New Zealand Journal of Zoology

ROYAL SOCIETY TE APĀRANGI

RESEARCH ARTICLE OPEN ACCESS

Nest Counts of Kororā/Little Penguins on Horomaka/Banks Peninsula, New Zealand

Rachel P. Hickcox[1] | Kaitlin Bowe[2] | Georgia Gwatkin[3] | Lucy Howell[3]

[1]Helps Pōhatu Conservation Trust, Akaroa, New Zealand | [2]University of Otago, Dunedin, New Zealand | [3]University of Canterbury, Christchurch, New Zealand

Correspondence: Rachel P. Hickcox (rphickcox@gmail.com) | Lucy Howell (lucy.howell@pg.canterbury.ac.nz)

Received: 1 April 2025 | **Revised:** 16 July 2025 | **Accepted:** 22 July 2025

Keywords: Aotearoa | citizen science | community science | kororā | little penguin | nest survey | New Zealand | white-flippered penguin

ABSTRACT

To better understand the population trends of kororā/little penguins (*Eudyptula minor*), the Horomaka/Banks Peninsula Kororā Survey of nesting colonies was conducted across two consecutive breeding seasons (November–January 2020/2021 and 2021/2022). Due to the number of sites and time requirements, volunteers were recruited to search 89 breeding sites. This community science approach resulted in a count of 1969 nests, 14 sites (16%) had 0 nests, 28 sites (31%) had 1–4 nests, 32 sites (36%) had 5–20 nests, 9 sites (10%) had 21–50 nests, and 6 sites (7%) had more than 50 nests. The five largest colonies ranged in size from 51 nests (Te Oka Bay) to 928 nests (Pōhatu/Flea Bay) and contributed 63.2% of the total nests. Habitat type and nest type were also summarised for each breeding area. These findings provide updated nest counts across the region, although future work is needed to survey additional breeding areas and to estimate the total little penguin population size on Horomaka/Banks Peninsula. This project highlights the value of engaging communities in conservation science, demonstrating how local volunteers can contribute to large-scale ecological monitoring and provide essential data to inform conservation strategies.

1 | Introduction

Kororā/little penguins (*Eudyptula minor*) are found in southern mainland Australia, Lutruwita/Tasmania, Aotearoa/New Zealand, and the Rēkohu/Wharekauri/Chatham Islands. Despite being classified as 'least concern' by the International Union for Conservation of Nature Red List (BirdLife International 2020), the species is 'at risk-declining' in New Zealand (Robertson et al. 2021) due to localised population declines at colonies across their range (e.g. Challies and Burleigh 2004; Clitheroe 2021; Colombelli-Négrel, 2015; Mattern and Wilson 2019; Stevenson and Woehler 2007). Many areas across New Zealand are also data deficient with regards to kororā population sizes and threats. In New Zealand, penguins face many marine and terrestrial threats that contribute to these localised population fluctuations, including human disturbance, unregulated tourism, fisheries interactions, climate change, and predation by introduced mammals like dogs (*Canis lupus familiaris*), feral cats (*Felis catus*), and mustelids (family Mustelidae) (Allen et al. 2011; García-Borboroglu and Boersma 2013; Mattern and Wilson 2019).

While the taxonomy is currently unresolved, recent genetic analyses suggest that there are distinct Australian/Otago and New Zealand clades within little penguins (*E. minor*; see Banks et al. 2002; Banks et al. 2008; Clark et al. 2013; Grosser and Waters 2015; Grosser et al. 2015; Grosser et al. 2017). Although once considered a subspecies of *E. minor*, the white-flippered penguin (*E. minor albosingata*) is now commonly called a morphological variant of the New Zealand clade of little penguins. They are endemic to Te Pataka o Rakaihautū/Banks Peninsula (more colloquially called Horomaka) and Motunau Island in Canterbury (Banks et al. 2002; Allen et al. 2011). Compared to other New Zealand and Australian little penguins, white-flippered penguins are slightly larger and have a paler blue plumage and two white

Kaitlin Bowe, Georgia Gwatkin, and Lucy Howell contributed equally to this study.

margins along the front and back edges of the dorsal flipper surface (Allen et al. 2011). They also exhibit some behavioural and vocalisation differences compared to the Australian clade (Grosser et al. 2015). Hereafter, the terms kororā/little penguins encompass the species, without distinguishing between the clades or white-flippered penguins specifically, although most penguins on Banks Peninsula are the white-flippered morphotype.

Kororā nest in burrows, holes, or crevices which they excavated themselves or that were found in naturally occurring formations like rock piles or dug by other animals (e.g. rabbit burrows). They also burrow in tree or rock crevices, caves, lava tunnels, root systems, underground in pasture, and under dense vegetation or nest under buildings or other man-made structures (Challies and Burleigh 2004; Allen et al. 2011; Cargill et al. 2022). At some sites, artificial nesting boxes provide alternative nesting locations for penguins (Allen et al. 2011; Agnew 2014). Most previous surveys of kororā colonies searched for signs of activity: presence of adults, chicks, eggs (dead or alive) (e.g. Challies and Burleigh 2004; Dann 1994; Sutherland and Dann 2014), guano, tracks (e.g. Braidwood et al. 2011), odour, scratch marks in rocks and dirt, or sounds of penguin vocalisation (e.g. Challies and Burleigh 2004; Cargill et al. 2022). The use of remote camera monitoring is not typically used for burrowing species such as kororā due to limited visibility, inaccurate counts/small sample size, and cost.

The last survey of active or suspected nests on Banks Peninsula, located on the eastern coast of New Zealand's South Island, was conducted by the Department of Conservation during November-January of the 2000/2001 and 2001/2002 breeding seasons (Challies and Burleigh 2004). They found 2112 nests at 68 colonies around Banks Peninsula and estimated a population size of 5870 penguins, including juveniles (fledgeling to first moult at 1 year old). Including previous estimates of 1650 nests on Motunau Island (once the largest offshore colony of kororā), they further estimated a total population of 10,460 kororā (Challies and Burleigh 2004). Prior to this, the population size was unknown as much of the coastline of the Banks Peninsula is inaccessible from land and had not previously been surveyed. The Pōhatu/Flea Bay colony, the largest mainland colony in New Zealand, is surveyed every 4 years, with 892 active nests in 2004, 1063 in 2008, 1304 in 2012, and 1260 in 2016 (Helps Pōhatu Conservation Trust, *unpubl. data*).

Nest surveying is resource-intensive, time-consuming, expensive, and logistically challenging, often leading to infrequent surveys and knowledge gaps in population trends (McKinley et al. 2017). There is also asynchrony in the presence of penguins on land and breeding activities; for instance, a penguin can be on land but not breeding or they can be breeding but at sea during the survey. Hence, volunteers play a key role in addressing these challenges by assisting with data collection, enabling broader spatial and temporal coverage, and fostering community engagement in conservation (Bonney et al. 2009; Kosmala et al. 2016; McKinley et al. 2017). Community science (or citizen science), where non-professionals assist to collaboratively collect or analyse scientific data, has become a valuable tool in ecological research (Kosmala et al. 2016; McKinley et al. 2017). Efforts to engage more volunteers at a larger scale have increasingly shifted their contributions from acknowledgments to essential components of scientific methodologies. Examples include community groups of volunteers monitoring little penguin colonies in Australia and New Zealand, analysing little penguin vocalisations to estimate population size at two colonies in Australia (Colombelli-Négrel 2023), and volunteers analysing thousands of images from remote cameras monitoring penguin colonies in Antarctica and several sub-Antarctic islands, as part of Zooniverse Penguin Watch (Jones et al. 2018).

