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RESEARCH PAPER

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Conservation measures for the Caspian Tern *Hydroprogne caspia* at the largest colony in Sweden

Bevarande av skräntärnan Hydroprogne caspia *vid Sveriges största koloni*

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WE PRESENT CONSERVATION ACTIONS during 2007–2020 as part of the national Caspian Tern *Hydroprogne caspia* species action plan at Stenarna in the Björn archipelago, Uppland, the largest colony in Sweden. We applied a combination of monitoring, research, and management measures conducted within an adaptive approach framework, using both established and novel techniques. The implementation of conservation measures led to increased breeding success, from 0 fledglings per pair in 2007 to 1.3 in 2020. A surveillance video camera installed in 2009 aided in monitoring efforts and also revealed predation by Herring Gull *Larus argentatus* and White-tailed Eagle *Haliaeetus albicilla*, leading to species-specific control strategies. Management of the island and surrounding archipelago, including hunting of invasive American mink *Mustela vison*, vegetation removal, and habitat restoration after a severe storm, have also been instrumental to the success of the project. Implementation of projects such as this have the potential to improve conditions for continued viability of endangered species in a changing world and are likely to be useful to other conservation practitioners.

Keywords: Baltic Sea | breeding site | national action program | monitoring | predation | restoration | seabird

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Introduction

Seabirds are currently under threat, facing unprecedented pressures ranging from invasive and native predators and habitat degradation, to overfishing and increased severe weather events as a result of climate change (Croxall *et al.* 2012, Dias *et al.* 2019). Species-specific action plans can be an effective strategy to conserve vulnerable seabird populations (Croxall *et al.* 2012). In Sweden the nationally red-listed Caspian Tern *Hydroprogne caspia* (Near-threatened; NT) is one such threatened breeding seabird (SLU Artdatabanken, 2020). A national species action plan for the conservation of the Caspian Tern was implemented in 2007. The broad aim of the action plan was to increase breeding numbers of terns in Sweden, primarily via monitoring, establishment of a chick ringing program, hunting of the invasive predator North American mink *Mustela vison*, and habitat restoration (Staav 2007). As part of this national action plan, a conservation project at the largest breeding colony was also started in 2007. The project employed an adaptive management approach, whereby monitoring, research, and management are combined to achieve conservation goals (Salafsky *et al.* 2002). A combination of conservation action techniques, established as well as novel, were therefore used (Salafsky *et al.* 2008, Conservation Measures Partnership 2016).

This study presents the techniques used and their outcomes as applied to the largest Caspian Tern breeding colony in Sweden during 2007–2020. We show that Caspian Tern breeding success has increased as a result of employed measures and detail the identification of previously unknown problematic native species as well as the strategies used to lower their predation pressure. Finally, we discuss future challenges associated with the terns' particular breeding habitat requirements and climate change.

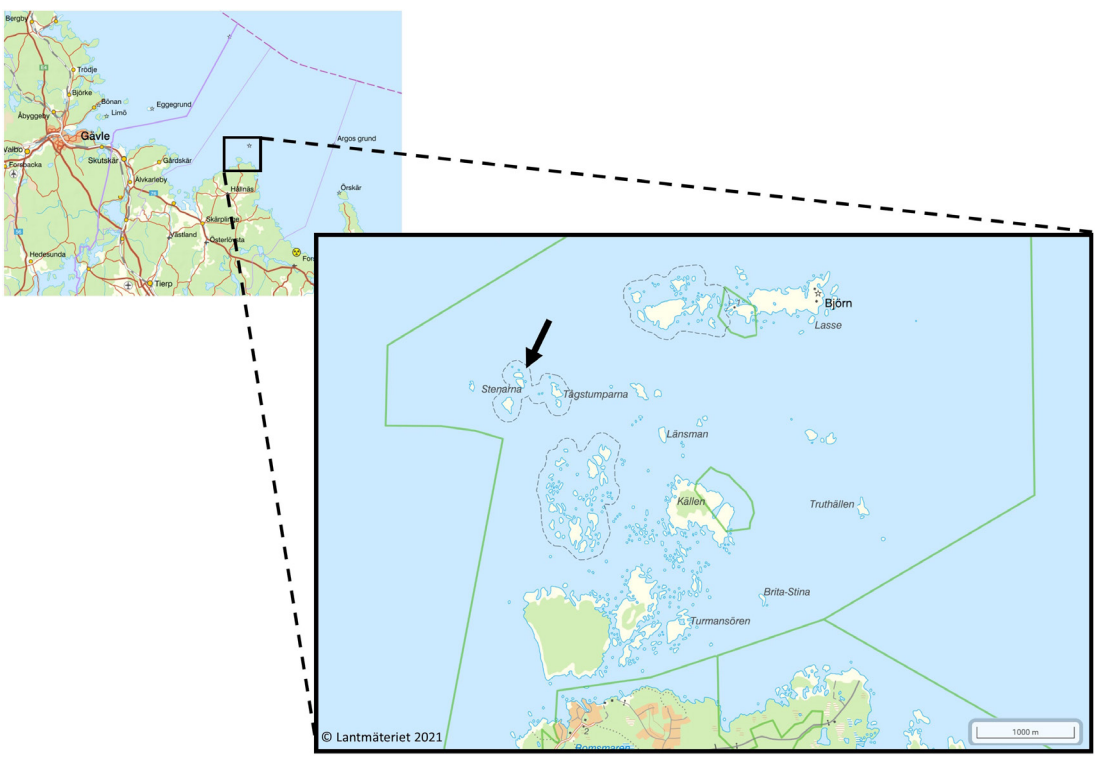

FIGURE 1. Map of the Björn archipelago, with the Caspian Tern *Hydroprogne caspia* colony at Stenarna (60°37'57.36"N, 17°55'43.57"E) marked with an arrow.
— Karta över Björns skärgård med skräntärnekolonin Hydroprogne caspia *på Stenarna (60°37'57.36"N, 17°55'43.57"E) markerad med en svart pil.*

