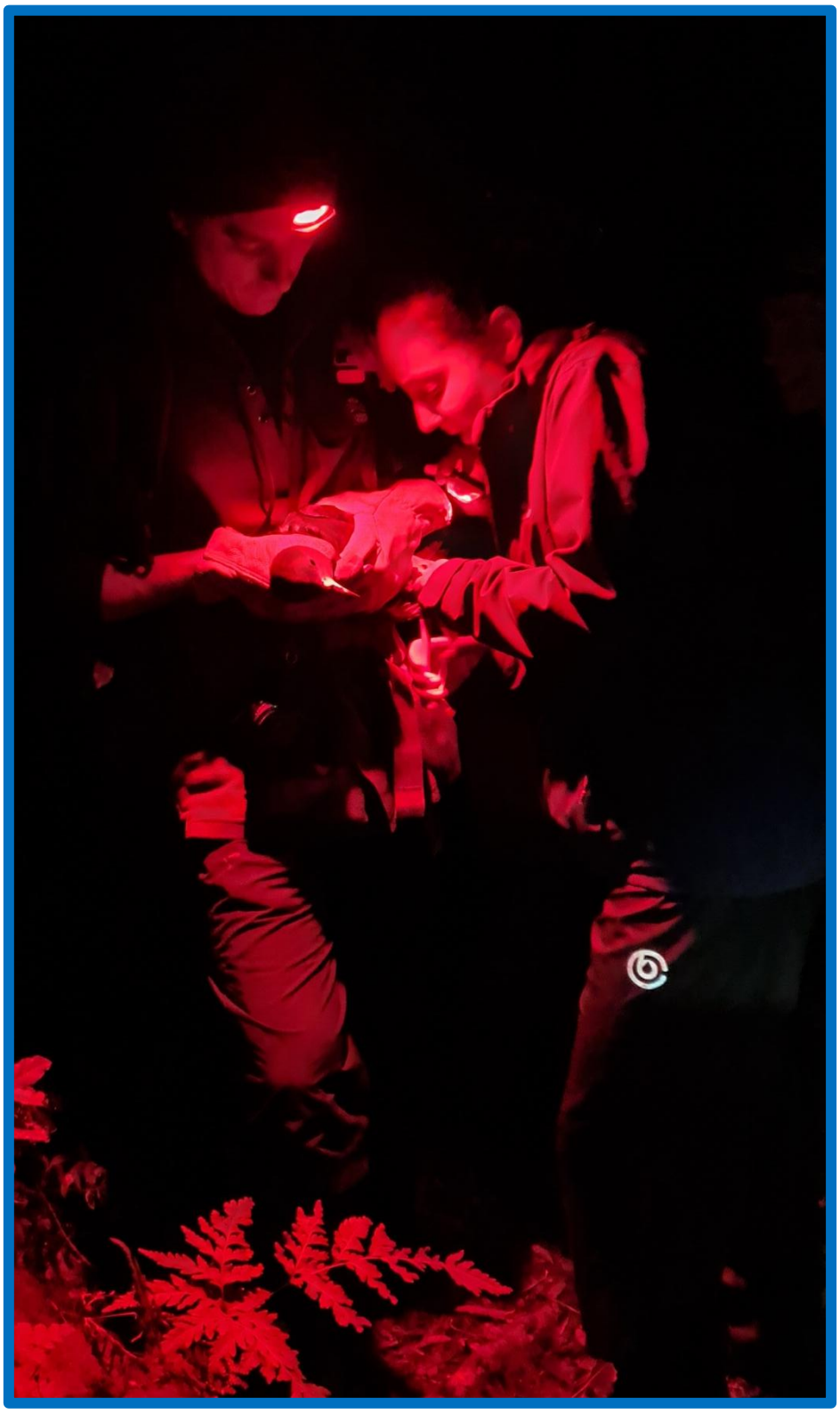
KEY DEMOGRAPHIC PARAMETERS AND POPULATION TRENDS OF TĀKOKETAI/BLACK PETRELS (*PROCELLARIA PARKINSONI*) ON AOTEA/GREAT BARRIER ISLAND: 2024/25



Key demographic parameters and population trends of tākoketai/black petrels (*Procellaria parkinsoni*) on Aotea/Great Barrier Island: 2024/25

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1	Bell *et al.*	4 July 2025	First iteration.
FINAL	Bell *et al.*	19 August 2025	Final version following client and stakeholder review.

Cover Image: Banding a tākoketai/black petrel (*Procellaria parkinsoni*) during nocturnal surveys on Aotea/Great Barrier Island, December 2024 (© Janet Houston).

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EXECUTIVE SUMMARY

This report is part of the ongoing study of the tākoketai/black petrel (*Procellaria parkinsoni*) on Aotea/Great Barrier Island that began in the 1995/96 breeding season.

During the 2024/25 breeding season, 486 tākoketai study burrows were intensively monitored within the Mt Hobson/Hirakimata study area on Aotea.

Throughout the study colony, there were 313 (64.4%) burrows occupied by breeding pairs, 106 (21.8%) occupied by non-breeding birds, and 67 (13.7%) were unoccupied at the time of check. Overall, 212 chicks were produced from the study burrows that are estimated to fledge representing a breeding success rate of 67.7%. This does not include one chick that was banded in April 2025 but subsequently found dead outside the Department of Conservation Okiwi office, later on in June 2025, having presumably crash-landed on its maiden voyage.

Nine census grids were monitored within the study area and accounted for 200 of the inspected study burrows. Of these, 121 were occupied by breeding pairs (60.5%) and 78 chicks were produced representing a fledging success rate of 64.4%.

A total of 714 adults and 218 fledgling chicks were captured during the 2024/25 field season of which with 143 adults were banded this season. Of the 218 fledgling chicks banded during the 2024/25 field season, 213 were banded in study burrows and five chicks were banded in unmarked burrows.

There have been nocturnal surveys undertaken throughout the 30-year study period, but only over the past four seasons (2021/22 to 2024/25) has this effort been increased to 6-8 hour (between 9.15 pm to 5.15 am) searches each night. Over 940 nights of ad-hoc surveys undertaken between 1995/96 and 2020/21, 811 adults were recaptured, of which 365 were already banded and 108 were returned chicks. Over 51 nights of intensive surveys between 2021/22 and 2024/25, 516 adults were recaptured, of which 285 were already banded and 106 were returned chicks. At-sea surveys have also been conducted by WMIL over this same period with only 22 banded birds being caught and nine being recaptured chicks (Burgin 2024). The percentage of banded tākoketai caught out of all captures is higher for intensive night surveys (51.3%) than the ad-hoc surveys (45%). This pattern is also the same for the percentage of returned chicks captured (intensive 19.4%, ad-hoc 13.3%), for the number of banded tākoketai caught per survey (intensive n=5.3, ad-hoc n=2.1) and for returned chicks caught per survey (intensive 2.0 returned chicks/survey, ad-hoc 0.6 returned chicks/survey).

There have been a total of 491 returned chicks recaptured at the colony since they were banded prior to fledging. Of these, 138 returned chicks were identified during the 2024/25 breeding season; 34 of which were caught for the first time at the colony. Not all cohorts were represented this season as no re-captures of returned chicks were made from the 1995/96, 2000/01 and 2002/03 cohorts. Nonetheless, this season saw the highest number of cohorts represented (by at least one individual).

Over the entire study, the majority of the 491 returned chicks were from the 2010 /11 cohort followed by the 2006/07 cohort. Understanding the factors affecting return rates of chicks within the 35-ha study site is vital. It is important to determine whether it is related to low juvenile survival and/or recruitment or if it is simply due to a lack of detection. Understanding juvenile survival and recruitment is necessary for accurate demographic modelling and for species risk assessment modelling. Therefore, it is recommended that efforts to obtain this data is completed with urgency.

There was a single feral cat predation event on an unbanded adult tākoketai (not an individual from the study burrows but found in the wider study area) and two rat predation events at the study colony on Hirakimata this season. Introduced species still pose a threat to the tākoketai population and it is imperative pest control measures continue.

WMIL recommends that:

- Intensive population monitoring using the study burrows on Aotea continues with three visits (i.e., at egg-laying (December); at chick hatching/chick guard in late January/early February and at chick fledging in late April/early May) per season to the colony to track population trends and determine impacts to the birds and colony.
- Multiple-night expeditions to focus on recruitment (i.e., nocturnal surveys to capture pre-breeders and returned chicks) to the Aotea study colony continue to determine juvenile survival and recapture probabilities.
- Implement a remote/trail camera monitoring network at key-launch sites around the colony to identify potential time-windows of peak population activity outside the routinely monitored timeframes
- Sexing of all tākoketai caught during the recruitment expedition and in the study, burrows is completed to determine any sex biases and survival differences between sexes at the colony and within the study burrows.
- A focused, consistent and repeatable mark/recapture session (e.g., a 2-hour capture period at known launch sites) is completed over a number of nights to capture as many banded and unbanded birds as possible. Data can then be used to provide another population estimate and compared to estimates obtained from at-sea captures and burrow monitoring.
- Transect surveys across the core tākoketai habitat (1000 ha around the summit) are undertaken to provide an updated population estimate for the core breeding area of Aotea.
- Satellite tracking of chicks to, and in, South American waters is undertaken to determine migration routes and foraging areas to estimate risk in these areas.
- The possibility of collaborative at-sea capture expeditions in Ecuador is investigated. Discussions between DOC and New Zealand Government with Ecuadorian Government and researchers will have to be conducted to enable this type of collaborative work. At-sea work in Ecuador could determine the level of juvenile tākoketai presence in this area and risk within this area, and this mark/recapture work could provide another population estimate to compare with the New Zealand data.
- Further investigation to determine whether particular areas of the colony are more at risk to rainfall events than others (e.g., burrows in flatter areas being more prone to flooding) as a preliminary assessment on climate resilience.
- In-depth modelling on the effect of age, age difference in pairs, and experience on breeding success is completed to understand this relationship in tākoketai.
- Analysis of, and comparison between, breeding success in public, and non-public, access areas is completed to determine whether human disturbance is a factor at the Aotea colony.
- Investigation into possible deterrence methods of all predators, but specifically feral pigs and feral cats, should be continued at Cooper's Castle.

Key demographic parameters and population trends of tākoketai/black petrels (*Procellaria parkinsoni*) on Aotea/Great Barrier Island: 2024/25

1. INTRODUCTION

1.1 Introduction

Tākoketai/black petrels (*Procellaria parkinsoni*) are a medium–sized endemic seabird that only breeds on Te Hauturu–o–Toi/Little Barrier Island and Aotea/Great Barrier Island in the Tīkapa Moana/Hauraki Gulf of Aotearoa New Zealand. Tākoketai are ranked as Nationally Vulnerable under the New Zealand Threat Classification System and Vulnerable on the IUCN Red List of Threatened Species (BirdLife International 2020, Robertson *et al*. 2021). They are recognised to be at risk of being adversely impacted by high rates of bycatch in commercial fisheries within New Zealand's Exclusive Economic Zone (Richard *et al*. 2020). Of the 196 observed captures of tākoketai recorded between 2002 and 2021, 51.5% of captures occurred in bottom-longline fisheries, 30.1% in surface-longline fisheries and 18.4% in trawl fisheries (https://protectedspeciescaptures.nz/PSCv7/; accessed 18/7/2024). Tākoketai and their offspring on Aotea are also exposed to threats on land, principally depredation by ngeru mohoao/feral cats (*Felis catus*), kiore/rats (*Rattus* spp.) and poaka/feral pigs (*Sus scrofa*) (Bell 2013).

To monitor the ongoing population-level impacts of commercial fisheries on tākoketai, it is necessary to quantify population parameters such as annual burrow occupancy rates, annual reproductive success as well as both adult and juvenile annual survival rates to create accurate assessments of population trends. To this end, a long-term research project aimed at quantifying these population parameters was initiated in 1995/96 (Bell & Sim 1998).

During this first season, three 40 m x 40 m study grids were set up within the largest known breeding colony on Hirakimata/Mt Hobson on Aotea, and all burrows within the grids were marked and monitored. Additional burrows located within 10 m of the public walking tracks were also monitored. In 1998/99, the number of study grids was increased to six, and then to nine in 1999/00 (Bell & Sim 2000a, Bell & Sim 2000b). Over the years, additional burrows situated near the public walking tracks have continued to be added (Bell *et al*. 2023), so that by the 20224/25 season a total of 486 study burrows were being monitored by Wildlife Management International Limited (WMIL).

This report provides a summary of the results of the monitoring work undertaken on Aotea by WMIL in the 2024/25 season, with updates on the trends in several population parameters including both annual burrow occupancy and annual reproductive success.

Te Reo names are used throughout the document for all bird species and locations after the first use (e.g., tākoketai/black petrel or Aotea/Great Barrier Island) and common English names for all mammalian predator species after the first use (e.g., ngeru mohoao/feral cat).

1.2 Objectives

This project extends on demographic work funded by commercial fisheries levies and the Department of Conservation (DOC) and Ministry for Primary Industries/Fisheries New Zealand (MPI/FNZ) since 1996.

As tākoketai are a species at high risk from commercial fisheries in northern New Zealand, continuing research on this species is necessary to gather current rates of adult mortality, breeding success,

juvenile survival and recruitment until suitable mitigation methods significantly reduce the capture risk to this species.

The main objectives for the 2024/25 season are:

a. To monitor the key demographic parameters at the breeding colony of this threatened seabird to reduce uncertainty or bias in estimates of risk from commercial fishing.

b. Capture tākoketai in burrows and on the surface on the upper slopes of Hirakimata to identify returning known aged birds. This is a priority task to determine if low return rates are due to lack of philopatry to the study area rather than high mortality rates.

2. METHODS

2.1 Study site and field methods

The colony residing around the Hirakimata summit represents the highest density of logistically accessible tākoketai on Aotea and has historically been the site of previous research prior to the establishment of WMIL's monitoring programme (Hunter *et al*. 2001, Imber 1976, Imber 1987, Imber *et al*. 2003a, Scofield 1989). Since the 1995/96 season, a network of study burrows (burrows where demographic data is recorded) have been progressively established within a c. 35-ha study area in the vicinity around the Hirakimata summit over the past 30 years and to date include a total of 486 study burrows (Figure 1).

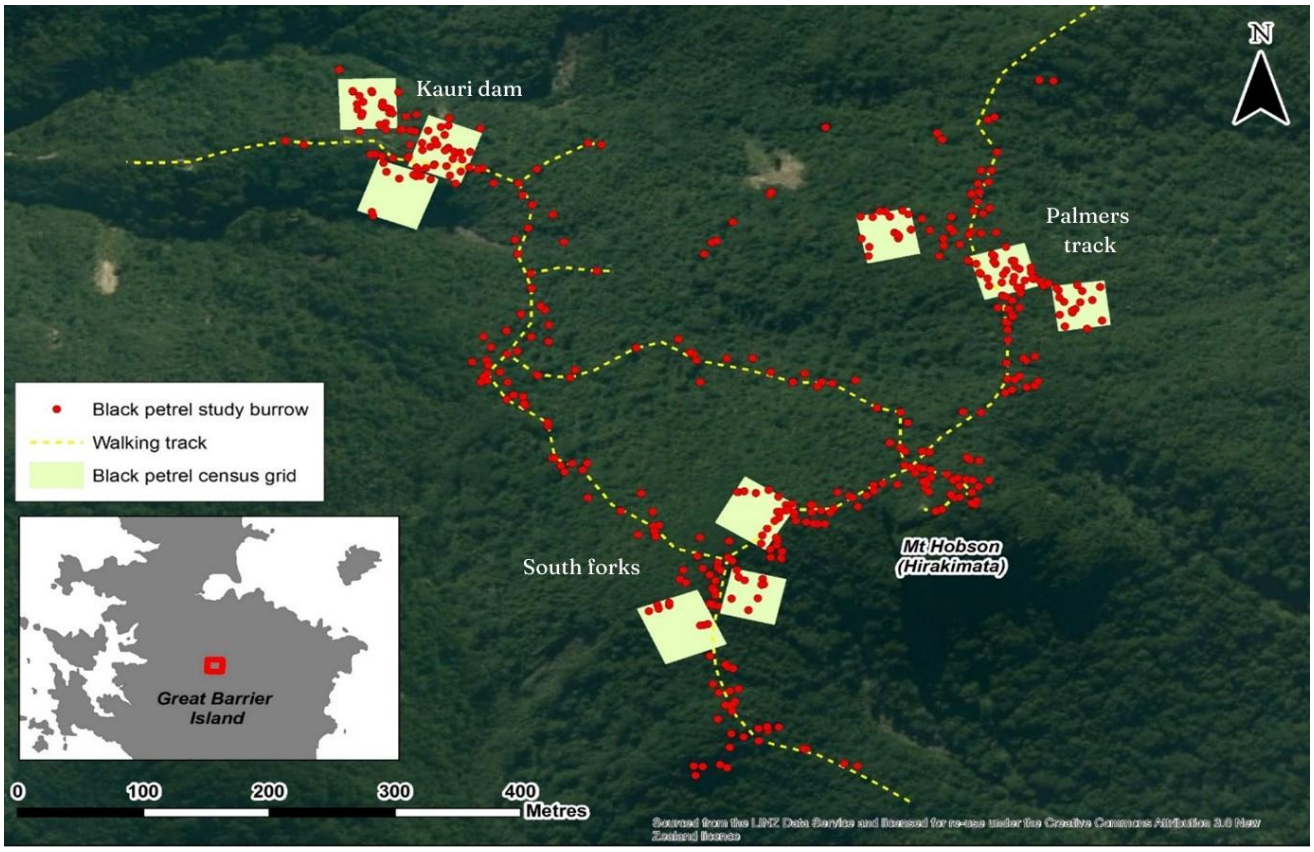

Figure 1: *Map of the 486 tākoketai/black petrel (Procellaria parkinsoni) study burrows (red points) that have been established in the vicinity of Mt Hobson/Hirakimata on Aotea/Great Barrier Island. Yellow dashed lines are public walking tracks and highlighted squares are census grids (Kauri Dam, South Forks and Palmers Track).*

Of those 486 study burrows, 200 are located within nine 40 m x 40 m census grids (census grid burrows) and the other 286 burrows (non-census grid burrows) were arbitrarily established due to their close proximity (within 25 m) of the public walking tracks (Figure 1; Figure 2). The first three census grids were established within previously known high density tākoketai breeding habitat located over ridgelines in remnant (un-milled) podocarp broadleaf mixed forest. The boundaries of the second three and last three census grids were randomly selected within appropriate habitat hypothesised to maintain breeding populations (e.g., over ridgelines within either remnant forest or secondary re-growth forest (where kauri, *Agathis australis*, was only logged selectively in the past; Figure 1). Burrow occupancy rates in the nine study grids likely provide the most consistent and representative measure of burrow occupancy across the study area, as they are unaffected by the occasional preferential addition of active breeding burrows to the study burrow network outside of the study grids that has occurred in previous years. For this reason, trends in burrow occupancy rates within the study grids provide the best measure of whether tākoketai burrow occupancy is increasing or decreasing within the study area.

