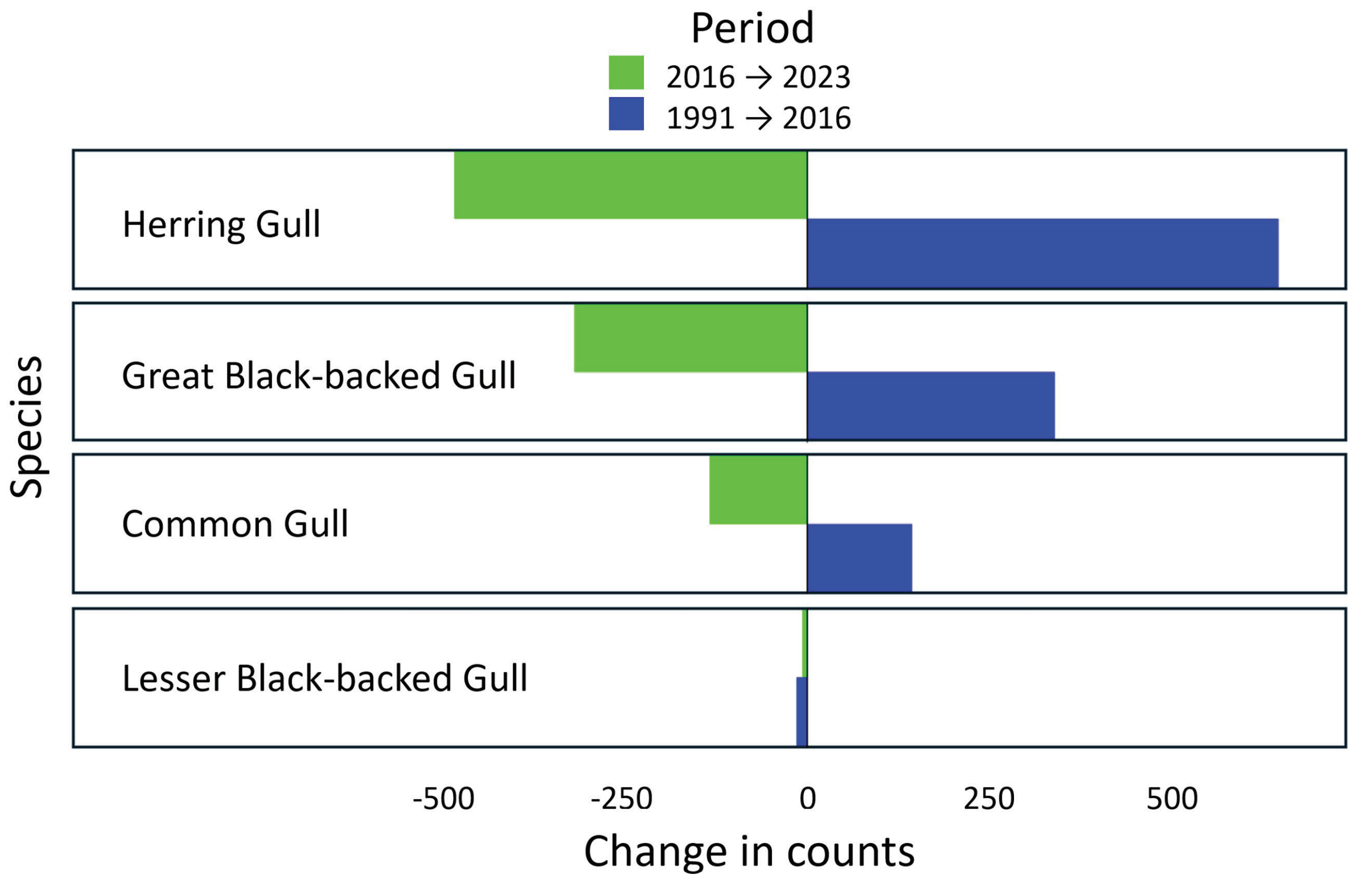

Figure 4. Change in counts of gulls between 2016 and 2023 (green) and between 1991 and 2016 (blue).

mink were caught in traps, although exact numbers removed by each method (trapping versus shooting) were not consistently recorded. Dogs were used in coordinated hunting events in 2015 and 2022, which substantially increased removal success and resulted in the highest annual catches (50 and 51 mink, respectively). Because detailed effort data, such as trap nights or the proportion of individuals removed by each method, were not systematically documented, it was not possible to calculate standardized capture effort. The numbers reported here therefore reflect total removals across all methods rather than method-specific effort or efficiency.