FIGURE 2. The surveillance camera at Stenarna as of 2013. This camera can rotate and zoom in on details thanks to the remote-control function, making it possible to read a large number of color rings as well as some metal rings on birds in the colony. Photo: Ulrik Lötberg.
— Den uppgraderade webbkameran på Stenarna. Med denna kan vi rotera kameran och zooma in på detaljer hos tärnorna, t.ex. ringar. Med kameran har många färgringar lästs av men även ett antal metallringar. Foto: Ulrik Lötberg.

Material and methods

STUDY SPECIES AND SITE

While the Caspian Tern breeds on all continents except South America and Antarctica, there are only three European populations of approximately 4,500 breeding pairs along the coasts of the Caspian, Black, and Baltic Seas (Svensson *et al.* 1999, BirdLife International 2021). The Baltic Sea population is isolated from the other European populations and currently comprises c. 1,700 breeding pairs, a decline from the peak of 2,500 pairs in 1971 (Staav 1979, Hario *et al.* 1987, Svensson *et al.* 1999). The Swedish sub-population has also declined since 1971, from c. 900 to just over 600 pairs in the early 2000s, resulting in its current national red-list status of near-threatened (Staav *et al.* 1972, Staav 2005, SLU Artdatabanken 2020).

The largest and oldest known colony of Caspian Terns in Sweden is on the island of Northern Stenarna (60°37'57.36"N, 17°55'43.57"E, hereafter referred to as Stenarna) in the Björn archipelago in northern Uppland (Figure 1; Staav 1979). The colony, 190 breeding pairs as of 2020, accounts for c. 12% of the Baltic Sea breeding population of Caspian Terns (Lötberg *et al.* 2020). Stenarna is made up of narrowly connected islets, as well as several surrounding small holms. Most of the island consists of smooth, low boulders, with a gravel bank at its southernmost tip. The vegetation is sparse, consisting mainly of grasses and herbaceous plants with the occasional shrub growing in the cracks between boulders and along the borders of the gravel bank. There is a colony of Black-headed Gulls *Chroicocephalus ridibundus* (ca. 700 breeding pairs in 2020) that breed among the boulders and vegetation, while the Caspian Terns breed exclusively on the gravel bank (Lötberg *et al.* 2020). Stenarna is an Important Bird Area (IBA) and the Björn archipelago within which it is located is both a Natura 2000 area and a nature reserve (Staav 2007, Länsstyrelsen Uppsala Län 2018).

MONITORING AND RESEARCH

From 2007 to 2020, breeding population monitoring

took place annually through four colony censuses during the breeding season, designed to capture information from the egg-laying, incubation, chick-rearing and fledging periods (Burger and Lawrence 2000, Morris *et al.* 2003). The first census, performed in May, was a boat-based visual estimate of the number of individuals present at the colony. In June, one to two direct ground counts took place where Apparently Occupied Nests as defined in Morris *et al.* (2010) and any eggs or chicks therein were tallied, and chicks with sufficiently developed tarsi were ringed. The final census in July recorded breeding success through counting the number of fledged young at the colony (Hutchinson 1980, Morris *et al.* 2003). During all ground counts, the causes of nest failure were determined where possible, any evidence of predation was recorded (e.g. broken eggs, bitten chicks), and the presence of mink was assessed (e.g. through observation of scats).

To help with monitoring efforts, a surveillance video camera was installed at the colony in 2009. The first camera set-up, used during 2009–2013, consisted of a stationary Mobotix M12D-IT camera mounted on a c. 1.8 m high stainless-steel pole on a base with car batteries and antenna with accompanying modem, router, charging regulator, and cables, stored inside waterproof housing (Peli Stormcase IM2450, https://peliproducts.co.uk/im2450-storm-case). In 2013 the camera was changed to a Pelco Spectra Professional PTZ dome camera (Figure 2) with the following specifications: HD 1080p, 2.1 megapixel max resolution, 30 frames per second, 20× optical zoom, 0.3 lux, and 360 degrees continuous pan capabilities (details: https://www.pelco.com/products/cameras/ptz-cameras/spectra-enhanced/). The batteries were also replaced with two 120W solar panels and a solar cell battery. The video footage from the camera was stored on local hard drives, accessible both in real time and retroactively via the software 'Milestone' (https://www.milestonesys.com/).

CONSERVATION MEASURES

During the 1980s the American mink, an invasive species introduced in Sweden via escaped animals from commercial mink farms, migrated into the Björn archipelago and the number of nesting birds dropped drastically (Andersson 1992, Amcoff 2001). From 1997 onwards, including during the study period 2007–2020, mink were hunted in the archipelago and in surrounding areas along the eastern Hållnäs coast and in the Gräsö archipelago. This was carried out by licensed hunters using dogs, leaf blowers, and mink traps be-

FIGURE 3. The restoration of the gravel bank at Stenarna, 19 December 2007, showing the helicopter approaching Stenarna with a barrel loaded with pebble gravel (left) and distribution of the gravel by hand at the colony (right). Photo: Niina Salmén.
— Restaurering av grusbanken vid Stenarna 19 december 2007. Helikoptern på väg in över Stenarna med tunnan fylld av grus (vänster). Ulrik Lötberg och Per Nordkvist styr lasten till rätt plats och tömmer tunnan med grus (höger). Foto: Niina Salmén.

