Drone Survey Reveals a Severe Chinstrap Penguin Decline and a Novel Gentoo Colony in an Antarctic Specially Protected Area

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Abstract. We provide an updated population assessment for chinstrap penguins (*Pygoscelis antarcticus*), gentoo penguin (*P. papua*) and Antarctic shags *(Leucocarbo bransfieldensis*), in the Antarctic Specially Protected Area 133 on Nelson Island using drone-based nest counts. Our results reveal a pronounced 57% decline in chinstrap penguins since the 1990s, stability in a local gentoo penguin population, an 84% increase in Antarctic shags, and the first population estimate for a large gentoo colony at the Toe (4,641 nests). These divergent trends align with broader regional patterns of ecosystem change in the Antarctic Peninsula region. This study provides critical baseline data for monitoring the impacts of ongoing environmental change on these sensitive indicator species.

Keywords. breeding colony, drone-based aerial imagery, *Pygoscelis*, Shags

Statements and Declarations

Competing Interests. Authors declare no conflict of interests.

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Data Availability Statement. Data is available in repository (Krüger, *et al.* 2025).

Introduction

The Maritime Antarctic Peninsula has experienced some of the most rapid warming in recent decades, leading to significant changes in sea ice dynamics, prey availability, and habitat conditions that affect seabird species. Among these, the Antarctic shag (*Leucocarbo bransfieldensis*), chinstrap penguin (*Pygoscelis antarcticus*), and gentoo penguin (*Pygoscelis papua*) occupy significant ecological niches (Lynch *et al.* 2012). Gentoo penguins have demonstrated a capacity for range expansion and population growth, with increasing abundances and a southward distribution shift (Clucas *et al.* 2014, Herman *et al.* 2020). In contrast, chinstrap penguins have shown population declines across multiple regions, potentially linked to changes in krill availability and sea ice conditions (Trivelpiece *et al.* 2011, Strycker *et al.* 2020).

The Antarctic Specially Protected Area (ASPA) No. 133 on Nelson Island, South Shetland Islands, comprises two summer ice-free areas: Harmony Point and the Toe (Fig 1a-c). Harmony Point is an important breeding site for seabird species, especially chinstrap penguins (Silva *et al.* 1998). Although historical population data are available for some species, there are gaps in consistent monitoring (Casaux & Barrera-Oro 2016, Oosthuizen *et al.* 2020), particularly for penguins; the last available data for this site date back to the mid-1990s (Silva *et al.* 1998). Recent advancements in drone technology and photogrammetric techniques have created new opportunities for more accurate and comprehensive seabird monitoring in remote and inaccessible locations (Borowicz *et al.* 2018).

This study aims to provide an updated population assessment of Antarctic shags, chinstrap penguins, and gentoo penguins in ASPA 133, a protected area without direct anthropogenic pressure, using drone-based imagery and photogrammetric analysis. By comparing current population estimates with historical data, we seek to contribute to the understanding of long-term population dynamics of these key indicator species in the rapidly changing Antarctic ecosystem.

Methods

Aerial imagery was collected using a DJI Mavic 3 unmanned aerial vehicle (UAV) equipped with a high-resolution camera at Harmony Point (Fig 1a,b,c). A total of 14 flights were conducted during the peak of the penguin incubation period in December 2024, at an altitude of 100 m above ground level and a speed of 5 m/s, ensuring uniform image resolution while minimizing disturbance to breeding birds (Ratcliffe *et al.* 2015). Flights were conducted only under favorable weather conditions. Multiple images were captured with 50% to 70% overlap, totalling 5,932 images. The collected drone imagery was processed using Agisoft Metashape Professional software to generate high-resolution orthomosaic images. Flight operations adhered to guidelines established by the Scientific Committee on Antarctic Research (SCAR) and complied with all permit requirements for drone use in ASPAs.