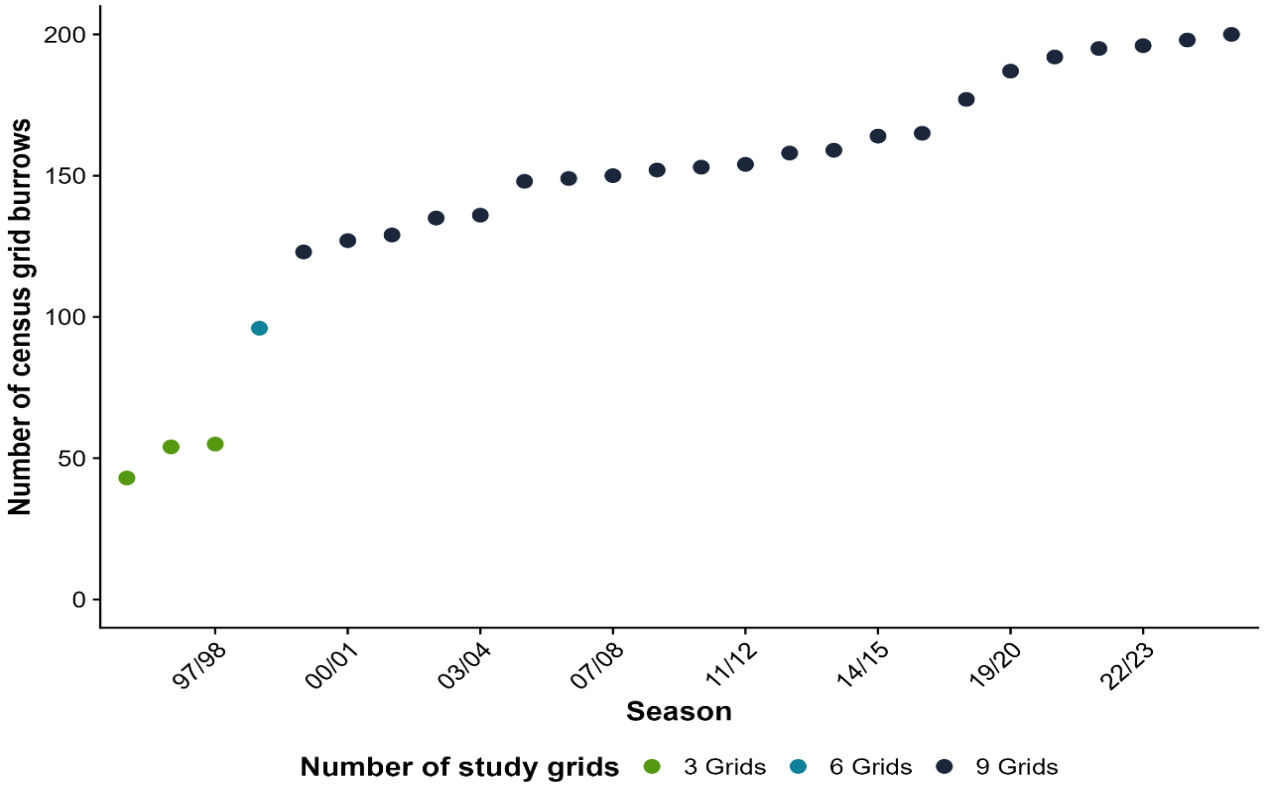

***Figure 2**: The total number of tākoketai/black petrel (Procellaria parkinsoni) census grid burrows monitored each breeding season on Aotea/Great Barrier Island between 1995 to 2025.*

Census grid sizes at the start of the study were 100 m^2 in January 1996 and subsequently increased to 1,600 m^2 by April 1996 during the chick fledging period. Being within the vicinity of public walking tracks allows faster traversing of the study site. The average distance from the centre of the nine census grid ranges between 1 to 61.7 m (mean distance is 25 m ± 17.4 m SD) from walking tracks. At the establishment of a census grid, an exhaustive grid-like search was conducted on foot by researchers traversing together in a line one metre apart within the grid boundaries. All occupied, empty, and potential (burrows in the process of being dug out) were recorded. On three separate occasions (December 2009, January 2010, and December 2015) further searches by a seabird detection dog was conducted in each census grid to identify any missed burrows.

Up until the 2018/19 season, when burrows are found outside of census grids, they are automatically added into the study if they are found within c. 10 m of the public walking tracks, or if the burrow when found, contained a breeding adult that was previously banded as a chick. Currently any new burrows

that are found are only added into the study if they are within the census grids (Figure 2; Figure 3) or contain a breeding adult that was previously banded as a chick. In the 2024/25 season, two burrows were found in the S1 and P1 grids (Figure 2; Figure 3).

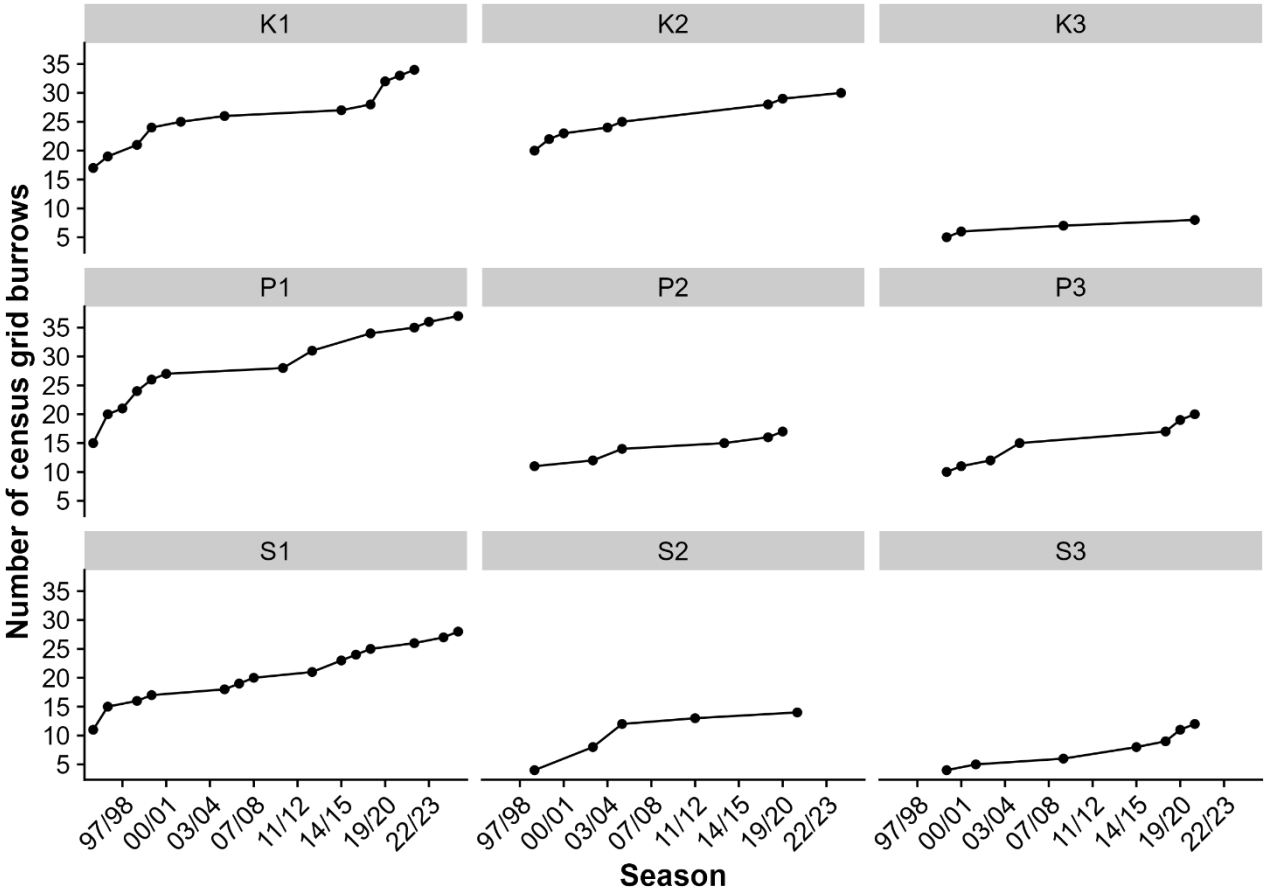

Figure 3: *The cumulative number of tākoketai/black petrel (Procellaria parkinsoni) census grid burrows added to each census grid on Aotea/Great Barrier Island between 1995/96 and 2023/24 breeding seasons (Note: the first point for each study grid indicates when the study grid was first established. Only the breeding seasons where burrows were added are included along the x-axis). S indicates the three South Forks grids; K indicates the three Kauri Dam grids; and P indicates the three Palmers grids.*

The additional 286 arbitrarily selected study burrows were found through a combination of haphazard searching and seabird detection dogs. Other burrows that are found further than c. 10 m from public walking tracks are noted and are often returned to in subsequent seasons in order to increase the number of banded birds into the study but data on breeding status and occupancy is not collected.

To facilitate accurate monitoring, 331 study burrows have had study hatches installed (68.4%), providing easier access to one or more chambers within the burrow and to reduce interaction time with the bird by the researchers. Of these burrows with hatches installed, larger/internally complex burrows have had two (18 burrows, 3.7%) or three (10 burrows, 2%) hatches installed. Depending on the internal complexity of the burrow, and accessibility and temperament of the bird within the burrow, retrieval of the bird may take between 1-30 min.

The first visit to the Hirakimata study area occurred from 13 to 18 December 2024 (Trip 1) and was focused on identifying recruits (i.e., birds banded as chicks returning to the colony to breed). Timing of this trip was aimed at coinciding with the end of the pre-egg laying exodus and the start of the egg laying period when large numbers of birds would be returning to the island. During the recruitment trip, the field team systematically searched the colony each night from 9.15 pm (approximately 1 hour after dusk when the first non-breeding tākoketai began calling) to 5.15 am (dawn). Birds were captured on the surface, at launch sites, and in burrows. For all night-work, captured birds were checked for bands, and

any band numbers were recorded. If unbanded, a band was applied to the bird's leg, before being subsequently released. Before release, a small mark was made on each bird's forehead using white correction fluid to provide a means of visually checking whether a bird had already been captured, if encountered again on the same or another subsequent night.

The study burrows were monitored during Trip 1 as well as again in two subsequent trips to the colony. The second visit occurred from 22 January to 4 February 2025 (Trip 2) and coincided with late incubation/hatching/early chick rearing. Trip 3 occurred from 9 April to 12 April 2025 and coincided with the late chick rearing/chick fledging period. The number and timing of trips to the colony each breeding season vary from year to year depending on additional project goals, but at a minimum will contain two trips to cover the late incubation/hatching/early chick rearing and late chick rearing/fledging (Figure 4).

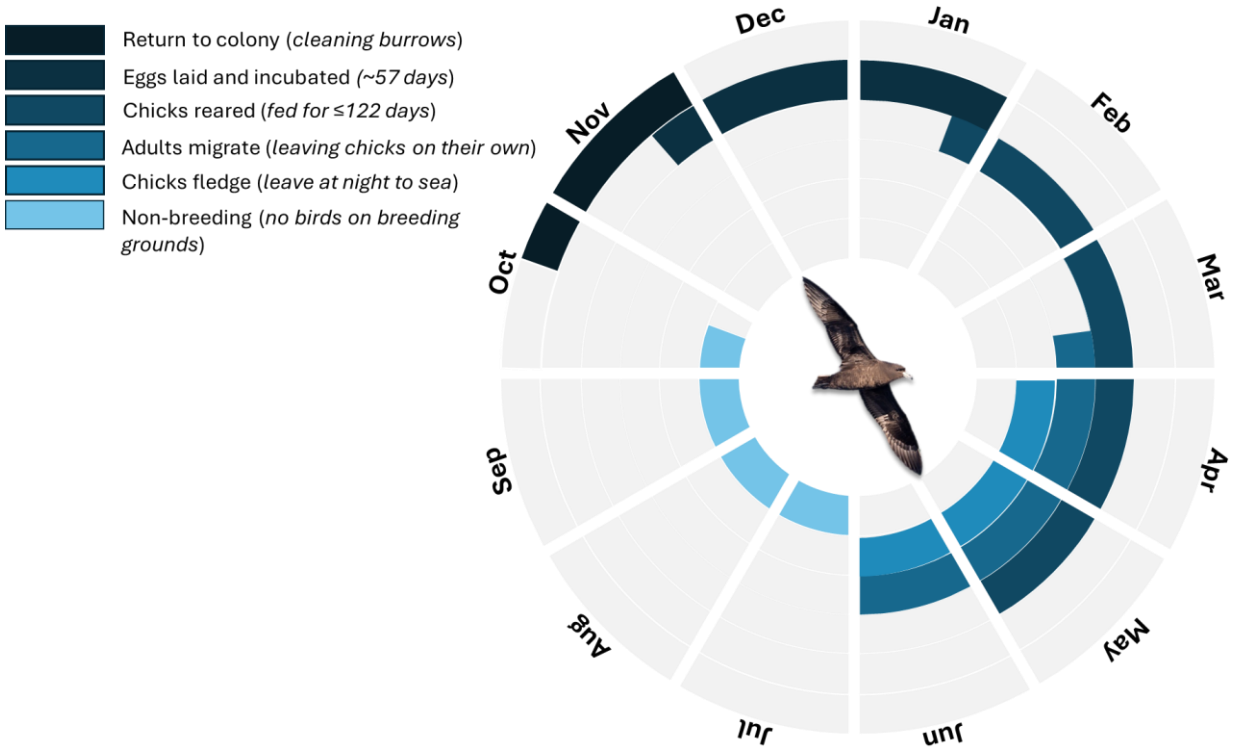

Figure 4: *Breeding cycle of tākoketai/black petrel (Procellaria parkinsoni) on Aotea/Great Barrier Island (WMIL, unpublished data; also see Imber 1987).*

To determine the breeding status and breeding outcome for each burrow, and to record the adult occupants of each burrow, each study burrow was checked once in Trip 1, at least twice during Trip 2 and once in Trip 3. During each burrow check, any resident adults were removed from the burrow and checked for bands. If banded, the band number of each bird was recorded, otherwise the bird was banded with an individually numbered size H stainless steel band. Unbanded adult petrels that are caught in a burrow on an egg or with a chick are given an age estimate of eight years (from the average age of first breeding; Appendix 1), whereas an unbanded adult caught on the surface or in a burrow without an egg or chick was assumed to be at least five years of age (estimated from median age of first return; Appendix 1). Before being returned to the burrow, a small mark was made on each bird's forehead using white correction fluid to provide a means of visually checking whether the same bird was still occupying the burrow during subsequent checks, without having to remove the bird to read its band. The presence of an egg or chick was also recorded. After each check, a palisade of twigs was erected over the burrow entrance to provide a quick means of checking for recent activity (i.e., arrivals and departures of parents switching incubation/brooding duties) during subsequent checks of the same burrow. As Trip 2 was carried out during hatching/early chick rearing a large amount of these

burrow checks were carried out at night, particularly during the second half of the trip, to intercept adults returning to feed chicks. During the final trip of each season (Trip 3), fledgling chicks found in the study burrows were extracted and banded.

For the two trips focused on assessing the burrow demographics (Trip 2 and Trip 3) the field team also spent several nights walking the public track system within the 35-ha study area, capturing any tākoketai found on the ground.

2.2 Blood and feather collection

In collaboration with Auckland Council (Gaia Dell'Ariccia, Senior Seabird Scientist, Environmental Evaluation and Monitoring Unit) feather samples were collected from a sample of breeding adults and their chicks in order to estimate levels of contamination by heavy metals, especially mercury, and evaluate the inherent health risk. Five chest feathers were plucked from 57 breeding adults in the study burrows during the January/February site visits and 48 chicks in the April/May site visits between 2021 and 2025 seasons (Table 1). The feathers were stored in an individual feather envelope with band number, date, and burrow number recorded. Auckland Council will be analysing this data and reporting separately.

In collaboration with the University of Tasmania (Dr Lauren Roman, DECRA Fellow, Institute for Marine and Antarctic Studies) blood samples were collected from known age adults this season and last season, and from this season's chicks with the aim of developing a DNA ageing tool for petrels. Blood was taken from 36 known-age adults captured from within the study burrows or on the surface during nocturnal surveys in the 2023 and 2024 December site visits and 21 chicks from study burrows in the 2025 April site visit (Table 1). Samples were collected using a small gauge needle to collect a drop of blood from the tarsal vein. The drop of blood was swabbed onto a DNA collection card. An ethanol swab was used to clean the skin and if required, a cotton swab was used to stop the bleeding. The University of Tasmania will be analysing the data and reporting separately.

Table 1: *Collection date and number of blood and feather samples from tākoketai/black petrel (Procellaria parkinsoni) collected between 2020/21 and 2024/25 seasons, Aotea/Great Barrier Island.*

Site Visit (Season)	Feather samples		Blood samples	
	Adult	Chick	Known-age adult	Chick
April 2025 (2024/25)				21
December 2024 (2024/25)			3	
April 2024 (2023/24)		9		
January 2024 (2023/24)	25			
December 2023 (2023/24)			33	
May 2022 (2021/22)		35		
January 2022 (2021/22)	25			
May 2021 (2020/21)		4		
January 2021 (2020/21)	7			
Total	**57**	**48**	**36**	**21**

2.3 Data entry and analysis

All mark–recapture and breeding status data were entered into a Microsoft Access™ database at the completion of each trip. Microsoft Excel™ was used to calculate breeding occupancy and breeding success as percentages which was then compared to previous years. The statistical software R (R Core Team 2022) using the '*ggplot2*' package (Wickham 2016) was also used to visualise a variety of demographic parameters (e.g., number of burrows within the study, the age distribution and mean age and its standard deviation, and number of birds banded as chicks re-sighted at the colony from each cohort).

3. RESULTS

3.1 Burrow occupancy and breeding success

The number of census grid burrows has continued to increase over time since 1995 from 43 in 1995/96 to 200 in 2024/25, with two burrows added in the current season (Figure 2 and 3). One of the new burrows was discovered in the S1 grid being dug out by a non-breeder during trip 1. The other burrow was discovered during trip 3 and contained a healthy chick.

Some study burrows within the grids have been abandoned and are not used by breeding tākoketai, but these burrows are still checked each season on the chance that may become re-occupied. Tākoketai are highly unlikely to be displaced by other seabird species present on Aotea. The only other burrow-nesting seabird that nests inland on Aotea and overlaps with the habitat of tākoketai is the tītī/Cook's petrel (*Pterodroma cookii*), approximately 65% smaller in size than tākoketai (Bell & Sim 1998, Imber et al. 2003b). However, due to sustained predation by mammalian predators, this species is at an extremely low density on Aotea (Imber et al. 2003b), and within the study site only seven tītī breeding burrows have ever been found.