FIGURE 4. The restoration of the gravel bank at Stenarna, 19 December 2007, showing the helicopter approaching Stenarna with a barrel loaded with pebble gravel (left) and distribution of the gravel by hand at the colony (right). Photo: Niina Salmén.
— Restaurering av grusbanken vid Stenarna 19 december 2007. Helikoptern på väg in över Stenarna med tunnan fylld av grus (vänster). Ulrik Lötberg och Per Nordkvist styr lasten till rätt plats och tömmer tunnan med grus (höger). Foto: Niina Salmén.

fore and after the breeding season in early spring and autumn, respectively (Roos & Amcoff 2010).

In January 2007 the colony was hit by an extreme weather event, the storm 'Per', during which the gravel bank was washed out to sea. Consequently, while the terns did attempt to nest in the following breeding season, no chicks fledged that year. Restoration of the gravel bank was therefore carried out on 18–19 December 2007. During two days, approximately 150 tons of pebble gravel was transported to the island by helicopter and distributed by hand to mimic how the area previously looked (Figure 3). Every year since, just after the breeding season in the autumn, a visit was made to the island to remove excess vegetation in and around the gravel bank.

The surveillance camera installed in 2009 revealed that invasive mink was not the only predator of Caspian Tern eggs and chicks at this colony; native Herring Gull *Larus argentatus* and White-tailed Eagle *Haliaeetus albicilla* were also predating the terns. In the Herring Gull case, two pairs were nesting near the terns, and therefore eggs from these nests were removed during the breeding seasons of 2011–2015 until the pairs relocated to a neighbouring island. To counteract the White-tailed Eagles, an "eagle scarecrow" was deployed at Stenarna in May 2019. The scarecrow consisted of a wooden cross dressed in clothes and mounted in a boat, to mimic a human fisher (Figure 4). The boat was anchored just off the south-eastern shore of Stenarna and only moored in the bow, allowing it to move with the wind and waves for greater realism.

Results

MONITORING

The number of breeding pairs varied between 40 and 225 and the number of fledged young per pair from 0 to 1.3 during 2007–2020 (Figure 5).

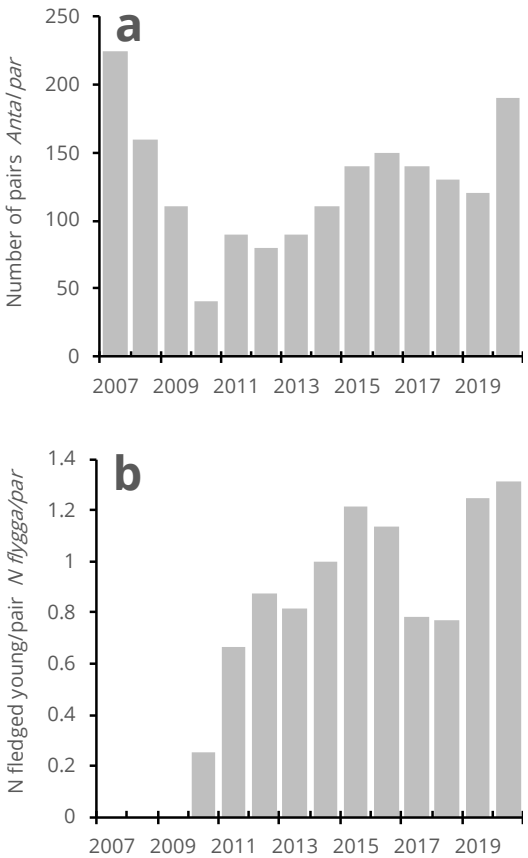

FIGURE 5. Breeding of Caspian Terns *Hydroprogne caspia* at Stenarna 2007–2020: (**a**) Numbers of breeding pairs and (**b**) numbers of fledged young per pair.
*— Antalet (**a**) häckande par skräntärnor* Hydroprogne caspia *på Stenarna under perioden 2007–2020 och (**b**) antalet flygga ungar per par under samma period.*

CONSERVATION MEASURES

The number of minks killed by hunters during early spring and autumn in Björns archipelago varied between 0 and 23 per year (Figure 6).

The restoration of the gravel bank in 2007 led to the entire colony reassembling in 2008 and attempting to breed during the following breeding seasons, as confirmed by the surveillance camera in 2009 (Figure 7).

As alluded to in the Material and Methods section, the surveillance camera revealed that predation by Herring Gulls and White-tailed Eagles was a major factor behind the low breeding success in 2008–2009. Predation by the two species together contributed to an 82% decline of breeding pairs between 2007 and 2010 and the result that no chicks fledged in 2008–2009 (Figure 5). In particular, two Herring Gull pairs were found to feed on Caspian Tern chicks, and a pair of adult White-tailed Eagles were found to predate on Caspian Tern eggs and chicks, as well as on Black-headed Gulls (Figure 8). The camera footage revelaed that the two pairs of Herring Gulls were nesting adjacent to the tern colony at Stenarna. The removal of gull eggs from the nests of the two pairs resulted in the pairs relocating to a neighbouring island south of Stenarna and ceasing predation on the terns in the following seasons.

