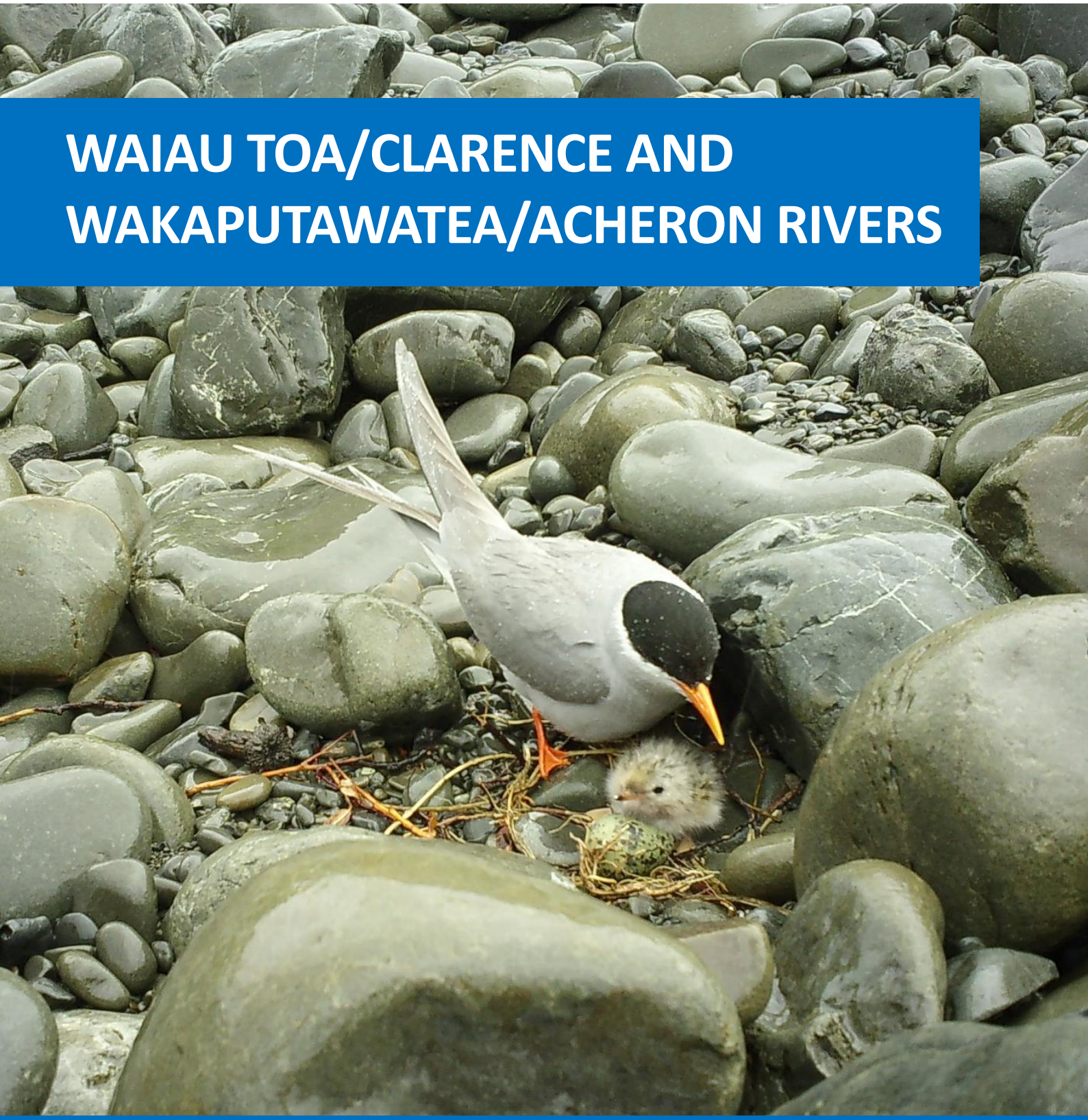
# WAIAU TOA/CLARENCE AND WAKAPUTAWATEA/ACHERON RIVERS



***Waiau Toa/Clarence and Wakaputawatea/Acheron River tarapirohe/black-fronted tern monitoring project - 2022/23 operational report.***

WMIL Wildlife Management International

TOITŪ CARBON ZERO ISO 14064-1 ORGANISATION

# Waiau Toa/Clarence and Wakaputawatea/Acheron River tarapirohe/black-fronted tern monitoring project- 2022/23 operational report.

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Cover Image: Three stages of life. Adult black-fronted tern (*Chlidonias albostriatus*) caring for newly hatched chick and egg during 2022/23 season, photographed using a remote trail camera, December 2022.

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# EXECUTIVE SUMMARY

This report summarises the results of the second year of a second five-year collaborative project to test a new conservation management regime aimed at improving the nesting success of tarapirohe/black-fronted terns (*Chlidonias albostriatus*) on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers in Canterbury, New Zealand.

One of the main changes between the first five-year project and the current five-year project is the increased treatment zone area (where the treatment zone area is defined as a continuous stretch of river under predator control). The treatment zone is now determined by the length of the extended trapping line which covers a 26km stretch of the Waiau Toa/Clarence River. Chick shelters were also deployed at colonies within the treatment zone, both on island and mainland colonies.

Habitat enhancement actions were carried out in March and April 2022 at five islands within the treatment zone where island heights were raised, smoothed over, and cleared of vegetation. Enhancements also included widening, deepening, and clearing channels surrounding each island. However, summer drought during the breeding season caused channels of two enhanced islands to dry out, causing the islands to become connected to the mainland, which reduced their effectiveness for the 2022/23 breeding season.

Predator trapping using a combination of DOC150, DOC200, DOC250, SA1 and SA2 kill traps was carried out in a 26 km trapping line along both sides of the Waiau Toa/Clarence River, resulting in 766 predators being caught. This included 520 hedgehogs (*Erinaceus europaeus*) (0.257 catches/100 trap nights), 11 possums (*Trichosurus vulpecula*) (0.005 catches/100 trap nights), 74 weasels (*Mustela nivalis*) (0.037 catches/100 trap nights), 11 ferrets (*Mustela furo*) (0.005 catches/100 trap nights), 38 stoats (*Mustela erminea*) (0.019 catches/100 trap nights), 18 rats (*Rattus rattus*) (0.009 catches/ 100 trap nights) and 17 cats (*Felis catus*) (0.008 catches/ 100 trap nights).

Overall breeding success of black-fronted terns was higher at both treatment and non-treatment colonies throughout the 2022/23 season compared to the previous five-year study (2015/16 – 2019/20) and only a slight decrease from the 2021/22 season results. Hatching success was slightly less in treatment sites compared to non-treatment sites (treatment hatching success= 52%; non-treatment hatching success= 65%), partially due to a range of more suitable, robust islands that were nested on within the non-treatment zone, and thus had reduced predators access over the breeding season, compared to treatment zone colonies where only five islands were colonised. Observed fledging success was the third highest recorded over the last seven monitored seasons. The treatment colonies resulted in having lower fledging rates (0.36 chicks/nest), compared to non-treatment colonies (0.51 chicks/nest). This was likely due to large population of breeding pairs that nested on the mainland within the treatment zone. Fledgling productivity on treatment and non-treatment islands were very similar with both zones reaching 0.61 fledglings/nest.

In total, 142 black-fronted tern chicks were observed to have fledged from monitored colonies along the rivers during the 2022/23 season, 38 from treatment colonies and 104 from non-treatment colonies. This compares to the previous 5-year study where an average of 110 chicks fledged per year between 2015/16 to 2019/20.

# *Waiau Toa/Clarence and Acheron River tarapirohe/black-fronted tern monitoring project - 2022/2023 operational report*

## 1. INTRODUCTION

The tarapirohe/black-fronted tern (*Chlidonias albostriatus*) is ranked as Nationally Endangered under the New Zealand Threat Classification System, with an estimated population of between 1,000 and 5,000 mature individuals and a predicted rate of decline of around 50% over the next three decades (O'Donnell & Hoare 2011, Robertson et al. 2021).

This ongoing decline is the result of several interacting threats, including depredation by introduced mammals (particularly cats [*Felis catus*], ferrets [*Mustela furo*] and hedgehogs [*Erinaceus europaeus*]) and habitat loss as a consequence of the invasion of braided riverbeds by woody weeds (Balneaves & Hughey 1990, Keedwell et al. 2002, Sanders & Maloney 2002, Keedwell 2005, Bell 2017).

The braided rivers of Canterbury are currently considered to be the global stronghold for black-fronted terns (hereafter tern or terns) and are estimated to support around 60% of the breeding population of this species (O'Donnell & Hoare 2011). Several of these Canterbury rivers have recently been identified as Important Bird Areas by Forest & Bird/Birdlife International on the basis that they each support >1% of the global population of terns including the Waiau Toa/Clarence, Wakaputawatea/Acheron and Saxton River system, and the Waiau-Uwha, Hurunui, Ashley, Waimakariri, Rakaia, Ashburton, Rangitata, Tasman, Godley, Cass, and Ahuriri rivers (Forest & Bird 2016).

Between 2012 and 2020 the Department of Conservation (DOC) and Wildlife Management International Ltd. (WMIL) monitored the population trends and breeding success of terns on the upper Waiau Toa/Clarence and Wakaputawatea/Acheron rivers in the Canterbury region. Over the 2012/13, 2013/14, and 2014/15 breeding seasons, tern productivity was low primarily due to predation by introduced mammals (Bell 2017).

A five-year intensive programme of predator control (i.e., trapping) and habitat enhancement was instigated at three colony sites on the upper Waiau Toa/Clarence River between 2015/16 and 2019/20 with the goal of increasing tern productivity. Throughout this period a combined total of 2,203 nests were monitored. Three treatment colony sites (enhanced island colonies with trapping networks surrounding the islands) on the upper Waiau Toa/Clarence River had a combined apparent (observed) hatching success of 41.9% over the five-year period, whilst the non-treatment colony sites (non-enhanced island and mainland colonies with no trapping) had 34.8% hatching success. The fledging productivity differed greatly between treatment and non-treatment sites (treatment = 0.61/nest, non-treatment = 0.17/nest) (Connor-McClean & Bell 2020).

Each season a subsample of nests at both treatment and non-treatment zone sites were filmed using motion-activated trail cameras. Footage showed that most nest failures were either caused by flooding or by eggs or chicks being depredated by introduced mammalian predators and other pest species, particularly kāhu/Australasian harriers [*Circus approximans*], cats, ferrets, karoro/southern black-backed gulls [*Larus dominicanus*] and hedgehogs (Connor-McClean & Bell 2020). Physical habitat enhancement is shown to increase the likelihood of nests withstanding flooding, and proximity to traplines is shown to decrease the likelihood of nest predation. The improvement in

tern productivity at treatment zone sites is therefore a direct reflection of the combined management of predator control and habitat enhancement actions carried out.

In response to the successes of the initial five-year programme, a second intensive five-year programme of predator control and habitat enhancement has been instigated on a 26 km stretch of the upper Waiau Toa/Clarence River. This 26km stretch of trapping along the Waiau Toa/Clarence River is now classed as the treatment zone for the following five seasons. Co-funded by Environment Canterbury (ECan), DOC, Land Information New Zealand (LINZ, manged by Boffa Miskell), and the Canterbury Water Management Strategy Kaikōura Zone Committee, this project aims to test whether a new combination and layout of localised predator control, weed control and physical habitat (island) enhancement could significantly improve breeding success of terns on an increased number of colonies that receive this management.

Work began on the second five-year management programme in winter 2020. A new predator trapping regime was designed in 2020 and implemented in June 2021, which covered both sides of a 26 km stretch of river (classed as the treatment zone). Habitat enhancement work was carried out prior to the start of the tern nesting season in 2021 and 2022, with the intentions of forming five to six different colony sites within the treatment zone. Enhancements included increasing island height, clearing broom [*Sarothamnus scoparius*] and other weeds, increasing channel width and depth, and maintaining the disconnection between colony islands and mainland. The aim of these enhancements was to increase the resilience of an island's structure to withstand large floods, provide a larger area of suitable nesting gravels within the treatment zone, and prevent incursions of mammalian predators onto islands. Two additional islands previously enhanced in other seasons required no further maintenance this season resulting in seven enhanced islands available for tern use within the treatment zone for the start of the 2022/23 season.

Chick shelters were also added to all island and mainland colonies within the treatment zone. This was to provide newly hatched chicks with shelter from intensive heat conditions and aerial predators.

This report provides a summary of the results of the second monitoring season of the current five-year tern project (2021/22- 2025/26). The results of various habitat enhancement and predator control work carried out at treatment zone colonies over the past 12 months are reported on, together with tern breeding success results from the 2022/23 breeding season. Recommendations for future tern conservation efforts are also provided.