Nest counts were conducted manually by placing a point on each identified nest structure within the orthomosaic images. The positions of Gentoo penguin breeding groups at Harmony Point were marked on-site using a handheld GPS (Garmin Montana I7) to aid in species identification within the orthomosaic images. We did not have access to the Toe site, so the drone was launched from Harmony Point (≈ 3km). Although it is possible to distinguish

between the two penguin species based on nest density, additional imagery was captured at an 80 m altitude to confirm species identification. For Antarctic shags, a nest was defined as a bird and its corresponding anatomical structure. For penguin species, a nest was considered occupied if a bird was observed in an incubation posture within the boundary of a guano stain. The topography of Harmony Point was estimated from previous drone flights (Santa Cruz & Krüger 2023).

Current population estimates were compared with historical data from previous studies at Harmony Point. For Antarctic shags, Casaux & Barrera-Oro (2016) and Oosthuizen *et al.* (2020) provide information on population estimates, while for chinstrap and gentoo penguins Silva et al. (1998). A review of all available data in the late 1970s is available (Croxall & Kirkwood 1979), however, the data from these early assessments were primarily rough estimates (or 'guesstimates'), with an assumed accuracy between 25% to 50%. In contrast, drone-based estimations, such as those in this study, are assumed to have errors between 5% to 10% (Humphries et al. 2017).

Results

Chinstrap penguins occupied most of the ice-free areas along the shoreline and rocky outcrops (Fig 1d,e). A total of 38,080 and 8,153 nests were recorded in the 2024 season at Harmony Point and the Toe, respectively. Chinstrap penguins occupied elevations mostly between 9.8 m and 32.9 m, on slopes of 1.8º to 5.6º inclination, and were typically found within 104 m of the coastline. This represents a 57% and 74% decrease from the 1990s and 1980s estimates respectively, for Harmony Point (Fig 2a). For the Toe colony, it represents a 45% decrease from the 1970s, but the error around that estimation is too high to have a good confidence in this percentage (Fig 2b).

Gentoo penguins nests were estimated at 3,659 and 4,641 in the 2024 austral summer season at Harmony Point and the Toe, respectively (Fig 1d,e). Most nests were located at elevations between 10.3 m and 36.0 m, on smooth slopes with inclinations of 1.0º to 5.4º, and at distances of 67.3 m to 151.7 m inland. Previous assessments indicate that the Harmony Point colony has fluctuated between 3,000 and 4,000 pairs since the late 1980s, with one earlier estimate of 1,642 pairs in 1966 (Fig 2c), representing an 122% increase since the 1960s.

A total of 127 Antarctic shag nests were recorded at Harmony Point (Table 1, Fig 1f). This represents an 84% increase compared to the previous assessment in the 2018/19 breeding season but falls within the expected variability considering counts between 1980 and 2010 (Fig 2b). Compared to the penguin colonies, shags occupied lower elevations (11.2 m to 17.0 m), on relatively steeper slopes (10.4º to 18.4º), and closer to the coastline (within 15 m inland).

Discussion

Our results update the population numbers of *Pygoscelis* penguins in ASPA 133, which had not been revised since the 1990s. We highlight a 57% decrease in one of the largest chinstrap penguin colonies in the South Shetlands and report a new, large gentoo penguin colony at the Toe, with over 4,500 pairs.

The number of chinstrap penguins exhibited a clear decrease from the last available count of nearly 90,000 pairs in the mid-1990s (Silva *et al.* 1998). This 57% decrease over 30 years is consistent with regional declines (Krüger 2023, Talis *et al.* 2023). Many chinstrap colonies in the Antarctic Peninsula lack recent accurate quantification (Harris *et al.* 2015). The alignment of the Harmony Point population decline with the broader regional trend (Talis *et al.* 2023) underscores the robustness of this decrease. The number of nests in other colonies without recent data may be predicted based on these levels of decline. Such a pronounced decline is consistent with a threatened status (Krüger 2023), although the underlying causes are not fully understood. Factors potentially affecting chinstrap penguin population dynamics include the combined effects of climate change on chick survival (Salmerón *et al.* 2023), shifts in prey distribution synergistically with increasing krill fishing (Watters *et al.* 2020, Krüger *et al.* 2021), and competition with recovering whale populations (Savoca et al. 2024). We hypothesize that the cumulative effects of multiple factors are likely responsible for the observed trends. The Maritime Antarctic Peninsula holds one-third of the global chinstrap penguin population (Strycker *et al.* 2020). Even assuming the remaining two-thirds of the population is stable, the observed decline suggests a substantial global reduction.