This article presents the findings of the Horomaka Kororā Survey, a community science project that counted kororā nests across 89 breeding sites on Banks Peninsula, New Zealand during the 2020/2021 and 2021/2022 breeding seasons. The distribution, abundance, and characteristics of observed nests are summarised. Methodology improvements compared to the 2000 survey are explained and benefits and difficulties encountered when using a community science approach are discussed. Considering the last survey on Banks Peninsula was over 20 years ago and population estimates have likely changed in that time due to aforementioned threats, it was imperative that a contemporary survey be conducted to update the population counts for this area. Furthermore, understanding fundamental population demographics is the first step in implementing conservation actions for kororā and provides a foundation for further research and management efforts in this region.

2 | Methods

2.1 | Study Sites and Survey Logistics

Horomaka/Banks Peninsula is an elliptical area of dissected volcanic hills jutting from the east coast of New Zealand's South Island, east of the Canterbury Plains and north of the Canterbury Bight. The rocky coastline spans more than 300 km, with two main harbours, Akaroa Harbour and Lyttelton Harbour, and many smaller bays. Extensive erosion has resulted in steep bluffs, dramatic headlands, and sea caves (Bräger and Stanley 1999; Challies and Burleigh 2004). Pasture and shrubland dominate the once forested landscape, with patches and corridors of dense, regenerating native vegetation.

During the 2020–2021 and 2021–2022 breeding seasons, the Horomaka Kororā Survey was coordinated by Pōhatu Penguins/Plunge, an ecotourism company, and the Helps Pōhatu Conservation Trust, under the consent of the Department of Conservation. Several formal training days were held, where participants were briefed on the survey objectives, goals, health and safety, and data collection protocols, as well as how to identify active penguin nest sites, follow transect lines, mark the nests, and use handheld GPS devices. Dr. Matiu Payne (Te Rūnanga o Koukourarata) presented the protocols for reporting and respecting any Māori burial sites or remains found during the survey. Anyone accessing sites by boat or kayak received kayak self-rescue training in the Pōhatu Marine Reserve, marine radio training, and more detailed health and safety training. Additional training was provided at the beginning of each survey day and as necessary in 2021, to attempt to reduce observer subjectivity.

For white-flippered penguins, the breeding season begins at the end of August (incubation) to January-February (chick fledging), although there is some asynchrony in timing depending on the year. There were 51 survey days (depending on sea conditions, weather, and volunteer availability) during peak periods of breeding and burrow occupancy between 31 October 2020–31 January 2021 (2020 breeding season) and 21 October 2021–08 December 2021 (2021 breeding season). This mostly coincides with incubation and chick rearing. Given the large number of survey sites, the asynchrony of breeding, the nature of volunteer involvement, and the variability in weather conditions, it was not possible to further synchronise surveys to better align with the temporal patterns of bird phenology.

Of the 89 sites surveyed, 19 were accessible by land (e.g. bays with four-wheel drive or beach access). Landowner permission (and occasionally participation) was obtained prior to and on the day of the survey to approve access. All other sites were accessed by kayaks that were launched from a local tour boat or from the beach. Coastal areas did not require permissions to survey. An observer monitored all teams using binoculars from the boat for health and safety purposes.

Depending on the size of the survey area and volunteer availability, survey teams consisted of an average of five volunteers with a range of experience, with at least one experienced team leader with extensive knowledge of nest searching, penguin behaviour, and local habitat. Most sites took 1–2 days to survey. The largest colonies at Pōhatu/Flea Bay and Stony Bay required 20–60 volunteers across multiple survey days. Over 100 volunteers and four school groups conducted an estimated 2200 h of surveying (about 366 6-h days), which was calculated as the sum of survey hours*surveyors per site, with an estimated 6 h of surveying per day. About 45% of those survey hours were contributed by twelve primary surveyors.

2.2 | Data Collection

Survey sites, most of which were identified and surveyed in 2000 (Challies and Burleigh 2004), were determined prior to surveying, considering weather conditions, volunteers available, access permissions, previous transect lines, and logistics. Areas were searched by individuals or pairs following transect lines about 5–10 m apart depending on the site, where possible. Start and end points were physically identified by flagging tape and GPS points to avoid duplication, and where possible, transects were aligned with landscape features such as fence lines to facilitate easier navigation and planning of adjacent transects. Surveyors were instructed to search 2–5 m each side of their line or position. Due to the terrain, true transect lines were difficult to maintain and the length of the transect lines and number of volunteers were variable. Thus, exhaustive searches were conducted of many areas where transect surveys were impossible, relying on suspected penguin paths or signs of penguin activity. Identified nests were marked with flagging tape or chalk to prevent double counting. Disturbance was minimised (e.g. silence during nest check, moving away from nest as quickly as possible, etc.), and penguins were not handled.

Data was collected using a custom-built Horomaka Kororā Survey smartphone app built using Kobo Toolbox (https://www.kobotoolbox.org/) by Orbica (Christchurch, NZ; Supplementary material Figure S1). Both volunteers and team leaders operated the app offline on their personal smartphones and synchronised data when internet access was restored. If needed, paper datasheets (Supplementary Figure S2) were used and later entered into the app. The following descriptive information was collected for each nest.

2.2.1 | Nest Occupancy

To determine if a nest was active (i.e. there was evidence of activity/a breeding attempt at some point during the current breeding season), the presence or absence of adult penguins, live chicks, recently dead chicks, and eggs were recorded. A redlight torch was used to visually inspect nest contents. In many cases, the occupancy could not be determined if the back or whole nest could not be viewed and was recorded as "unseen". It was not permitted to insert anything into the nest to confirm occupancy. Other signs of an active nest were also recorded, such as the presence of fresh guano, egg fragments, new nesting material, or deceased penguins. Sometimes, chicks or adults could be heard but not seen in a nest, and this was likewise recorded. Kororā are one of the only burrow-nesting seabirds in the region, apart from sooty shearwaters (*Puffinus griseus*); their eggs, guano, and vocalisations are distinctive, so misidentification was unlikely.

2.2.2 | Location and Datetime

Nest latitude and longitude (World Geodetic System 1984 WGS 84 coordinate reference system) was obtained using the smartphone GPS, accurate to $\approx$5 m. When a coordinate could not be determined due to poor GPS signal (e.g. inside caves), the coordinate of the colony was used. Date and time were also automatically recorded as the time of entry.

2.2.3 | Surveyor Information

The name of the person recording the nest in the app (i.e. recorder) and observing the contents of the nest (i.e. observer, relaying information to the recorder) was included for each record. Whenever possible, we ensured that, in a pair, the same person investigated the nest and recorded data in the app, to mitigate additional observer bias when identifying nest contents and habitat type.