In 2009, 2013, 2016, 2017, and 2018 eagles visited the colony on an almost daily basis between late May and early June (c. 21 May to 11 June). While not every visit resulted in predation, it became clear that the effect of eagle presence in the colony in the early stages of breeding had a greater effect than just nest predation (Figure 9). The eagles scared away terms that had not yet laid eggs, but were in the process of establishing themselves in the colony. When the eagles visited the colony early in the season the number of terns often decreased by 50–100 individuals, sometimes more. During most of June and the beginning of July, there were hardly any White-tailed Eagles visiting the colony. From mid-July onwards they often returned to the colony and hunted

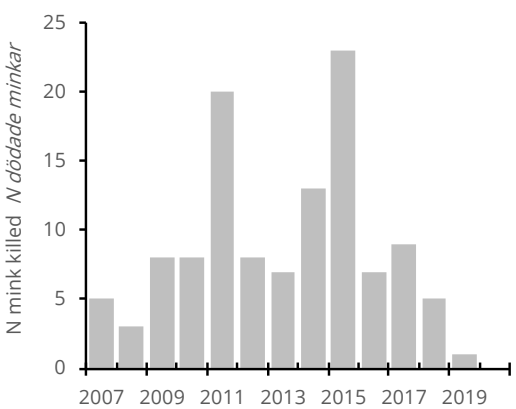

FIGURE 6. Numbers of American minks *Mustela vison* killed by hunters in the Björn archipelago 2007–2020 as part of the measures taken by the County Administrative Board to control mink predation of seabird eggs and chicks.
— Avskjutning av mink Mustela vison *i Björns skärgård 2007–2020. Jakten har utförts av Upplandsstiftelsen och är en del av de åtgärder som Länsstyrelsen beslutat om inom ramen för åtgärdsprogrammet för skräntärna* Hydroprogne caspia.

FIGURE 7. Photo taken by the surveillance camera in 2009, 1.5 years after the gravel bank restoration, showing acceptance by the Caspian Terns *Hydroprogne caspia*.
— Den restaurerade grusbanken accepterades av skräntärnorna Hydroprogne caspia*, här på en bild tagen med webbkamera under häcknings-säsongen 2009.*

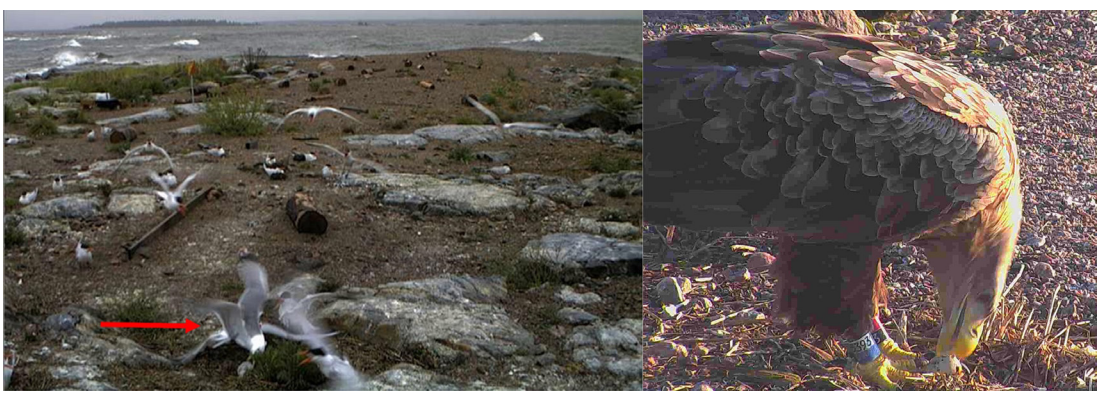

FIGURE 8. Left: A Herring Gull *Larus argentatus* (indicated by red arrow) in June 2009 kills a Caspian Tern *Hydroprogne caspia* chick during parental change-over during chick guarding at Stenarna (bottom of the picture); the gull attack is over in a few seconds. Right: An adult White-tailed Eagle *Haliaeetus albicilla* eats a Caspian Tern egg at the colony on 29 April 2016.
— Vänster: En gråtrut Larus argentatus *tar en skräntärneunge* Hydroprogne caspia *när föräldrarna växlar vem som ruvar/värmer ungarna i juni 2019 (i nederkanten på bilden, markerat med en röd pil); attacken är över på några få sekunder. Höger: En gammal havsörn* Haliaeetus albicilla *som äter skräntärneägg 29 april 2016.*

large Caspian Tern chicks. Since many chicks fledge during this time, they often got away by leaving the colony with their parents. However, the terns that had re-laid their clutch later in the season were less successful at producing fledged young.

Upon the launch of the eagle scarecrow (Figure 4) in mid-May 2019, after a period of extensive predation from the eagles, the number of eagle visits decreased (Figure 9). No White-tailed Eagles visited the colony at Stenarna until the second half of July, at which time only a few nests were left with small chicks and eggs. In previous years, visits continued into early June, which was also when most predation occurred. In 2020, the eagle scarecrow was deployed again after a White-tailed Eagle visited the colony on one occasion in early May. On this occasion the eagle was mostly in the Black-headed Gull part of the colony, so only two Caspian Tern nests were predated (Figure 9). The eagles did not visit the breeding colony again for the rest of May and June, only returning in mid-July. The majority of the 220 Caspian Tern pairs bred successfully in 2020 (Figure 5b).