The number of gentoo penguins at Harmony Point has increased since the 1960s but appears to have stabilized in recent decades (Croxall & Kirkwood 1979, Silva *et al.* 1998). As a species with greater dietary flexibility than other pygoscelids, gentoo penguins have demonstrated a capacity to adapt to environmental change in the region (Miller *et al.* 2009, McMahon *et al.* 2015), allowing them to maintain stable abundances while other sympatric species decline (Talis *et al.* 2023). With no previous data for the Toe colony, the present results serve as a baseline for future trend estimations.

Antarctic Shag historical data from 1964 to the present reveal substantial fluctuations in colony size over time, with the current count of 127 nests being the highest yet recorded, though within the expected range. This pattern aligns with previous research highlighting high spatial and temporal variability in Antarctic shag populations throughout the Antarctic Peninsula region (Casaux & Barrera-Oro 2006, 2016, Schrimpf *et al.* 2018).

Our results also highlight nesting habitat segregation among the species, primarily characterized by the distance inland, with Gentoo penguins occupying the most inland areas. These differences reflect not only habitat preferences but also the ability of gentoos to colonize new areas. As ice-free area increases due to rising temperatures (Lee *et al.* 2022), it is likely that expanding Gentoo colonies are colonizing these newly exposed inland habitats.

ASPAs such as Harmony Point are crucial for conserving seabird hotspots, as they provide protected refuges where direct human disturbances, such as tourism and research station infrastructure, are minimized. ASPAs help protect local ecosystems, promoting stability in species interactions within these sensitive habitats, as shown for benthic species (Moya *et al.* 2025). However, ASPAs are not a complete solution to global threats like climate change, pollution, or fisheries, which affect seabirds on regional scales and in indirect ways. Rising temperatures, sea ice reductions, and alterations in prey availability impact birds beyond the boundaries of ASPAs. Therefore, while these protected areas are a key component of conservation, they must be complemented by larger-scale measures that address the effects of climate change and its implications for Antarctic biodiversity.