2.2.4 | Site and Nest ID

Each survey site had a unique alphanumeric ID assigned during the 2000 survey (Challies and Burleigh 2004). New survey sites were assigned an ID following the same naming conventions. Each nest was also assigned a nest ID, unique to each survey site but not always unique across sites. Post-processing of data generated a unique nest ID as SurveyYear|SiteID|NestID; for instance, a nest called AP1 found at site Q3 during 2020 was called "2020Q3AP1".

2.2.5 | Physical Characteristics

Nest characteristics (e.g. ease of finding, ease of access, and exposure to terrestrial predators) were recorded as binary questions, with free text fields for additional comments. Although these characteristics are subjective, the simplified yes/no answers allowed for standardisation and efficiency while surveying but still allowing for qualitative information to be captured.

2.2.6 | Nesting Habitat/Vegetation

Thirteen predetermined habitat types (Figure 1) were used to subjectively classify the environment around each nest, based on those used in Challies and Burleigh (2004), where a single nest may have multiple habitat types. Rocky habitats included coastal rock (land/beach with rocks >1 cm and boulders >1 m), rock pile (of any size), debris slope (sand, dirt, vegetation, and rock cascading down a slope), and cave (horizontal depth > entrance height in rock bluffs). Habitats actively grazed by domesticated animals,

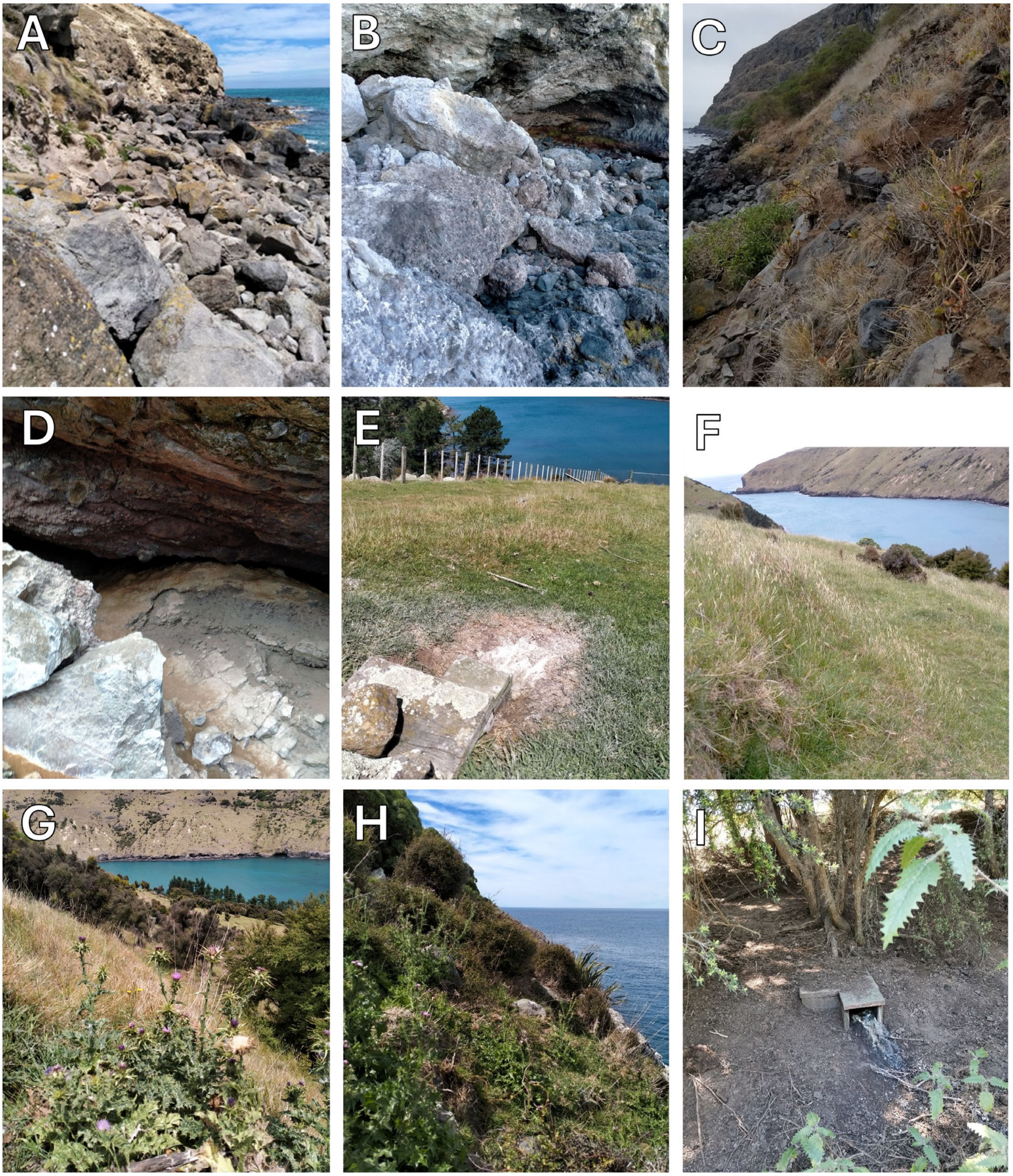

FIGURE 1 | Types of habitats where nests were found during the Horomaka Kororā Survey in 2020-2021: (A) coastal rock, (B) rock pile, (C) debris slope, (D) cave, (E) pasture, (F) pasture shrubland, (G) patchy shrubland, (H) dense shrubland, and (I) forest.

often fenced, were classified as pasture (covered with grass and other short vegetation), pasture shrubland (pasture with an abundance of larger, non-grazed shrubs), or pasture mixed (pasture with multiple other types of vegetation including non-grazed shrubs and forest). Vegetated habitats included patchy shrubland (low shrubs covering < 50% of the ground, no large trees), dense shrubland (low shrubs covering > 50% of the ground, no large trees), and forest (abundance of trees). Other habitat types include buildings (under or inside a man-made structure), islands (smaller land masses separated from the mainland at low tide), and other (habitats not fitting other classes).

2.2.7 | Nest Type

Ten predetermined nest types (Figure 2) were used to classify characteristics of substrate or location where the nest was built (Figure 2), based on those used in Challies and Burleigh (2004), with multiple types possible. Earth burrows were those dug directly into the ground, rock burrows were under or inside a rock crevice, and root-log burrows were under or adjacent to tree roots or logs. Burrows were also found inside lava tunnels (colloquially referred to as 'under runners' since they are often found underground) or under/inside buildings. Artificial nestboxes,

FIGURE 2 | Types of kororā nests found during the Horomaka Kororā Survey in 2020-2021: (A) surface nest, (B) earth burrow, (C) nestbox, (D) rock burrow, (E) root-log burrow, (F) lava tunnel/under runner, (G) earth burrow, and (H) buildings.

typically made of wood, are used at some colonies. Surface nests were open, shallow depression in the ground surrounded by vegetation or other debris (i.e. not a burrow). Nests that did not conform to another category were classified as 'other'; for example, man-made seawall or wood pile on private property.