Breeding occupancy within the 200 census grid burrows was 60.5%, with breeding success estimated at 78 tākoketai chicks likely to fledge (64.5%) from their burrows in the 2024/25 season (Table 2; Figure 5). For the 286 monitored non-census grid burrows, breeding occupancy was recorded at 67.1% and breeding success estimated at 134 tākoketai chicks likely to fledge this season (70.2%,Table 2; Figure 5; Figure 6). Since the beginning of the study, breeding occupancy in the census grid burrows has typically been lower than the breeding occupancy recorded in non-census grid burrows. This pattern has continued this season with breeding occupancy in census grid burrows sitting 5.7 percentage points lower than non-census grid burrows (Figure 5). Whereas estimated breeding success between the two burrow sets typically mirror one another from season to season (Figure 6), however the drop in estimated breeding success in census grid burrows this season compared to the previous season was slightly more pronounced (5.7 percentage points) than in the non-census grid burrows (3.5 percentage points, Table 2) compared to the previous season. Additionally, breeding occupancy and estimated breeding success in both sets of burrows fell below their long-term averages (Figure 5; Figure 6).

Table 2: *Summary of breeding success of tākoketai/black petrels (Procellaria parkinsoni) (percentage of breeding burrows that fledged a chick; number of successful fledglings followed in parentheses) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island between 1995 and 2025 within census grid study burrows, non-census grid burrows and all burrows combined. The number of census grid, non-census and total number of study burrows are the number of burrows where a breeding attempt was observed.*

Breeding season	Census grid burrows breeding success % (no. of chicks fledged)	No. of census grid burrows occupied by breeders % (total census grid burrows)	Non-census grid burrows breeding success % (no. of chicks fledged)	No. of non-census grid burrows occupied by breeders % (total no. non-census burrows)	Total Breeding success % (No. of chicks fledge)	Total no. of study burrows occupied by breeders % (total no. study burrows)
2024/25	65.0% (78)	60.0% (200)	70.2% (134)	66.8% (286)	68.2% (212)	64.0% (486)
2023/24	70.2% (85)	61.1% (198)	73.7% (137)	65.0% (286)	72.3% (222)	63.4% (484)
2022/23	56.3% (67)	60.7% (196)	63.0% (121)	67.8% (283)	60.5% (188)	64.9% (479)
2021/22	77.3% (99)	65.6% (195)	71.4% (142)	70.1% (284)	73.7% (241)	68.3% (479)
2020/21	72.4% (84)	60.4% (192)	78.3% (159)	71.5% (284)	76.2% (243)	67.0% (476)
2019/20	71.6% (78)	58.3% (187)	78.9% (142)	64.5% (279)	76.1% (220)	62.0% (466)
2018/19	69.6% (71)	57.6% (177)	76.5% (143)	69.0% (271)	74.0% (214)	64.5% (448)
2017/18	63.5% (61)	54.2% (177)	62.6% (114)	67.2% (271)	62.9% (175)	62.1% (448)
2016/17	67.0% (69)	58.2% (177)	68.6% (129)	68.6% (274)	68.0% (198)	64.5% (451)
2015/16	62.6% (67)	64.5% (166)	68.9% (126)	67.8% (270)	66.6% (193)	66.5% (436)
2014/15	68.3% (69)	62.0% (163)	70.0% (133)	70.4% (270)	69.4% (202)	67.2% (433)
2013/14	68.4% (65)	60.1% (158)	71.1% (123)	65.0% (266)	70.1% (188)	63.2% (424)
2012/13	80.9% (72)	56.7% (157)	80.9% (152)	70.9% (265)	80.9% (224)	65.6% (422)
2011/12	82.0% (73)	57.8% (154)	70.3% (90)	50.4% (254)	75.1% (163)	53.2% (408)
2010/11	60.4% (58)	62.7% (153)	61.4% (105)	67.6% (253)	61.0% (163)	65.8% (406)
2009/10	73.3% (63)	56.6% (152)	73.1% (122)	65.5% (255)	73.1% (185)	62.2% (407)
2008/09	69.8% (67)	63.6% (151)	73.0% (127)	71.9% (242)	71.9% (194)	68.7% (393)
2007/08	71.0% (66)	62.4% (149)	80.7% (134)	72.8% (228)	77.2% (200)	68.7% (377)
2006/07	81.3% (78)	64.9% (148)	83.4% (136)	72.1% (226)	82.6% (214)	69.3% (374)
2005/06	70.7% (65)	62.6% (147)	60.8% (101)	75.5% (220)	64.3% (166)	70.3% (367)
2004/05	75.0% (63)	57.5% (146)	77.2% (115)	67.7% (220)	76.4% (178)	63.7% (366)
2003/04	79.2% (61)	58.3% (132)	63.6% (89)	70.7% (198)	69.1% (150)	65.8% (330)
2002/03	60.0% (45)	57.7% (130)	56.0% (70)	65.4% (191)	57.5% (115)	62.3% (321)
2001/02	76.3% (61)	64.5% (124)	66.1% (76)	69.7% (165)	70.3% (137)	67.5% (289)
2000/01	81.6% (62)	62.8% (121)	72.4% (71)	70.0% (140)	76.4% (133)	66.7% (261)
1999/00	67.1% (55)	69.5% (118)	77.8% (77)	72.8% (136)	72.9% (132)	71.3% (254)
1998/99	70.8% (46)	68.4% (95)	80.2% (65)	68.6% (118)	76.0% (111)	68.5% (213)
1997/98	77.1% (27)	67.3% (52)	81.4% (57)	70.7% (99)	80.0% (84)	69.5% (151)
1996/97	68.6% (24)	66.0% (53)	76.2% (48)	71.6% (88)	73.5% (72)	69.5% (141)
1995/96	87.0% (20)	53.5% (43)	94.7% (36)	80.9% (47)	91.8% (56)	67.8% (90)
Average	**71.5% (63)**	**61.2% (147)**	**72.7% (109)**	**69.0% (222)**	**72.3% (172)**	**66.0% (369)**

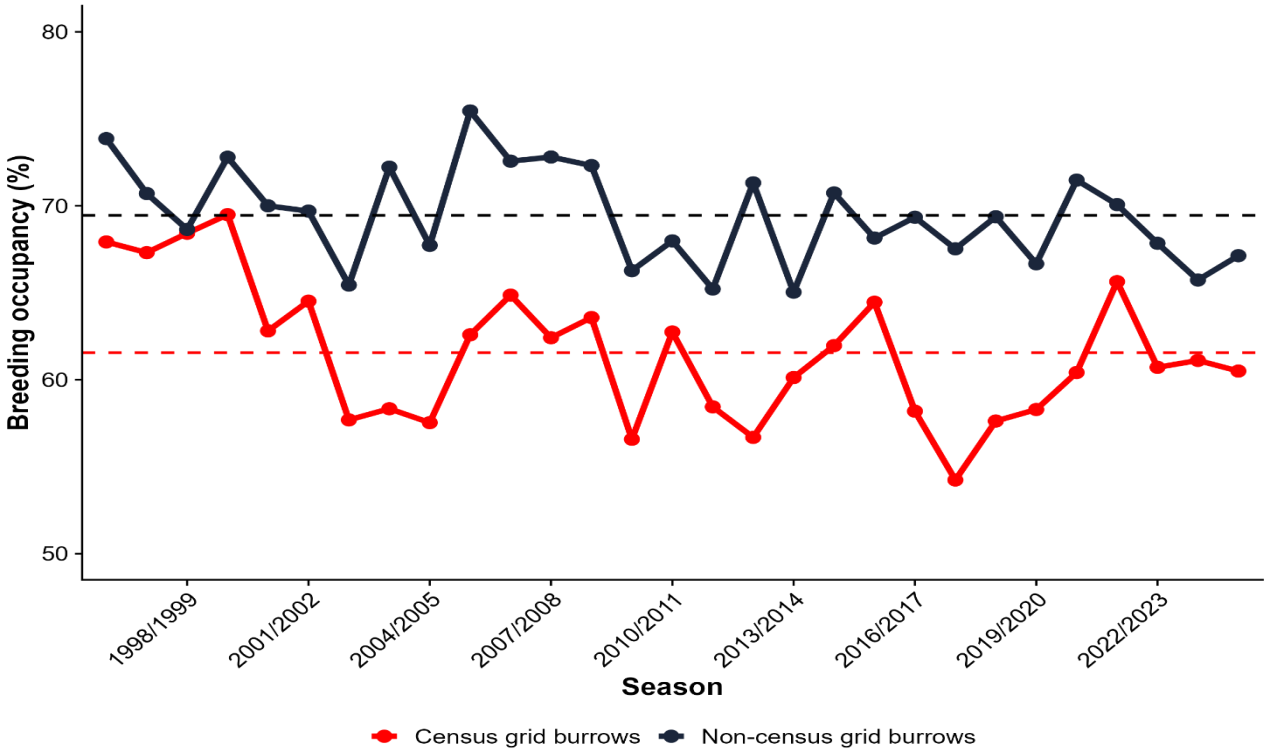

Figure 5: *Percentage of census grid burrows (n=200, red) and non-census study burrows (n=286, black) occupied by breeding tākoketai/black petrels (Procellaria parkinsoni) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island between 1997 and 2025 (dotted line represents the mean occupation of census grid burrows (red) and non-census study burrows (black) over 30 years by breeding tākoketai).*

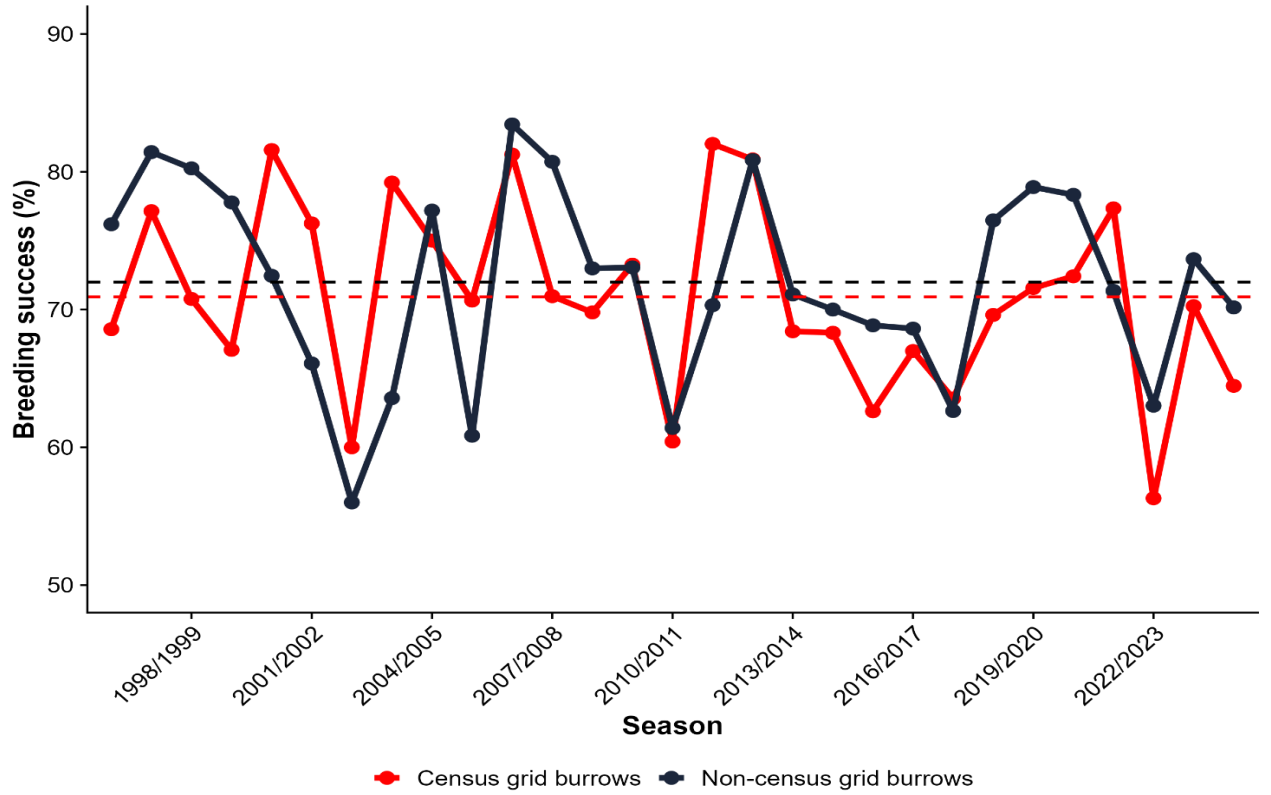

Figure 6: *Breeding success (percentage of breeding burrows that fledge a chick) of all tākoketai/black petrel (Procellaria parkinsoni) non-census study burrows (n=286, black) and census grid burrows (n=200, red) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island between 1996 and 2025 (the dotted line represents the mean breeding success of census grid burrows (red) and non-census grid burrows (black) over 30 years).*

A summary of breeding success and the number of chicks fledged each season is available in Appendix 1. See Appendix 2 for detailed histories of burrows within each census grid.

Causes of breeding failure in the 2024/25 breeding season included rat predation of two eggs found in burrows with rat chew marks (*n*=2), eggs or chicks that disappeared from breeding burrows (*n*=42), crushed eggs (*n*=19), infertile eggs (*n*=2), abandoned eggs (*n*=4), embryonic deaths (*n*=15) and chick deaths (*n*=16).

There were no detected feral cat predations on tākoketai chicks within the study burrows this season. However, there was one feral cat predation of an unbanded adult tākoketai within the study area, (not from a study burrow). Table 3 provides a summary of known feral cat predation events of tākoketai at the Hirakimata/Mt Hobson study site since 1995.

Table 3: *Number of tākoketai/black petrel (Procellaria parkinsoni) chicks from study burrows, chicks from non-study burrows and adults predated by ngeru mohoao/feral cats within the Hirakimata/Mt Hobson colony on Aotea/Great Barrier Island between 1995 and 2025.*

Season	Number of chicks from study burrows predated	Number of chicks from unmarked burrows predated	Number of adults predated
1995/96	0	1	2
1996/97	0	1	1
1997/98	0	0	1
1998/99	2	1	2
1999/00	2	1	2
2000/01	1	1	1
2001/02	2	1	1
2002/03	3	4	2
2003/04	2	1	1
2004/05	0	0	1
2005/06	2	1	1
2006/07	0	1	0
2007/08	0	0	0
2008/09	0	1	0
2009/10	0	0	0
2010/11	1	0	0
2011/12	0	1	1
2012/13	0	1	0
2013/14	0	1	0
2014/15	0	1	0
2015/16	0	2	0
2016/17	2	3	2
2017/18	0	0	1
2018/19	0	1	1
2019/20	0	1	1
2020/21	0	1	1
2021/22	1	1	1
2022/23	0	1	1
2023/24	0	0	0
2024/25	0	0	1
Total	**18**	**28**	**25**
Average	**0.6 ± 0.2 (SE)**	**0.9 ± 0.2 (SE)**	**0.8 ± 0.1 (SE)**

3.2 Population age structure of known aged breeding birds

Of the 189 breeding tākoketai identified within census grid burrows in 2024/25 season, 46 of those identified birds were of known age (banded as chicks) and the rest (144) had been first caught as adults.

The age range of known age breeding birds within the census grid burrows was between 3 and 27 years, with 12-year-old birds being the most frequently resighted (Figure 7). There were 302 breeding tākoketai identified in the non-census grid burrows in the 2024/25 season of which 48 were of a known age and the other 254 birds that had been banded as adults. The age range of known age birds in the non-census grid burrows spanned from 6 to 26 years old, with the most frequent ages concentrating around two peaks, one peak at 8 and 11 years and another peak at 18 and 20 years old (Figure 7).

Since monitoring began in 1995/96 the average known age of breeding tākoketai within study burrows located inside and outside the census grids has slowly increased over time from an average age of 5 and 6 ± 1.4 years in 1995/96 to an average age of 13.1 ± 5.3 and 13.3 ± 5.1, respectively (Figure 7). Overall, the average age of known age breeding birds within census grid burrows has been generally increasing every breeding season since the peak observed in 2002/03. The average age of known aged breeding bird in burrows not in the census grid burrows has largely followed the same pattern of birds within census grid burrows.

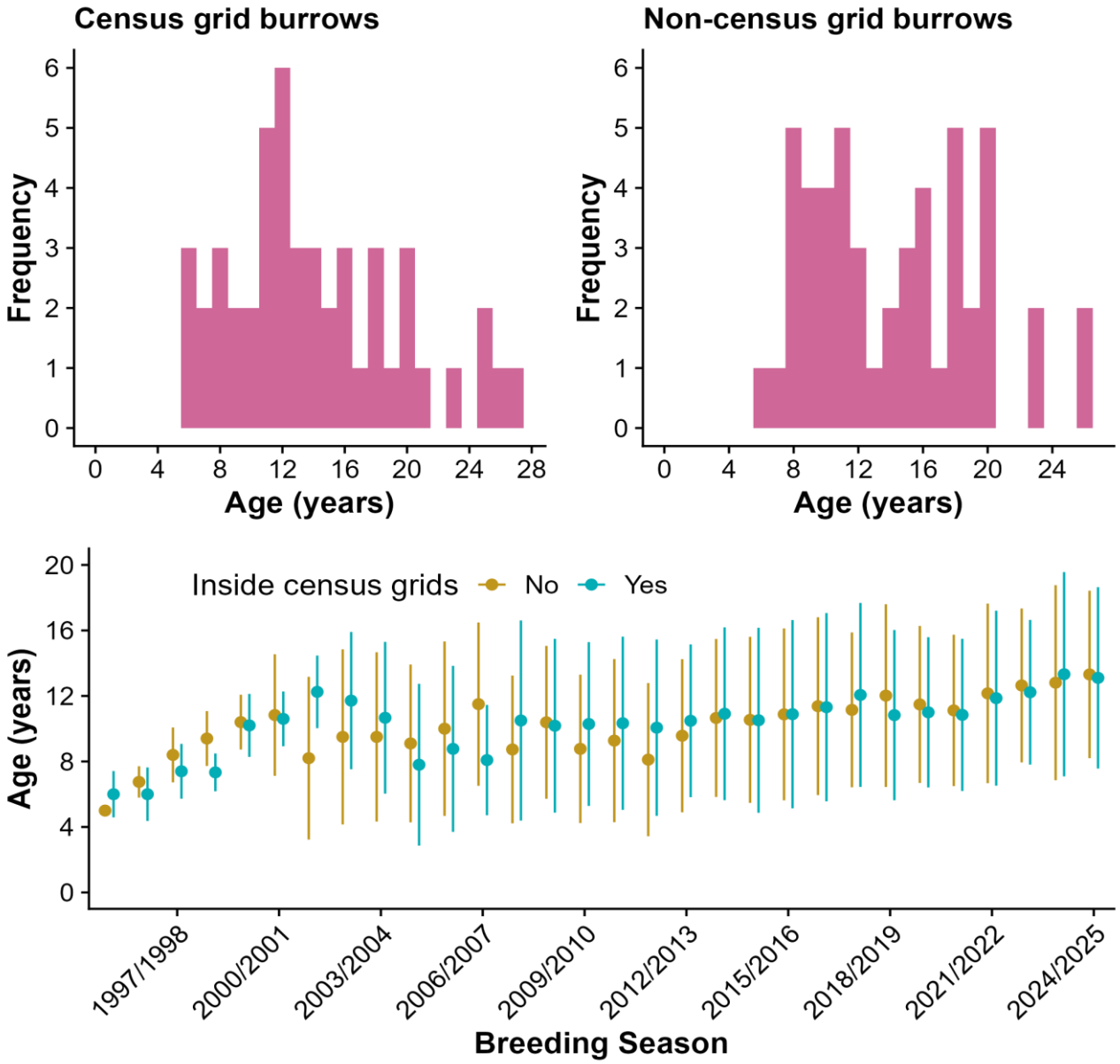

Figure 7: *The age distribution of the breeding tākoketai/black petrel (Procellaria parkinsoni) adults studied at Hirakimata/Mt Hobson on Aotea/Great Barrier Island located within study burrows within (top left graph, n=48 known aged birds) census grids and (top right graph, n=51 known aged birds) non-census grid burrows during the 2024/25 season, that are of known age and the mean (± standard deviation) age of known age breeding tākoketai/black petrels per season between 1995/96 and 2024/25 (bottom graph).*

3.3 Recaptures during intensive nocturnal surveys

There have been nocturnal surveys undertaken throughout the 29-year study period, but only over the past four seasons (2021/22 to 2024/25) has this effort been increased from ad hoc, 1 to 2-hour search of the colony per each night survey to a sustained 4 to 8-hour (between 9.15 pm to 5.15 am) search of the colony per each night survey. During the intensive survey period (2021/22 to 2024/25), between 10 and 16 surveys were undertaken each season equating to between 42.9% and 53% of all nights spent at the colony (Table 4). Prior to this intensive period (1995/96 to 2020/21), under 20% of nights spent at the colony had an ad-hoc night survey completed (Table 4). Over the past four years, a total of 41 intensive night surveys were undertaken, with 10-night surveys completed during the 2024/25 season (Table 4).