Species Diversity

An increase in diversity occurred from 2016 to 2023. The effect of year on the Shannon diversity index (H') revealed a statistically significant difference for all birds included in the study among the years 1991, 2016, and 2023 when all bird species were considered (repeated measures ANOVA: $F_{2,18} = 9.77$, $P = .002$; Fig. 5A). Post hoc comparisons indicated that H' increased significantly from 2016 to 2023 ($P = .004$, Tukey's HSD test), with a mean difference of 0.49 (95% confidence interval [CI]: 0.15–0.83). No significant differences were observed between 1991 and 2016 ($P = .090$) or between 1991 and 2023 ($P = .388$). When diversity was analysed by taxonomic groups—"ducks and geese" (Anseriformes) and shorebirds (Charadriiformes)—the increase in H' observed from 2016 to 2023 appeared to be primarily driven by Charadriiformes rather than Anseriformes (Figs. 5B, 5C).

Trends Among Terns, Gulls, Waders, and Ducks and Geese

For terns, counts varied significantly across years (Friedman test: $\chi^2 = 7.10$, $df = 2$, $P = .29$). Pairwise Wilcoxon signed-rank tests showed a significant decline between 1991 and 2016 ($P = .017$), followed by a non-significant increase between 2016 and 2023 ($P = .080$). Counts in 2023 remained lower than in 1991, though the difference was not statistically significant ($P = 0.063$). Gulls accounted for the largest group in terms of individual counts during the study (Fig. 6). Total gull numbers showed the greatest fluctuation, increasing from 1991 to 2016 before declining again in 2023. Wader numbers showed little change over time, whereas the total numbers of ducks and geese declined.

DISCUSSION

Key Findings and Context

Trends in seabird and shorebird populations from 1991 to 2023 were complex and varied among species. Overall, many species showed declines during this period, including most species of gulls as well as the Common Eider. However, some species showed positive population trends after 2016, when mink culling began in the area. Notable changes were observed among terns, which are vulnerable to mink predation due to their small body size and relatively late breeding phenology (Nordström et al., 2003). Terns showed a dramatic decline from 355 individuals in 1991 to 17 individuals in 2016, but numbers increased to 60 by 2023. Other species showing positive population trends were Red-breasted