# 2. METHODS

## 2.1 Habitat enhancement

### 2.1.1 Modification of islands and weed control

Using the knowledge gained from previous monitoring undertaken across five breeding seasons, five islands on the Waiau Toa/Clarence River within the 26 km stretch of river managed by predator control were chosen for island enhancements (Figure 1). Island priority selection was based on previous favourability to nesting terns, available access, enhancement work required, and native riverbed flora growing on islands. Modification of islands was based on the guidelines *A quick guide to creating bird nesting islands* produced by ECan and DOC (Appendix 1).

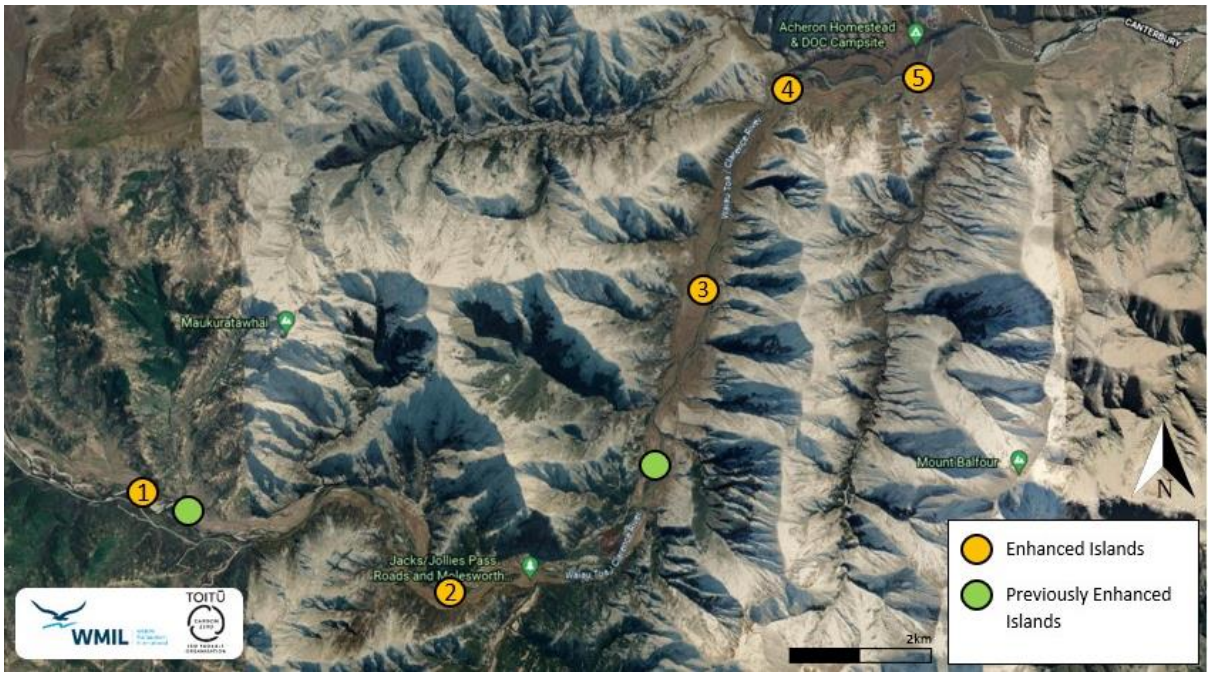


***Figure 1.*** *Location of enhanced islands along the Waiau Toa/Clarence River 2022/23. Green circles mark the location of Swimming Hole (left) and Mitchell's (right) Islands where further island enhancement were not necessary following on from the previous season.*

From 28 March to 1 April 2022, Lott Contractors Ltd and WMIL carried out mechanical excavation work at five different island sites to achieve habitat improvements (Figure 1). This work was carried out under Resource Consent CRC160509 granted to DOC under Section 104 of the Resource Management Act (1991). Island enhancements included clearing, deepening, and widening river channels surrounding the islands, raising island heights to approximately one meter above water level, smoothing over the island to remove large mounds, and removing weeds and woody debris (see example in Figure 2).

Enhanced island location coordinates and details on each island's works are presented in Appendix 2. A detailed report on the March/April 2022 Island enhancement was provided to DOC and ECan by WMIL (Connor-McClean & Bell 2021a).

***Figure 2.*** *Process of clearing invasive vegetation from an enhanced island on the Waiau Toa/Clarence River, 2022.*

## 2.2 Predator control

### 2.2.1 Trapping network overview

The current trapping network is composed of a continuous series of more than 1,170 traps running in parallel down a 26 km stretch on both the true left and true right side of the Waiau Toa/Clarence River (Figure 3).

These traps comprise 147 double-set DOC150 traps, 108 double-set DOC200 traps, 262 DOC250 traps, 143 double-set SA1 traps, and 112 SA2 traps. Traps are deployed at 100 m intervals (i.e., trap sites) in alternating combinations along the trapping network.

Trap sites are composed of either a DOC150 and SA1 or a DOC200 and a SA2 alternated with a single DOC250. A few trap sites have been re-configured to include other combinations (e.g., DOC150 and a SA2), where traps have been washed away in flooding.

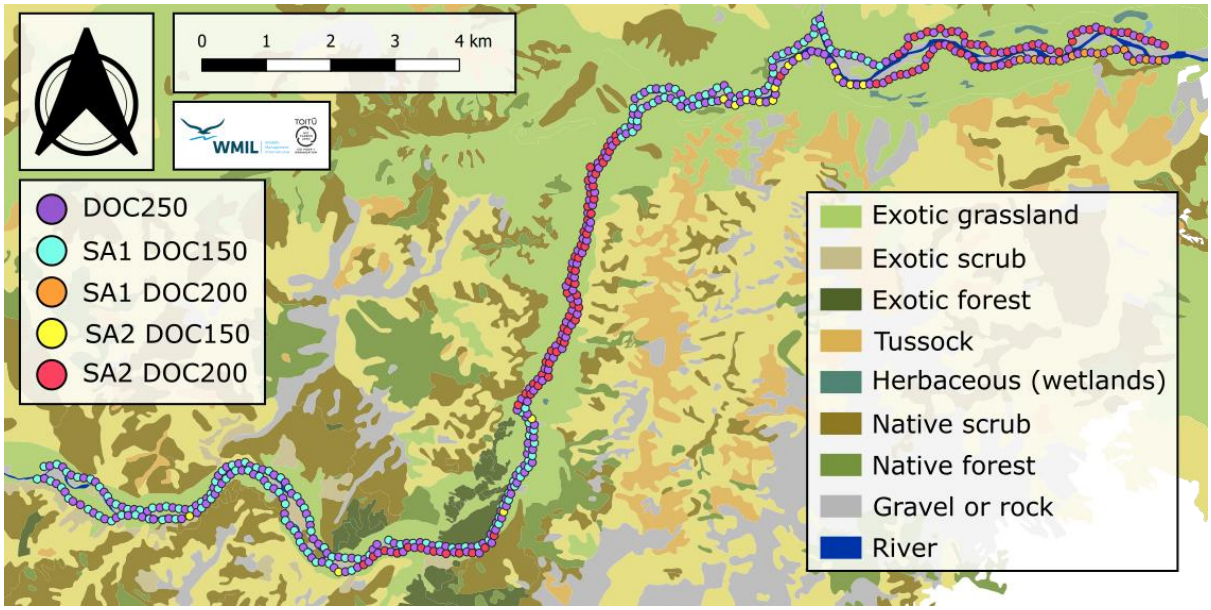


***Figure 3.*** *Waiau Toa/Clarence River trapping network in operation during the 2022/23 field season. Different combinations of traps (DOC250; SA1 + DOC150; SA1 + DOC200; SA2 + DOC150; SA2 + DOC200) at the same location are indicated by different coloured points. Different habitat types are depicted by the different colouration.*

The traps are primarily situated in exotic grassland (71.8 % of traps), or in gravel/rock along the margins of the river (24.5 % of traps; Figure 3; Table 1). A variety of other habitat types occur in small patches throughout the rest of the trapping network (between 0.6 and 0.9 % of traps occur in a different habitat type; Figure 3, Table 1). The spatial habitat type data shown here was downloaded from the New Zealand Land Cover Database (version 5), a publicly available dataset via Manaaki Whenua Landcare Research; https://lris.scinfo.org.nz/layer/48420-vegetative-cover-map-of-new-zealand/. We used the most recent dataset (2018) available. Use of the 2018 dataset may not be entirely representative of the current vegetation structure due to possible changeover in the last 4-5 years. Nonetheless, the 2018 vegetation map provides a best estimate for the vegetation type within the site. 'Ground-truthing' the vegetation structure in relation to the 2018 dataset was not done and is well beyond the feasible scope of the project. We combined sub-categories of vegetation types found within the trapping network into broader categories as defined in the Land Cover Database: 1) exotic grassland (high producing exotic grassland and low producing grassland), 2) tussock (tall tussock grassland), 3) exotic scrub (gorse [*Ulex europaeus*] and/or broom), 4) native forest (deciduous hardwoods and indigenous forest), 5) native scrub (manuka and/or kanuka).

Rock/gravel occurs along the borders of the river and can be considered habitat that is in the process of partially transitioning into either exotic grassland, exotic scrub, and/or tussock.

***Table 1.*** *The number of trap types per habitat type during the 2022/23 field season. The percentage (%) for a particular trap type for each habitat type follows in brackets. Note, for 'Total', the percentage following in brackets is summarised across habitat types (irrespective of trap type). Also note that exotic and native habitat types are abbreviated (E and N, respectively). The total number of traps deployed for each trap type follows its name in brackets. Note, DOC150, DOC200 and Steve Allan 1 traps are set as double-set traps at the same site.*

| Trap Site | Habitat Type | | | | | | |
|---|---|---|---|---|---|---|---|
| | Gravel/rock | E. grassland | E. scrub | E. forest | Tussock | N. scrub | N. forest |
| DOC 150 (294) | 78 (26.5) | 204 (69.4) | 2 (0.7) | 2 (0.7) | 4 (1.4) | 2 (0.7) | 2 (0.7) |
| DOC 200 (216) | 46 (21.3) | 168 (77.8) | - | - | - | - | 2 (0.9) |
| DOC 250 (262) | 61 (23.3) | 187 (71.4) | 1 (0.4) | 4 (1.5) | 3 (1.1) | 3 (1.1) | 3 (1.1) |
| Steve Allan 1 (286) | 80 (28) | 192 (67.1) | 4 (1.4) | 2 (0.7) | 4 (1.4) | 2 (0.7) | 2 (0.7) |
| Steve Allan 2 (112) | 22 (19.6) | 89 (79.5) | - | - | - | - | 1 (0.9) |
| **Total (1170)** | **287 (24.5)** | **840 (71.8)** | **7 (0.6)** | **7 (0.6)** | **11 (0.9)** | **7 (0.6)** | **10 (0.9)** |

### 2.2.2 Calibration

Prior to the opening of the traps for the field season, a series of two trap network maintenance and re-calibration sessions were undertaken (first session: 27 June to 1 July 2022; second session: 4 July to 7 July 2022). These calibration sessions involved calibrating the DOC150 and DOC200 traps to a firing weight of ≥ 100 g for DOC 150 and of ≥ 120 g for DOC250, as well as general cleaning and improved trap placement.

Additionally, SA2 traps were raised *c.* 12 cm off the ground (Figure 4) to increase the angle of the trap to bring it closer to the National Animal Welfare Advisory Committee (NAWAC) standards (Morriss 2017; NAWAC 2011). Standards set by NAWAC indicate that SA2 traps should be placed against trees at a 45° angle (Morriss 2017; NAWAC 2011), however, this set up is not feasible within the treatment zone as the landscape is dominated by expansive tussock/grassland and weed species (e.g., broom). As cats are a major predator of the endangered tern chicks and adults, and with no other cat specific traps on the New Zealand market, lifting the SA2 traps via blocks of wood to their current position was found to be a suitable compromise. Currently, NAWAC is in the trial stage of testing SA2s for the efficacy on the ground (Landcare Research Manaaki Whenua, n.d).

***Figure 4.*** *Example of the modification applied to Steve Allan 2 traps in the Waiau Toa/Clarence River trapping network.*

During the calibration sessions, the trap network was re-configured following discussions with key stakeholders regarding the incident near the end of the previous 2021/22 field season when one of the farm manager's dogs was caught in a SA2 trap on the true left side of the river. Following this incident, all SA2 traps (12 in total) were removed from Hossack's property in January 2022. During the calibration session, SA1 traps were shifted from other trap sites throughout the network and deployed on the Hossack's property so that cats could be targeted over the entire trapping network.