2.3 | Data Analysis

Manual data cleaning was conducted to correct survey site reference IDs, nest IDs, surveyor names, etc., and to remove duplicates or incorrect records (based on timestamp, nest IDs, and coordinates). Since multiple nest and habitat types could be selected to describe a nest, these categories were simplified. For nest type, any nest classification containing "nestbox", "under building", "lava tunnel", and "surface nest" were reclassified as such. All other classification changes can be found in Supplementary Material Table S1. For habitat type, any nest classification containing the category "cave", "building", "island/ islet", or "forest" were reclassified as such. All other classification changes can be found in Supplementary Material Table S2. Counts for each site reference were summed and mapped. All data processing was conducted using R (version 4.3.2) (R Core

Team 2023) using packages in the *tidyverse* (v2.0) (Wickham et al. 2019). The map was created using the free and open-source programme QGIS (v3.28.1) (QGIS.org. 2024).

3 | Results

3.1 | Nest Counts

In total, there were an estimated 1969 active nests (i.e. there was evidence of activity/a breeding attempt at some point during the current breeding season) on Banks Peninsula at 89 sites (Table 1). Of these, 52.8% ($n = 1040$) were actively occupied by at least one adult, chick, egg, or dead chick. There were 360 nests that were not occupied and 569 nests where occupancy could not be confirmed, although in 99.8% of nests ($n = 1965$), there was sign of activity (presence of scat/faeces, egg fragments, nest material, and/or noises). The four nests without active sign were actively occupied, and all boxes that were not actively occupied (or the occupancy was unconfirmed) all had signs of activity.

There were 1573 nests recorded at 58 sites during 2020–2021 and 396 nests recorded at 31 additional sites in 2021–2022. During the 2000 survey (Challies and Burleigh 2004), 121 sites were surveyed, with 68 sites having five or more nests. Of those 121 sites, 74 were surveyed again in 2020–2021. An additional 14 sites were surveyed that were not surveyed in 2000–2001. Therefore, there were 47 sites that were surveyed in 2000–2001 but not in 2020–2022. This was due mostly to an increased abundance of New Zealand fur seals (*Arctocephalus forsteri*) preventing safe landing and access to the colonies, although poor weather, time constraints, and boat availability also prevented surveying at some sites. There were 51 survey days across both years.

Over the 2020–2021 survey period, 14 sites (16%) had 0 nests, 28 sites (31%) had 1–4 nests, 32 sites (36%) had 5–20 nests, 9 sites (10%) had 21–50 nests, and 6 sites (7%) had more than 50 nests (Figure 3). Pōhatu/Flea Bay was the largest colony with 928 nests, followed by Stony Bay with 121 nests and Menzies Bay with 80 nests. The five largest colonies ranged in size from 51 nests (Te Oka Bay) to 928 nests (Pōhatu/Flea Bay) and contributed 63.2% of the total. Most larger colonies occurred on the southeastern side. A few other medium-sized colonies were found along the northern and eastern coasts.

3.2 | Nest and Habitat Type

Irrespective of colony size, most nests were rock burrows (1047 nests; 66.5%) or earth burrows (339 nests; 21.5%). Figure 4 shows the number of nests per nest type for small colonies (nests < 5; 63 total nests), medium colonies (nests ≥ 5 and ≤ 20; 327 nests), large colonies (>20; 651 nests), and extra-large colonies (Pōhatu/Flea Bay; 928 nests). Six colonies had one or more nestboxes, with a total of 242 nestboxes with nesting activity across the peninsula. The majority of these (88.0%) occurred at Pōhatu/Flea Bay.

Similarly, Figure 5 shows the number of nests per habitat type for small, medium, large, and extra-large colonies. Irrespective of colony size, 512 nests (25.9%) were found in coastal rock habitats (encompassing debris slopes on coastal rock and rocky/boulder beaches), since many breeding areas were found below coastal cliffs. There were 296 nests in pasture (15.0%) and 199 nests in patchy shrubland (10.1%). For most colonies, there was considerable variation in the types of habitats across and within colonies.

4 | Discussion

In 2020–2021, 89 breeding sites around Banks Peninsula were surveyed for kororā nests by over 100 volunteers and four school groups, with logistical support from 14 organisations. Assuming each nest with sign of penguin activity represents a breeding attempt, there was an estimated 1969 breeding pairs of kororā across the peninsula. Most breeding pairs on Banks Peninsula are likely white-flippered, supported by population data from Pōhatu/Flea Bay where 89% of 219 marked adults are white-flippered (Helps Pōhatu Conservation Trust, *unpubl. data*). Further assuming that there are two adults per nest, there was a minimum of 3938 breeding, adult white-flippered penguins attending these surveyed nests. There has not been a recent update of the juvenile to adult ratio, other than that presented in Challies and Burleigh (2004). Furthermore, a recent survey of Motunau Island has not been conducted due to access and logistical difficulties, so an estimate of the total kororā (specifically white-flippered penguin) population size is not possible. Population modelling would need to be conducted to get a predicted estimate.

It should be acknowledged that this estimate of breeding pairs assumes that all occupied nests or nests with signs of activity is a breeding pair. This may not hold true in all cases, if for instance the nest is occupied by a non-breeder or juvenile. There may be instances as well of a failed nest that is not evident. However, based on the methodology of the survey, this assumption was considered to derive a population estimate, although the estimate should be used with caution. Burrowscopes will be used in future surveys to better determine occupancy. Although the methods used in this survey were similar to those employed in the 2000 survey (Challies and Burleigh 2004), differences in search effort at several sites (both in area covered and number of volunteers) prevent true comparisons of estimates, and conclusions should be made cautiously. However, the 2020 estimate is within a reasonable range of the 2000 estimate of 2112 nests. For instance, it is unclear if the increase in nests at Stony Bay is due to a considerably greater search effort in 2020 or, more likely, an increase in consistent predator control and colony management.

Moreover, while the Pōhatu/Flea Bay colony increased from ≈717 nests to 928 nests over 20 years, the colony has been surveyed every 4 years since 2000, with an estimated 893 active nests in 2004, 1063 in 2008, 1304 in 2012, and 1260 in 2016 (Helps Pōhatu Conservation Trust, *unpubl. data*). Thus, there has been a large, estimated decline of 332 nests in 4 years (A. Parthonnaud, *pers. comm.*). Considering the findings of the 2020–2021 survey, it is unlikely that penguin from Pōhatu/Flea Bay have relocated, and the large size of the colony makes it a good representation of what could be occurring across the peninsula. This also suggests that more frequent surveys are required to understand both short- and long-term population trends.

Similarly, since the 2020 survey, a single smaller section of Pōhatu/Flea Bay has been surveyed annually. Kororā nest counts remained relatively stable: 129 in 2021, 117 in 2022, and 126 in 2023 (Helps Pōhatu Conservation Trust, *unpubl. data*). In 2024, the section was surveyed twice, in October (incubation/chick rearing) and

TABLE 1 | Nest counts for each surveyed site on Banks Peninsula in 2020 and 2021. Totals are provided for each breeding year and for both years combined. Reference codes indicate location of site on map in Figure 3.