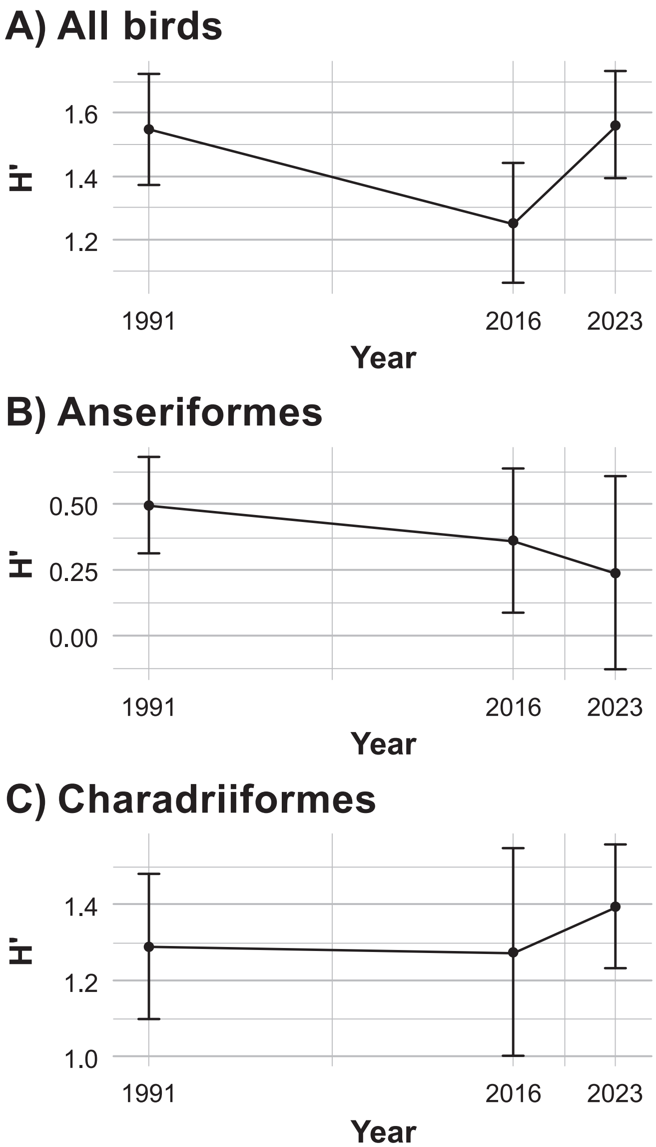

Figure 5. Mean Shannon diversity index (*H'*) across ten locations for (A) all birds combined, (B) Anseriformes, and (C) Charadriiformes, observed in Flatanger, Norway, a coastal region in Central Norway.

Merganser, Eurasian Curlew, and Common Snipe. The study was not designed to compare a control to a treatment group; rather, it examined population changes over time, particularly after the intensification of mink culling, with 2016 used as a reference point for assessing the effects of mink trapping. The culling program may have contributed to the observed increase in diversity among birds that utilise the coastal area for breeding and feeding. These results suggest that active management of invasive species may have beneficial effects on local ecosystems and could help preserve biodiversity, including that of endangered species.

The impact of mink culling

Previous research has shown that active and intensive mink culling benefits shorebird and seabird populations. For instance, Nordström et al. (2003) and Clode & Macdonald (2011) reported increased breeding success and population recovery in species such as terns, Rock Pipit, Common Ringed Plover *Charadrius hiaticula*, and Black Guillemot *Cepphus grylle* following mink removal. Additionally, Black Guillemot and Razorbill *Alca torda* returned to areas from which they had previously disappeared after the arrival of mink (Nordström et al., 2003). Craik (1997) found that mink control improved breeding success in several seabird species in western Scotland, supporting our findings of increased species richness and diversity following mink removal. Our findings also align with these observations, showing a notable rise in tern numbers. In Nordström et al. (2003), smaller changes in abundance were observed in Great Black-backed Gull, White Wagtail *Motacilla alba*, and Eurasian Oystercatcher *Haematopus ostralegus*. This agrees with our findings which show a decline in breeding Gull species between 2016 and 2023, and a steady decline in Common Eider and several other species. The ongoing decline in some shorebird and seabird populations in our study suggests that other factors may be influencing these trends. This aligns with the findings of Harris et al. (2015), who emphasised that seabird declines are often multifactorial and cannot be attributed to a single driver.