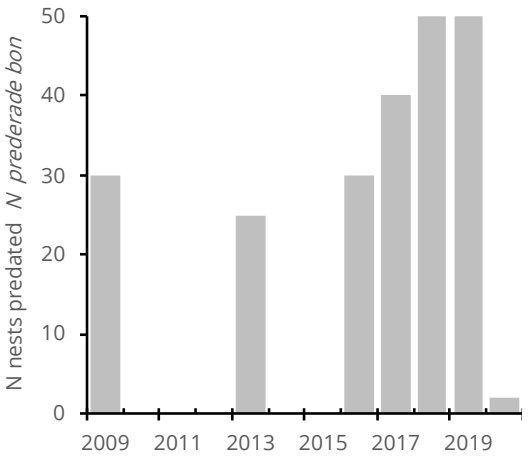

FIGURE 9. Numbers of Caspian Tern *Hydroprogne caspia* nests (all containing eggs) predated by White-tailed Eagles *Haliaeetus albicilla* at Stenarna in May and June 2009–2020.
— *Skräntärnebon* Hydroprogne caspia *prederade av havsörn* Haliaeetus albicilla *på Stenarna under maj och juni 2009–2020.*

Discussion

Seabirds are under threat globally and therefore a range of conservation actions are necessary to ensure viability of particularly threatened populations (Dias *et al.* 2019). Adaptive management advocates the use of a variety of techniques and tools at a range of scales to reach conservation targets (Salafsky *et al.* 2002). In this study we therefore document the use of an adaptive management strategy to protect the largest colony of Caspian Terns in Sweden. Until now the project has been a success, with around 250 chicks fledging in 2020, likely one of the highest numbers ever in a Caspian Tern colony in the Baltic Sea. Below, we discuss in more detail the results and experiences from the project, as well as the challenges and opportunities for the continued conservation of Caspian Terns at this colony, within Sweden, and in the Baltic Sea.

Predation from invasive alien species has been identified as one of the top threats to seabirds worldwide (Dias *et al.* 2019). Following the commencement of mink hunting in the archipelago in 1997, the number of minks has decreased and numbers of nesting birds have recovered (Roos & Amcoff 2010). The establishment of Eurasian otter *Lutra lutra* in the region has likely been a contributing factor, as they are putative competitors of mink (Bonesi & Macdonald 2004). As of 2020 no minks have been shot in the area (Figure 6). However, as the surveillance camera revealed, native predators can also be problematic (Dias *et al.* 2019). In the present case, disturbance and predation by Herring Gull and White-tailed Eagle contributed to the decline in tern pairs between 2007 and 2010 and to the lack of fledglings in 2008–2009 (Figure 5). While in the 20th century, gulls in northern Europe were seen as competitors and predators of other, rarer, coastal seabird species, and therefore controlled by mass egg removal and poisoning, this has been shown to neither be an effective nor appropriate conservation strategy (Herrmann 2009). Instead of widespread Herring Gull control due to the actions of one or two specialized individuals, we attained special dispensation to remove the eggs of the pairs responsible (non-lethal control, reviewed in Scopel & Diamond (2017)). The pairs eventually relocated to a neighboring island to breed. We presume that the gulls began to specialize on tern eggs and chicks due to their proximity to the colony, and that the targeted removal of these gull eggs also may have prevented other pairs from nesting so close to the terns in subsequent years. Specialist predation on Caspian Tern eggs and chicks has previously been

observed in Western *Larus occidentalis* and hybrid Glaucous-winged/Western Gulls *L. glaucescens* × *occidentalis* at the largest North American Caspian Tern colony at East Sand Island, Oregon, United States (Collar *et al.* 2017).

In the case of the White-tailed Eagles, it was necessary to "think outside the box" in terms of non-lethal control, as the species is of high conservation priority in Sweden (Sveriges Riksdag, 2007, SLU Artdatabanken 2020). Egg removal was therefore not an option. The preliminary solution was to build and deploy a mobile eagle scarecrow set up in a small boat to mimic human presence (Figure 4), as humans act as deterrents of White-tailed Eagles at other seabird colonies (Hentati-Sundberg *et al.* 2021). While the number of nests predated by eagles declined from 2019 to 2020, coinciding with the deployment of the scarecrow (Figure 9), only time will tell whether this method works in the long term, is merely a short-term solution, or even a coincidence. Other methods that do not disturb the nesting terns but deter the eagles without harming them, possibly activated via the camera, may need to be explored in future (Wang *et al.* 2019). It is noteworthy that during most of June and early July in 2019, there were nearly no White-tailed Eagles in the colony (as determined by camera observation), which could be due to White-tailed Eagles switching prey to high numbers of moulting Common Merganser *Mergus merganser*, Common Goldeneye *Bucephala clangula*, and Greylag Geese *Anser anser* in the area (*pers. obs.*). Such prey switching during the breeding season has been hypothesized to drive Bald Eagle *Haliaeetus leucocephalus* disturbance rates of North American Caspian Tern colonies, where eagles focus on terns when their primary prey are not available (Collar *et al.* 2017). Determining what drives the White-tailed Eagles to predate the Caspian Tern colonies during these periods could be key to reducing the top–down pressure exerted on the colony.

Caspian Terns require a very specific breeding habitat and preferably nest on low, flat, rocky islands with gravel or sandy substrate (Quinn *et al.* 1996, Quinn and Sirdevan, 1998, Wires & Cuthbert 2000). In Sweden, they prefer islands that lack trees and are located some distance from the coast in the outer archipelago. The largest colonies are often located on gravel islands or on a gravel-covered portion of an island, and as Caspian Terns are site faithful as long as the colony is viable, these islands become extremely important for population viability (Väisänen 1973, Staav 1979, Cuthbert 1988). Habitat maintenance must therefore be prioritized, especially at a large and old colony such as Stenarna, to ensure the preferred breeding habitat is kept intact. This means that annual maintenance (i.e. removal) of the vegetation at the colony is required, as well as readiness and resources to restore the gravel bank (Figure 3) should another storm, such as the one in 2007, occur. As the incidence and magnitude of extreme weather events are predicted to increase as a consequence of climate change (Wires & Cuthbert 2000, IPCC 2012, IPCC 2021), it becomes increasingly important to restore historical nesting islands nearby in order to prevent reproductive failure should Stenarna be rendered unsuitable. Candidate islands for restoration in the area are Klubbarna and Västerskian (Staav 2007).