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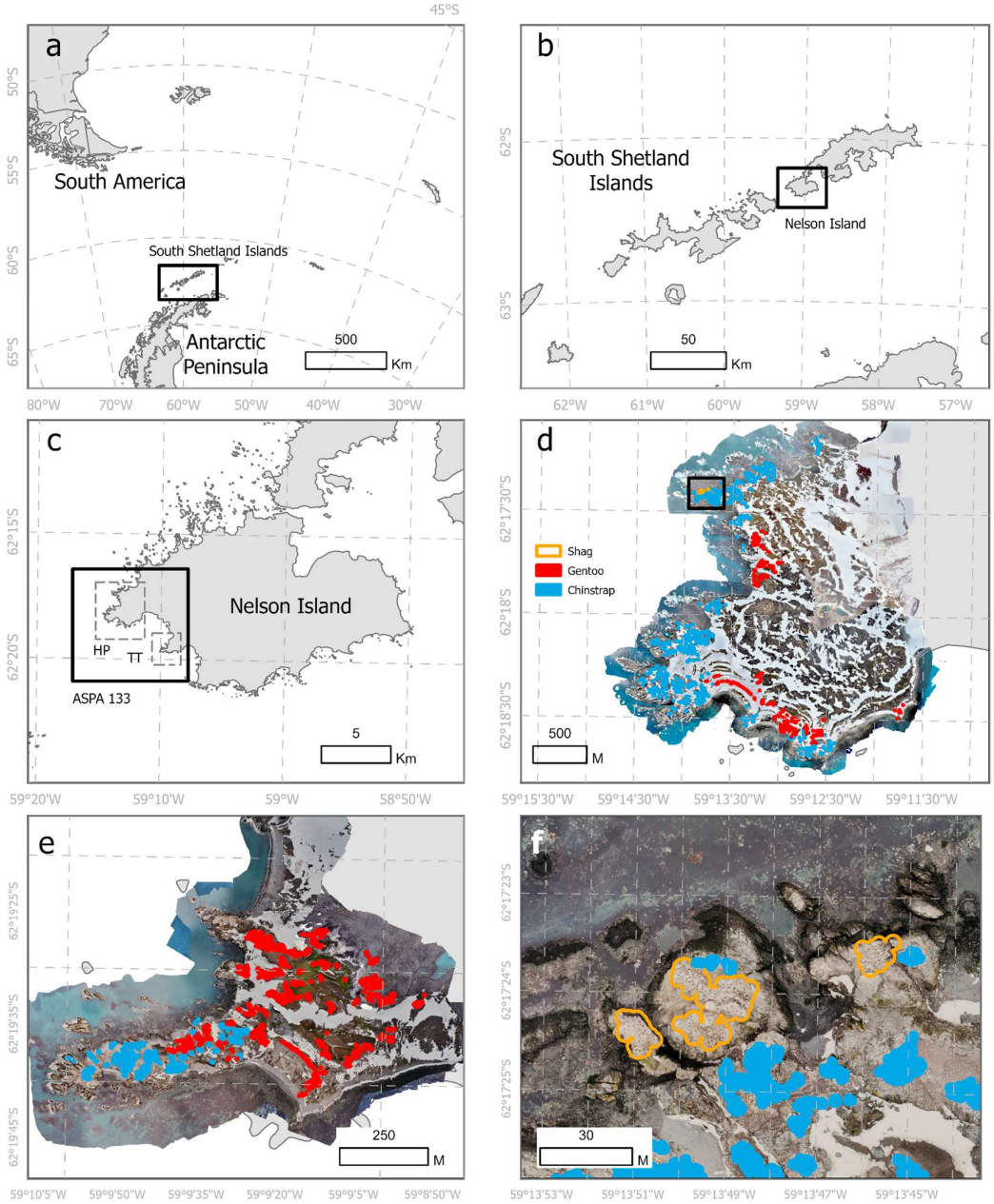


Fig 1. Location of the study area and distribution of seabird colonies. (a) Global context of the South Shetland Islands. (b) Position of Nelson Island within the Antarctic Peninsula. (c) Detail of Antarctic Specially Protected Area (ASPA) No. 133, showing the locations of Harmony Point (HP) and the Toe (TT) within the dashed squares. (d, e) Distribution of gentoo penguin (*Pygoscelis papua*) (red colour)

and chinstrap penguin (*Pygoscelis antarcticus*) (blue colour) colonies at Harmony Point (d) and the Toe (e). (f) Distribution of Antarctic shag (*Leucocarbo bransfieldensis*) colonies at Harmony Point (orange colour). All distributions are mapped on high-resolution orthomosaics derived from drone imagery.