### 2.2.3 Trapping regime

During the 2022/23 field season, traps were baited from 18 July, prior to the onset of the tern breeding season. Once traps were set, trap checks and re-baiting (with fresh rabbit meat) occurred approximately once a fortnight until November 2022. From November 2022 onwards, traps were re-baited with the longer lasting 'Muste-Bait' (Pest Control Solutions), a formula of dehydrated rabbit and fish oil, with trap checks occurring approximately once a month. In addition to Muste-Bait, a mustelid and cat lure spray: 'Muste-Bait Ultimate Spray Concentrate' (Pest Control Solutions) was also applied at trap entrances to further entice mammalian pests.

As the current (2022/23) trapping network follows predominantly the same structure and layout as the previous (2021/22) season, and as both field seasons have made use of the trapping database manager – 'trapNZ' – comparisons in the trapping outcomes are primarily made between these two field seasons. Data from previous field seasons are in Appendix 3.

In addition to reporting catch total per species (and trap type etc.), the amount of standardised 'trapping effort' is also reported. Standardisation of trapping effort enables more precise comparisons between differing trapping networks, for example when trapping networks differ by the number of traps deployed, frequency of checks etc. Trapping effort is calculated as the number of catches per 100 trap nights (Equation 1).

***Equation 1.*** $$catches\ per\ 100\ trap\ nights = \left(\frac{number\ caught}{number\ trap\ nights}\right) \times 100$$

Where trap nights are calculated as the number of nights elapsed between trap checks. When an animal was found to have been caught on a following trap check, (or if the trap is sprung but nothing was caught) the number of trap nights for that trap is halved for that interval. Halving the number of trap nights during these instances is common practice and follows DOC best practice (King, 1994),

though it should be noted that it is unknown when during the interval the trap was sprung. The number caught refers to any taxonomic level (e.g., mammals, a particular species, pest species in general, etc.)

### 2.2.4 1080 operation by OSPRI

During October 2022, OSPRI carried out an aerial sodium fluoroacetate (1080) operation targeting possums within the 'Acheron East block' (Figure 5), as part of ongoing possum control program 'TBfree' to prevent the spread of bovine tuberculosis (OSPRI 2022). The operational area borders the down-stream section of the trapping network, north of the Waiau Toa/Clarence River (Figure 5) and may have influenced the pest species caught within this section of the trapping network. We summarise the number of mammalian pest species caught before (July to September), during (October) and after (November to February) the 1080 operation from those traps located within the operational area (CL198 to CL264) and compare with those traps located approximately parallel on the opposite side of the river (CR195 to CR256) as a proxy to how the 1080 operation may have affected predator capture. Comparing these two parallel sections of the river assumes that each side acts independently of the other. However, this assumption does ignore the possibility of predators crossing the river. With this assumption in mind, we also assume the effects of secondary poisoning are likely to be localised on the operated side and thus reflect a reduction in captures.

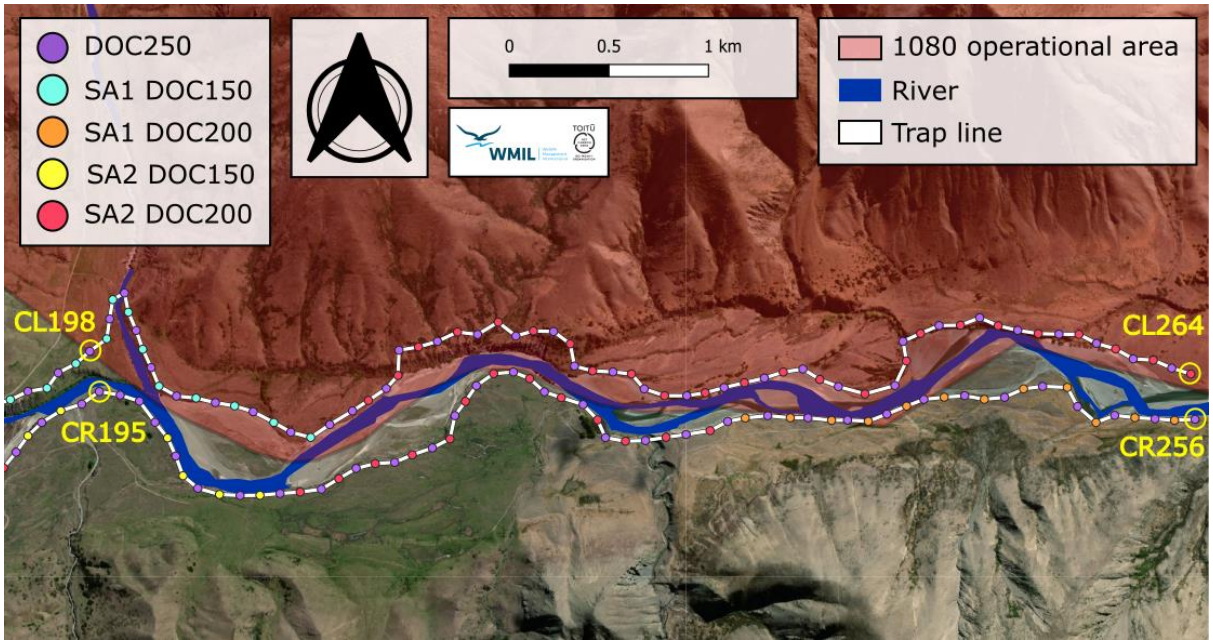


***Figure 5.*** *Map of the Waiau Toa/Clarence trapping network that overlapped with the October 2022 OSPRI 1080 operational area. Trap sites circled in yellow on the true left (CL) of the river indicate those that were within the operational area (trap sites CL198 to CL264). Trap sites highlighted on the true right (CR) of the river indicate trap sites (CR195 to CR256) that were approximately parallel to the traps within the operational area.*

## 2.3 Black-fronted tern nesting

### 2.3.1 River surveys

#### 2.3.1.1 Walk-through surveys

Walk-through surveys were carried out along the rivers during mid-October to early November 2022, to locate tern nesting colonies. During these surveys a single observer walked along the bed of the

river scanning un-vegetated gravel beaches and islands for terns. Each time a concentration of adult terns was found, the observer would walk through the area the terns were frequenting to check whether the birds showed any defensive behaviours. If defensive behaviours were observed (e.g., dive-bombing, alarm-calling or general agitated behaviour) the observer would then search the general area for active nests or freshly dug 'scrapes.' Once nests or fresh scrapes were found, the location of the colony site was then recorded using a Garmin™ GPSmap 64st handheld GPS unit so that the colony could be re-located easily during subsequent visits.

As the breeding season progressed, several short sections of riverbed were also re-surveyed in response to colony failures, to check for new colonies formed by birds re-locating from failed colonies and attempting to re-nest.

Areas targeted included gravel islands and areas where black-fronted terns had previously colonised.

#### 2.3.1.2 Helicopter survey

A helicopter survey was carried out along the upper rivers on 8 November 2022. The survey flight began from Lake Tennyson and travelled towards the end of the treatment zone downstream of the confluence, then flew to Severn shelter and continued down the Wakaputawatea/Acheron River until reaching the confluence.

The helicopter flew 20-30 ms above the ground at a speed of 30 knots to flush terns from their nests along the braided river. During this survey two observers counted the number of terns seen flying along the river along with a population count at each colony. Colony counts involved the helicopter hovering off to the side of the colony so the best angle to count all birds was achieved. The average count from each observer was recorded. Each observer covered one side of the helicopter during the survey, recording numbers on a sheet of paper that was tallied up at the end of the survey. A Garmin™ GPSmap 64st handheld GPS unit was used to identify locations of pre-existing colonies and to mark any new colonies found.

### 2.3.2 Nest and chick monitoring

Once a nesting colony had been located, it was then re-visited one to two times each week until either all active nests had failed, or the last chick had fledged. During each check an observer would walk slowly through the colony, locating nests either by systematically scanning the ground or by observing terns returning to nests after being disturbed. Once found, each nest was given a unique identification number, and its location was recorded using a handheld GPS unit and entered onto "Mergin Maps" app which was used as a database throughout the season. A small rock cairn was then erected approximately 1 m away in a downstream direction to assist with its re-location during subsequent visits. Each time the nest was checked, the status and contents of the nest was recorded onto the Mergin App. Nests were re-checked until they either failed, or the chicks had wandered away from the nest site. For screenshots of the app used, refer to Appendix 5.

During each colony visit, records were kept of the numbers of chicks and fledglings seen at each colony, to provide a conservative estimate of the number of chicks that successfully fledged from each colony.

### 2.3.3 Nest camera monitoring

At each colony, a sample of nests were chosen for camera surveillance to identify the causes of any failures that occurred at these nests, to quantify the relative impacts of various predators on tern hatching success, and to monitor chick shelter use. A minimum requirement of 10% of nests at each colony had cameras deployed at any one time. Within colonies, the nests at which cameras were set up were arbitrarily selected. Preference was given to filming nests situated on the mainland where these occurred, due to the higher likelihood that these nests would be depredated compared to

nests situated on islands. Cameras were only set up on nests containing two-egg clutches to reduce the risk of birds abandoning incomplete clutches in response to the presence of the camera. At each selected nest, a Browning Dark Ops Pro XD (BTC-6PXD) trail camera was mounted on a 0.4-m tall wooden stand approximately 1 m from the nest (Figure 6). Stands were anchored down with large river stones to prevent them from tipping over in the wind, during minor floods or when knocked by livestock. Each camera was powered by six AA batteries and an external Browning solar panel charger and was equipped with a 32 GB SD memory card. These cameras were programmed to take three photos each time the motion sensors were activated in response to movement around the nest (Appendix 6Appendix 6: Browning Dark Ops Pro XD (BTC-6PXD) trail camera settings.).

Cameras were checked at least 1-2 times per week and usually remained at the nest until it either failed or hatched. Cameras were temporarily retrieved if large amounts of rain were predicted to prevent them from being washed away.

***Figure 6.*** *Nest camera set up on a black-fronted tern nest along the Waiau Toa/Clarence River, 2019.*

### 2.3.4 Nest success analysis

Nest success (defined here as the proportion of clutches laid that hatched chicks) was calculated using apparent (observed) nest success. This was determined by calculating the proportion of nests monitored that successfully hatched one or more chicks. This measure of nest success has been reported for this tern population in previous years (Bell 2013, Bell & Mischler 2014, Bell 2015, Bell & McArthur 2016, Bell et al. 2018, Bell & Harborne 2019, Connor-McClean & Bell 2020, Connor-McClean et al. 2022), and has continued to be used so that comparisons with previous seasons can be made. Apparent nest success is also used as a measure of shorebird breeding success (e.g., Rebergen et al. 1998, Sanders & Maloney 2002).

### 2.3.5 Historical comparison data changes

Historical data comparison tables between seasons were recalculated to maintain consistency between Phase 1 and 2 data. The main change was to categorise “treatment” calculations as ‘trapped island nests (excluding mainland nests)’ and “non-treatment” as ‘non-trapped island nests and all mainland nests.’ This was done by going through each season’s nest data sheets and recalculating treatment island total nest counts, hatching success, failed percentages, predation, flooding and abandonment numbers and percentages. All mainland nests were separated and added onto the “non-treatment” pre-existing numbers to calculate new percentages. Upper Swimming

hole colony nests were all added to “non-treatment” for Phase 1. Fledgling numbers for each treatment colony was recalculated and adjusted. All Upper Swimming hole fledgling counts in Phase 1 were added to “non-treatment’ totals. New totals were created, and each comparison table was updated.

## 2.4 Banding and resighting

### 2.4.1 Kāhu banding

Nest predation by kāhu is known to have a significant impact on breeding terns (Bell & Harborne 2019). However, little is known on the population of kāhu around the Waiau Toa/Clarence River and the percentage of nests that are predated by different birds. To understand the extent of nest predation behaviour in the local kāhu population on tern nests a capture and banding scheme was organised. This is the second season of capturing and banding kāhu. Refer to Connor-McClean et al. (2022) for the previous season’s results.

From 22 to 25 August 2022, a total of 21 funnelled kāhu cage traps were set up along a 40 km stretch of the upper Waiau Toa/Clarence River from the furthest upstream known black-fronted tern colony to the confluence (Figure 7). Traps were spaced approximately 2 km apart from each other and about 30-100m from the roadside, and baited with possum, lamb, or rabbit carcasses (Figure 8). The 40 km stretch of river with kāhu traps was driven up to six times per day. Where traps were thought to be ineffective, they were moved to other potentially more suitable locations.