Reference	Site name	Nests	Reference	Site name	Nests
2020			**2021**		
A0	Sumner Beach	4	**H0**	Pigeon Bay Cave	4
A00	Lyttelton Port Company	12	**H00**	Pigeon Bay - boulder beach	2
A1	Taylors Mistake	8	**H1**	Pigeon Bay - east 1	4
B1	Otamahua/Quail Island- northwest	5	**H10**	Scrubby Bay - east	1
B2B3	New Zealand	5	**H11**	Scrubby Bay - west	1
B4	Naval Point	1	**H2**	Pigeon Bay - east 2	2
B5	Otamahua/Quail Island- west	7	**H4**	Pigeon Bay - west	64
C1	Governors Bay	0	**H6**	Pigeon Bay - Wakaroa Point	4
E1	Camp Bay	8	**H7**	Pigeon Bay - Wakaroa Point south	2
F4	Port Levy - Beacon Rock	0	**H8**	Whitehead Bay Head	8
G1	Port Levy - Islet Pukerauaruahe	8	**H9**	Whitehead Bay	15
G2	Port Levy - west	0	**J1**	Menzies Bay - west	11
G3	Port Levy - east	0	**J2**	Menzies Bay - west head	22
J0	Manuka Bay	0	**J3**	Menzies Bay - Otohuao Head	80
J4	Squally Bay	8	**J7**	Decanter Bay - northeast	4
L0	Okains Bay - south	9	**J8**	Menzies Bay - south	1
L1	Okains Bay - opposite old wharf	0	**K0**	Little Akaloa Bay - entrance	12
L2	Okains Bay - past old wharf	0	**K3**	East of Raupo Bay	2
L3	Okains Bay - West Head	0	**K4**	Little Akaloa Bay - east head 1	3
L4	Okains Bay - Spyglass Point	1	**K5**	Little Akaloa Bay - east head 2	1
L5	Okains Bay - Spyglass Point south	23	**K6**	Raupo Bay - Lookout Point	16
L7	Okains bay - north West Head	11	**K8**	Raupo Bay west	9
M1	Lavericks Bay - south	5	**K9**	Stony Beach	12
M10	Le Bons Bay	0	**O1**	Fishermans Bay	4
M11	Le Bons Bay - south	10	**O3**	Paua Bay	1
M12	Le Bons Bay - southwest	15	**P1**	Otanerito Cave	50
M13	Le Bons Bay - south harbour entrance	46	**V1**	Island Bay Heads	24
M18	Le Bons Bay - cave by the beach	28	**V3**	Island Bay - east	2
M9	Le Bons Bay - north	31	**V5**	Long Bay - west	1
N2	Hickory Bay - south East Head	2	**V6**	Long Bay - south	8
N5	Mainland north Crown Island	1	**W5**	Horseshoe Bay - Snuffle Nose	26
N8	Hickory Bay - north Head	0	**Total**		**396**
O2	Red/Shell Bay	10			
O6	Goughs Bay - north South Head	4			
O8	Goughs Bay - south	11			
P0	Otanarito- inner bay left	19			
P3	Sleepy Bay	2			
P4	Reef Nook	11			
P6	Stony Bay	121			
P8	Redcliff Nook cave	2			
Q1	Damons Bay	6			

(Continues)

TABLE 1 | (Continued)

Reference	Site name	Nests	Reference	Site name	Nests
2020			**2021**		
Q3	Pōhatu/Flea Bay	928			
R1	Akaroa Harbour - Wainui	0			
R2	Akaroa Harbour - south of Ohinepaka Bay	2			
U3	Akaroa Heads - harbour right 1	10			
U4	Akaroa Heads - harbour right 2	51			
U5	Akaroa Heads - harbour right 3	33			
U6	Akaroa Heads - Scenery Nook	16			
U8	Akaroa Harbour - left side 1	0			
U9	Akaroa Harbour - left side 2	0			
W1	Te Kaio Bay	0			
W2	Robin Hood Bay	8			
W3	Te Oka Bay	52			
W4	Tumbledown Bay	18			
X0	Hikuraki Bay	9			
X1	Tokoroa Bay Heads	2			
X2	Tokoroa Bay	7			
Y1	Oashore Bay	3			
TOTAL		**1573**			
NET TOTAL		**1969**			

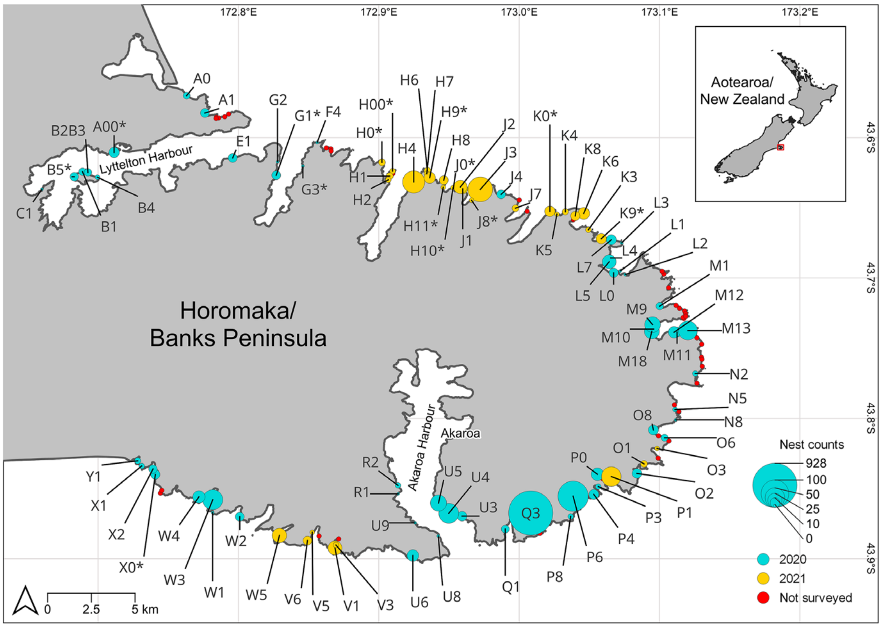

FIGURE 3 | Nest counts at surveyed breeding sites of kororā on Banks Peninsula. The circle size is proportional to the number of nests. Sites (see Table 1 for site names corresponding to each site ID) surveyed in 2020 are in blue, and sites surveyed in 2021 are in yellow. An asterisk indicates sites newly surveyed, compared to the 2000 survey. The map is projected in the WGS 84 coordinate reference system.