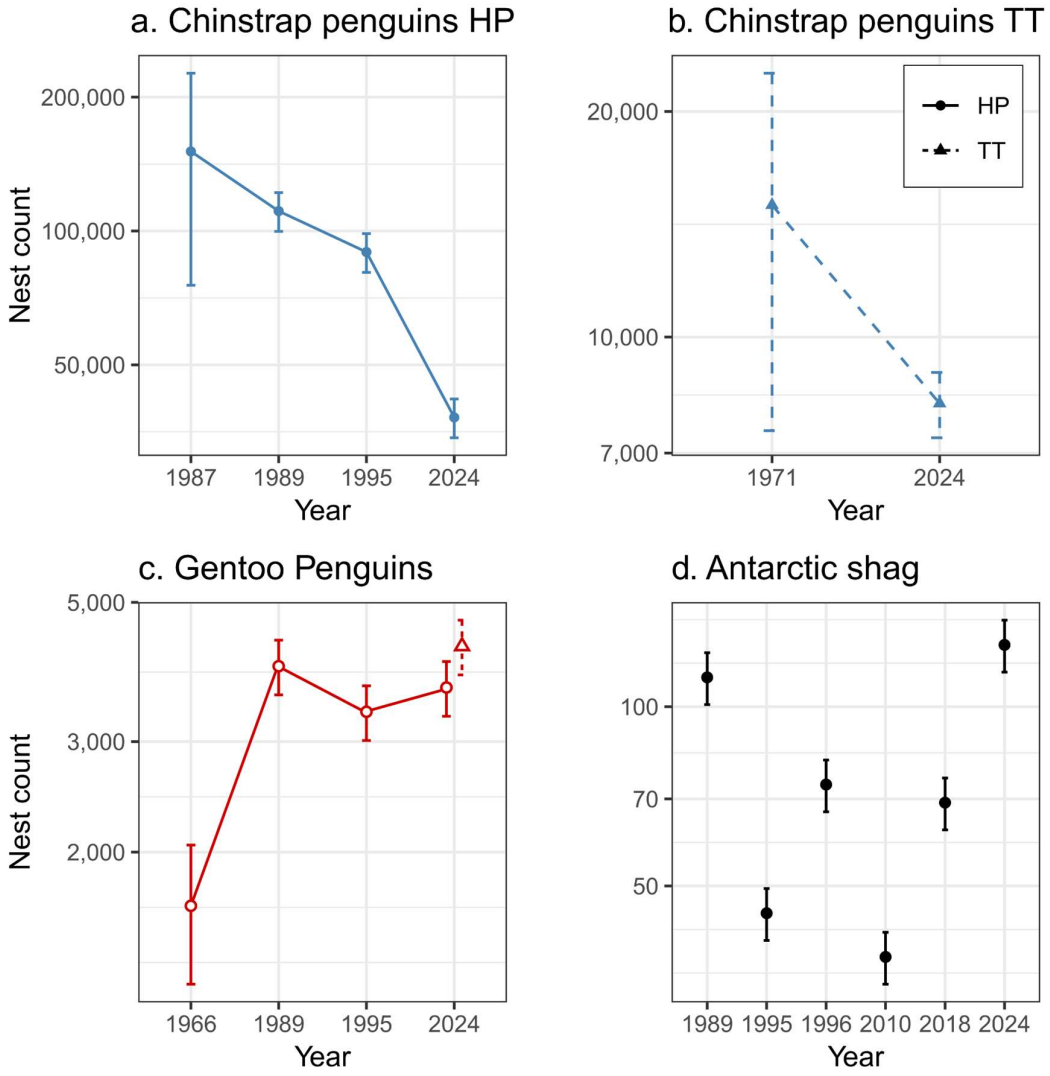