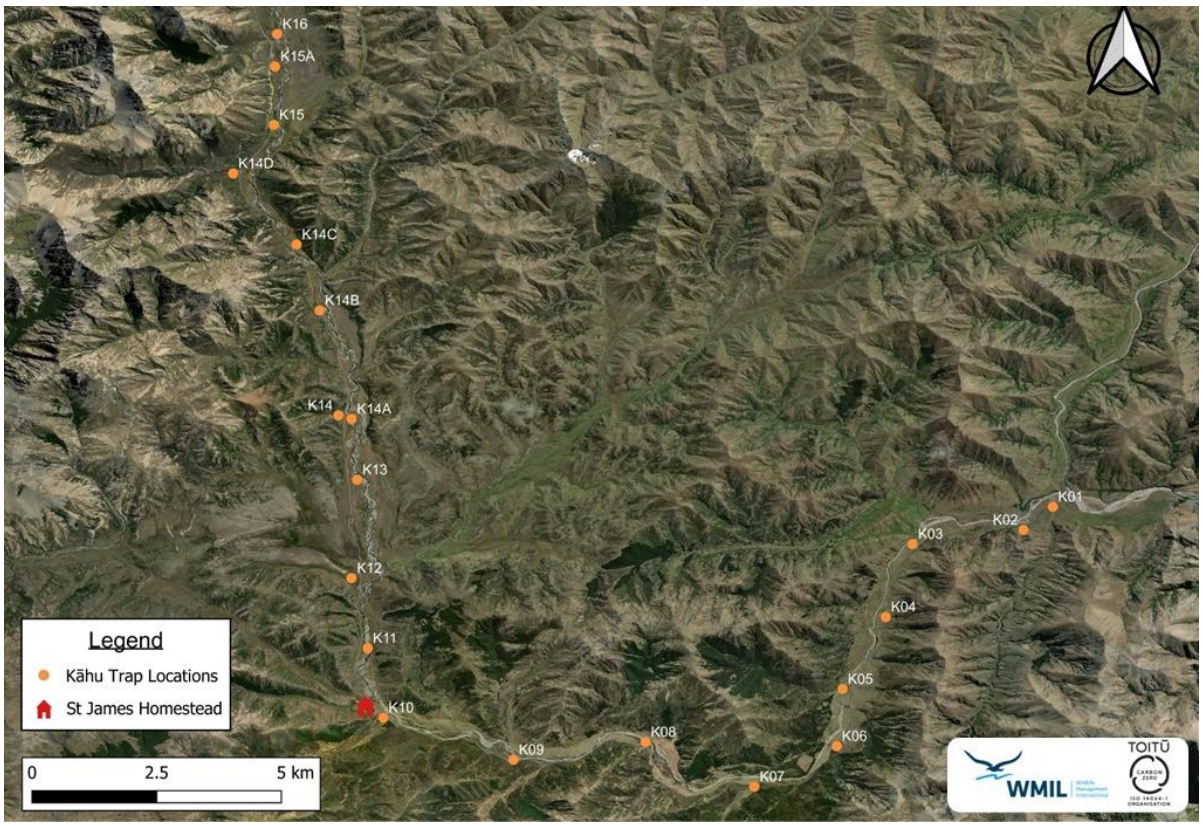


***Figure 7.*** *Kāhu trap locations along Waiau Toa/Clarence River (22 to 25 August 2022).*

***Figure 8.*** *Baited kāhu trap setup in the Molesworth Recreational Reserve, Waiau Toa/Clarence River, August 2022.*

Captured kāhu were retrieved from the cage traps and banded with a metal unique ID L-sized band along with a plastic individually numbered white darvic band to make field identification of individuals easier (Figure 9). Kāhu were then weighed, aged, and sexed before being released (under permit through the DOC contract DOC-6744957). All banding was conducted under the supervision of a certified level three bander (Mike Bell, Toroa Consulting).

To maintain animal welfare standards, traps were closed overnight or during the day if harsh weather conditions were forecast.


***Figure 9.*** *Darvic and metal bands on kāhu in the Molesworth Recreational Reserve, Waiau Toa/Clarence River.*

## 2.4.2 Black-fronted tern banding

### 2.4.2.1 Adults

From November to December 2022, tern banding took place at several large colonies along the upper Waiau Toa/Clarence River under permit through the DOC contract DOC-6744957.

Terns were captured using drop traps. At any one time, a maximum of two drop traps were set over nests with two eggs (Figure 10). When a bird was captured, an observer instantly collected the bird, placed it into a bird bag, and carried it to the banding station. The bird was weighed, then carefully removed from the bag and banded with a metal band and yellow flag with an ID code. The bird's wing length was measured, then the bird was released.


***Figure 10.*** *Drop traps set up over black-fronted tern nests on the Waiau Toa/Clarence River, 2022.*

### 2.4.2.2 Chick banding

Between 15 and 17 December 2022, all colonies were visited for chick banding under permit through the DOC contract DOC-6744957. All banding was supervised by two level three banders (Patrick Crowe [DOC], and Biz Bell [WMIL]).

At each colony a walk-through survey took place from the down-stream end of the island to the top. This ensured that any chicks in the water were caught before they were swept away. Any chicks found were caught by hand or with nets and were banded with metal bands (Figure 11). Chicks were then released back under a large rock to shelter (around 15 m away from the group of people), or safely away from the river's edge ensuring no chicks were tempted to run into the fast-flowing water.

***Figure 11.*** *Black-fronted tern chick being banded by Keegan Miskimmin (WMIL) under the close eye of Level 3 bander, Patrick Crowe (DOC) on the Wakaputawatea/Acheron River, 2022.*

WMIL: Connor-McClean et al. 2023

### 2.4.3 Band resighting

#### 2.4.3.1 Black-fronted terns

At the beginning of the breeding season (early October), clusters of terns are found resting on islands before nesting begins. This is the most suitable time to observe previously banded bird flags through binoculars or by photograph. Any flag identified was recorded along with its location and date. This data was then uploaded onto the FALCON database (NZ bird banding database; https://app.birdbanding.doc.govt.nz/) under the *Black-fronted tern study* project.

Nest camera footage was the most effective, non-invasive way to identify bird bands, when adults landed at the nest or walked in front of the camera (Figure 12). Several banded terns were also recaptured during adult tern banding trips in November and December 2022.


***Figure 12.*** *Yellow flag resighting (KE) shown in enlarged photograph at Upper Swimming Hole (CA), 27/11/2022, Waiau Toa/Clarence River. This bird was previously banded in 2016 as a chick at Swimming Hole Colony, Waiau Toa/Clarence River.*

#### 2.4.3.2 Kāhu

The most effective way to resight kāhu during the season was by using trail cameras at nests which kāhu have been previously known to predate.

Kāhu cage catching trips were also an effective way of recapturing previously banded birds.

## 2.5 Chick shelters

Two styles of chick shelters built from plywood were incorporated into the 2021/2022 black-fronted tern monitoring season. A total of 20 A-frame and 40 flat-roof chick shelter designs were built and distributed throughout treatment zone colonies during the 2022/23 season (Figure 13).

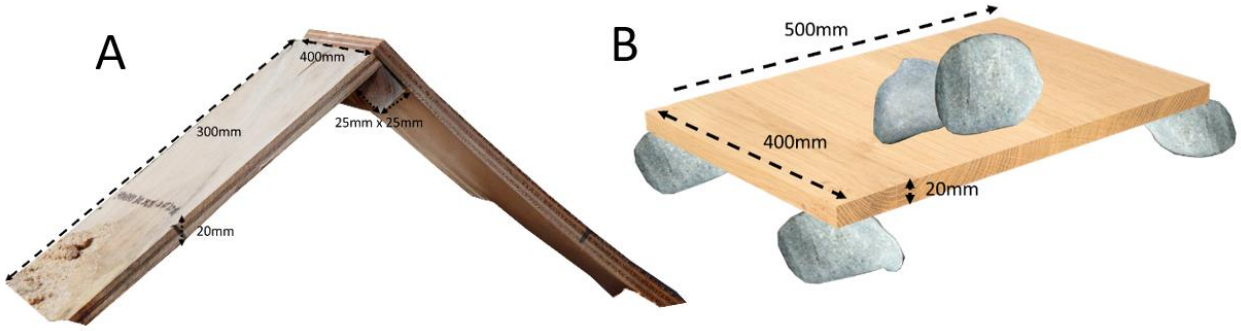


***Figure 13.*** *Chick shelter designs incorporated into the 2022/23 black-fronted tern breeding season on the upper Waiau Toa/Clarence River. Shelter A shows the A-frame design and measurements used. Shelter B shows the flat-roof design and measurements used.*

Once a tern nest with two eggs reached around day 20 of incubation, a chick shelter was deployed about 0.5m away from the nest and secured down by heavy rocks to prevent it from being blown away by strong winds or washed out by minor floods (Figure 14). Nests were then watched from a distance to ensure the nesting terns would return to their nests comfortably.

Many chick shelters were in view of monitoring nest cameras to capture footage of chick behaviour around these shelters after hatching.


***Figure 14.*** *Trail camera footage showing A-frame (left) and flat-roof chick shelters (right) deployed near active black-fronted tern nests along the upper Waiau Toa/Clarence River during the 2022/23 breeding seasons.*

# 3. RESULTS

## 3.1 Enhanced islands

Leading up to the start of the 2022/23 season, all available enhanced islands were suitable breeding islands (this included both Mitchell's and Swimming Hole Island which had no enhancement work carried out in March/April 2022).

During the winter of 2022, river flow rates were irregular, peaking at 106 $m^3$/second and reaching above 50 $m^3$/second during four different flooding events (Figure 15). Whilst these floods would have put a high pressure on the braided river formation, all the enhanced islands managed to withstand the pressure and keep their general form throughout the winter period. This compares to

the 2021 winter where river flow rates passed 150m$^3$/second on three separate occasions, peaking at 205 m$^3$/second (Figure 15). This resulted in only two enhanced islands maintaining their form.

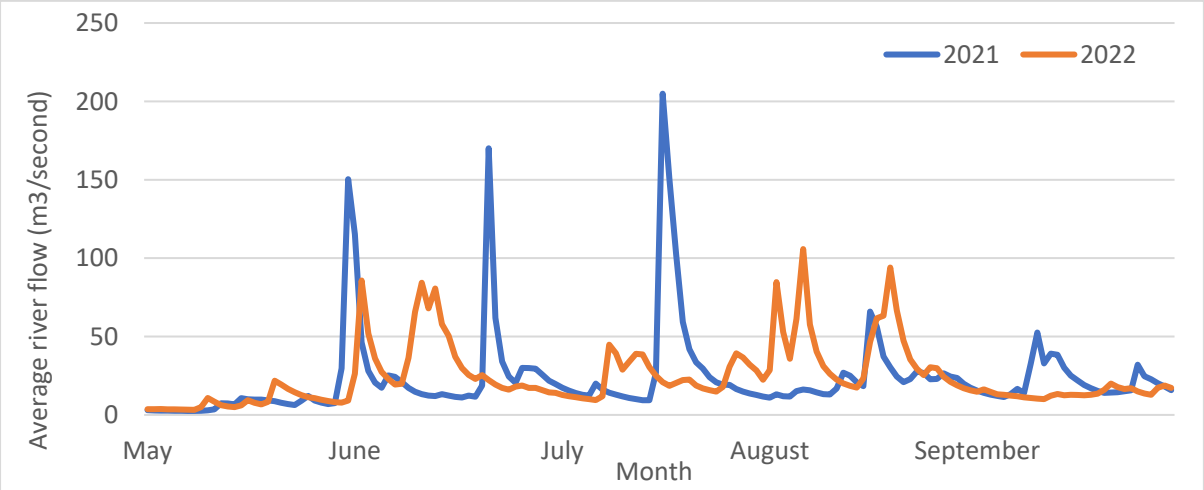


***Figure 15.*** *Comparison of average daily flow rates on the Waiau Toa/Clarence River during the months of May to October in 2021 and 2022.*

However, whilst enhanced island conditions were in acceptable states on 1 October 2022, throughout the 2022/23 season, decreasing river flow rates and increasing vegetation growth caused several islands to decrease in nesting suitability (Table 2). Sections in the river channels surrounding several islands dried up, and vegetation growth on a couple of islands may have been deemed unfavourable to nesting birds resulting in several islands to lose their "enhanced" status by the time the season ended (Figure 16 & Figure 17).