The census methods for population monitoring largely followed those described in Morris *et al.* (2003) and Burger & Lawrence (2000). While estimates of breeding pairs by boat during the first visit are in fact just estimates, the apparently occupied nest counts during later visits are exact (Figure 5a). Caspian Tern nests are easily distinguished by their size, shape, and the fish remains (i.e. bones) littered within. The potential for unmanned aerial vehicles (UAVs, also known as drones) to assist in future censuses, particularly during incubation, is being explored (Hodgson *et al.* 2016). Since Caspian Tern chicks are mobile at fledging age, it was not possible to obtain counts of fledged young per pair. Instead, these were calculated by dividing the number of fledged young counted at the last visit by the number of pairs for a colony-wide breeding success assessment. In the future, it may be possible to obtain pair-specific information by individually marking the nest sites and noting during the second and third visits which chicks belong to which nests. This procedure would also give more detailed data on re-laying rate.

While investigator disturbance due to prolonged cannon-netting has been reported as a cause of nest desertion (e.g. Cuthbert 1985), we found no evidence for nest desertion due to investigator presence at this colony. Caspian Terns are most sensitive to disturbance in the early period of the breeding season, before and during egg-laying (Bergman 1953), and therefore the

first census was conducted at c. 200 m distance by boat. During ground counts later in the season, the terns would indeed take to the air but would shortly thereafter (c. 10 minutes) begin to alight on the fringes of the colony. After investigator departure, the terns would normally return to the nests and continue incubating/brooding within 15 minutes (camera observations).

Concurrently with monitoring and management efforts presented here, chicks were ringed with both metal and color rings and a sample of adults and juveniles were outfitted with GPS loggers during the study period (Lötberg *et al.* 2020). Data from ringing and GPS tracking have already contributed to a better understanding of foraging areas, migratory routes, stop-over sites, and wintering grounds that can aid conservation efforts away from the breeding colony (Shiomi *et al.* 2015, Lötberg *et al.* 2020, Beal *et al.* 2022, Rueda-Uribe *et al.* 2021). Protection of important foraging, roost, and stop-over and wintering sites throughout the annual cycle will be important for the future viability of this population, as well as other populations in the Baltic Sea since conditions at their breeding sites are expected to fluctuate under climate change (Gill 2008, Marra *et al.* 2015, Suzuki *et al.* 2019). Ring re-sightings and GPS tracking will also be paramount to efforts to characterize connectivity with other large Baltic Sea colonies, such as those in Finland and Estonia (e.g. Astekari, Väinemeri; Byholm *et al.* 2019).

The combined use of traditional monitoring methods and novel tools has allowed this conservation project to identify and mitigate threats and stressors at the Caspian Tern colony at Stenarna. As a result of conservation actions, breeding success increased from 0 to 1.3 fledglings per pair during the study period (Figure 5b). Additionally, previously undetected problematic native predators were identified (i.e. Herring Gull and White-tailed Eagle), which will inform future conservation efforts. Importantly, this colony is located within an Important Bird Area and nature reserve, which has allowed regular habitat management, including mink hunting and nesting habitat restoration and maintenance. The designation of protected areas together with legislation protecting the species (e.g. EU Birds Directive; European Parliament 2009), is paramount to present and future conservation work, in the Baltic Sea and beyond.

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References

Amcoff M. **2001.** *Minkens inverkan på kustfågelbestånden i Uppsala läns skärgård*. Upplandsstiftelsen Stencil 22.

Andersson Å. **1992.** Sjöfågelbeståndens utveckling i Bullerö skärgård efter invanding av mink. *Ornis Svecica* 2: 107–118. https://doi.org/10.34080/os.v2.23053

Beal M, Byholm P, Lötberg U, Evans TJ, Shiomi K & Åkesson S. **2022.** Habitat selection and foraging site fidelity in Caspian Terns (*Hydroprogne caspia*) breeding in the Baltic Sea. *Ornis Fennica* 98: 128–141. https://doi.org/10.51812/of.113445

Bergman G. **1953.** Verhalten und Biologie der Raubseeschwalbe. *Acta Zoologica Fennica* 77: 1–50.

BirdLife International. **2021.** *Species factsheet:* Hydroprogne caspia. http://datazone.birdlife.org/species/factsheet/caspian-tern-hydroprogne-caspia

Bonesi L, Macdonald DW. **2004.** Impact of released Eurasian otters on a population of American mink: A test using an experimental approach. *Oikos* 106: 9–18. https://doi.org/10.1111/j.0030-1299.2004.13138.x

Burger AE & Lawrence AD. **2000.** Seabird Monitoring Techniqes. In *Status and Conservation of West Indian Seabirds* (Schreiber EA & Lee DS, eds). Society of Carribean Ornithology.

Byholm P, Below A & Piha M. **2019.** 2020: History, conservation status and new information on the winter quarters of Finnish Caspian Terns (in Finnish with English summary). *Linnut-vuosikirja* 2019: 72–77.