The data analysis included counts of selected species that may be particularly susceptible to mink predation at each location. It has been suggested that the presence of larger bird colonies can attract other bird species that benefit from the alarm calls produced when predators approach. This may be particularly relevant for colony-breeding gulls. Consequently, indirect effects on species that are not direct victims of predation should be accounted for in future surveys. Long-term population changes likely require several consecutive years without mink in breeding areas, as shorter periods of intensive mink culling appear to have limited effects on the abundance of many seabird species (Udø, 2005). Nordström & Korpimäki (2004) suggested that the long-term presence of mink during the breeding season can alter the nesting preferences of several bird species, with more isolated islets and islands further from the mainland favoured. The 10 locations in the present study were not as isolated as those examined by Nordström and Korpimäki (2004), meaning that mink likely had access to all locations by swimming from the mainland and between islands. This study lacks the data necessary to determine whether some of the seabirds or shorebirds in our area had moved to remote sites inaccessible to mink, as the spatial scope of the survey was limited. Nevertheless, our findings are consistent with previous studies suggesting that mink presence is an important factor contributing to a decline of certain bird populations, particularly given the large numbers of mink removed during the culling program between 2015 and 2023. As mentioned, the effect was most pronounced for terns, and mink have been observed to completely eradicate tern colonies when given the opportunity (Craik, 1995). The mink is an efficient predator of birds and their eggs and can have severe consequences for ecosystems and species (Burness & Morris, 1993; Craik, 1997; Ibarra et al., 2009; Nordström & Korpimäki, 2004). In Flatanger, mink were captured regularly throughout the study period, but this does not mean that the monitored locations were entirely free of mink. For example, the use of dogs in 2015 and 2021 doubled the number of captures in those years, indicating that traps alone were not sufficient to reduce mink numbers to very low levels. It is therefore likely that the full effects on bird populations will only become evident after sustained culling over longer periods using multiple methods, including traps, hunting, and dogs. Because detailed data on trapping effort (e.g., trap nights, number of traps/km, or person-days with dogs) were not systematically recorded, it was not possible to assess