***Figure 16.*** *Comparison between Lower Bush Gully enhanced island on 1 Oct 2022 at 15 m$^3$/second (left), and 13 January 2023 at 3.4 m$^3$/second (right).*

***Figure 17.*** *Comparison between Swimming Hole enhanced island on 1 Oct 2022 at 15 m$^3$/second (left), and 13 January 2023 at 3.4 m$^3$/second (right). Low river flow and vegetation coverage throughout the season diminishes the island's enhanced value.*

***Table 2.*** *Condition of enhanced islands on the Waiau Toa/Clarence River at the end of the 2022/23 season and maintenance required. Note, red= top priority, orange= mid-priority, yellow= low priority, green= no enhancement work required.*

| River | Code | Site | Condition at end of 2022/23 season | Maintenance Required |
|---|---|---|---|---|
| Waiau Toa/Clarence River | C1 | Upper Swimming Hole | Island remains in good condition. Channels wider than 3 m on either side at minimal river flow levels keeping island separated from the mainland. In areas, water is shallow with several stepping-stones. Parts of area vegetated with grasses and woody debris, however, terns appeared to favour nesting in these areas. Island raised above medium flood levels. | True left channel of island could be re-cleared and deepened. |
| | C2 | Cow Island | Island remains surrounded by wide channels at low water flow except for one small stepping-stone island. Island height raised to avoid moderate to high floods. Small, vegetated patch on the island used by fledglings to hide in. Large amount on available nesting habitat. | True left channel of island could be cleared and widened to eliminate shallow gravel islands and stepping-stones. |
| | C3 | Eddy's Inlet | True left side of island dried up and attached to the mainland during low flow. The end of the "channel" at downstream end of island is relatively built-up providing stepping-stone pathways across to island during higher water flow. No vegetation on island. Island raised enough to avoid moderate to high flood events. | True left channel needs to be opened at the top of the island and cleared through to the bottom of the island. |
| | C4 | Upper Bush Gully | True right channel of island dried up during low flow connecting island to mainland. Upper end of island has been flattened over. Island elevation raised at downstream end. No vegetation on island. | True right channel needs to be opened and cleared through. Upper end of island needs to be raised higher. |
| | C5 | Bridge Island | True left channel thins out during very low flow. Island surface has vegetation sprouting. Island surface is quite silty creating good conditions for vegetation growth- difficult to maintain. Overall, still maintains a good percentage of nesting habitat. | Weed spraying could occur here. River flow could be evened out at the top of the river. However, when river flow is low, it will inevitably thin out. |
| | A | Swimming Hole | Channel remains surrounding island during low river flow. Island is now heavily vegetated with grasses, broom, and other smaller plants. Island surface is silty, creating a good environment for vegetation growth which is difficult to clear. Island raised above moderate to high river flow events. | Island needs to be cleared or vegetation sprayed. |
| | B | Mitchell's | Island remains surrounded by wide channels at low water flow. Island contains a suitable amount of nesting habitat. Island raised above medium to high river flow events. | No maintenance required. |

## 3.2 Predator control

### 3.2.1 Summary overview

Over the course of 201,556 total trap nights, a total of 766 mammalian predators were caught in kill traps along the upper Waiau Toa/Clarence River during the 2022/23 field season, resulting in a catch rate of 0.38 captures per 100 trap nights. This included 17 feral cats, 11 ferrets, 520 hedgehogs, 77 mice, 11 possums, 18 rats, 38 stoats, and 74 weasels (Table 3). Each trap type caught a mixture of predator species (Table 3). Higher rates of predators were caught in DOC250 traps, followed by double-set DOC200 and double-set DOC150. Double-set SA1 and SA2 traps caught substantially fewer than all other traps, in particular SA2 traps caught a fifth of the numbers caught by SA1. However, SA2 traps performed similarly in catching cats (the targeted species for this trap type).

For species that are specifically targeted by the trapping network (mustelids, cats, and hedgehogs), the rate of capture for a particular trap was lowest for ferrets (0.005 captures per 100 trap nights) and highest for hedgehogs (0.258 captures per 100 trap nights; Table 4).

***Table 3.*** *Total number of mammalian predators caught in kill traps during the 2022/23 field season. The total number of traps deployed follows each trap type in brackets. Note, DOC150, DOC200 and Steve Allan 1 traps are set as double-set traps at the same site.*

| Predator | Trap type | | | | | |
|---|---|---|---|---|---|---|
| | DOC 150 (294) | DOC 200 (216) | DOC 250 (262) | Steve Allan 1 (286) | Steve Allan 2 (112) | Total (1170) |
| Cat | 2 | 3 | 5 | 3 | 4 | **17** |
| Ferret | 1 | 1 | 3 | 4 | 2 | **11** |
| Hedgehog | 102 | 157 | 180 | 74 | 7 | **520** |
| Mouse | 25 | 32 | 20 | - | - | **77** |
| Possum | - | 6 | 2 | 1 | 2 | **11** |
| Rat | 5 | 6 | 7 | - | - | **18** |
| Stoat | 15 | 7 | 13 | 1 | 2 | **38** |
| Weasel | 34 | 18 | 22 | - | - | **74** |
| **Total** | **184** | **230** | **252** | **83** | **17** | **766** |

***Table 4.*** *The rate of capture (number of catches per 100 trap nights) for each mammalian predator for each trap type during the 2022/23 field season. The total number of traps nights per trap type follows each trap type in brackets. Note, DOC150, DOC200 and Steve Allan 1 traps are set as double-set traps at the same site.*

| Predator | Trap type | | | | | |
|---|---|---|---|---|---|---|
| | DOC 150 (51,000) | DOC 200 (35,797.5) | DOC 250 (42,726) | Steve Allan 1 (51,632) | Steve Allan 2 (20,029.5) | All traps combined (202185) |
| Cat | 0.004 | 0.008 | 0.012 | 0.006 | 0.019 | **0.008** |
| Ferret | 0.002 | 0.003 | 0.007 | 0.008 | 0.010 | **0.005** |
| Hedgehog | 0.200 | 0.439 | 0.421 | 0.143 | 0.033 | **0.257** |
| Mouse | 0.049 | 0.089 | 0.047 | - | - | **0.038** |
| Possum | - | 0.017 | 0.005 | 0.002 | 0.010 | **0.005** |
| Rat | 0.010 | 0.017 | 0.016 | - | - | **0.009** |
| Stoat | 0.029 | 0.020 | 0.030 | 0.002 | 0.010 | **0.019** |
| Weasel | 0.067 | 0.050 | 0.051 | - | - | **0.037** |

***Table 5.*** *The number of species caught per habitat type during the 2022/23 field season. Percentage (%) caught for a particular species for each habitat type follows the catch numbers in parentheses. The percentage (%) of traps located within a particular habitat (and thus the expected frequency of capture relative to the number of available traps) is listed after habitat type in parentheses. Note, for 'Total', the percentage following in brackets is summarised across habitat types (irrespective of species). Also note that exotic and native habitat types are abbreviated to E. and N., respectively.*

| Predator | Habitat type | | | | | | |
|---|---|---|---|---|---|---|---|
| | Gravel/rock (24.5) | E. grassland (71.8) | E. scrub (0.6) | E. forest (0.6) | Tussock (0.9) | N. scrub (0.6) | N. forest (0.9) |
| Cat | 3 (17.6) | 12 (70.6) | - | - | - | - | 2 (11.8) |
| Ferret | - | 11 (100) | - | - | - | - | - |
| Hedgehog | 90 (17.3) | 409 (78.7) | 3 (0.6) | 6 (1.2) | 9 (1.7) | 2 (0.4) | 1 (0.2) |
| Mouse | 17 (22.1) | 58 (75.3) | - | - | 1 (1.3) | - | 1 (1.3) |
| Possum | 2 (18.2) | 9 (81.8) | - | - | - | - | - |
| Rat | 2 (1.1) | 15 (83.3) | - | - | - | - | 1 (5.6) |
| Stoat | 9 (23.7) | 27 (71.1) | 1 (2.6) | - | - | 1 (2.6) | - |
| Weasel | 24 (32.4) | 48 (64.9) | - | - | 1 (1.4) | 1 (1.4) | - |
| **Total** | **147 (19.2)** | **589 (76.9)** | **4 (0.5)** | **6 (0.8)** | **11 (1.4)** | **4 (0.5)** | **5 (0.7)** |

### 3.2.2 Effect of 1080 operation on pest species

There were no noticeable differences in the number of pest species caught before, during or after the 1080 operation (Table 6) when comparing the parallel sides of the river. For most species, there tended to be higher numbers caught after the 1080 operation, which is likely due to changes in breeding behaviour and activity patterns coinciding with warmer temperatures. The only noticeable difference was the reduction in hedgehog captures in the months following the 1080 operation, all other species appeared unaffected based on this data.

***Table 6.*** *Catches of mammalian pests before (July to September), during (October), and after (November to February) the 1080 operation that occurred during the 2022/23 field season. Note, catch data from the true left side of the Waiau Toa/Clarence River includes only traps that were inside the 1080 operation boundary (from CL198 to CL264). Catch data from the true right of the river are from traps (from CR195 to CR256) that were approximately parallel in their geography to the traps contained within the 1080 operational area.*

| Predator | True left (1080 side) | | | True right (non 1080 side) | | |
|---|---|---|---|---|---|---|
| | Before | During | After | Before | During | After |
| Cat | - | - | 2 | 1 | - | 3 |
| Ferret | 1 | - | 2 | 1 | | 1 |
| Hedgehog | 4 | 18 | 40 | 12 | 6 | 72 |
| Mouse | 1 | - | 3 | 3 | - | 1 |
| Possum | 2 | 1 | - | - | - | 3 |
| Rat | 3 | - | 1 | - | 1 | - |
| Stoat | 1 | - | 2 | 1 | - | - |
| Weasel | 2 | - | 4 | 3 | 1 | 3 |
| **Total** | **14** | **19** | **54** | **21** | **8** | **83** |

### 3.2.3 Target species overview

#### 3.2.3.1 Cats

Cats were caught across all trap types in the trapping network. Among trap types, SA2 traps had the highest rates of catching cats at more than double the rate of SA1 traps. Among the DOC series traps, DOC250 traps caught a greater number of cats compared to the SA series and caught at double the rate of SA1 traps. Catch numbers and catch rates of DOC150 and DOC200 traps compared to SA1s were also similar. Between field seasons, the capture rate was relatively similar until summer (January to February), where capture rates substantially increased in the 2022-23 season (Figure 18). Most cats were caught in exotic grassland, with a handful caught in gravel/rock and native forest (Figure 19). However, traps within native forest caught relatively high numbers of cats when considering their low availability whereas cats caught in exotic grassland and gravel/rock were caught at either similar or lower proportions relative to trap availability, respectively (Table 5).

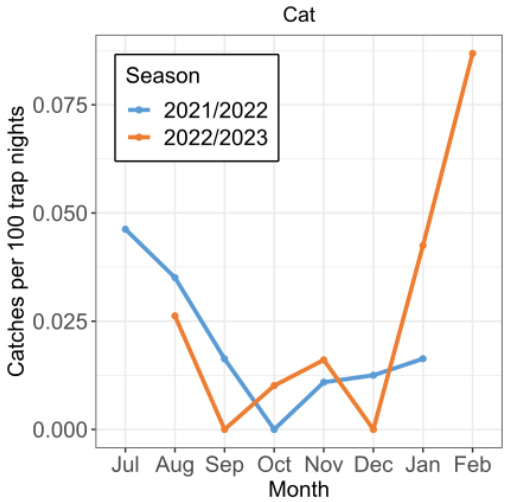


***Figure 18.*** *The rate of capture (catches per 100 trap nights) per month for cats during the 2022/23 and 2021/22 field seasons along the Waiau Toa/Clarence River.*

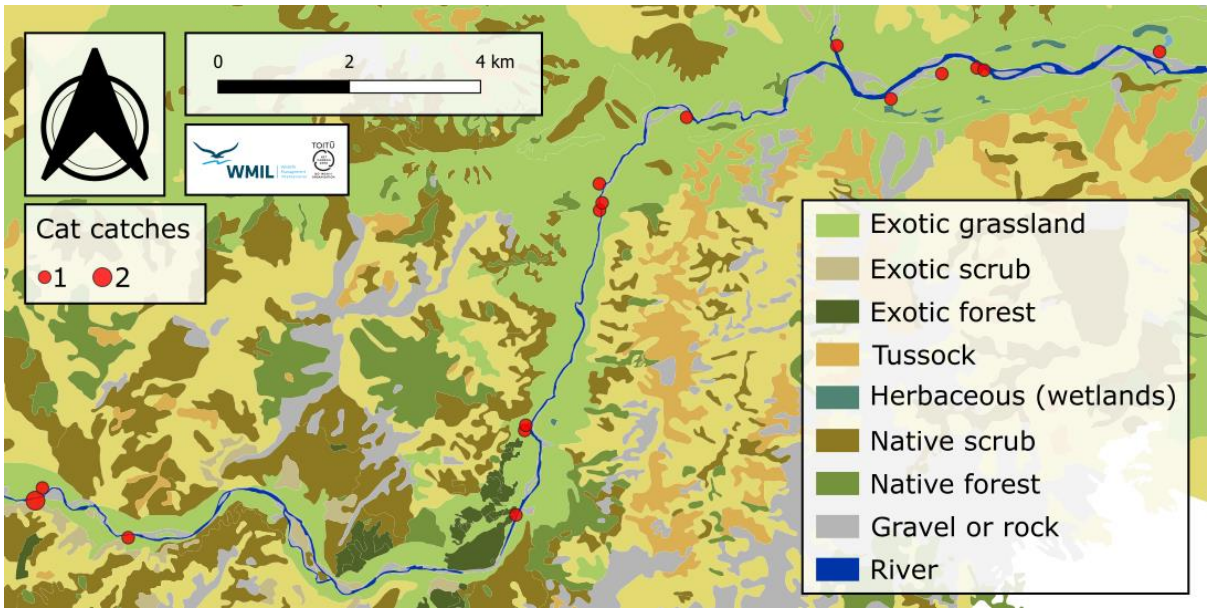


***Figure 19.*** *Number and location of cats caught along the Waiau Toa/Clarence River during the 2022/23 field season. The size of points indicates the number caught at a particular trap site. Broad habitat types are shown in different colours.*

WMIL: Connor-McClean et al. 2023

#### 3.2.3.2 Mustelids: ferrets, stoats, and weasels

The majority of ferrets were caught in SA1 and DOC250 traps but SA2 traps caught ferrets at a slightly higher rate (Table 3). All trap types caught at least one ferret during the 2022/23 field season (Table 3). Capture rates for ferrets appeared to show a similar pattern between field seasons, high during trap opening, followed by a drop, and then peaking the month after, albeit the pattern has shifted by a month later during the current field season. Interestingly, ferret capture rates ranged between double and triple throughout the season compared to the previous season. After November, ferret captures continued to decline until the trapping network closure, whereas in the previous season ferret captures were zero from November to January. Ferrets were only caught in exotic grassland, whereas stoats and weasels were caught in roughly the same proportions across in gravel/rock, exotic grassland, and native scrub habitat types (Table 5; Figure 21). Of the mustelids, only stoats were caught in exotic scrub, whereas weasels were the only mustelid to be caught in tussock vegetation (Table 5; Figure 21).