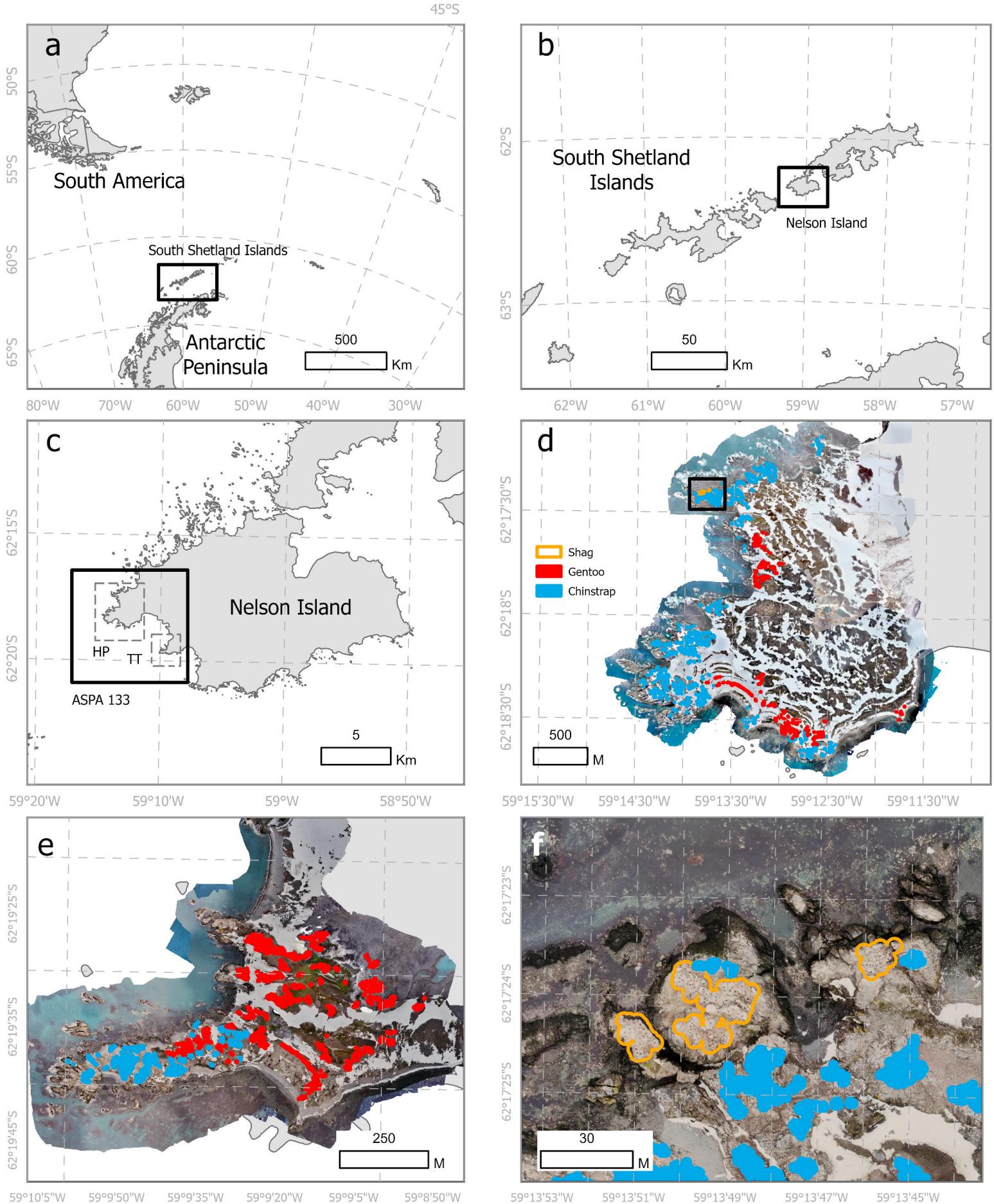