Table 4: *Number of tākoketai/black petrels (Procellaria parkinsoni) caught during night surveys within the Hirakimata/Mt Hobson colony on Aotea/Great Barrier Island between 1995 and 2025.*

	Ad-hoc on-land surveys (1995/96 to 2020/21)	Intensive on-land night surveys					All on-land night surveys combined (all years)
		2021/22	2022/23	2023/24	2024/25	All intensive on-land surveys combined	
Number of days at colony	940	25	28	37	19	**109**	1049
Number of surveys	171	13	12	16	10	**51**	222
Percentage of night surveys over trip	18.2%	52.0%	42.9%	43.2%	52.6%	**46.8%**	21.2%
Total number of birds	811	55	264	108	134	**561**	1372
Number of new (unbanded) birds	446	24	127	57	68	**276**	722
Number of banded birds	365	31	137	51	66	**285**	650
Number of returned chicks	108	13	52	18	23	**106**	214
Average number of birds caught per survey	4.7	4.2	22.0	6.8	13.4	**11.6**	10.2
Average number of new (unbanded) birds caught per survey	2.6	1.8	10.6	3.6	6.8	**5.7**	5.1
Average number of banded birds caught per survey	2.1	2.4	11.4	3.2	6.6	**5.9**	5.0
Number of returned chicks caught per survey	0.6	1.0	4.3	1.1	2.3	**2.0**	1.0
Percentage of banded birds out of all birds caught	45.0%	56.4%	51.9%	47.2%	49.3%	**50.8%**	47.4%
Percentage of returned chicks out of all birds caught	13.3%	23.6%	19.7%	16.7%	17.2%	**18.9%**	15.6%
Percentage of new (unbanded) birds out of all birds caught	55.0%	43.6%	48.1%	52.8%	50.7%	**49.2%**	52.6%

The percentage of banded tākoketai caught out of all captures is higher for intensive on-land night survey work (50.8%) than the ad-hoc on-land night surveys (45%) (Table 4). This pattern is also the same for the percentage of returned chicks captured (intensive 18.9% vs ad-hoc 13.3%) (Table 4). The number of banded tākoketai caught per survey is also higher for the intensive on-land night surveys (6.6 tākoketai caught/survey) compared to the ad-hoc on-land night surveys (2.1 tākoketai caught/survey)

(Table 4). Again, this pattern continues for the number of returned chicks caught per survey, with intensive surveys (2.3 returned chicks/survey) being higher than ad-hoc surveys (0.6 returned chicks/survey).

3.4 Banding and recaptures

A total of 714 adults and 218 fledgling chicks were captured during the 2024/25 season (Table 5). Of those adults caught, a total of 143 adults were banded during the 2024/25 season (Table 5), of which 76 were captured in study burrows, 11 were captured in unmarked burrows and 56 were caught on the forest floor. There were 74 adults banded during the recruitment trip in December. Of the 218 fledgling chicks banded during the 2024/25 season, 213 were from study burrows and five were from unmarked burrows (Table 5). One chick was known to have died, possibly in the process of fledging (leaving the burrow and on its maiden flight from the colony). The chick was banded on 11 April and was subsequently found on the 5 June outside the DOC office in Okiwi, likely having crash landed. It is unknown the reason why this occurred. This chick's death has been taken into account on the calculations of this season's breeding success estimate. The remains of a banded chick from the previous season was found in its burrow this season indicating it did not fledge. The previous season's breeding success data was updated with this new information.

Table 5: *Summary of the number of tākoketai/black petrels (Procellaria parkinsoni) captured, banded, re-captured adults and chicks (i.e., resighted at the colony after fledging) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island between 1995 and 2025.*

Breeding season	Total number captured	Number of all adults recaptured	Number of adults banded	Number of fledglings banded in study burrows	Total number fledglings banded
2024/25	932	571	143	213	218
2023/24	853	504	121	214	228
2022/23	793	490	174	119	129
2021/22	999	638	107	227	254
2020/21	1103	703	136	233	264
2019/20	960	636	154	155	170
2018/19	898	562	122	201	214
2017/18	800	541	84	154	175
2016/17	1074	476	244	173	354
2015/16	978	617	177	171	184
2014/15	918	536	167	200	215
2013/14	860	539	120	185	201
2012/13	1021	546	249	212	226
2011/12	551	340	48	161	163
2010/11	685	457	83	139	145
2009/10	789	510	107	160	172
2008/09	875	489	183	191	203
2007/08	594	347	56	191	191
2006/07	672	371	85	210	216
2005/06	632	332	155	141	145
2004/05	650	330	135	177	185
2003/04	536	358	67	108	111
2002/03	637	392	182	60	63
2001/02	621	346	115	136	160
2000/01	555	320	98	128	137
1999/00	542	257	150	130	135
1998/99	404	158	130	111	116
1997/98	296	151	59	81	86
1996/97	300	51	180	67	69
1995/96	129	30	40	48	59

Of the parents occupying the 313 breeding study burrows (121 breeding census grid burrows, 192 non-census grid breeding burrows) during the 2024/25 breeding season, a total of 491 (78.4%) were captured and identified (190 burrows had both parents identified, 102 burrows had one parent identified and 13 burrows had no parents identified (either chicks alone or a failed breeding attempt before its first check during the December trip; Table 6). The percentage of parents captured within census grids was 78.5% (a total of 190 of 242 parents were identified and captured within the 121 census grid burrows where a breeding attempt took place). In the non-census grid burrows, the percentage of parents captured was 80.2% (a total of 308 of 384 parents where a breeding attempt took place).

Table 6: *Summary of the number of tākoketai/black petrel (Procellaria parkinsoni) study burrows where a breeding attempt took place where either no parents, one parent, or two parents were identified during the 2024/25 breeding season at the Hirakimata/Mt Hobson on Aotea/Great Barrier Island.*

Number of parents identified	In study burrows	In census grid burrows	In non-census grid burrows
0 parents	13	8	5
1 parent	102	36	66
2 parents	198	77	121
Total breeding study burrows	**313**	**121**	**192**

3.5 Recaptures of returned chicks

The cumulative number of birds banded as chicks returning back to the colony (returned chick), either as a breeding or non-breeding adult continues to steadily increase over time (Figure 8). In the 2024/25 breeding season the cumulative number of returned chicks recorded back at the colony to date was 491, with 138 returned chicks recaptured at the colony this season (Figure 8).

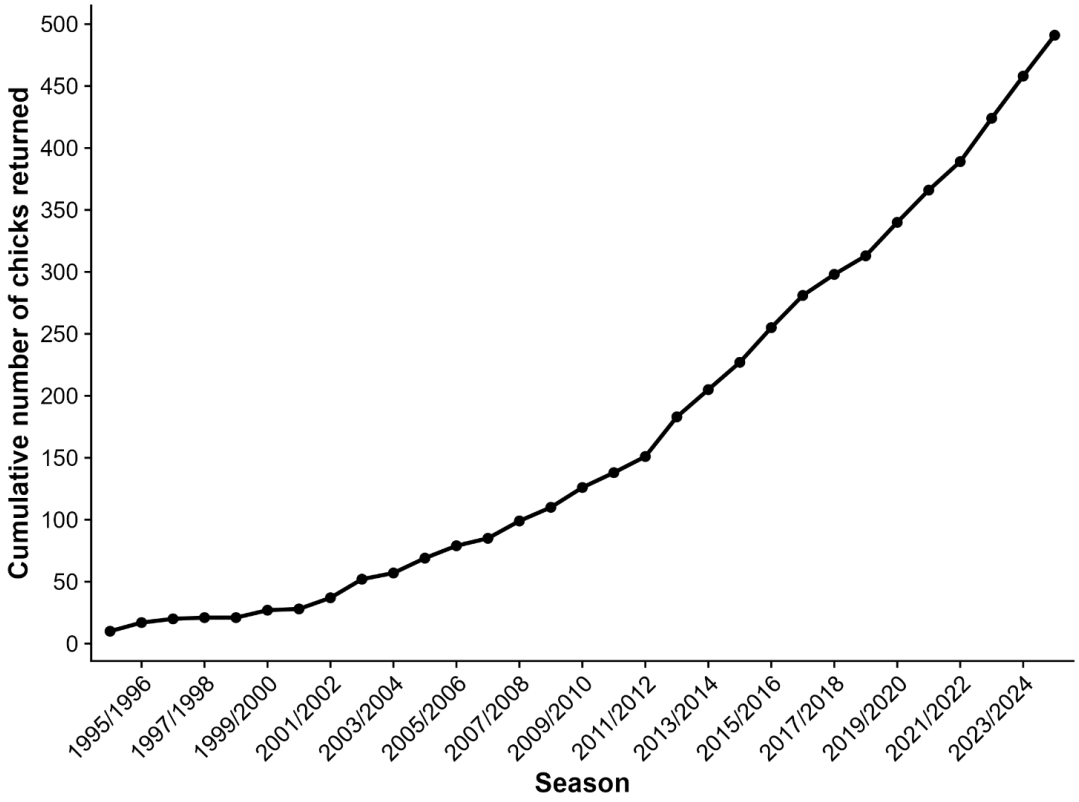

Figure 8: *The cumulative number of tākoketai/black petrel (Procellaria parkinsoni) adults banded as chicks that have returned to the colony as adults at Hirakimata/Mt Hobson on Aotea/Great Barrier Island. Note: the time period before 1995 encompasses approximately 20 years of chick banding records (1972-1992; e.g., the first returned chick was banded in 1972 and recaptured again in 1977).*

Of the 138 returnees identified this season, 33 returned chicks that had not been previously recorded since being banded prior to fledging. Of those 33 returnees, 11 were found as non-breeders in study burrows, 10 were found in study burrows as breeders, with 1 returnee found breeding in an unmarked burrow. The rest (12 birds) were found on the surface during nocturnal searchers of the colony. The median return age of these 33 returnees was 6 years (mean return age was 7.7 ± 4.4 (sd); min and max 4-19 years).

The minimum age at which tākoketai are generally first detected back at the at the Hirakimata colony after fledging is from 4 years of age onwards, though a small proportion have been resighted as young as 3 years of age (Figure 9). Returnees aged 4, 5, 6 and 7 years make up the largest age groups of birds that are first detected after fledging, after which, first detections of birds aged 8 or older decrease substantially (Figure 9). The median age at first detection at the colony was 6 years old (mean 7.0 ± 3.5 (sd); min and max 3-35 years).

Age at first detected breeding is observed in birds as young as four years old but detections generally peak at birds that detected at 6 or 7 years old (Figure 9). The median age of breeding at first detection was 7 years old (mean 8.1 ± 3.4 (sd); min and max 4-27 years). Similarly for birds that are detected breeding successfully for the first time, age at first detection can also be as young as four years old, but detections also generally peaks around 7 years of age (Figure 9). The median age of successful breeding at first detection was 8 years old (mean 8.4 ± 3.2 (sd); min and max 4-27 years).

Despite the ongoing bi-annual visits to the study colony since 1995/96, some birds can remain undetected for many years. The oldest tākoketai recaptured for the first time since being banded as a chick, occurred during the 2022/23 season when a 34.7-year-old was caught on the surface clacking outside a random, non-monitored burrow. The oldest returned chicks detected for the first time this season were two birds aged 19 years old, both found breeding in study burrows.

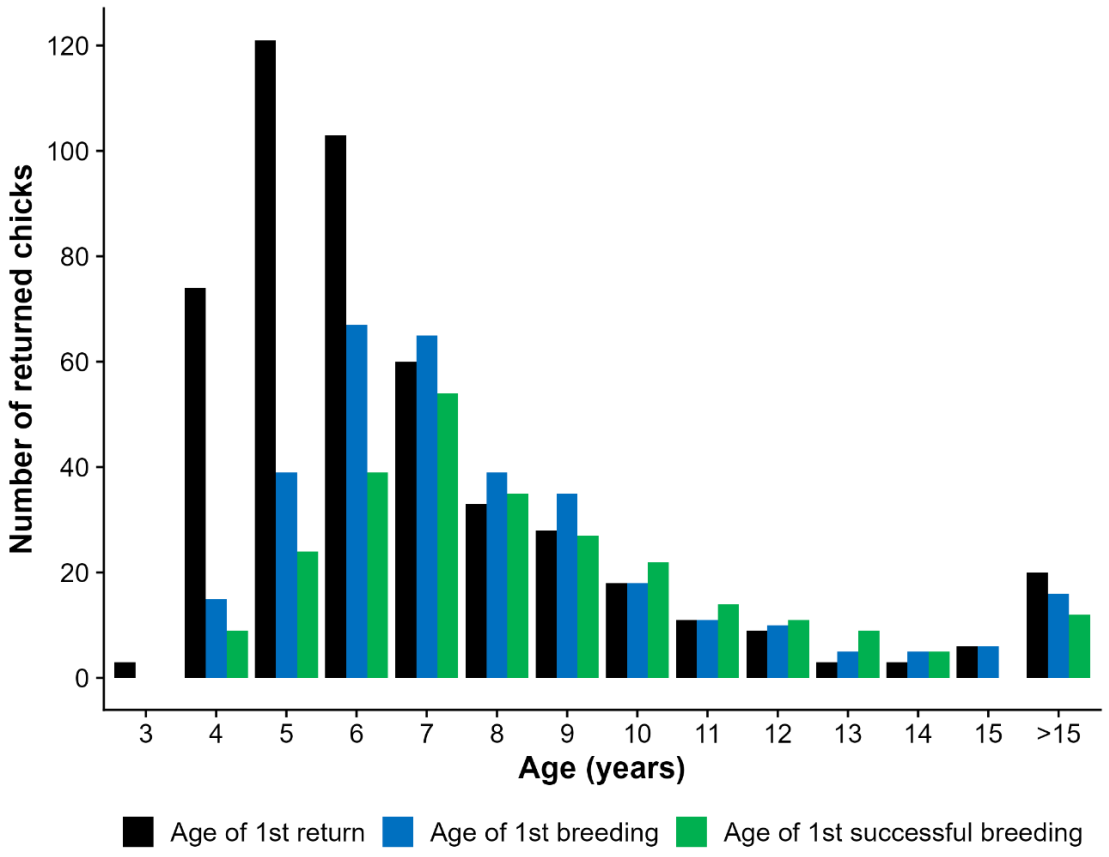

Figure 9: *The age of tākoketai/black petrels (Procellaria parkinsoni) that were banded as chicks that have been resighted back at the colony after fledging for the first time (black bars), when they were first detected breeding (blue bars) and when they were first detected successfully breeding (green bars) on Aotea/Great Barrier Island.*

Among birds whose breeding status could be determined at first detection after fledging, the youngest individuals were mostly non-breeders (Figure 10). As age at first detection increased, the proportion of birds that were identified as non-breeders declined, and birds identified breeding at first detection increased. By 7 years post-fledging, the majority of birds were classified as breeders upon their first detection at the colony (Figure 10).

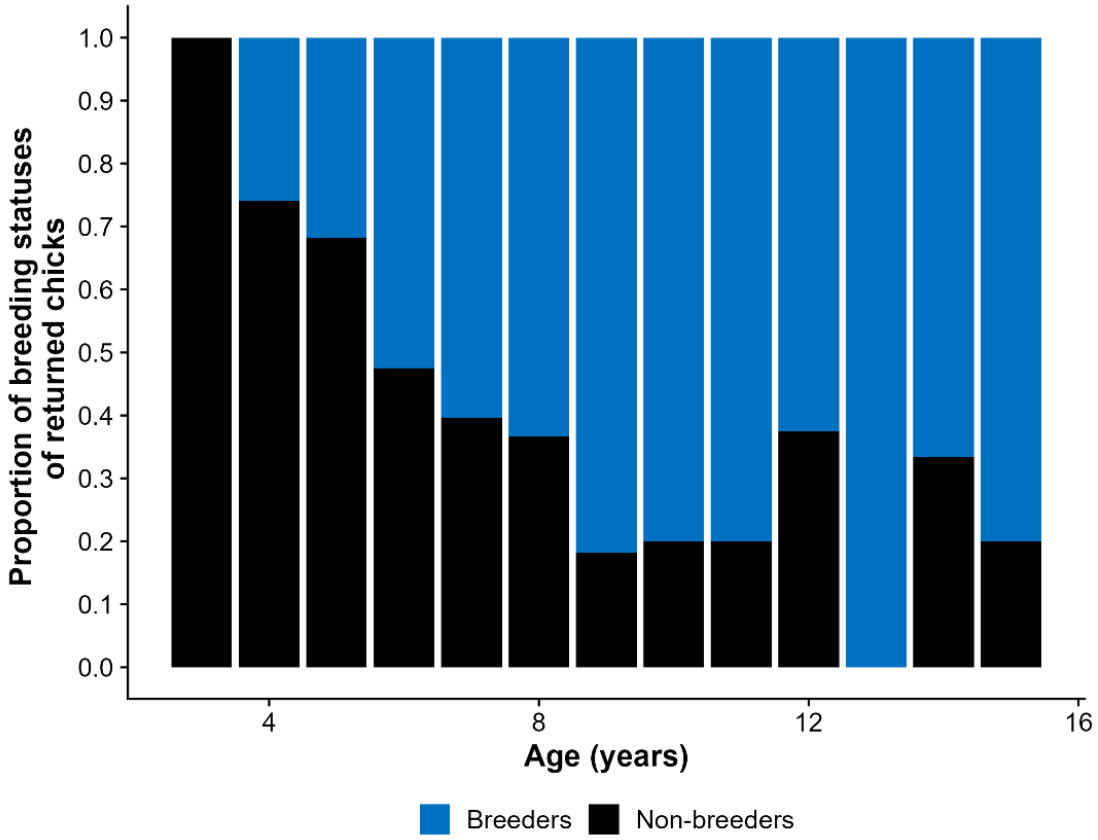

Figure 10: The proportion of non-breeders (black bars) and breeding (blue bars) of tākoketai/black petrels (Procellaria parkinsoni) at the age of first detection (where breeding status could be determined) back at the Hirakimata colony after fledging (returned chick), on Aotea/Great Barrier Island. Note, birds older than 15 years were excluded.