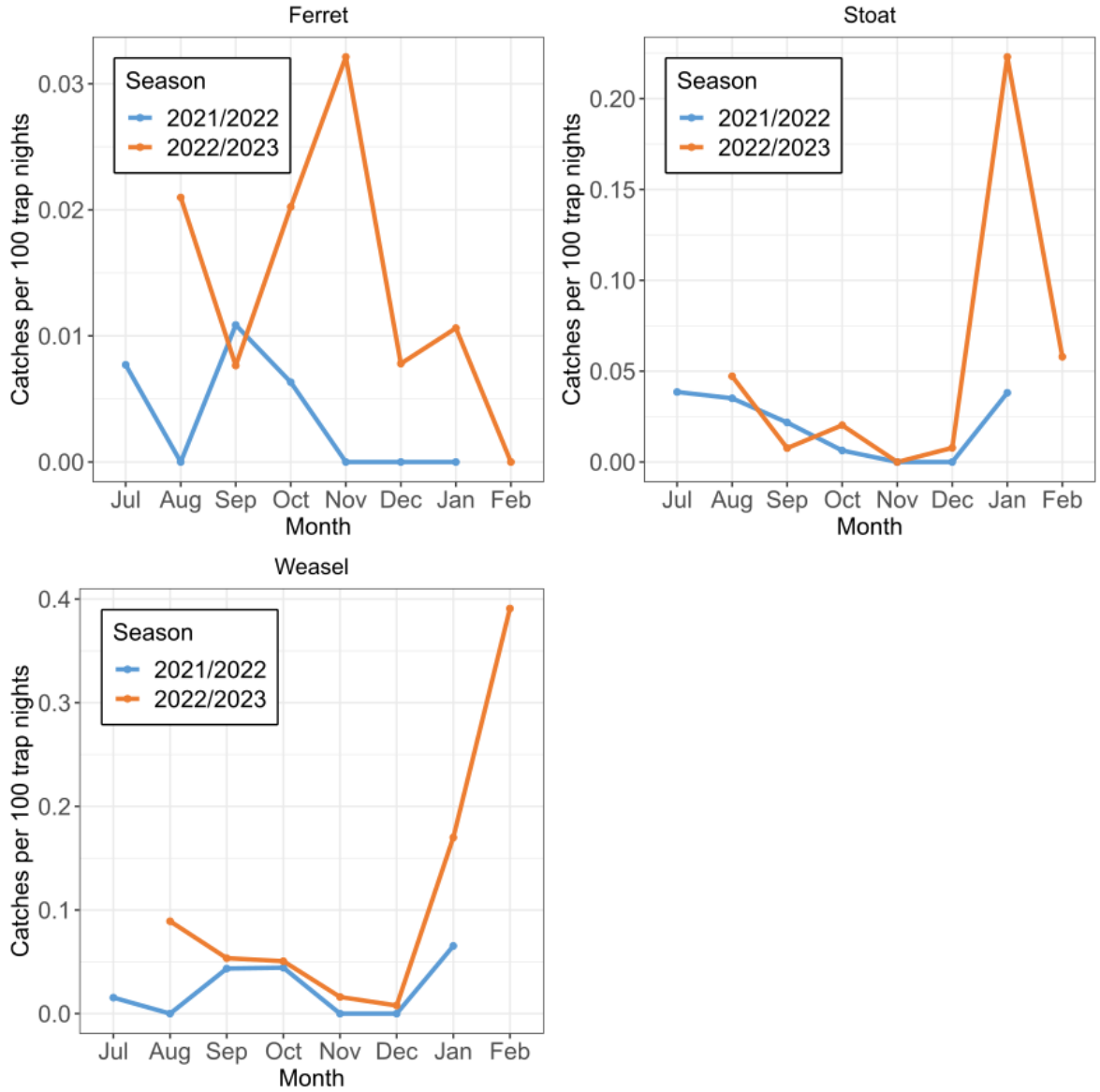


***Figure 20.*** *The rate of capture (catches per 100 trap nights) per month for mustelids (i.e., ferrets, stoats, and weasels) during the 2022/23 and 2021/22 field seasons along the Waiau Toa/Clarence River.*

There were nearly double the number of weasels caught compared to stoats during the 2022/23 season (Table 3). Only the DOC series traps caught weasels, whereas stoats were caught across all trap types (Table 3). Numbers of stoat captured in the 2022/23 field season were double the previous season (19 in 2021/22), but still a third of the 2020/21 season (92 in 2020/21). Weasel captures were much higher during the 2022/23 season compared to the previous two field seasons (29 and 32 in 2021/22 and 2020/21, respectively).

For stoats, the rate of capture over time between field seasons tended to oscillate between similar values and overall tended to follow a downward trajectory until the arrival of summer where rates of capture jumped (Figure 20). Stoat capture rates peaked in January but remained high into February when compared to the rest of the 2022/23 field season. For weasels, the rate of capture from October to December followed a similar rate between this field season and the previous field season. However, capture rates during August were far above the usual rate seen (Figure 20). Moreover, from January until the closure of the trapping network in February weasel capture rates massively increased compared to the rest of the field season (Figure 20).

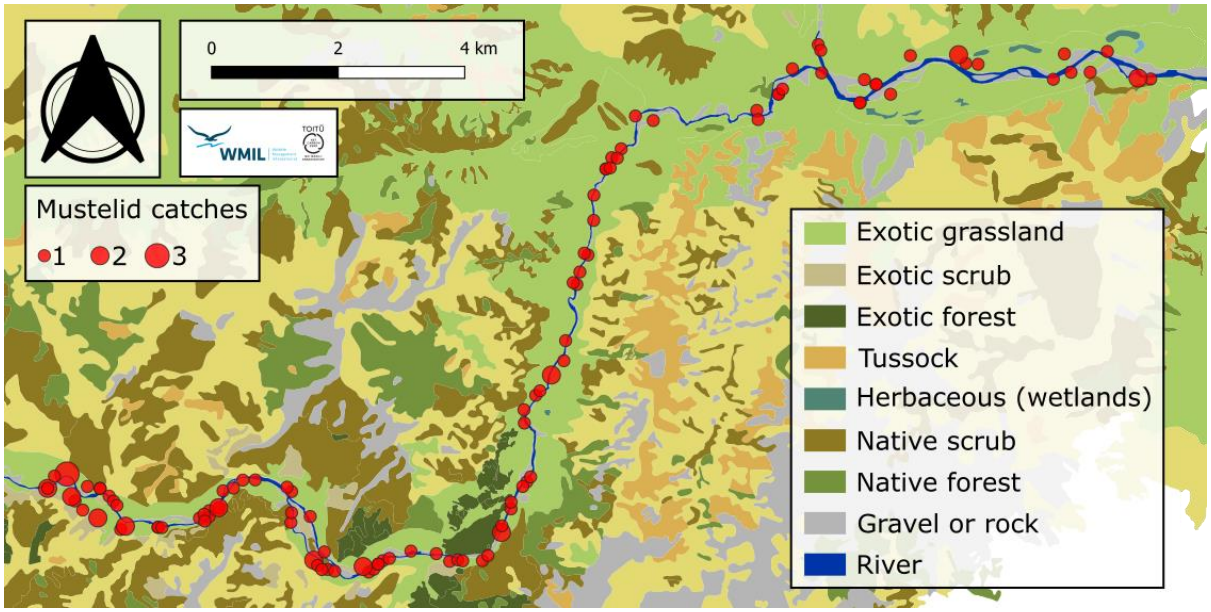


***Figure 21.*** *Number and location of mustelids (ferrets, stoats, and weasels) caught along the Waiau Toa/Clarence River during 2022/23 field season. The size of points indicates the number caught at a particular trap site. Broad habitat types are shown in different colours.*

#### 3.2.3.3 Hedgehogs

Hedgehogs were the most frequently caught mammalian pest species during the 2022/23 field season. DOC250 traps caught the highest number, but DOC200 and DOC250 traps caught hedgehogs at similar rates (Table 3). Both DOC150 and SA1 traps caught hedgehogs at a much lower rate compared to the other DOC series traps, however SA2 traps were the least effective at catching hedgehogs, catching both the least and at the lowest catch rate by a significant margin (Table 3). At the landscape level, hedgehogs were caught throughout the trapping network. Of the trap sites that caught hedgehogs (271 trap sites caught hedgehogs), half caught at least one hedgehog throughout the field season with a few trap sites catching hedgehogs at higher rates. For instance, two trap sites caught eight and nine hedgehogs each. Hedgehogs were caught in all habitat types but were caught most often in exotic grassland (Table 3; Figure 23) at higher proportion relative to available traps. Traps in exotic scrub, exotic forest and tussock caught hedgehogs at the same or greater proportion whereas traps in gravel/rock, native scrub, and native forest caught less hedgehogs in regard to their availability. Interestingly, during the current field season some hedgehogs were beginning to emerge in August, much earlier than expected, whereas in the field season prior capture rates at the same

time were almost nil. By October, the 2022/23 hedgehog capture rates were similar to rates in the previous field season, but continued to climb and peaked a month later in November (Figure 22).

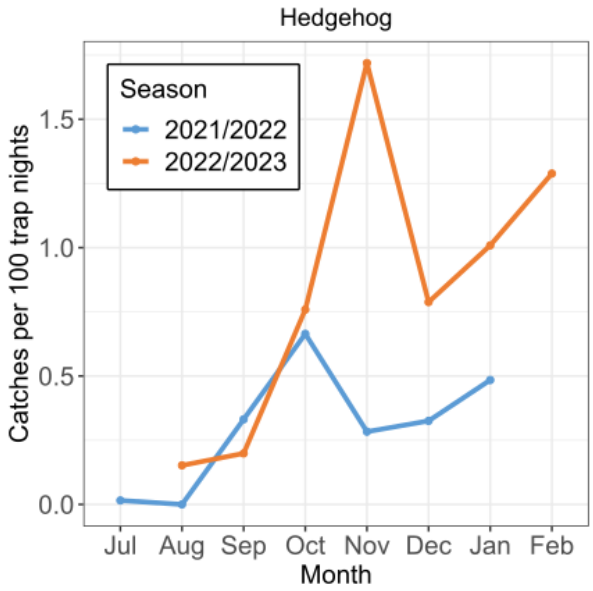


***Figure 22.*** *The rate of capture (catches per 100 trap nights) per month for hedgehogs during the 2022/23 and 2021/22 field seasons along the Waiau Toa/Clarence River.*