December (chick rearing/fledging). There were 84 nests during the first count which increased to 127 nests during the second count (Helps Pōhatu Conservation Trust, *unpubl. data*). This increase can be attributed to several factors. The first survey was conducted by a larger number of volunteers with different skill levels and during a time when there were fewer signs of activity (e.g. guano, smell, and sound) since it was early in the breeding season, making nests more cryptic. The second survey was done by four experienced searchers

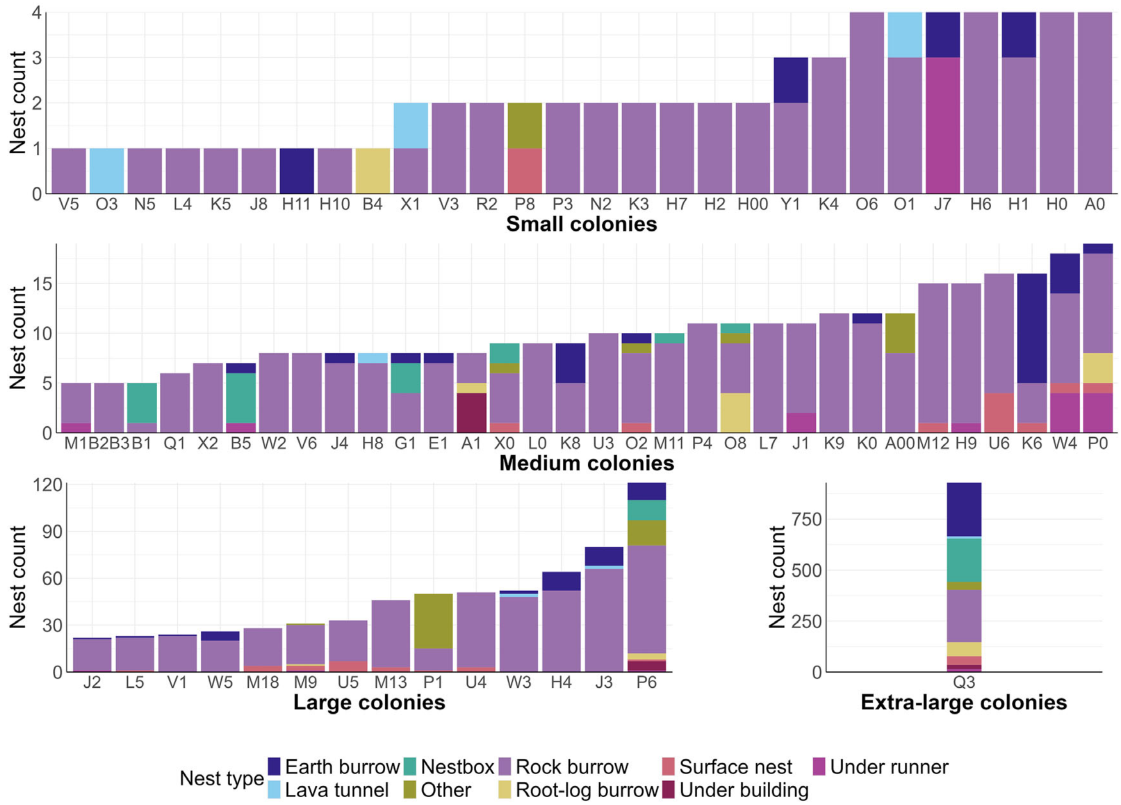

FIGURE 4 | Nest counts for each nest type for small colonies (nests < 5), medium colonies (nests ≥ 5 and ≤ 20), large colonies (>20), and extra-large colonies (Pōhatu/Flea Bay; 928 nests). See Table 1 for colony abbreviations. Note the different *y*-axis scales.

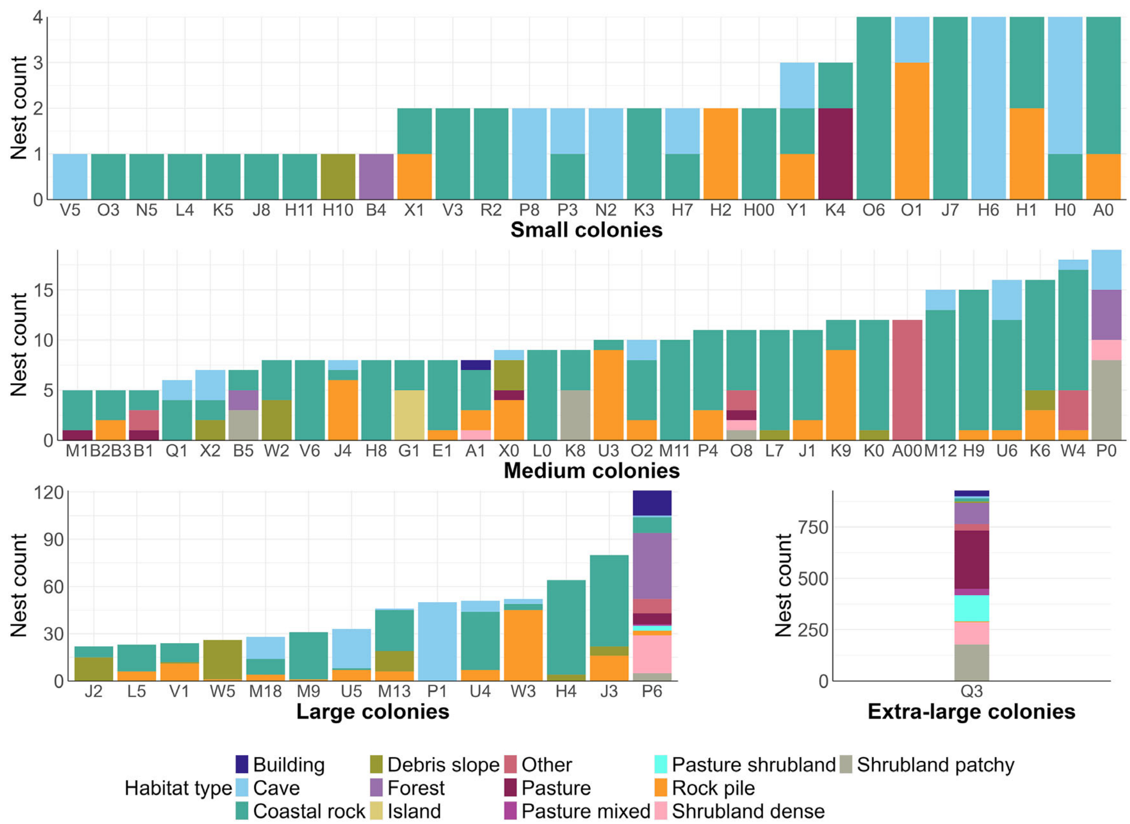

FIGURE 5 | Nest counts for each habitat type for small colonies (nests < 5), medium colonies (nests ≥ 5 and ≤ 20), large colonies (>20), and extra-large colonies (Pōhatu/Flea Bay; 928 nests). See Table 1 for colony abbreviations. Note the different *y*-axis scales.

when nests were more obvious due to the larger chicks occupying the nests during the day.

While some nest count changes may result from successful conservation efforts, such as predator control, further investigation is needed into factors driving population declines. Potential contributors include human disturbances, predation, habitat degradation, and climate change (Allen et al. 2011; García-Borboroglu and Boersma 2013; Mattern and Wilson 2019). For example, significant stoat (*Mustela erminea*) predation was noted at an Akaroa Harbour site, necessitating regular predator trapping and surveying that is currently ongoing. Targeted actions like habitat restoration, predator management, and public awareness are crucial for the penguins' long-term survival.