In addition to sightings at the study colony, 24 adults that were banded as chicks have to date been resighted at sea. These include 9 sightings by WMIL, 11 sightings by The Seabird Trust (formerly the Northern New Zealand Seabird Trust), and four incidental sightings by members of the public and other research vessels (Burgin 2024; Gaskin & Whitehead 2024). The age distribution of these recaptures is skewed toward young birds, with 6 years old being the most frequent, followed by 7 and 5 years old (Figure 11). The sighting of a 2-year-old was made on an Australian research vessel located in Bass Canyon off East Gippsland, Victoria, Australia, representing the youngest re-sighting of a tākoketai to date. Four of those returnees were birds banded on Hauturu, the rest being banded on Aotea. Only four birds have additional re-sighting data back at the Hirakimata colony.

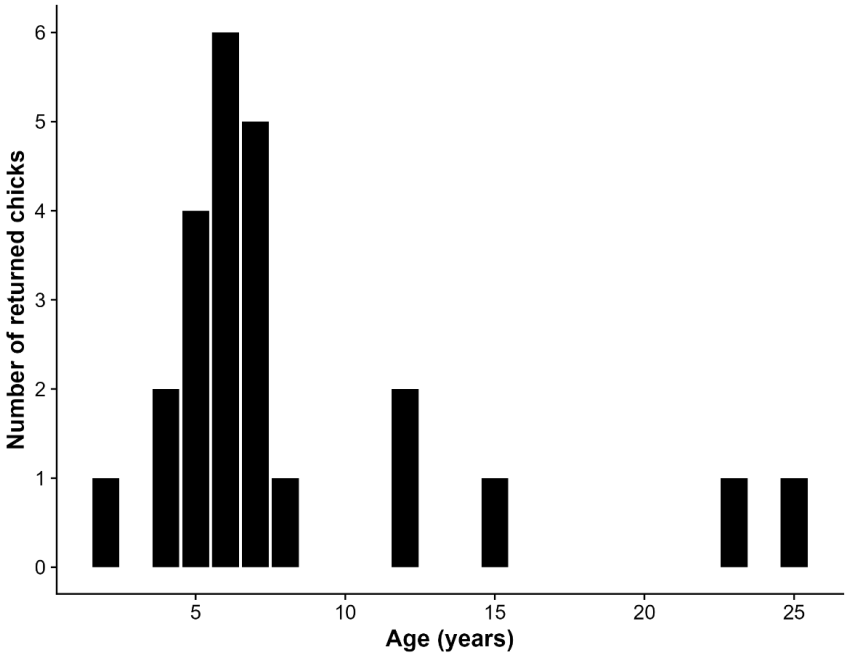

Figure 11: The age of tākoketai/black petrels (Procellaria parkinsoni) that were banded as chicks (either on Aotea/Great Barrier Island or Hauturu/Little Barrier Island that have been resighted back at sea.

Despite a similar number of chicks being banded each year prior to fledging (Figure 12), the percentage of chicks (from each cohort) returning to the colony at Hirakimata on Aotea as adults over the life-time of the study remains very low (Figure 13). Over the lifetime of the study, a cohort's return rate averages at 10.9 % ± 2.8 (SD) of the chicks banded during that season being resighted again. Excluding the most recent cohort that have individuals returning (cohorts 2020/21), the rate of return of each cohort ranges as low as 6.7% returned (1995/96) and as high as 15.9% (2010/11) with the majority of cohorts (again excluding the most recent cohort), having had at least 10% of the chicks that were banded in that season being resighted back at the colony at some point over the study (Figure 13).

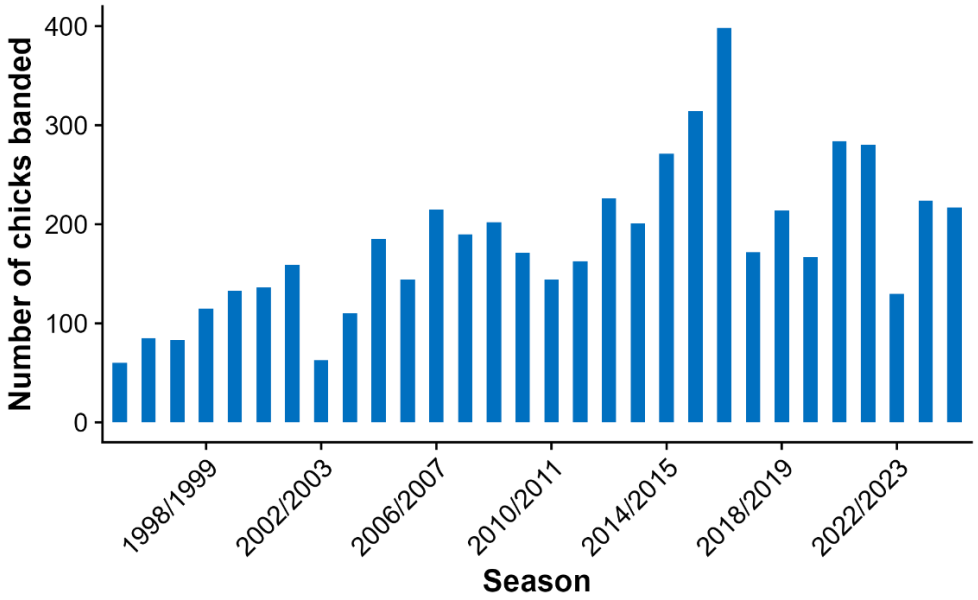

***Figure 12:** The number of tākoketai/black petrel (Procellaria parkinsoni) chicks banded per year at Hirakimata/Mt Hobson on Aotea/Great Barrier Island. Note: the number of chicks banded before 1995 (583) was intentionally not plotted. There was a higher number of chicks banded in 2016/17 (n=395) due to random transect surveys undertaken within the 35-ha study area in May 2017 resulting in chicks in random burrows being banded. There was a reduced number of chicks banded in 2022/23 (n=130) due to the reduced breeding success caused by Cyclone Gabrielle and poor weather conditions over the chick banding period.*

Of the 138 returnees resighted during the 2024/25 breeding season, the majority (*n*=12, 8.7%) of returned chicks were from the 2016/17 breeding season (3.4% of the total number of chicks banded that season), followed closely by the 2013/14 cohort (*n*=11, 8.0%, or 5.5% of that cohort) (Figure 13).

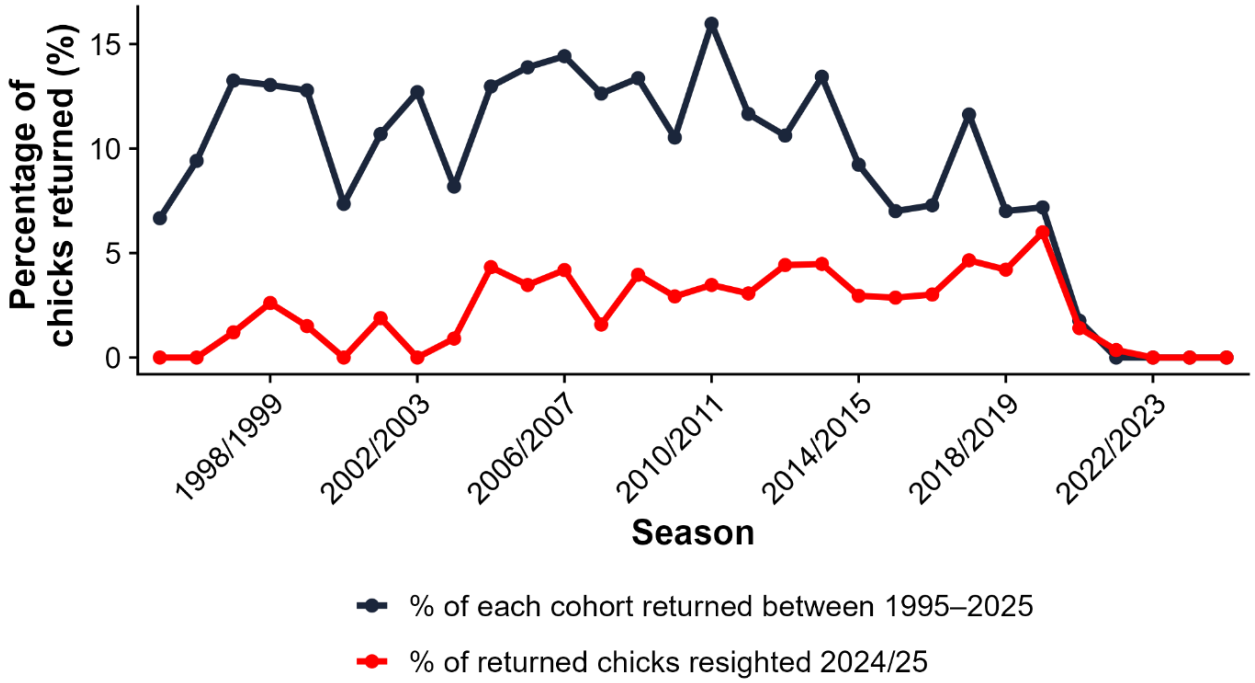

Figure 13: *The percentage of all banded chicks (1995-2025 black points and line; 2024/25 breeding season red points and line) from a particular breeding season cohort returning to the colony at Hirakimata/Mt Hobson on Aotea/Great Barrier Island as adults. Note: the number of chicks banded, and percentage returned before 1995 was intentionally not plotted. There were 583 chicks banded before 1995 and of these 6.0% have been re-observed as adults.*

The composition of each breeding seasons' cohort (i.e., the breeding season the chick hatched in) continues to vary each breeding season (Figure 14; Figure 15). Across the entirety of the study, the number of adults that were banded as chicks that subsequently returned to the colony as adults has increased steadily since the study's inception. Owing to the time lag between fledging and maturity, for the first five years of the study, only pre-1995 returned chicks are represented, which then steadily increase overtime (Figure 14; Figure 15). Changes in effort (e.g., increased night-work, multiple trips per year, use of detection dogs, etc.) likely accounts for the increase in re-sightings from 2011/12 to 2012/13 and 2019/20 onwards (Table 3).

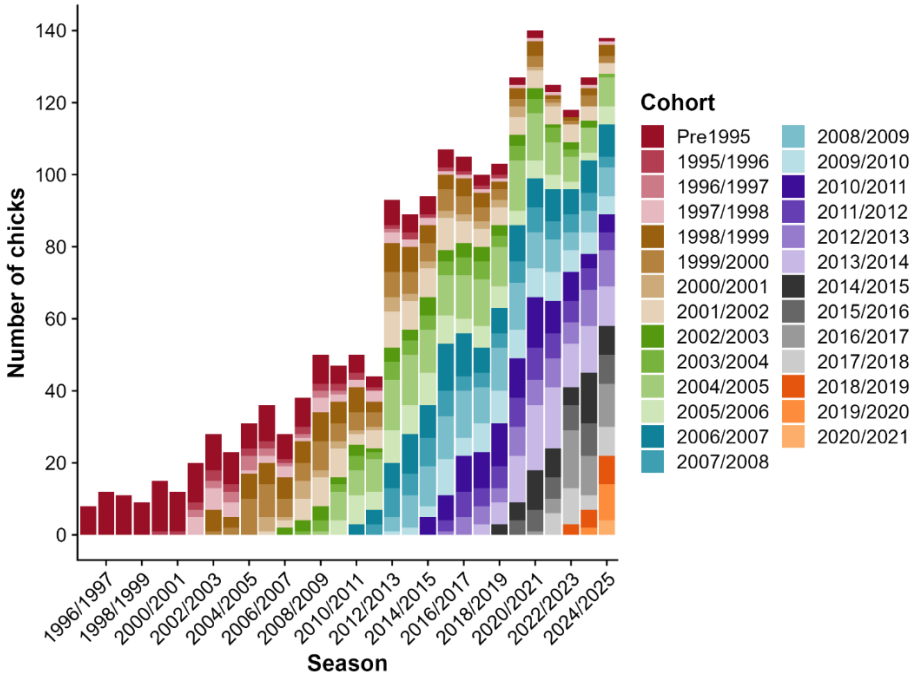

Figure 14: *The number of tākoketai/black petrel (Procellaria parkinsoni) returned chicks (banded as chicks and re-observed as adults) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island during each breeding season (from 1995/96 to 2024/25), categorised by the breeding season the bird was born in (i.e., breeding season cohort). Note: the time period before 1995 encompasses approximately 20 years of chicks banding records (1972–1992, e.g., the first returned chick was banded in 1972 and recorded again in 1977).*

Whilst the proportion of individuals representing different cohorts fluctuates from year to year, the proportion of individuals representing older cohorts tend to diminish over time as younger cohorts return to the breeding colony (Figure 15). For instance, in the 2024/25 breeding season, the pre-1995, 1997/98, 2003/04 cohort were each only represented by a single individual

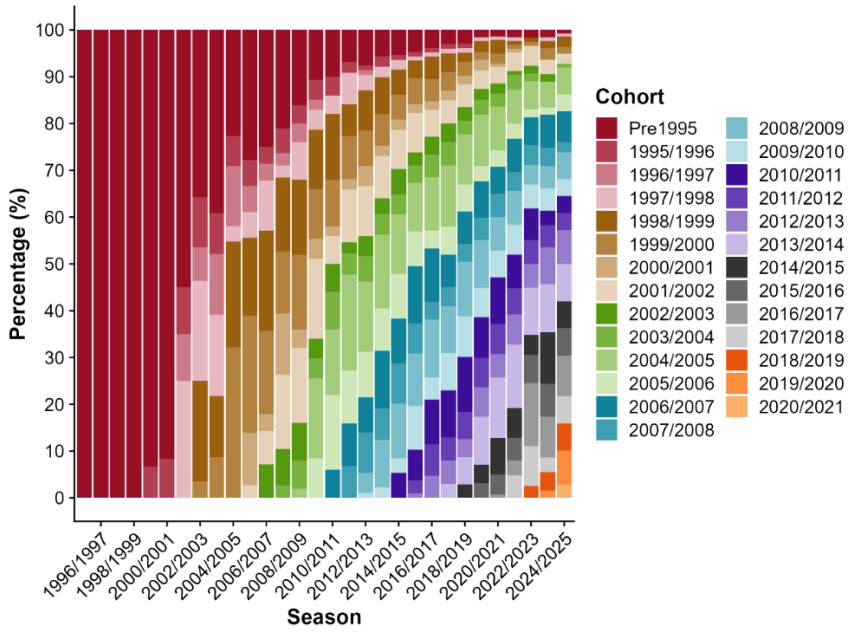

Figure 15: *The composition of each breeding seasons returned tākoketai/black petrel (Procellaria parkinsoni) chicks - proportion of returned chicks (banded as chicks and re-observed as adults) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island during each breeding season (from 1995/96 to 2023/24), categorised by the breeding season the bird was born in (i.e., breeding season cohort). Note: the time period before 1995 encompasses approximately 20 years of chicks banding records (1972–1992, e.g., the first returned chick was banded in 1972 and recorded again in 1977).*

Almost all cohorts (prior to the 2021/22 cohort) of chicks that were banded since the study began in 1995/96 were represented by at least one individual present around the colony this season, with the number of unique cohorts represented at its highest level since the study began (Figure 16). No chicks from the 1995/96, 2000/01, or 2002/03 cohorts were seen back at the colony this season.

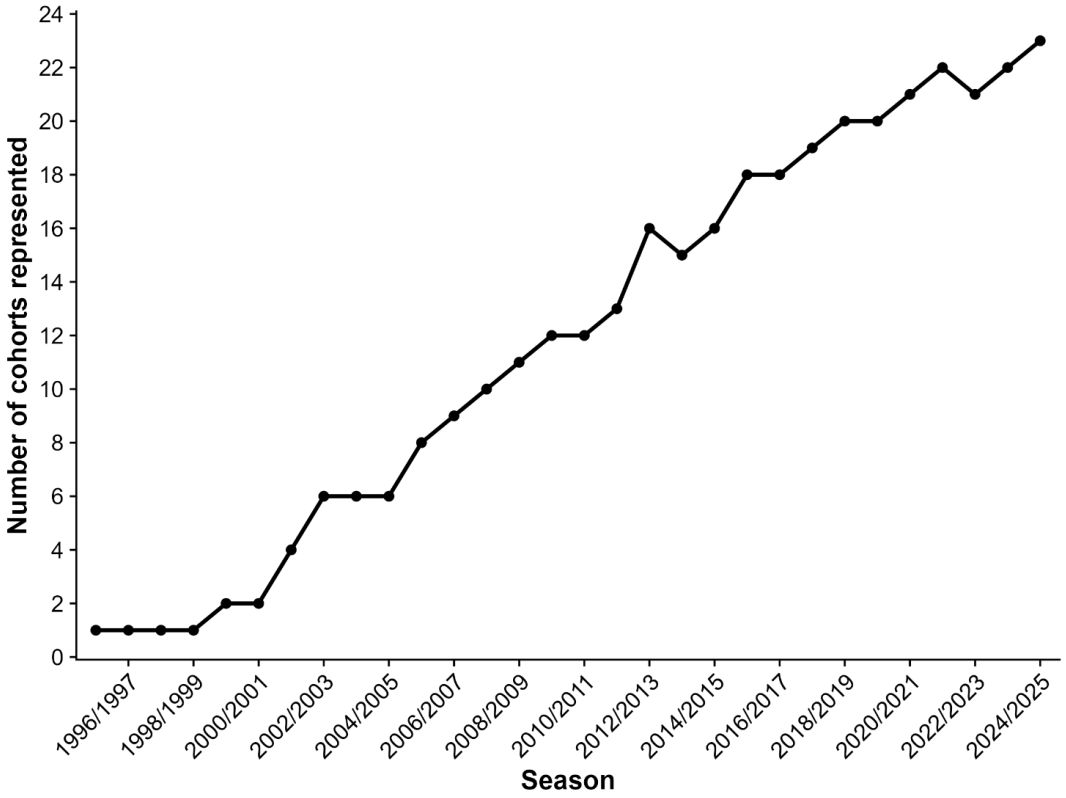

Figure 16: *The number of different breeding season cohorts represented by tākoketai/black petrel (Procellaria parkinsoni) returned chicks (banded as chicks and re-observed as adults) at Hirakimata/Mt Hobson on Aotea/Great Barrier Island during each breeding season (from 1995/1996 to 2024/25). Note: the time period before 1995 encompasses approximately 20 years of chicks banding records (1972–1992, e.g., the first returned chick was banded in 1972 and recorded again in 1977).*

4. DISCUSSION

4.1 Breeding Success and Population Demography

The 2024/25 season's tākoketai estimated breeding success was mixed between the two sets of study burrows. Whilst estimated breeding success in the non-census grid burrows, 70.2% fell just below the long-term average of 72%, estimated breeding success in the census grid burrows ended up being much lower at 64.5%, falling 6.4 percentage points below the 30-year average (70.9%) (Table 2; Figure 6). For the most part since the inception of the study, estimated breeding success between the two sets of study burrows have tended to mirror one another over time. The average absolute difference in estimated breeding success between the two sets of study burrows has become narrower over time. On average, the absolute difference between the two sets of study burrows over the lifetime of the study is 5.8 % ± 3.9 (standard deviation, range, 0-15.6%), indicating that census grids continue to be useful representatives of tākoketai breeding success across the wider landscape. In both sets of study burrows, estimated breeding success has been trending slightly negatively over time (Figure 6).