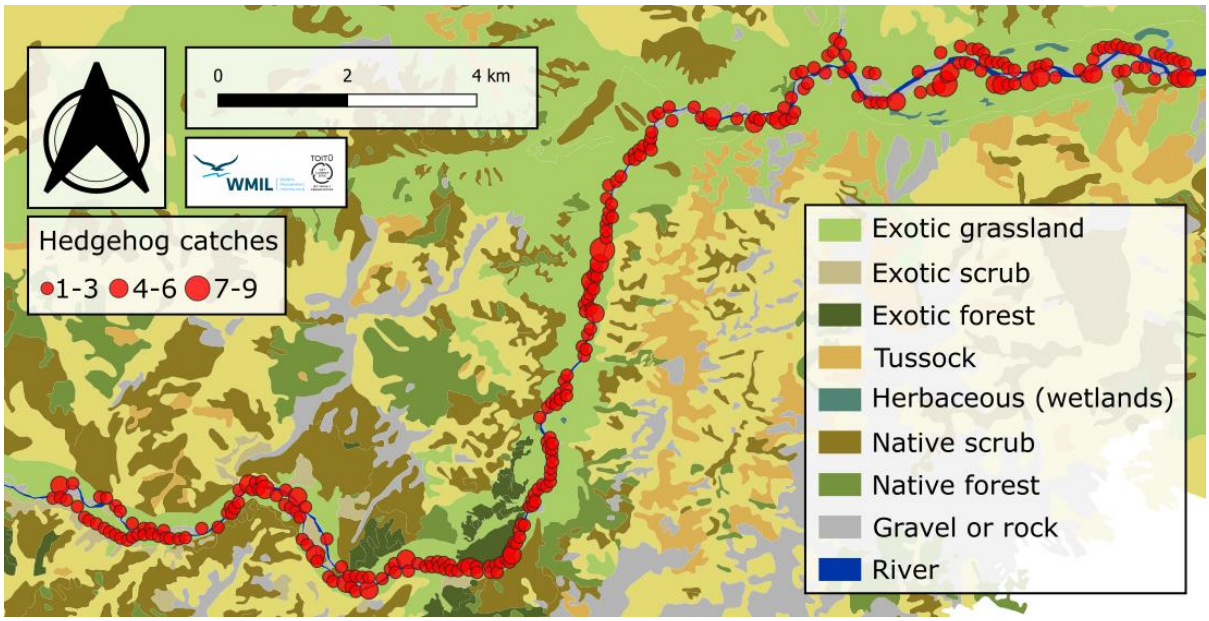


***Figure 23.*** *Number and location of hedgehogs caught along the Waiau Toa/Clarence River during 2022/23 field season. The size of point indicates the number caught at a particular trap site. Broad habitat types are shown in different colours.*

### 3.2.3.4 Rodents: Rats and mice

Both mice and rats were only caught in the DOC series traps during the 2022/23 field season. More than four times the number of mice were caught compared to rats, with the DOC200 having the highest catch rate for both species. Interestingly captures of rats followed a nearly symmetrical 'u'-shaped pattern throughout the season, decreasing through August to October and dropping to zero in November. After November the catch rate steadily increased until traps were closed for the season, almost mirroring the rate observed prior to November (Figure 24). The trapping network (except for

the 2019/20 field season) typically catches either none or very few (up to two) rats each field season, making this field season highly unusual.

Mice catches were low from trap opening onwards until October which was similar to what occurred during the previous field season. After October, the catch rate of mice jumped considerably and continued to climb until it peaked in February (Figure 24). Across different habitat types, mice were caught in similar proportions to available traps, whereas rats were caught in exotic grassland and native forest in greater number relative to available traps. Traps located in gravel/rock habitats caught rats are very low frequency relative to the number of traps.

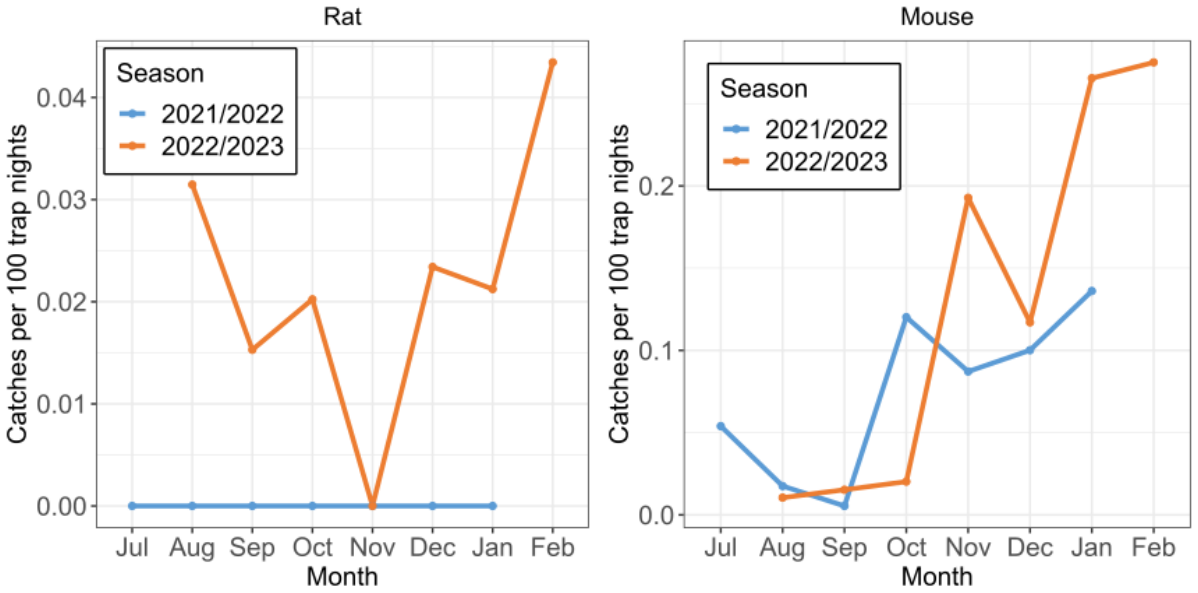


***Figure 24.*** *The rate of capture (catches per 100 trap nights) per month for rodents (rats and mice) during the 2022/23 and 2021/22 field seasons along the Waiau Toa/Clarence River.*

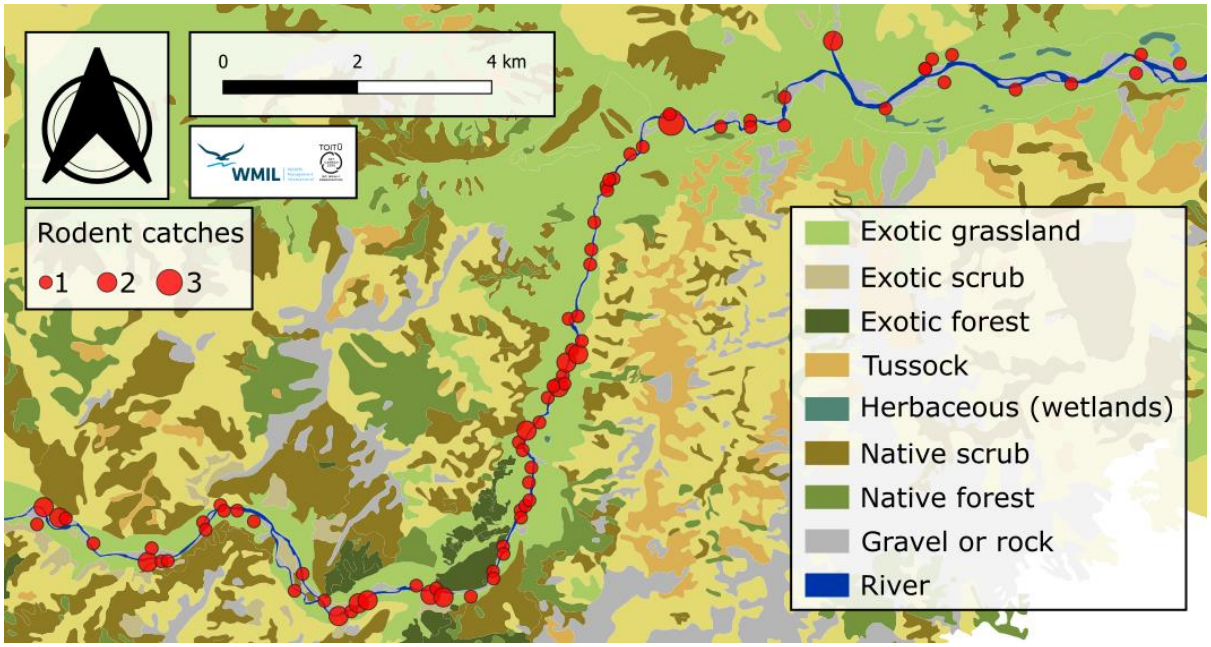


***Figure 25.*** *Number and location of rodents (mice and rats) caught along the Waiau Toa/Clarence River during 2022/23 field season. The size of point indicates the number caught at a particular trap site. Broad habitat types are shown in different colours. Note: all rats caught were ship rats (R. rattus).*

WMIL: Connor-McClean et al. 2023

#### 3.2.3.5 Possums

The DOC200 traps caught the most possums and at more than double the rate compared to most other traps. Moreover, when compared to SA2 traps, DOC200 traps caught triple the number and at a rate that was nearly double. Excluding the DOC200 traps, all other traps caught a similar number of possums.

In the previous field season, rates of capture for possums peaked in July (same month that traps were opened), whereas in the current field season, the peak occurred in November (Figure 26). Excluding July of the previous year, capture rates tended to follow the same general patterns between field seasons (Figure 26). Possums were caught by traps only located in either gravel/rock or exotic grassland. In proportion to the number of traps within each habitat type, catches in exotic grassland comprised the majority of possum catches, whereas traps in gravel/rock caught relatively fewer.

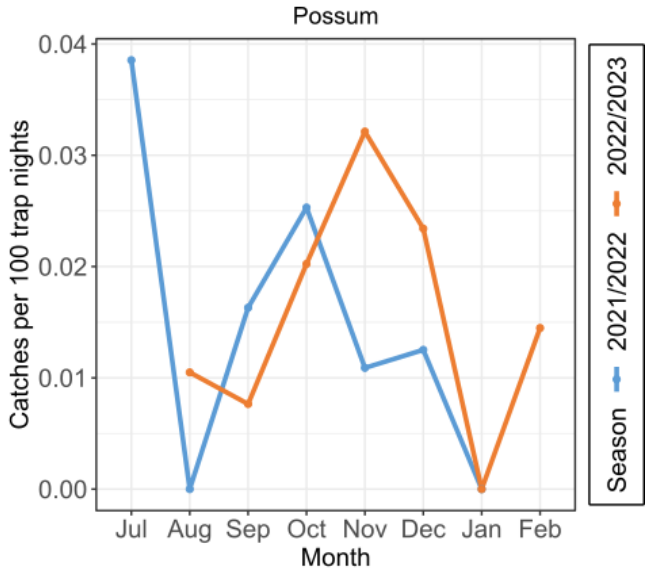


***Figure 26.*** *The rate of capture (catches per 100 trap nights) per month for possums during the 2022/23 and 2021/22 field seasons along the Waiau Toa/Clarence River.*

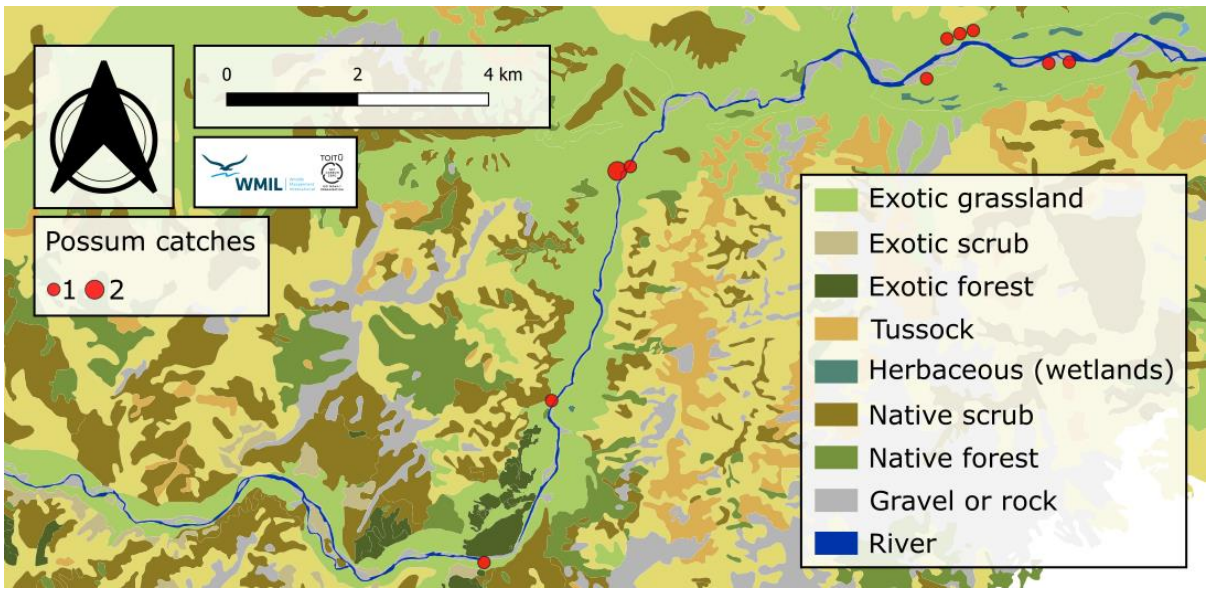


***Figure 27.*** *Number and location of possums caught along the Waiau Toa/Clarence River during 2022/23 field season. The size of points indicates the number caught at a particular trap site. Broad habitat types are shown in different colours.*

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## 3.3 Kāhu banding

A total of 21 birds were caught during the three days of trapping (Table 7). The catch rate in terms of sex was comparatively even, with eight females caught in total compared to seven new males (Table 7). Most female birds caught were second year birds, with five second years caught compared to one third year (or older) and two first year birds caught (Table 7). Male birds caught were evenly spread between age groups (Table 7). A total of six banded birds were recaptured (Table 7).