Collar S, Roby DD & Lyons DE. **2017.** Top-Down and Bottom-Up Interactions Influence Fledging Success at North America's Largest Colony of Caspian Terns (*Hydroprogne caspia*). *Estuaries and Coasts* 40: 1808–1818. https://doi.org/10.1007/s12237-017-0238-x

Conservation Measures Partnership, **2016.** *CMP Conservation Actions Classification v 2.0*. https://docs.google.com/spreadsheets/d/1i25G-TaEA80HwMvsTiYkdOoXRPWiVPZ5l6KioWx9g2zM/

Croxall JP, Butchart SHM, Lascelles B, Stattersfield AJ, Sullivan B, Symes A & Taylor P. **2012.** Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International* 22: 1–34. https://doi.org/10.1017/S0959270912000020

Cuthbert FJ. **1985.** Intraseasonal Movement between Colony Sites by Caspian Terns in the Great Lakes. *Wilson Bulletin* 97: 502–510. https://www.jstor.org/stable/4162144

Cuthbert FJ. **1988.** Reproductive Success and Colony-Site Tenacity in Caspian Terns. *Auk* 105: 339–344. https://doi.org/10.2307/4087499

Dias MP, Martin R, Pearmain EJ, Burfield IJ, Small C, Phillips RA, Yates O, Lascelles B, Borboroglu PG & Croxall JP. **2019.** Threats to seabirds: A global assessment. *Biological Conservation* 237: 525–537. https://doi.org/10.1016/j.biocon.2019.06.033

European Parliament. **2009.** Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version). *Official Journal of the European Union L 20* 53: 7–25. https://doi.org/10.3000/17252555.L_2010.020.eng

Gill RE. **2008.** Caspian Terns nesting in Alaska: prophecy, serendipity, and implications for regional climate-related change. *Western Birds* 39: 97–100.

Hario M, Kastepöld T, Kilpi M, Staav R & Stjernberg T. **1987.** Status of Caspian Terns *Sterna caspia* in the Baltic. *Ornis Fennica* 64: 154–157. https://lintulehti.birdlife.fi:8443/pdf/artikkelit/647/tiedosto/of_64_154-157_artikkelit_647.pdf

Hentati-Sundberg J, Berglund PA, Hejdström A & Olsson O. **2021.** COVID-19 lockdown reveals tourists as seabird guardians. *Biological Conservation* 254: 17–20. https://doi.org/10.1016/j.biocon.2021.108950

Herrmann C. **2009.** The so-called "gull problem" in Germany in the 20th century: historical development in Germany and population control on the Baltic Sea coast of the GDR. *Vogelwelt* 130: 25–47.

Hodgson JC, Baylis SM, Mott R, Herrod A & Clarke RH. **2016.** Precision wildlife monitoring using unmanned aerial vehicles. *Scientific Reports* 6: 22574. https://doi.org/10.1038/srep22574

Hutchinson AE. **1980.** Estimating numbers of colonial nesting seabirds: A comparison of techniques. *Proceedings of the Colonial Waterbird Group* 3: 235–244. https://www.jstor.org/stable/4626718

IPCC. **2012.** *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/CBO9781139177245.009

IPCC. **2021.** *Climate change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK. https://doi.org/10.1080/03736245.2010.480842

Länsstyrelsen Uppsala Län. **2018.** *Björns skärgård. Naturreservat*. https://www.lansstyrelsen.se/uppsala/besoksmal/naturreservat/bjorns-skargard.html

Lötberg U, Isaksson N & Åkesson S. **2020.** *The Caspian terns of Fågelsundet – a report on Caspian terns in Björns archipelago*. BirdLife Sweden, Mörbylånga, Sweden. https://cdn.birdlife.se/wp-content/uploads/2020/11/Report_Caspian_terns_of-Fagelsundet.pdf

Marra PP, Cohen EB, Loss SR, Rutter JE & Tonra CM. **2015.** A call for full annual cycle research in animal ecology. *Biology Letters* 11: 20150552. https://doi.org/10.1098/rsbl.2015.0552

Morris RD, Weseloh DV, Cuthbert FJ, Pekarik C, Wires LR & Harper L. **2010.** Distribution and abundance of nesting common and Caspian terns on the North American Great Lakes, 1976 to 1999. *Journal of Great Lakes Research* 36: 44–56. https://doi.org/10.1016/j.jglr.2009.09.008

Morris RD, Weseloh DV & Shutt JL. **2003.** Distribution and Abundance of Nesting Pairs of Herring Gulls (*Larus argentatus*) on the North American Great Lakes, 1976 to 2000. *Journal of Great Lakes Research* 29: 400–426. https://doi.org/10.1016/S0380-1330(03)70447-X

Naturhistoriska Riksmuseet. **2021.** *Ringmärkningscentralen*. https://www.nrm.se/forskningochsamlingar/miljoforskningochovervakning/ringmarkningscentralen.214.html (accessed 15 February 2021)

Quinn JS, Morris RD, Blokpoel H, Weseloh DV & Ewins PJ. **1996.** Design and management of bird nesting habitat: Tactics for conserving colonial waterbird biodiversity on artificial islands in Hamilton Harbour, Ontario. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 45–57. https://doi.org/10.1139/cjfas-53-s1-45

Quinn JS & Sirdevan J. **1998.** Experimental measurement of nesting substrate preference in Caspian terns, *Sterna caspia*, and the successful colonisation of human constructed islands. *Biological Conservation* 85: 63–68. https://doi.org/10.1016/S0006-3207(97)00142-0

Roos S & Amcoff M. **2010.** *Fågelfaunans utveckling i Uppsala läns skärgård efter införandet av jakt på mink*. Länsstyrelsens Meddelandeserie 2010: 04. Naturmiljöenheten, Länsstyrelsen Uppsala län. http://www.upplandsstiftelsen.se/UserFiles/Archive/622/LstC4_2010Minkens_paverkan.pdf

Rueda-Uribe C, Lötberg U, Ericsson M, Tesson SVM & Åkesson S. **2021.** First tracking of declining Caspian terns *Hydroprogne caspia* breeding in the Baltic Sea reveals high migratory dispersion and disjunct annual ranges as obstacles to effective conservation. *Journal of Avian Biology* 52: e02743. https://doi.org/10.1111/jav.02743