Breeding occupancy in the census grid and non-census grid burrows was recorded at 60.5% and 67.1%, respectively. Both sets of study burrows straddled their long-term averages, with census grid burrows recorded at 1.1 percentage points below its long-term average (61.6%) and non-census grid burrows

dipping slightly lower at 2.4 percentage points from its long-term average (69.5%). The wide gap in breeding occupancy between census grid and non-census grid burrows (Figure 5) is possibly reflective of how burrows have been added into the study over time. Non-census grid burrows have been added haphazardly and opportunistically over time, largely due to their accessibility for researchers such as being in close proximity to walking tracks, which are also likely to be near take-off points. This may have inadvertently selected burrows that are located in higher quality micro-habitat and so may be more likely to be occupied by a breeding pair, than not. Whereas all burrows in census grids have been added, which has potentially mitigated inadvertent biases of the researchers over time. Future studies into a burrow's micro-habitat features (e.g., substrate, topography) would be useful to gauge what factors may influence its perceived quality how that in terns influences occupancy, breeding success and their resilience to extreme weather events, which are likely to increase in frequency and in magnitude under climate change (Lunquist et al. 2011, Harrington et al. 2023).

The average age of the (known aged) tākoketai breeding population has trended slowly upwards over time in both census grid burrows and non-census grid burrows (Figure 7). This season saw the average age of breeding birds in non-census grid burrows increase from 12.8 ± 6 years to 13.3 ± 5.1 years and in census grid burrows and the average age of breeding birds maintained a similar value at 13.3 ± 6.2 to 13.1 ± 5.5, compared to last season (Figure 7). Breeding success and reproductive performance in long-lived seabirds is affected by age, age at first reproduction, senescence, and experience (Aubry et al. 2009, Limmer & Becker 2010), so it will be important to continue to monitor the tākoketai population on Aotea as the known age breeding population continue to age. Interestingly, the distribution of ages substantially contracted compared to the previous season with the maximum age recorded in census grid and non-census grid burrows being an individual aged 27 years old and two individuals aged 26 years old, respectively (Figure 7). Last season, the maximum age of a breeding tākoketai was a 36- and 35-year-old in the census grid and non-census grid burrows, respectively. This season one of those individuals was found to be a non-breeder attempting to attract a mate, and the other was not resighted.

The average age of first detection for all birds recaptured on Aotea is (mean 7.0 ± 3.5 (sd) years. It is interesting to note that tākoketai as young as 4-year-olds are successfully breeding at the colony, even if only a small proportion of the returnees (Figure 9). It poses an interesting question about when the timing of pair-bonding for these young individuals occurs and whether pair-bonds and breeding can co-occur in the same year or pair-bonds for these individuals occurred at a time of the year when routine monitoring is not occurring such as pre-exodus or at the tail end of the breeding season. The detection of birds that are younger than 4 years old is extremely rare with only three individuals resighted back at the colony at 3 years over the entirety of the 30-year study (Figure 9). Younger individuals that are re-sighted are made up of proportionally more non-breeders than breeders (when breeding status could be assigned), which then expectedly shifts as age at detection increases. At sea captures of returned chicks show a similar skew to younger birds, peaking at 6 years of age (Figure 11). The resighting of the 2-year-old in Bass Cayon, off Victoria Australia, shows that pre-breeders at this age are at least completing their migration journey back from their wintering grounds around Ecuador to the southern hemisphere. Due to the continued sparsity of recaptures of young returnees at sea, it still remains unknown whether these young pre-breeding individuals principally stay within the seas around Aotea and Hauturu during the breeding season before they reach the age in which they would begin prospecting for a mate, or whether they will go further afield as is the case with the bird re-sighted off Australia.

A trip to the colony during the pre-laying exodus focused on identify recruits may be beneficial to understanding this aspect of tākoketai biology and thus provide more insight in recruitment. Trips during October have occurred in the past, but these trips have primarily focused on assessing birds found during the day in study burrows rather nocturnal activity. To further identify productive windows to visit the colony, a network of trail cameras set up to record how activity patterns of the population throughout the year at key-launch sites would also be beneficial. Focusing recapture effort at launch sites as well as surveys throughout the colony area is also likely to increase recapture rates. A focused

effort (i.e., number of hours at specific launch sites over a number of nights) to determine the rate of banded to new (unbanded) birds could also give an indication of population size and would be comparable between seasons.

4.2 Predation

There was one instance of feral cat predation on an adult tākoketai within the wider colony area, but no predation events occurred within the study burrows this season. Live cage traps targeting feral cats are located around the Hirakimata summit and run prior to, and throughout the tākoketai breeding season. The Tu Mai Taonga (https://www.tumaitaonga.nz/) project aims to protect and restore native species and ecosystems through feral cat removal and intensified rat control, initially in the Aotea Conservation Park and Northern Aotea area. The Tu Mai Taonga team are monitoring these feral cat traps across the study colony and surrounding area, and in conjunction with DOC, will target any feral cats that are reported within the tākoketai study colony by the WMIL field team. There were two recorded instances of rat predation on eggs during the 2024/25 season, which was similar to the previous two seasons. Despite the low number of recorded rat predation incidences, rats, particularly ship rat, remain a common sight within the area. A trial of Good Nature A-24 traps is currently underway at Hirakimata, and tracking tunnel monitoring is showing a reduction in rat numbers across the summit area (S. Dwyer, DOC, *pers. comm*.).

4.3 Returned chicks

The highest number of tākoketai fledging cohorts (23) were recorded this season at the Hirakimata colony (represented by at least 1 individual; Figure 8). One more than the previously highest recorded number of cohorts (22) in the 2021/22 and 2023/24 breeding seasons. It was suspected that over the last four previous, the number of unique cohorts was showing signs of plateauing. It will be interesting to see whether the number of cohorts represented will continue to climb into the future, or whether this season represents a new ceiling. Some cohorts were not represented this season (excluding cohorts 2021/22 and above), no birds were re-sighted from the 1995/96, 2000/01, or 2002/03 cohorts. This is the third season in a row where no birds were resighted from the 1995/96 cohort. It is perhaps unsurprising that representation of the 1995/96 has diminished over recent time considering how few chicks were banded that season relative to other cohorts. This is a similar situation for the 2002/03 cohort where the number of fledglings was substantially lower owning to the poor breeding success that season. The reason for the absence of an individual from the 2000/01 cohort is unclear. At least one individual was resighted from the other two absent cohorts in the previous season.

The number of chicks banded each season has ranged from 59 in 1995/96, during the establishment of the study, 354 chicks in 2016/17 (where both demographic monitoring and population survey of the Hirakimata colony took place), averaging at 71 ± 14 chicks banded per year during the first three seasons when only three census grids were established to an average of 187 ± 57 chicks banded per year once all 9 census grids were established (Table 5; Figure 12) . However, to date, less than 10.0% of all tākoketai chicks banded at the Aotea study colony have been re-captured in subsequent field seasons (Figure 13). There is a real lack of understanding whether the low return rates relates either to low juvenile survival and/or recruitment probability or is purely due to a lack of detection of banded birds within the 35-ha study site and emigration is the main source for low number of resighting relative to the number of birds banded. Survival effort estimates, especially juvenile survival and recruitment are vital for accurate population estimates and risk assessment modelling, and it is highly recommended that effort to obtain data to fill this knowledge gap for tākoketai is completed with urgency.

Ad-hoc nocturnal surveys have been undertaken throughout the 29-year study period resulting in 108 returned chicks being recaptured over 117 surveys nights whereas focused intensive survey effort over the past three seasons results in 106 returned chicks caught over 51 survey nights (Table 4). Results from these intensive surveys were consistently higher that the ad-hoc surveys for percentage of banded tākoketai caught out of all captures (intensive 50.8% vs ad-hoc 45%), percentage of returned chicks

captured (intensive 18.9% vs ad-hoc 13.3%), the number of banded tākoketai caught per survey (intensive 5.9 vs ad-hoc 2.1) and for returned chicks caught per survey (intensive n=2 vs ad-hoc n=0.6; Table 4). Although ad-hoc surveys have provided recruitment data, these results highlight the value of focused intensive effort at the colony to recapture returned chicks and it is recommended that these intensive nocturnal surveys continue.

Of the 106 returned chicks recaptured during the intensive surveys, 23 (27.7%) were caught for the first time. This suggests that the intensive nocturnal effort has increased the detections of returned chicks at the colony. The detection rates for pre-1995 birds at the colony is lowering as these birds age, and the number of recaptures of returned chicks banded before 2000 is also declining. Additional surveys should be factored into subsequent breeding seasons to increase the number of returned chicks being recaptured. An increased team size could allow for more ground at the colony could be covered, which in turn could increase the chance of recapturing returned chicks. Focusing recapture effort at launch sites as well as surveys throughout the colony area is also likely to increase recapture rates. A focused effort (i.e., number of hours at specific launch sites over a number of nights) to determine the rate of banded to new (unbanded) birds could also give an indication of population size and would be comparable between seasons.

In order to fill this knowledge gap regarding recruitment and juvenile survival, it is recommended that additional methods including focused nocturnal effort at launch sites, seabird detection dogs, and additional transect surveys within core areas, should be employed in unison with on the ground study burrow monitoring. The dedicated nocturnal monitoring should be repeated with a bigger team to locate and identify returned tākoketai chicks within the current 35-ha study area. Tākoketai are nocturnal and are highly vocal in the late evening. During the breeding season, un-paired males ‘clack’ (perform attraction calls) from or near their burrows to attract an un-paired female (Warham 1988). In addition, returning birds are easily located by the crashing sounds made through the forest canopy as they land to return to their burrows.

Another recommended method is the employment of seabird detection dogs to locate burrows occupied by breeding and non-breeding birds. Seabird detection dogs have been used successfully in the past within localised areas on Aotea and Hauturu (Bell et al. 2016a, Bell et al. 2016b). Expanding this effort into the wider core breeding area around Hirakimata will help to identify tākoketai hotspots and increase the probability of detecting returning birds. Previous experience with seabird detection dogs has found detection ability via scent of occupied, or recently occupied, burrows was up to 10 metres on either side of the track on calm days, with greater distances on the windward side of the track (up to 30 metres; Bell et al. 2016a). Tākoketai carry a distinctive smell that is immediately apparent when handling, but because burrow entrances can often be cryptic and hidden within dense vegetation the scenting ability of trained seabird detection dogs confers a unique advantage over other methods (e.g., transect surveys) and makes their use a highly effective tool to complement current methods.

At-sea captures have been another effective method to catch large numbers of birds within short time periods; rafting birds can be caught by throwing a cast net, or firing a net gun, and quickly pulled up onto the boat to be processed (Burgin 2024, Gaskin & Whitehead 2024). Between 2021 and 2024, over 15 surveys WMIL caught and banded 460 tākoketai, of which nine birds were recaptured chicks (Burgin 2024) and between 2023 and 2024, over seven surveys, Northern New Zealand Seabird Trust caught and banded 268 tākoketai, of which 11 were recaptured chicks (Gaskin & Whitehead 2024). These expeditions occurred between December and April, and the use of at-sea captures during the peak breeding season (November to January) will likely result in a higher volume of banded tākoketai identified and incorporated into the study. There is a possibility that at-sea captures may target birds that might not be able to be caught during burrow monitoring e.g., pre- or non-breeders (immature individuals or those that have failed to attract/find a mate), or birds that have a failed breeding attempt and have subsequently returned to sea. Like other *Procellaria*, tākoketai are highly philopatric (Warham 1996), and are suspected to exhibit sexed biased dispersal within the colony site. Males are suspected of returning closer to their natal areas whereas females are suspected of dispersing farther afield. Some males have been documented usurping their father and occupying their natal burrow (unpublished

WMIL data). Because of this, we suspect that the identified returned chicks are predominantly male, however genetic confirmation of sex identity is needed to establish this trend, which is lacking for most individuals. At-sea captures would therefore likely reduce the likelihood of sex-biased detection.

A combination of these recommendations such as night banding, at-sea captures, transect surveys, and conservation dogs will work to improve detection probability and more accurately determine survival effort estimates as well as juvenile survival and recruitment. The implementation of these methods is crucial for the survival, determining population trend, and management of this endangered species.

5. RECOMMENDATIONS

WMIL recommends that:

- Intensive population monitoring using the study burrows on Aotea continues with three visits (i.e., at egg-laying (December); at chick hatching/chick guard in late January/early February and at chick fledging in late April/early May) per season to the colony to track population trends and determine impacts to the birds and colony.
- Multiple-night expeditions to focus on recruitment (i.e., nocturnal surveys to capture pre-breeders and returned chicks) to the Aotea study colony continue to determine juvenile survival and recapture probabilities.
- Implement a remote/trail camera monitoring network at key-launch sites around the colony to identify potential time-windows of peak population activity outside the routinely monitored timeframes
- Sexing of all tākoketai caught during the recruitment expedition and in the study burrows is completed to determine any sex biases and survival differences between sexes at the colony and within the study burrows.
- A focused, consistent and repeatable mark/recapture session (e.g., a 2-hour capture period at known launch sites) is completed over a number of nights to capture as many banded and unbanded birds as possible. Data can then be used to provide another population estimate and compared to estimates obtained from at-sea captures and burrow monitoring.
- Transect surveys across the core tākoketai habitat (1000 ha around the summit) are undertaken to provide an updated population estimate for Aotea.
- Satellite tracking of chicks to, and in, South American waters is undertaken to determine migration routes and foraging areas to estimate risk in these areas.
- The possibility of collaborative at-sea capture expeditions in Ecuador is investigated. Discussions between DOC and New Zealand Government with Ecuadorian Government and researchers will have to be conducted to enable this type of collaborative work. At-sea work in Ecuador could determine the level of juvenile tākoketai presence in this area and risk within this area, and this mark/recapture work could provide another population estimate to compare with the New Zealand data.
- Further investigation to determine whether particular areas of the colony are more at risk to rainfall events than others (e.g., burrows in flatter areas being more prone to flooding) as a preliminary assessment on climate resilience.
- In-depth modelling on the effect of age, age difference in pairs, and experience on breeding success is completed to understand this relationship in tākoketai.
- Analysis of, and comparison between, breeding success in public, and non-public, access areas is completed to determine whether human disturbance is a factor at the Aotea colony.

- Investigation into possible deterrence methods of all predators, but specifically feral pigs and feral cats, should be continued at Cooper's Castle.

6. ACKNOWLEDGEMENTS

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8. APPENDICES

8.1 Appendix 1: Summary of nesting success and the number of chicks produced in census gird (Figure 17) and non-census grid study burrows (Figure 18).

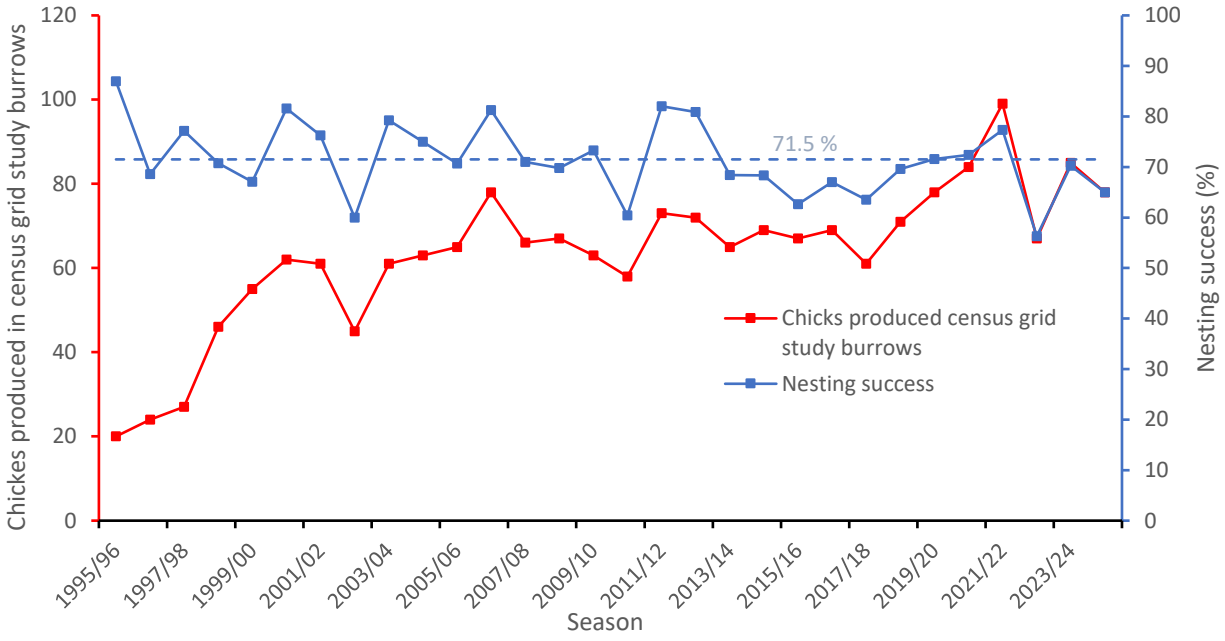


Figure 17: *Nesting success and the number of tākoketai/black petrel (Procellaria parkinsoni) chicks fledged from census grid study burrows at Hirakimata/Mt Hobson on Aotea/Great Barrier Island between the 1995/96 and 2024/25 season. The dotted blue line indicates the mean nesting success over the 30-year study period.*