Figure 2. Colony size ± 10% or ± 50% (for penguins counts before 1985) error for chinstrap penguin (a,b), *Pygoscelis antarcticus* (blue filled shapes), gentoo penguin (c), *Pygoscelis papua* (red empty shapes), and Antarctic shag (*Leucocarbo bransfieldensis*) (d), measured as number of nests, in Harmony Point (HP, circle) and the Toe (TT, triangles), ASPA 133, Nelson Island. Year 2024 corresponds to data from this study, as previous years are from previous publications (please see methods section).


a
45°S
50°S
55°S
60°S
65°S
South America
South Shetland Islands
Antarctic Peninsula
500
Km
80°W
70°W
60°W
50°W
40°W
30°W
b
62°S
63°S
South Shetland Islands
Nelson Island
50
Km
62°W
61°W
60°W
59°W
58°W
57°W
c
62°15'S
62°20'S
Nelson Island
HP
TT
ASPA 133
5
Km
59°20'W
59°10'W
59°W
58°50'W
d
62°17'30"S
62°18'S
62°18'30"S
Shag
Gentoo
Chinstrap
500
M
59°15'30"W
59°14'30"W
59°13'30"W
59°12'30"W
59°11'30"W
e
62°19'25"S
62°19'35"S
62°19'45"S
250
M
59°10'5"W
59°9'50"W
59°9'35"W
59°9'20"W
59°9'5"W
59°8'50"W
f
62°17'23"S
62°17'24"S
62°17'25"S
30
M
59°13'53"W
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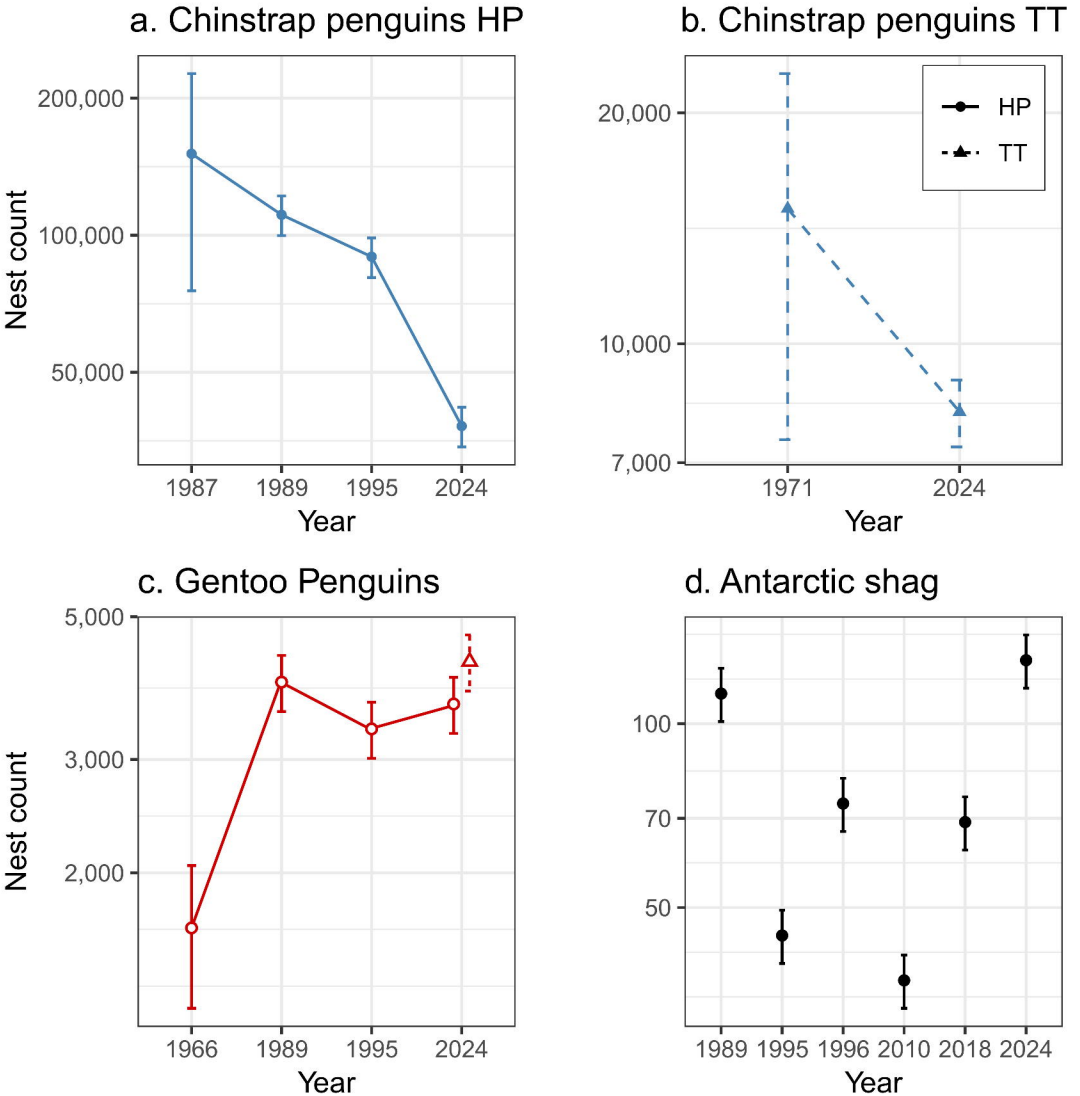
a. Chinstrap penguins HP
Nest count
200,000
100,000
50,000
1987
1989
1995
2024
Year
b. Chinstrap penguins TT
20,000
10,000
7,000
1971
2024
Year
HP
TT
c. Gentoo Penguins
Nest count
5,000
3,000
2,000
1966
1989
1995
2024
Year
d. Antarctic shag
100
70
50
1989
1995
1996
2010
2018
2024
Year