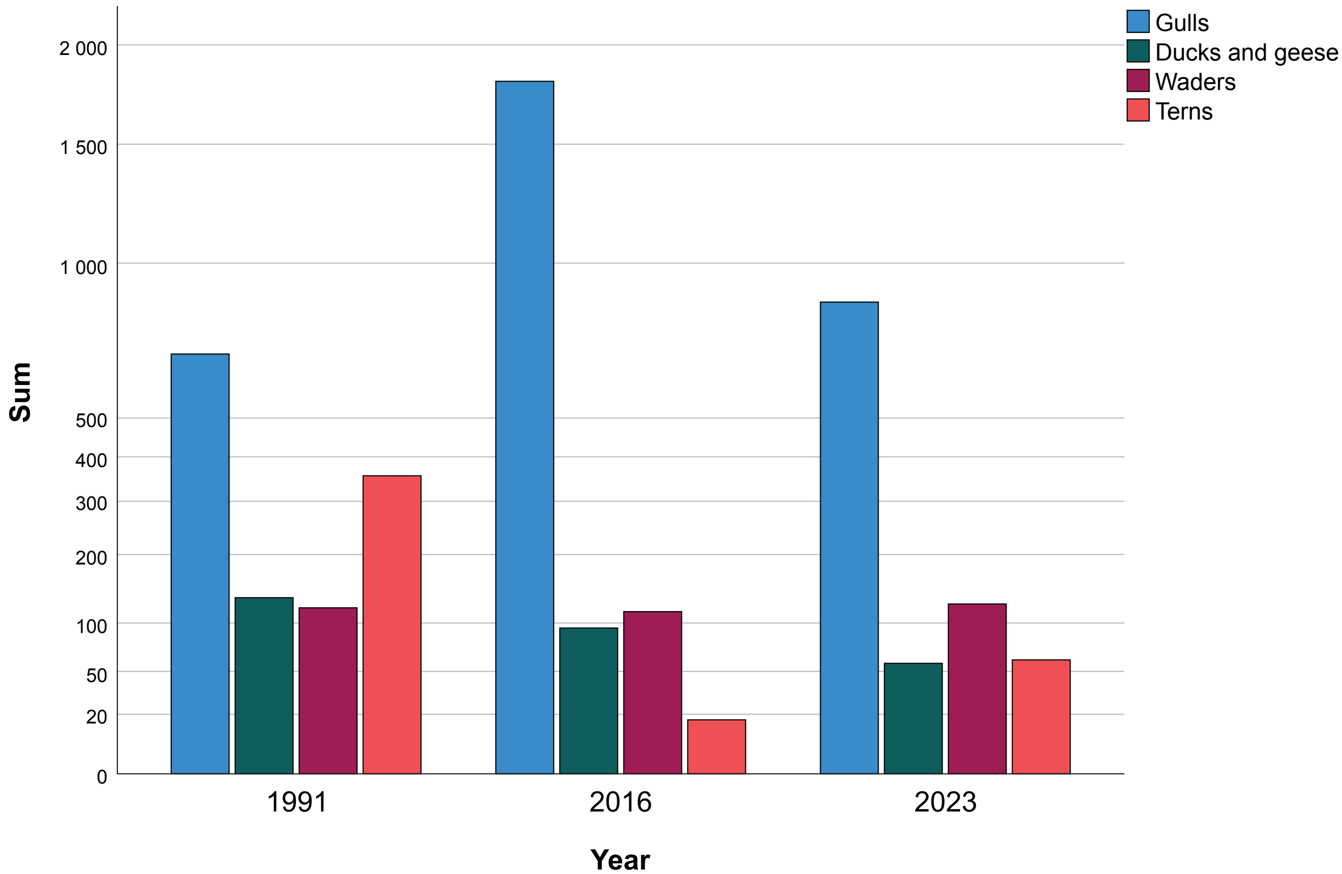

Figure 6. Counts of gulls, ducks and geese, waders, and terns in Flatanger, Norway, based on data from ten locations in 1991, 2016, and 2023.

trapping efficiency or effectiveness. Consequently, the analysis was restricted to describing overall mink removal and concurrent changes in bird populations at the community level, rather than attempting to quantify removal efficiency. To improve future evaluations of mink control, standardized reporting of trapping effort and hunting activity will be essential.

Limitations and Future Research

Temporal variability unrelated to mink culling—such as weather conditions, food availability, or migration patterns—may also have influenced observed trends (Cury et al., 2011; Dias et al., 2019; Frederiksen et al., 2008). An additional consideration is that the culling program itself may have been only partially effective. Because detailed data on trapping effort (e.g., trap-nights) were not recorded, it was not possible to calculate trapping efficiency. Previous research indicates that trapping efficiency for American Mink depends on factors such as bait type, trapping duration, and spatial coverage (López et al., 2023), emphasizing the importance of standardized effort metrics for evaluating the effectiveness of invasive predator control programs. Although 247 mink were removed from 2015 to 2023, captures fluctuated annually and trapping effort was not systematically recorded, making it difficult to assess the overall efficiency of the program. Inefficient or inconsistent mink control could therefore reduce the potential benefits for bird populations. Nevertheless, our findings are broadly consistent with other studies showing that mink removal can support bird diversity (Burness & Morris, 1993; Craik, 1997; Nordström et al., 2003). To strengthen the argument for causality, future studies should compare bird population trends across coastal areas with different levels of mink control, ideally including both areas without culling and areas with well-documented, intensive culling programs. Such comparative approaches would help clarify whether the intensity of mink control is a major driver of observed changes in bird communities.

CONCLUSION

Mink control may help improve seabird and shorebird populations and increase biodiversity in coastal areas; however, our study did not directly assess the level of effort required to achieve these outcomes. Our results, together with findings from other studies, suggest that sustained and well-documented culling over multiple years is likely necessary to produce measurable ecological benefits. Future mink control programs in Norway would benefit from incorporating standardized measures of trapping effort and evidence-based strategies, such as those described by López et al. (2023), to increase capture efficiency and allow more robust evaluation of management outcomes.

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STATEMENT ON THE USE OF GENERATIVE AI

ChatGPT (OpenAI, GPT-5o) was used for language proofreading.

AUTHOR CONTRIBUTIONS

Conceptualization: FRS. Methodology: FRS, TN. Data curation: FRS, TN. Formal analysis: FRS, TN. Funding acquisition: FRS, TN. Writing—original draft: FRS and TN. Writing—review & editing: FRS, TN.

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