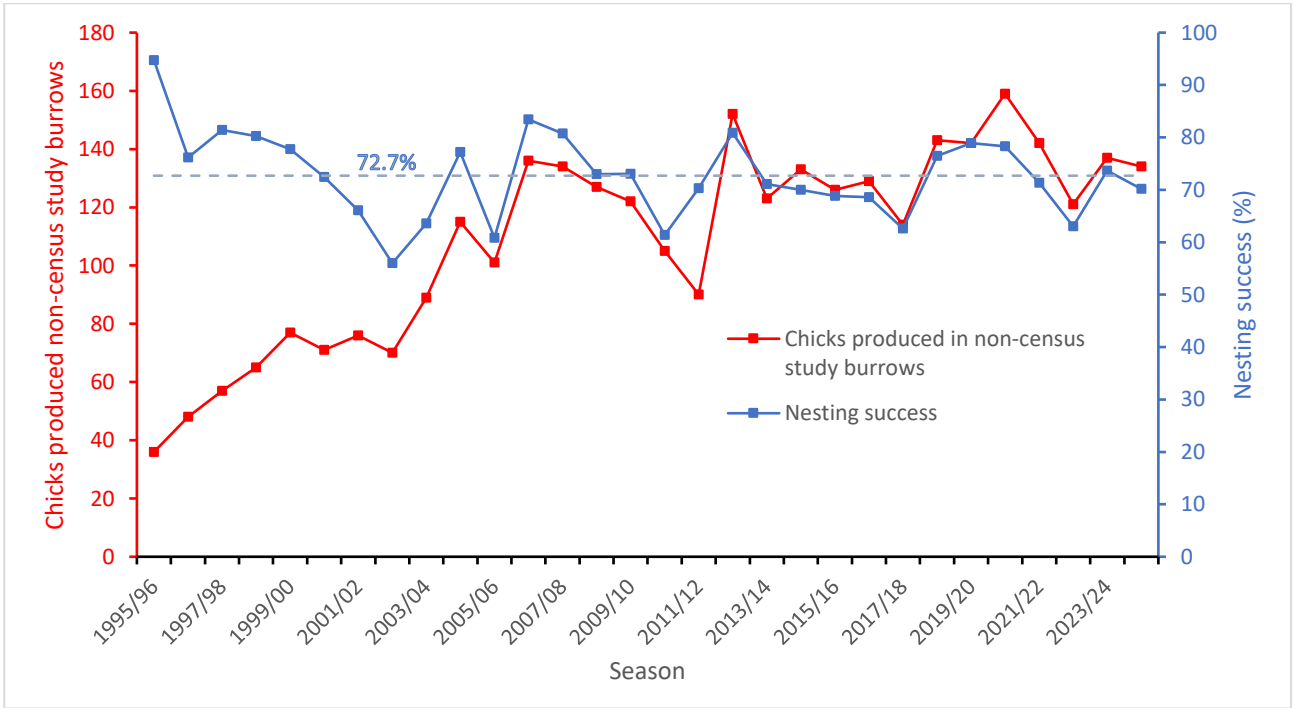
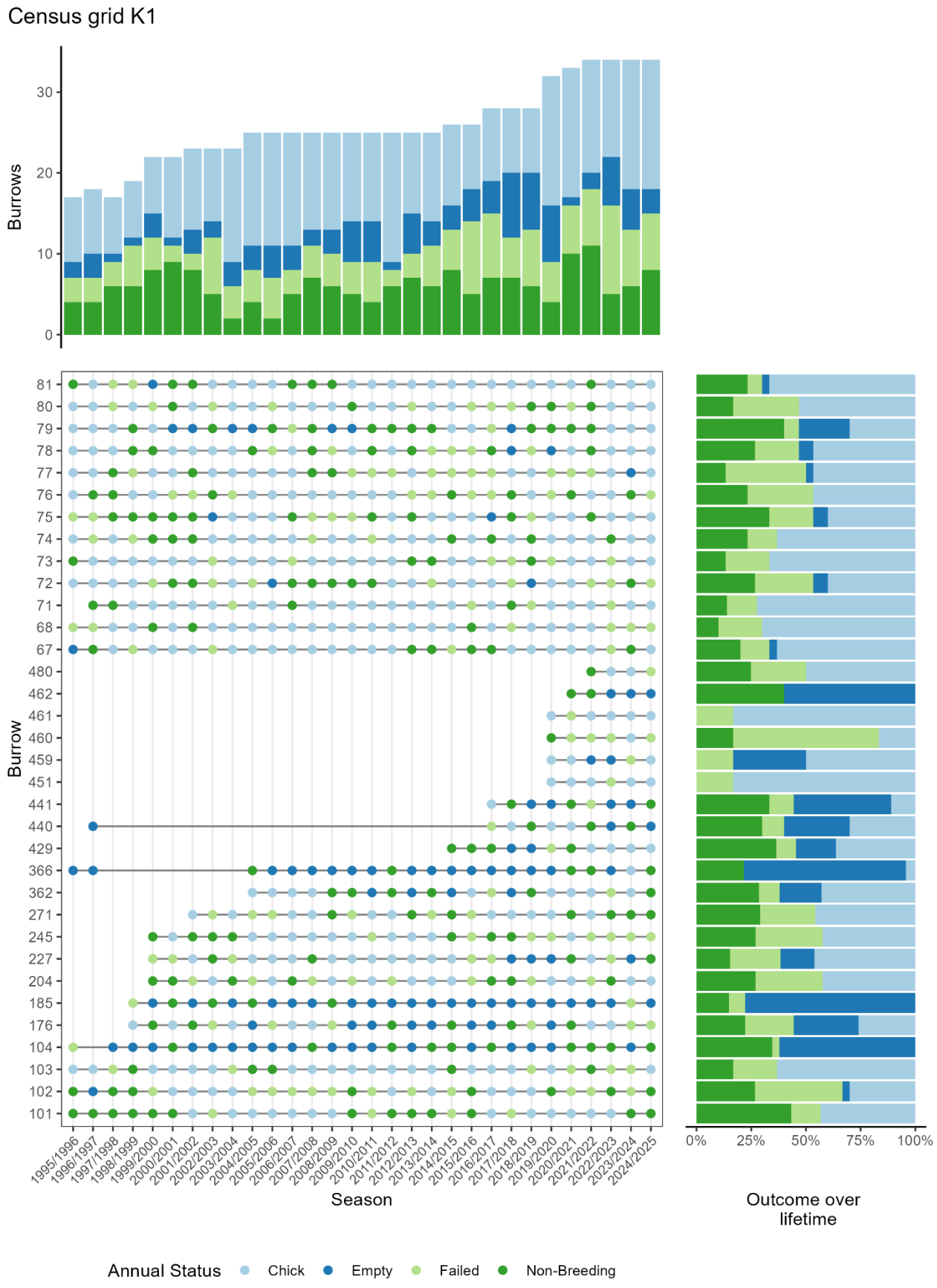


Figure 18: *Nesting success and the number of tākoketai/black petrels (Procellaria parkinsoni) chicks fledged from non-census grid study burrows at Hirakimata/Mt Hobson on Aotea/Great Barrier Island between the 1995/96 and 2024/25 season. The dotted blue line indicates the mean nesting success over the 30-year study period.*

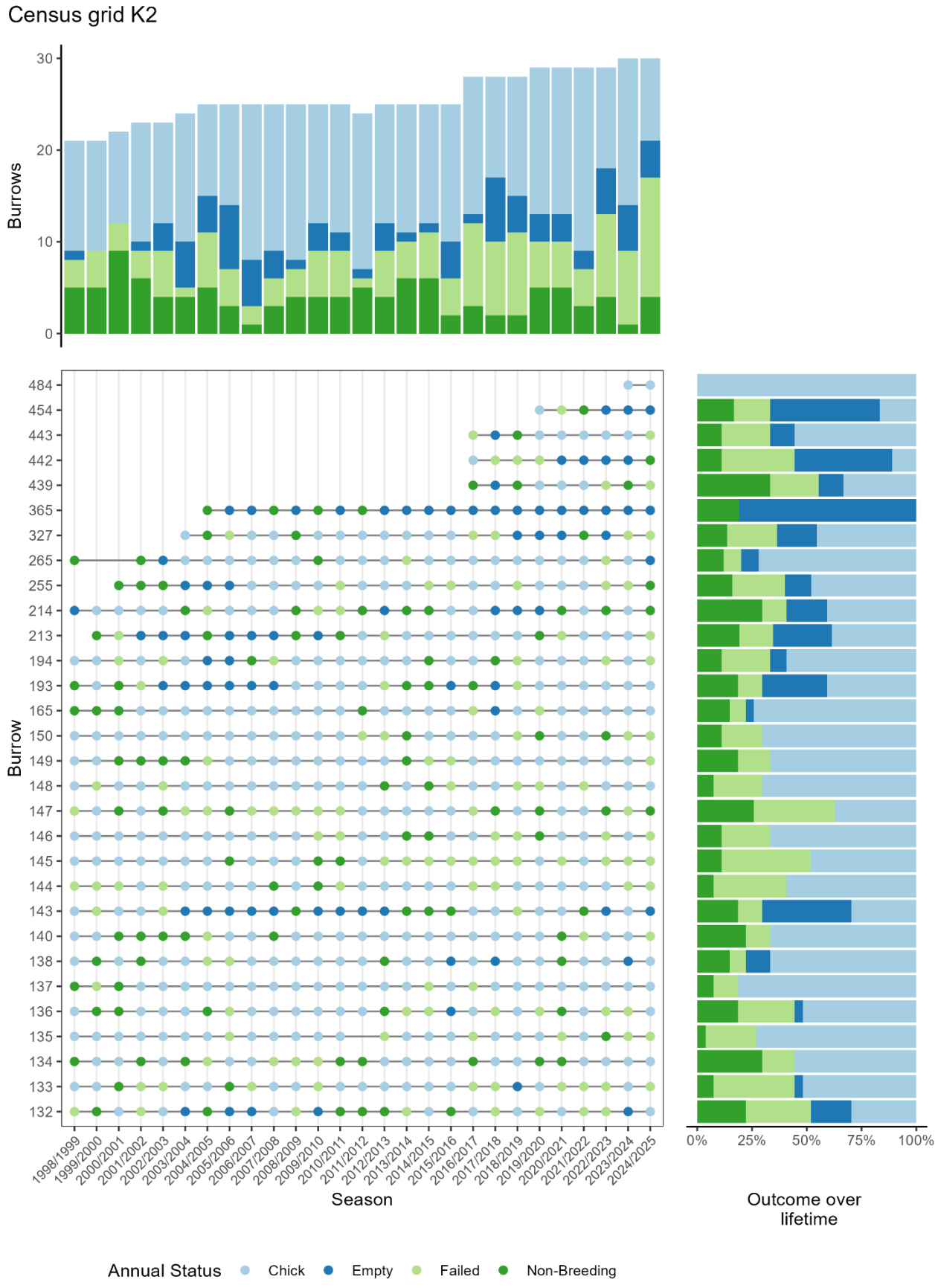
8.2 Appendix 2: Summary of breeding history and outcome of census grid burrows.

Breeding history and outcome of each census grid burrow throughout the study between the 1995/96 and 2024/25 breeding season (where K1 = Kauri Dam Grid 1, K2 = Kauri Dam Grid 2, K3 = Kauri Dam Grid 3, P1 = Palmers Track Grid 1, P2 = Palmers Track Grid 2, P3 = Palmers Track Grid 3, S1 = South Forks Grid 1, S2 = South Forks Grid 2, and S3 = South Forks Grid 3). Top graph depicts the total number of burrows and their outcome for a particular breeding season. Right hand graph depicts the breeding outcome for each census grid burrow. Middle graph depicts the breeding outcome for each census grid burrow over its lifetime. Breeding outcome is represented by each colour (dark blue = empty burrow; green = burrow occupied by non-breeding individuals; light green = failed breeding attempt; light blue = successful breeding attempt).

Appendix 2a: Summary of breeding history and outcome of census grid burrows in Kauri Dam Grid 1.

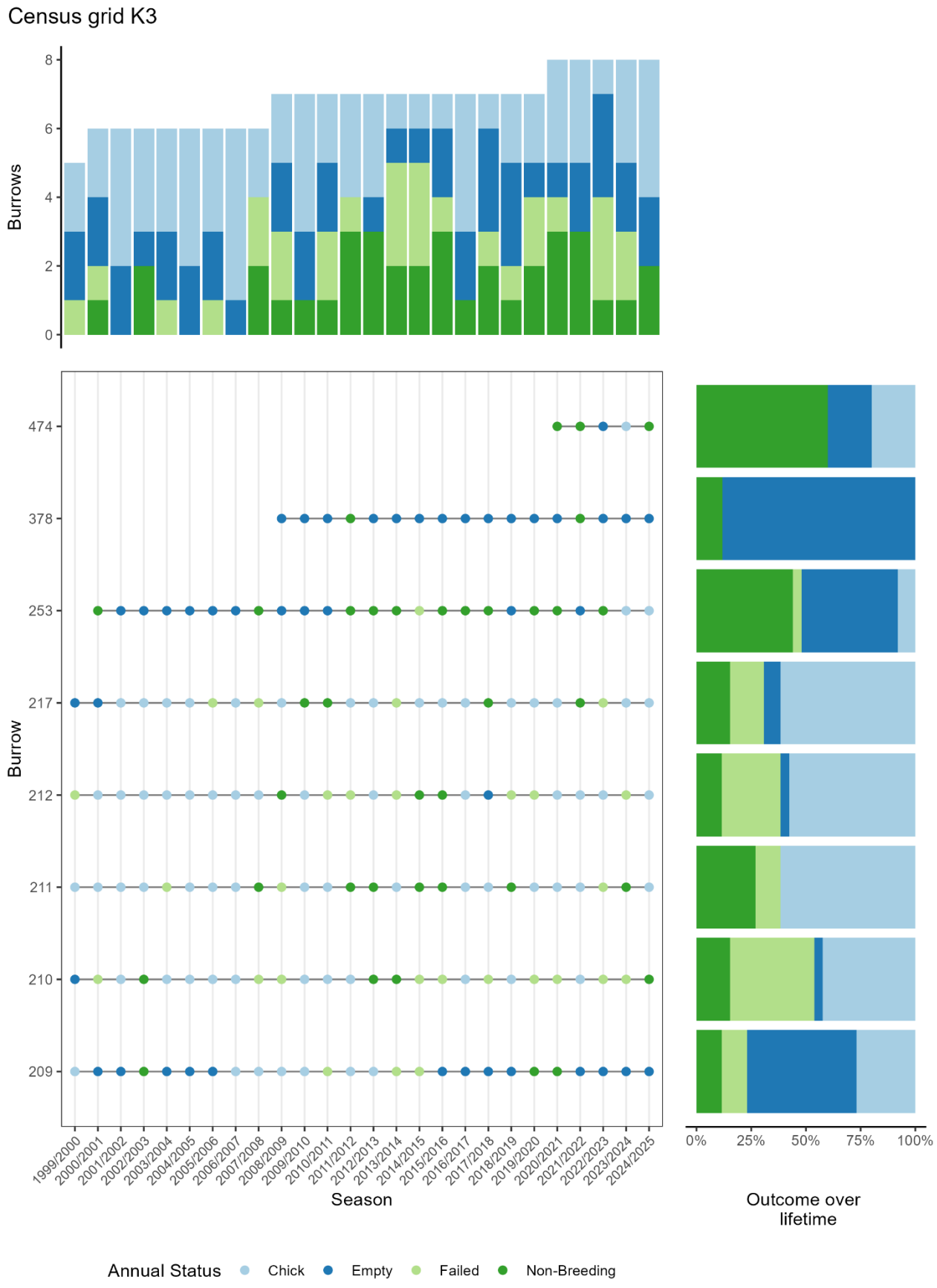


Appendix 2b: Summary of breeding history and outcome of census grid burrows in Kauri Dam Grid 2.



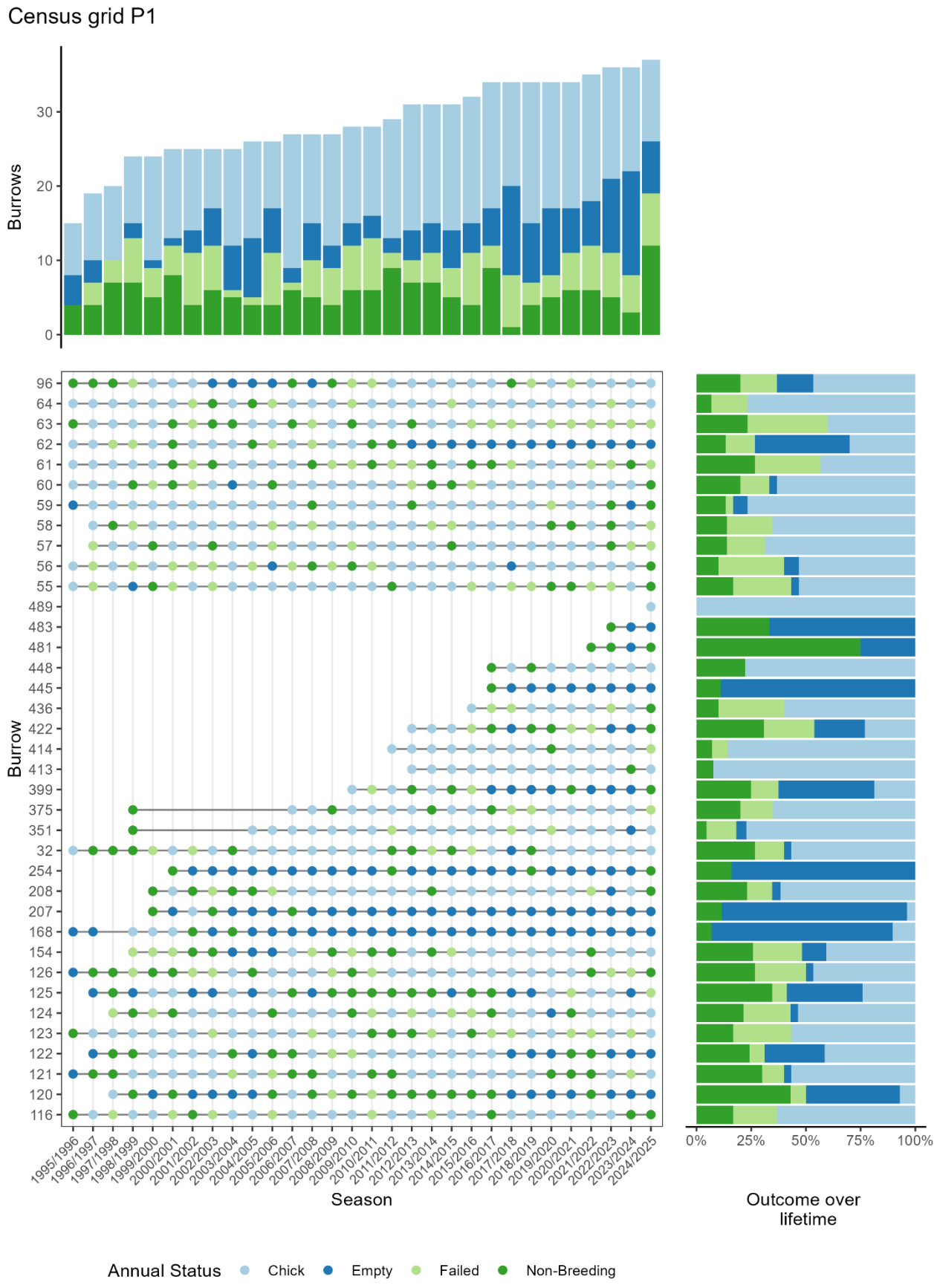
WMIL: Bell, *et al*. 2025

Appendix 2c: Summary of breeding history and outcome of census grid burrows in Kauri Dam Grid 3.