The Horomaka Kororā Survey exemplifies the power of community or citizen science in conducting comprehensive nest surveys and generating valuable data for conservation efforts. This project primarily engaged volunteers from the Banks Peninsula community and rūnanga (tribal council or assembly), as well as students and international volunteers. Actively involving the community in data collection not only fosters a sense of stewardship and connection to local ecosystems but also provides opportunities for education and awareness, empowering participants to become advocates for wildlife conservation (Bonney et al. 2009; McKinley et al. 2017; Rögele et al. 2022). Many participants returned for the 2021 surveys, with some continuing their involvement in the 2024 Pōhatu/Flea Bay survey. This project also demonstrated that effectively surveying kororā colonies across Banks Peninsula required more effort than a small team of experienced surveyors can manage, especially within the restricted peak breeding season. Leveraging volunteers enabled sites to be surveyed simultaneously and across a wider geographic area, due to the diverse range of skills.

The survey was primarily conducted on private or conservation land with limited access, minimising the risk of public interference post-survey. At Pōhatu/Flea Bay, a managed colony of kororā on private land with a long-term conservation programme, the large volunteer groups played a key role. Conservation efforts at Pōhatu/Flea Bay are deeply intertwined with community and citizen science initiatives. For decades, the landowners have led initiatives such as advocating for marine protected areas, establishing predator trapping, installing nestboxes, planting native vegetation, and engaging with iwi to identify and assist in protecting indigenous sites. Organisations such as the ecotourism company and conservation trust were founded on this legacy, making them uniquely positioned to support a citizen science programme along with other educational and conservation projects. Collaborations and partnerships have also been established because of this survey, thus contributing to the wider conservation and research of kororā in New Zealand. While challenges exist when conducting a community science project such as this survey, it illustrates how community-driven conservation initiatives can thrive with the support of citizen scientists.

5 | Challenges and Recommendations

Survey challenges in 2020 mirrored those of 2000, affecting coverage and data accuracy. Access at many sites was difficult or impossible due to steep terrain, dense vegetation, and the notable increase in the number of New Zealand fur seals since 2000. Some sites were accessible only by boat and kayak. True transect surveys were not feasible, although efforts were made to maintain transects where possible. Moreover, volunteer involvement, while valuable, introduced variability in survey methods and observer biases. Despite standardised protocols and training, nest identification varied, and subjective interpretation of habitat or nest type occurred; for instance, habitat or nest type could be interpreted differently by different people. The lack of consistent survey effort and tracked paths prevented reliable population estimates.

This survey and the 2024 survey of Pōhatu/Flea Bay highlight the need for methodological changes in future surveys, especially considering the increase in fur seal numbers and revegetation. Greater standardisation, additional training, and GPS tracking for all surveyors using their personal smartphone are essential to reduce variability and bias. Variability in georeferencing accuracy should also be addressed for better spatial analysis of nest distributions. Less intensive, partial surveys with true transect or distance sampling could improve statistical robustness. Burrowscopes and detection dogs could be used for more difficult sites. Continued app improvements are also needed. A smaller, experienced survey team and ongoing community engagement will help ensure long-term support for these surveys.

While this type of community-driven conservation project presents clear benefits, there are limitations and sources of bias. Observer variability, uneven survey effort, and land accessibility may all introduce subjectivity and restrict the applicability or generalisation of results. Additionally, the presence of volunteers can influence detection rates, particularly in habitats where burrows are cryptic and difficult to locate.

Nevertheless, citizen science remains one of the only feasible methods to conduct a large-scale census of coastal, burrow-nesting kororā. The logistical and resource demands of surveying these seabirds across their range are immense, and community engagement provides both the participation and the long-term commitment necessary to address this challenge. This survey illustrated not only the difficulty of surveying kororā but also how citizen scientists can make critical contributions to understanding and protecting the species.

To guide future monitoring and conservation efforts, a clear prioritisation of sites on Banks Peninsula would be valuable for a more strategic and effective approach to kororā conservation. This could be based on factors such as population viability, site accessibility, and exposure to threats like predation or human disturbance. High-risk but accessible sites may warrant more frequent monitoring and immediate management, while low-risk or remote sites could be surveyed less often. Considering the population size at sites like Pōhatu/Flea Bay and Stony Bay, these sites should also be prioritised for ongoing monitoring and conservation. More importantly, a national threat management plan is needed to map kororā distribution across New Zealand and apply site prioritisation, ensuring effective and efficient use of resources and targeted conservation actions.

6 | Conclusions

The Horomaka Kororā Survey provided an updated nest count of kororā on Banks Peninsula. By engaging citizen scientists and leveraging innovative survey methodologies, the study provides crucial data for conservation planning and management. While community science has its challenges that require further improvement, the benefits of public engagement/outreach, increased awareness, and collecting otherwise often unobtainable data outweigh these considerably. Collaborative efforts between researchers, conservation practitioners, local communities, and policymakers are essential to safeguarding the future of kororā populations in New Zealand's coastal ecosystems.

Author Contributions

RH designed/modified some of the survey protocols and data collection methods, analysed the data, and wrote the manuscript. All authors edited and approved the manuscript.

Acknowledgments

As a community-led survey, many organisations, groups, and volunteers were involved in the survey of Banks Peninsula. We thank Pōhatu Penguins/Plunge NZ Ltd. and the Helps Pōhatu Conservation Trust for conceiving and coordinating the survey, especially Averil and Kevin Parthonnaud. We also acknowledge the kaitiaki of Te Rūnanga o Koukourarata and Te Rūnanga o Ōnuku and their support and consultation on the survey. We would also like to thank Dr. Matiu Payne, Dr. Chris Challies, James Nikitine (Blue Cradle), Alice Webster (Banks Peninsula Conservation Trust), Robin Burleigh, Anita Spencer, Francis Helps, and Shireen Helps for their time and advice. Our thanks to Orbica for volunteering their time to create the survey app. See supplementary material for a complete list of organisations and volunteers that participated in the survey and provided funding, land and sea transportation, technology development, and volunteer assistance. Thank you to two reviewers for comments that improved this manuscript.

Open access publishing facilitated by University of Canterbury, as part of the Wiley - University of Canterbury agreement via the Council of Australian University Librarians.

Funding

This work was partially funded by a community grant to Blue Cradle by Environment Canterbury. Additional support was received from the Rātā Foundation, Pōhatu Penguins/Plunge NZ Ltd., and volunteers. See Supplementary material for full funding list.

Ethics Statement

All fieldwork was carried out with acknowledgement from the Department of Conservation. No penguins or wildlife were handled at any time. Private land access was consented to by all landowners.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Agnew, P. 2014. "Demographic Parameters, Foraging and Responses to Environmental Variation of Little Penguins (Eudyptula Minor)." PhD diss., University of Otago.

Allen, W. J., F. W. Helps, and L. E. Molles. 2011. "Factors Affecting Breeding Success of the Flea Bay White-Flippered Penguin (*Eudyptula Minor Albosignata*) Colony." *New Zealand Journal of Ecology* 35, no. 3: 199–208.

Banks, J. C., A. D. Mitchell, J. R. Waas, and A. M. Paterson. 2002. "An Unexpected Pattern of Molecular Divergence Within the Blue Penguin (*Eudyptula Minor*) Complex." *Notornis* 49, no. 1976: 29–38.