Salafsky N, Margoluis R, Redford KH & Robinson JG. **2002.** Improving the practice of conservation: A conceptual framework and research agenda for conservation science. *Conservation Biology* 16: 1469–1479. https://doi.org/10.1046/j.1523-1739.2002.01232.x

Salafsky N, Salzer D, Stattersfield AJ, Hilton-Taylor C, Neugarten R, Butchart SHM, Collen B, Cox N, Master LL, O'Connor S & Wilkie D. **2008.** A standard lexicon for biodiversity conservation: Unified classifications of threats and actions. *Conservation Biology* 22: 897–911. https://doi.org/10.1111/j.1523-1739.2008.00937.x

Scopel LC & Diamond AW. **2017.** The case for lethal control of gulls on seabird colonies. *Journal of Wildlife Management* 81: 572–580. https://doi.org/10.1002/jwmg.21233

Shiomi K, Lötberg U & Åkesson S. **2015.** Seasonal distributions of Caspian Terns *Hydroprogne caspia* from Swedish populations, revealed by recoveries and resightings of ringed birds. *Ringing & Migration* 30: 22–36. https://doi.org/10.1080/03078698.2015.1059637

SLU Artdatabanken. **2020.** *Artfakta. Skräntärna* Hydroprogne caspia. https://artfakta.se/naturvard/taxon/hydroprogne-caspia-100134 (accessed 13 February 2021)

Staav R, Almkvist B & Hedgren S. **1972.** Skräntärnan *Hydroprogne tschegrava* i Sverige 1971. *Vår Fågelvärld* 31: 241–246.

Staav R. **1979.** Dispersal of Caspian Terns Sterna caspia in the Baltic. *Ornis Fennica* 56: 13–17. https://lintulehti.birdlife.fi:8443/pdf/artikkelit/896/tiedosto/of_56_13-17_artikkelit_896.pdf

Staav R. **2005.** Skräntärnan i Sverige: Status och Reproduktion 2001–2004. *Vår Fågelvärld* 44: 34–41.

Staav R. **2007.** *Åtgärdsprogram för skräntärna 2007–2011.* Naturvårdsverket, rapport 5702. https://www.naturvardsverket.se/globalassets/media/publikationer-pdf/5700/978-91-620-5702-2.pdf

Suzuki Y, Bishop MA, Roby DD & Bixler KS. **2019.** Colony Connectivity and the Rapid Growth of a Caspian Tern (*Hydroprogne caspia*) Colony on Alaska's Copper River Delta, USA. *Waterbirds* 42: 1–7. https://doi.org/10.1675/063.042.0101

Svensson S, Svensson M & Tjernberg M. **1999.** *Svensk Fågelatlas.* Vår Fågelvärld, Supplement 31. Sveriges Ornitologiska Förening, Halmstad.

Sveriges Riksdag. **2007.** *Artskyddsförordning (2007:845).* https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/artskyddsforordning-2007845_sfs-2007-845

Väisänen RA. **1973.** Establishment of Colonies of Caspian Tern *Hydroprogne caspia* by Deserting Flights in the Northern Gulf of Bothnia. *Ornis Scandinavica* 4: 47–53. https://doi.org/10.2307/3676289

Wang Z, Griffin AS, Lucas A & Wong KC. **2019.** Psychological warfare in vineyard: Using drones and bird psychology to control bird damage to wine grapes. *Crop Protection* 120: 163–170. https://doi.org/10.1016/j.cropro.2019.02.025

Wires LR & Cuthbert FJ. **2000.** Trends in Caspian Tern Numbers and Distribution in North America: A Review. *Waterbirds* 23: 388–404. https://doi.org/10.2307/1522176

Svensk sammanfattning

Vi presenterar skyddsåtgärder som vidtagits som en del av åtgärdsprogrammet ”Projekt Skräntärna” under perioden 2007–2020 i Sveriges största koloni, Stenarna i Björns skärgård, Uppland. En kombination av övervakning, forskning och förvaltningsåtgärder genomfördes enligt en flexibel strategi, där både etablerade och nya tekniker användes. Varje år under häckningssäsongen gjordes fyra besök för att räkna häckande par, bon, ungar och flygga ungar, samt kontrollera predation.

En övervakningskamera som installerades under 2009 har möjliggjort avläsning av både färg- och metallringar, dessutom har den påvisat predation av både gråtrut *Larus argentatus* och havsörn *Haliaeetus albicilla* på framför allt ägg och ungar. Gråtrutspredation hanterades effektivt genom att ta bort ägg från de par som hade bon precis intill skräntärnekolonin. En ”havsörnsskrämma” som placerades ut första gången 2019 har reducerat havsörnsbesöken men det återstår att se om detta är en effektiv lösning på lång sikt. Varje år innan och efter häckningssäsongen har dessutom minkjakt utförts i området och vegetation har röjts ifrån häckningsplatsen, en grusbank på södra delen av ön.

När stormen ”Per” i januari 2007 spolade bort större delen av grusbanken, och inga ungar blev flygga, restaurerades grusbanken efter häckningssäsongen samma år. Under projektets gång har häckningsframgången ökat från noll till 1,3 flygga ungar per par, med omkring 250 flygga ungar under 2020.

Identifiering av tidigare okända problematiska inhemska predatorer med hjälp av övervakningskameran samt restaurering och förvaltning av häckningsplatsen (grusbanken) har visats sig vara oumbärliga för projektets framgång. Resultat av åtgärderna visar att denna typ av projekt kan förbättra förhållandena för hotade arter och bidra till deras fortsatta existens i en föränderlig värld.

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