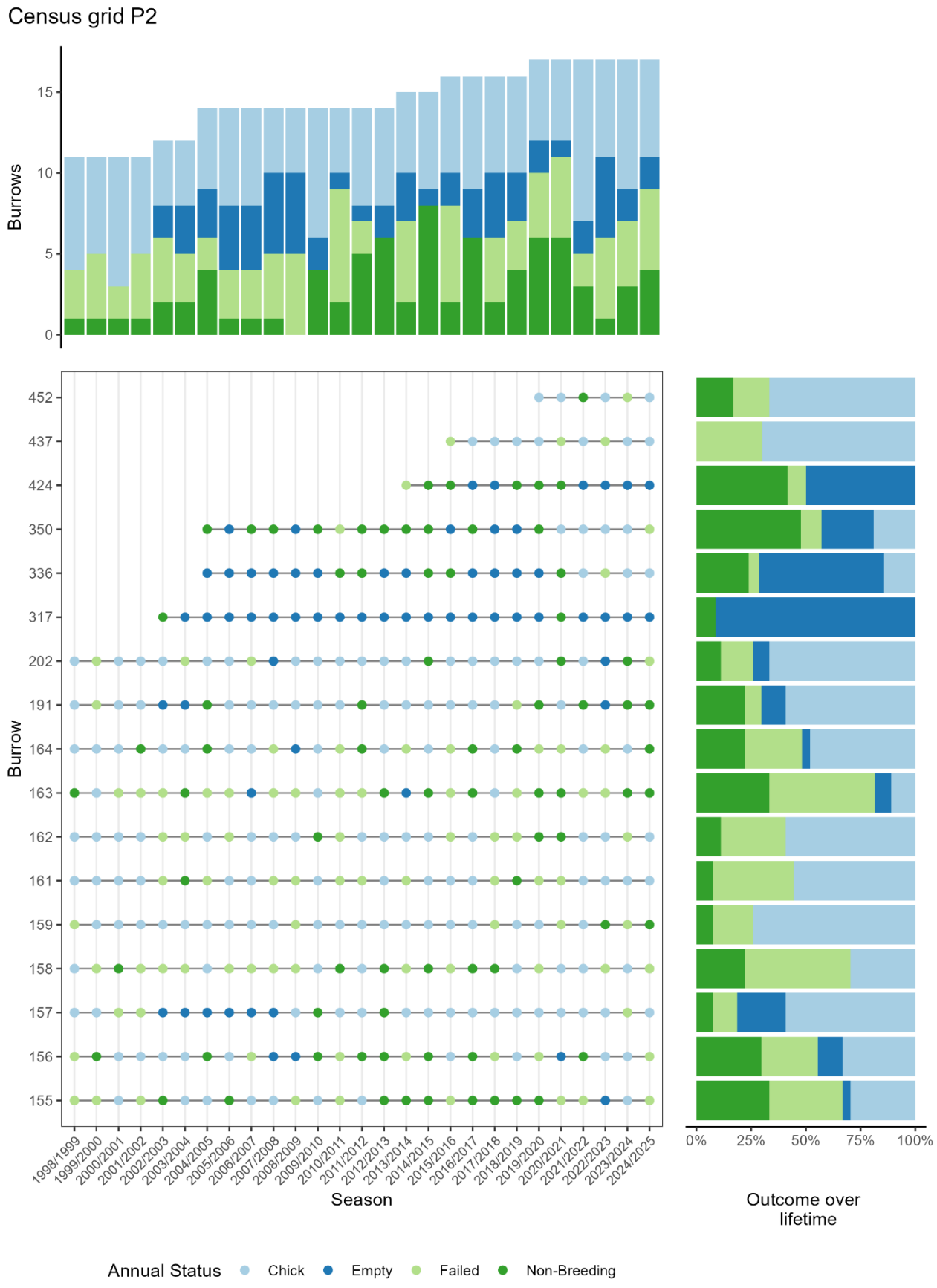


WMIL: Bell, *et al*. 2025

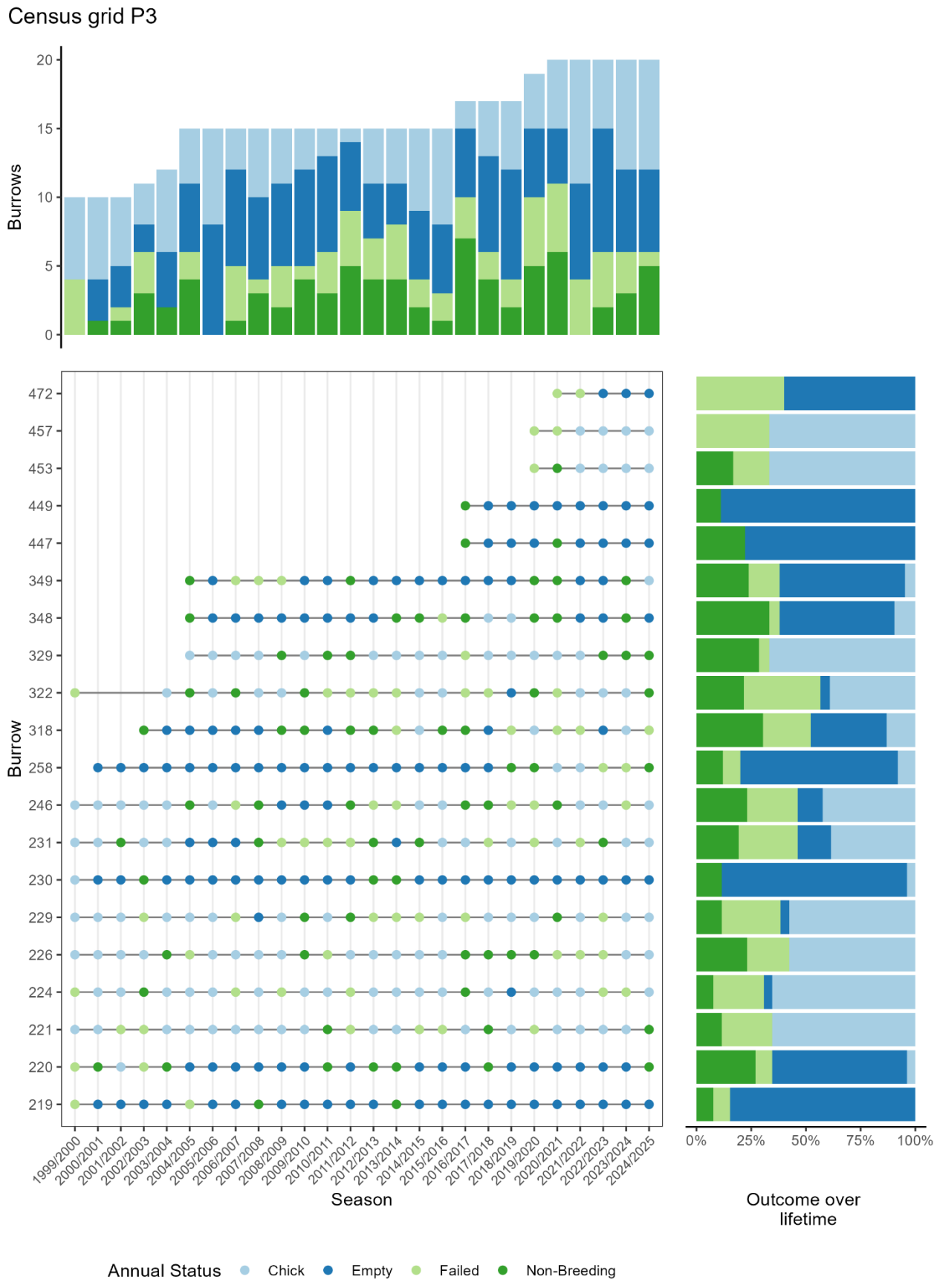
Appendix 2d: Summary of breeding history and outcome of census grid burrows in Palmers Track Grid 1.



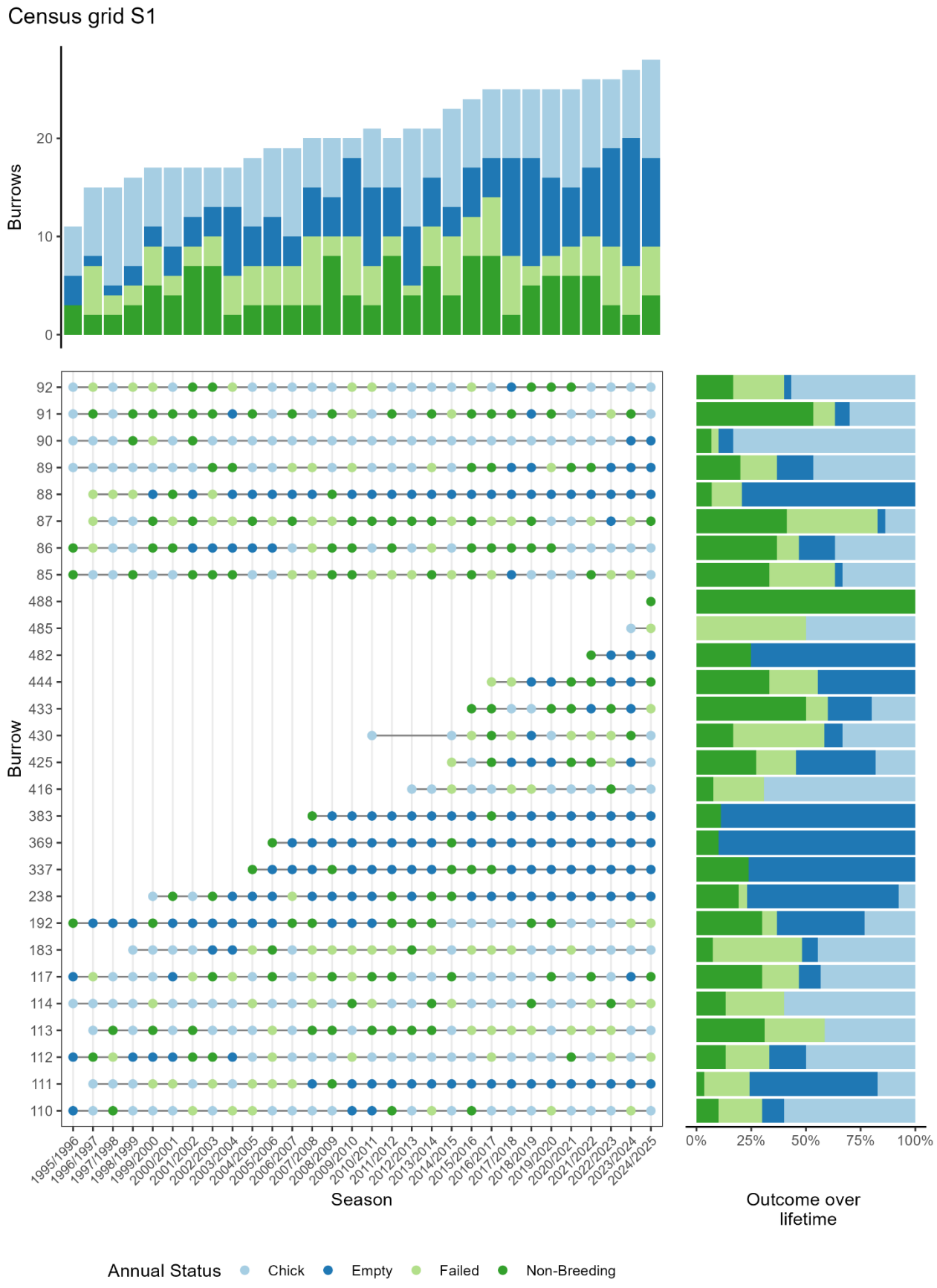
Appendix 2e: Summary of breeding history and outcome of census grid burrows in Palmers Track Grid 2.



Appendix 2f: Summary of breeding history and outcome of census grid burrows in Palmers Track Grid 3.

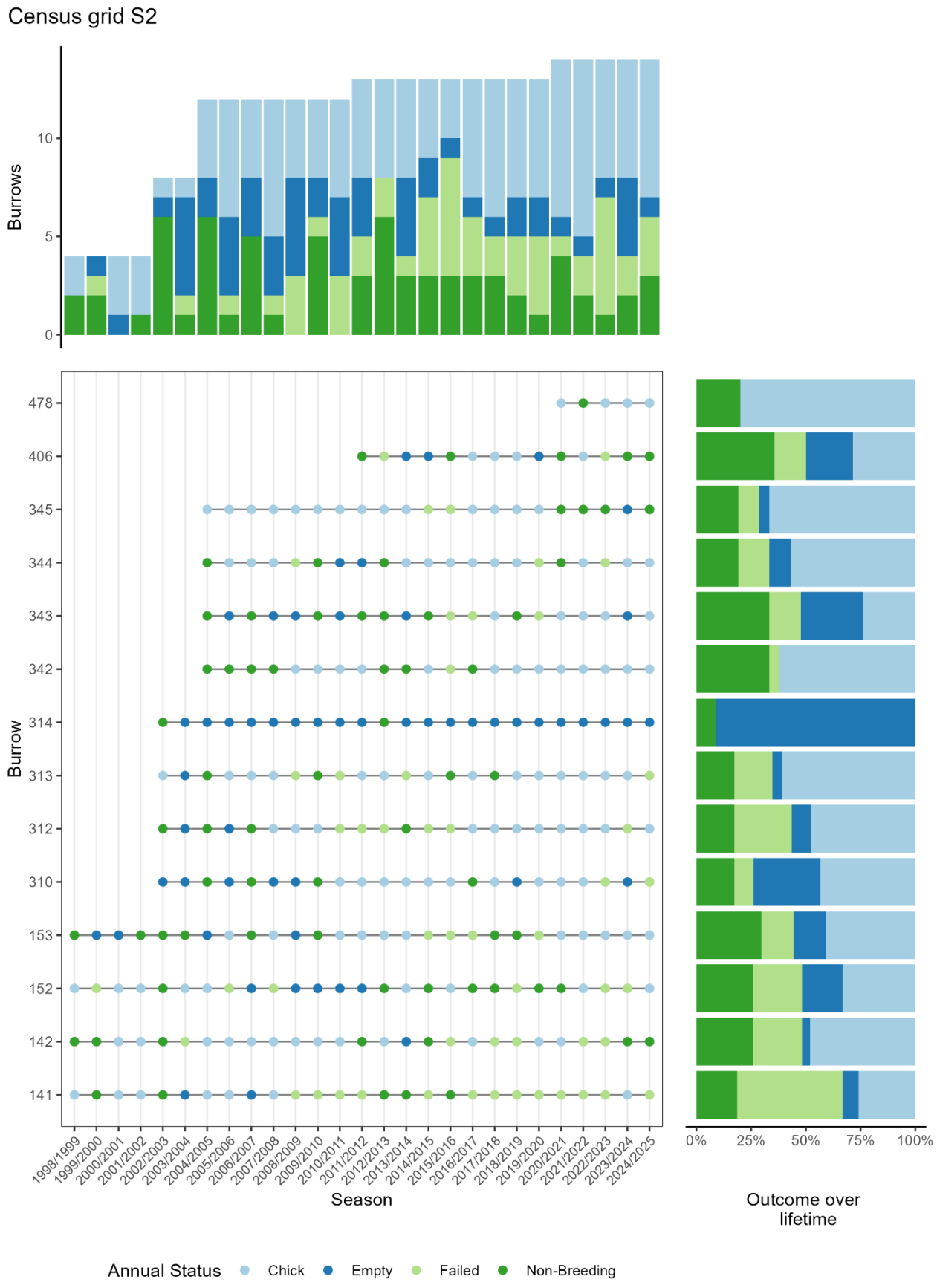


Appendix 2g: Summary of breeding history and outcome of census grid burrows in South Forks Track Grid 1.

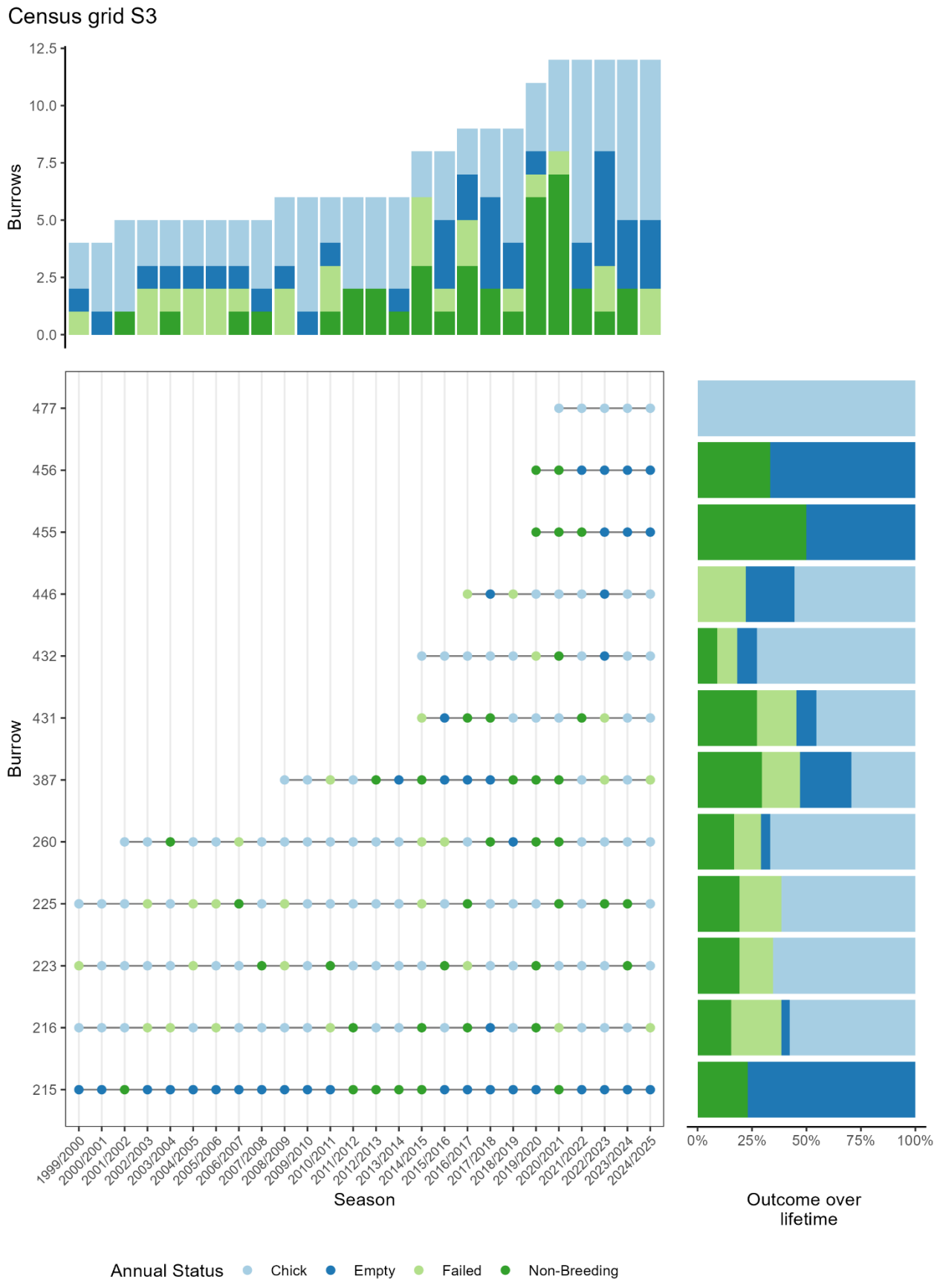


WMIL: Bell, *et al*. 2025

Appendix 2h: Summary of breeding history and outcome of census grid burrows in South Forks Track Grid 2.



Appendix 2i: Summary of breeding history and outcome of census grid burrows in South Forks Track Grid 3.



WMIL: Bell, *et al*. 2025