Banks, J. C., R. H. Cruickshank, G. M. Drayton, and A. M. Paterson. 2008. "Few Genetic Differences between Victorian and Western Australian Blue Penguins *Eudyptula Minor*." *New Zealand Journal of Ecology* 35, no. 3: 265–270. https://doi.org/10.1080/03014220809510123.

BirdLife International. 2020. "Eudyptula minor (errata version published in 2021)." IUCN Red List Threatened Species 2020, e.T22697805A202126091. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T22697805A202126091.en.

Bonney, R., C. B. Cooper, J. Dickinson, et al. 2009. "Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy." *BioScience* 59, no. 11: 977–984. https://doi.org/10.1525/bio.2009.59.11.9.

Bräger, S., and S. Stanley. 1999. "Near-Shore Distribution and Seasonal Abundance of White-Flippered Penguins (*Eudyptula Minor Albosignata*) at Banks Peninsula New Zealand." *Notornis* 46, no. 3: 365–372.

Braidwood, J., J. Kunz, and K.-J. J. Wilson. 2011. "Effect of Habitat Features on the Breeding Success of the Blue Penguin (*Eudyptula Minor*) on the West Coast of New Zealand." *New Zealand Journal of Zoology* 38, no. 2: 131–141. https://doi.org/10.1080/03014223.2010.535498.

Cargill, C. P., A. G. Judkins, and J. S. Weir. 2022. "Distribution of Little Penguins (*Eudyptula Minor*) along the Greater Kaikōura Coastline New Zealand." *New Zealand Journal of Marine and Freshwater Research* 56, no. 1: 43–58. https://doi.org/10.1080/00288330.2020.1844766.

Challies, C. N., and R. R. Burleigh. 2004. "Abundance and Breeding Distribution of the White-Flippered Penguin (*Eudyptula Minor Albosignata*) on Banks Peninsula New Zealand." *Notornis* 51, no. 1: 1–6.

Clark, J. A., J. C. Banks, J. R. Waas. 2013. "Economical genotyping of little blue penguin (*Eudyptula minor*) clades from feather-based DNA." *New Zealand Journal of Ecology* 37, no. 1: 146–150.

Clitheroe, E. 2021. "Can Artificial Habitat Mitigate Impacts of Climate Change? Quantifying Nesting Habitat Microclimate and use by Little Penguins (Eudyptula Minor)." PhD thesis, Murdoch University.

Colombelli-Négrel, D. 2015. "Low Survival rather than Breeding Success Explains Little Penguin Population Decline on Granite Island." *Marine and Freshwater Research* 66, no. 11: 1057–1065. https://doi.org/10.1071/MF14098.

Colombelli-Négrel, D. 2023. "Estimating Little Penguin Population Sizes Using Automated Acoustic Monitoring and Citizen Science." *Ibis* 165, no. 4: 1423–1431. https://doi.org/10.1111/ibi.13201.

Dann, P. 1994. "The Abundance, Breeding Distribution and Nest Sites of Blue Penguins in Otago." *New Zealand. Notornis* 41, no. 3: 157–166.

García-Borboroglu, P., and P. D. Boersma. 2013. Penguins: Natural History and Conservation. University of Washington Press.

Grosser, S., and J. M. Waters. 2015. "Development and Characterisation of 20 novel Microsatellite Markers for the Little Blue Penguin (*Eudyptula Minor*) Using Next-Generation Sequencing." *Conservation Genetics Resources* 7, no. 1: 143–145. https://doi.org/10.1007/s12686-014-0313-6.

Grosser, S., C. P. Burridge, A. J. Peucker, and J. M. Waters. 2015. "Coalescent Modelling Suggests Recent Secondary-Contact of Cryptic Penguin Species." *PLoS ONE* 10, no. 12: e0144966. https://doi.org/10.1371/journal.pone.0144966.

Grosser, S., R. P. Scofield, and J. M. Waters. 2017. "Multivariate Skeletal Analyses Support a Taxonomic Distinction between New Zealand

and Australian *Eudyptula* Penguins (*Sphenisciformes: Spheniscidae*).” *Emu - Austral Ornithology* 117, no. 3: 276–283. https://doi.org/10.1080/01584197.2017.1315310.

Jones, F. M., C. Allen, C. Arteta, et al. 2018. “Time-Lapse Imagery and Volunteer Classifications from the Zooniverse Penguin Watch Project.” *Scientific Data* 5: 180124. https://doi.org/10.1038/sdata.2018.124.

Kosmala, M., A. Wiggins, A. Swanson, and B. Simmons. 2016. “Assessing Data Quality in Citizen Science.” *Frontiers in Ecology and the Environment* 14, no. 10: 551–560. https://doi.org/10.1002/fee.1436.

Mattern, T., and K.-J. Wilson. 2019. *New Zealand Penguins – Current Knowledge and Research Priorities*. Penguin Archive.

McKinley, D. C., A. J. Miller-Rushing, H. L. Ballard, et al. 2017. “Citizen Science Can Improve Conservation Science, Natural Resource Management, and Environmental Protection.” *Biological Conservation* 208: 15–28. https://doi.org/10.1016/j.biocon.2016.05.015.

QGIS.org. 2024. “QGIS Geographic Information System” QGIS Association. Accessed October14, 2024. http://www.qgis.org.

Robertson, H. A., K. A. Baird, G. P. Elliott, et al. 2021. “Conservation Status of Birds in Aotearoa New Zealand.” In *New Zealand Threat Classification Series* (Vol. 36). Department of Conservation.

Rögele, A., K. Scheiter, and C. Randler. 2022. “Can Involvement Induced by Guidance Foster Scientific Reasoning and Knowledge of Participants of a Citizen Science Project?.” *International Journal of Science Education, Part B* 12, no. 2: 94–110. https://doi.org/10.1080/21548455.2022.2043567.

Stevenson, C., and E. J. Woehler. 2007. “Population Decreases in Little Penguins *Eudyptula Minor* in Southeastern Tasmania, Australia, over the past 45 years.” *Marine Ornithology* 35, no. 1: 71–76.

Sutherland, D. R., and P. Dann. 2014. “Population Trends in a Substantial Colony of Little Penguins: Three Independent Measures over Three Decades.” *Biodiversity and Conservation* 23, no. 1: 241–250. https://doi.org/10.1007/s10531-013-0597-y.

Wickham, H., M. Averick, J. Bryan, et al. 2019. “Welcome to the Tidyverse.” *Journal of Open Source Software* 4, no. 43: 1686.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Supporting Fig. S1:** Kobo Toolbox application to collect survey data. **Supporting Fig. S2:** Example datasheet for (A) each site and (B) each nest. These forms were used in the event of technical problems preventing the use of the Kobo Toolbox application. The Kobo Toolbox application was designed based on these forms. **Supporting Table S1:** Multiple nest types could be chosen for a single nest. The original categories were simplified into new, higher-level nest types. **Supporting Table S2:** Multiple habitat types could be chosen for a single nest. The original categories were simplified into new, higher-level habitat types.