***Table 7.*** *Total number of kāhu caught and/or recaptured in the Molesworth Recreational Reserve, Waiau Toa/Clarence River, 22-25 August 2022.*

| Date | Female | | | Male | | | Total | Recaptures |
|---|---|---|---|---|---|---|---|---|
| | *Adult (3+ Yr)* | *2 Yr* | *1 Yr* | *Adult (3+ Yr)* | *2 Yr* | *1 Yr* | | |
| **23/08/2022** | 0 | 2 | 0 | 0 | 0 | 1 | **3** | 2 |
| **24/08/2022** | 0 | 2 | 0 | 1 | 0 | 0 | **3** | 4 |
| **25/08/2022** | 1 | 1 | 2 | 1 | 2 | 2 | **9** | 0 |
| **Total** | **1** | **5** | **2** | **2** | **2** | **3** | **15** | **6** |
| | **8** | | | **7** | | | | |

### 3.3.1 Total catch by trap

Catch totals per trap are shown in Figure 28 and summarised in Table 7 and Table 8. Not all traps caught kāhu. Certain locations picked up more individuals than others. Traps were moved when the traps were not being effective and added in-between successful site areas. These additional trap locations are represented with 'A' or 'B' after the trap number (Figure 28).

***Table 8.*** *Total kāhu captures for each trap, including recaptures in the Molesworth Recreational Reserve, Waiau Toa/Clarence River, 22-25 August 2022.*

| Trap Number | New Captures | Recaptures | Total Catch |
|---|---|---|---|
| **1** | | 1 | **1** |
| **2** | 4 | | **4** |
| **7** | 2 | 1 | **3** |
| **8** | 1 | 1 | **2** |
| **9** | 1 | | **1** |
| **10** | 1 | | **1** |
| **11** | 1 | 2 | **3** |
| **15** | 3 | | **3** |
| **14A** | 2 | | **2** |
| **14B** | | 1 | **1** |
| **Totals** | **15** | **6** | **21** |

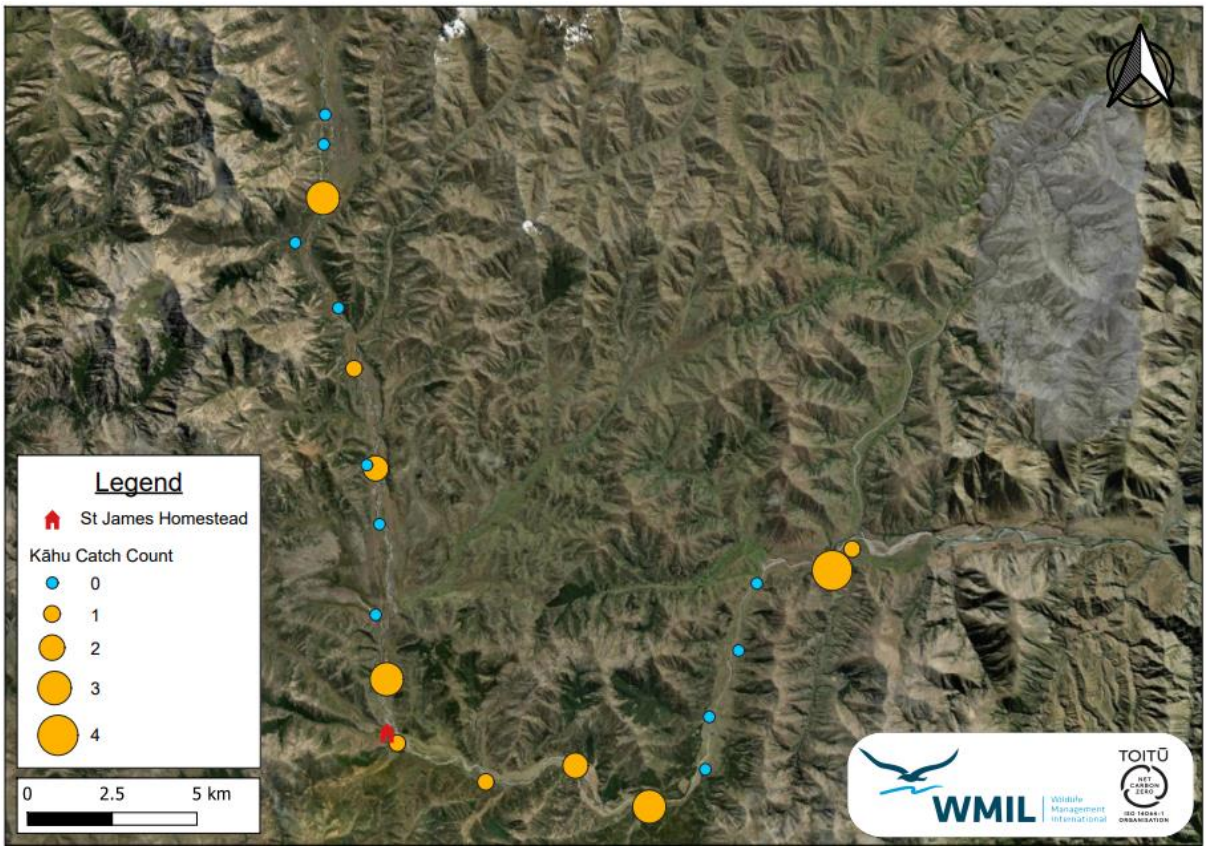


***Figure 28.*** *Location of kāhu captures for each trap in the Molesworth Recreational Reserve, Waiau Toa/Clarence River, 22-25 August 2022.*

## 3.4 Black-fronted terns

### 3.4.1 Waiau Toa/Clarence and Wakaputawatea/Acheron River Surveys

#### 3.4.1.1 Initial walk-through surveys

The first walk-through surveys were conducted on 19 October 2022 on the Waiau Toa/Clarence River in areas where terns were colonising.

During this survey, several scrapes were found, and terns displayed behaviours of agitation at several colony sites, but no nests were detected. A second survey was carried out a week later in which the same behaviour and scrape activity was observed.

The first nests were found on Mitchells Island (CE) on 27/10/2022 and then on Upper Swimming Hole (CA) on 02/11/2022.

The Wakaputawatea/Acheron River and sections of the Waiau Toa/Clarence River were again surveyed on foot before the helicopter survey on 8 November 2022, with three new colonies found (two on the Waiau Toa/Clarence River, one on the Wakaputawatea/Acheron).

Subsequent surveys were conducted along the Waiau Toa/Clarence River throughout the season where suspicious black-fronted tern behaviour occurred.

#### 3.4.1.2 Helicopter survey

On 8 November 2022, a helicopter survey was undertaken. This survey covered from Lake Tennyson to the end of the treatment zone, downstream of the Acheron and Waiau Toa/Clarence River confluence and covered from Severn Shelter down to the Acheron and Waiau Toa/Clarence River confluence (Figure 29).

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During the helicopter survey, 14 tern colonies were found, and estimated populations were counted (Table 9). Of these 14 colonies, six had not already been found due to their location and difficulty to access. A total of 350 terns were counted along the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers with the largest colony count reaching 50 estimated birds (Table 9). For location coordinates of all colonies found, refer to Appendix 7.

***Table 9.*** *Black-fronted tern colonies and population counts during the helicopter survey along the upper Waiau Toa/Clarence and Wakaputawatea/Acheron rivers during the 2022/23 breeding season. Highlighted green colonies represent new colonies discovered on the helicopter survey. Note: Bridge Island was the only island where no nests/terns were found during ground surveys.*

| River | Colony Name | Survey GPS Code | Colony Code | Estimated count |
|---|---|---|---|---|
| Waiau Toa/ Clarence | Nightingale Island | 1 | CG | 30 |
| | Seymour | 2 | CH | 10 |
| | Heli Colony | 3 | CF | 15 |
| | St James Island | 4 | CJ | 15 |
| | Upper Swimming Hole | 5 | CA | 40 |
| | Mike's rock | 6 | CB | 8 |
| | Fisherman's | 7 | CC | 30 |
| | Cow Island | 8 | CD | 6 |
| | Mitchell's | 9 | CE | 3 |
| | Upper Bush Gully | 10 | CI | 15 |
| | Bridge Island | 11 | NA | 15 |
| **Other birds seen away from colonies** | | | | 65 |
| **Total** | | | | **252** |
| Wakaputawatea/ Acheron | Acheron Island | A | AC | 20 |
| | The Zoo | B | AB | 8 |
| | Grader Island | C | AA | 50 |
| **Other birds seen away from colonies** | | | | 20 |
| **Total** | | | | **98** |
| **Combined Total** | | | | **350** |

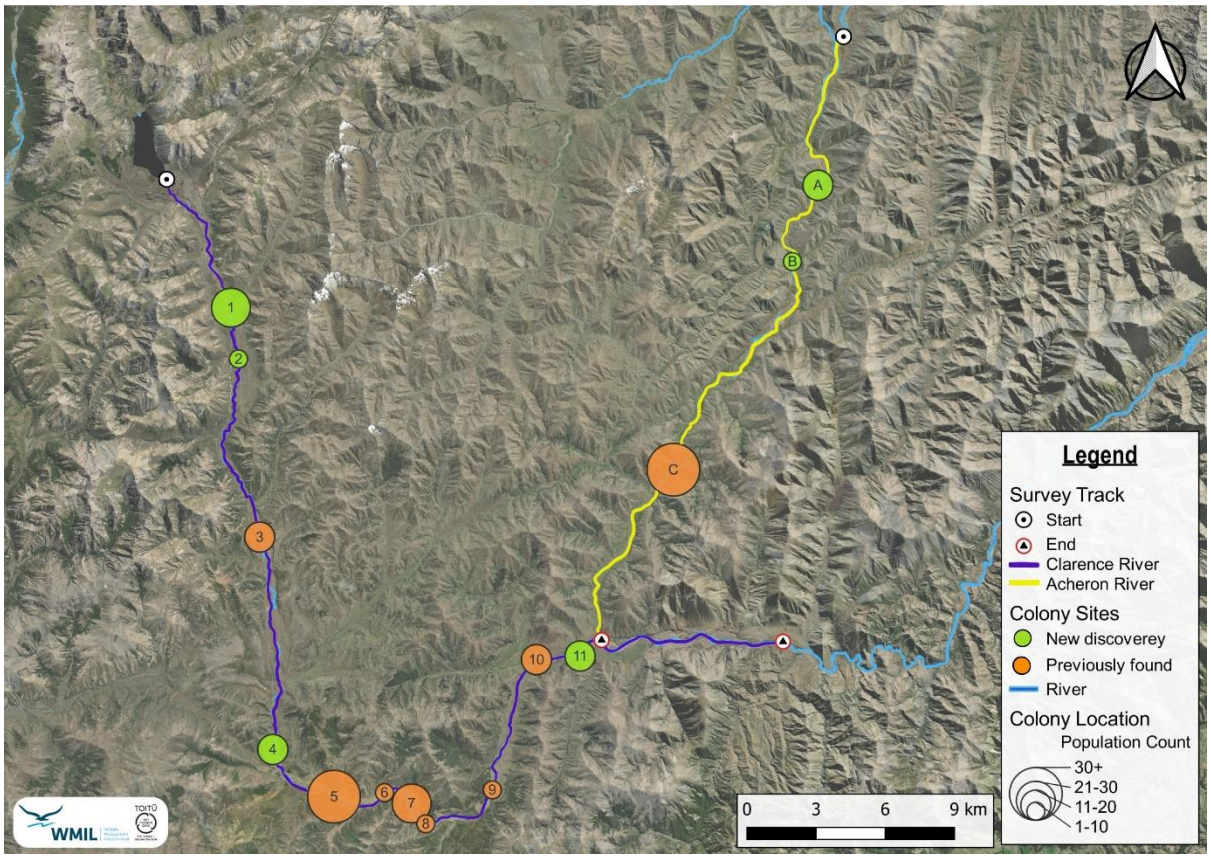


***Figure 29.*** *Locations of black-fronted tern colonies and their population size during the 2022 helicopter survey along the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers, 8 November 2022.*

### 3.4.2 Local population size and distribution of breeding colonies

A total of 21 tern nesting colonies were located on the upper Waiau Toa/Clarence and Wakaputawatea/Acheron rivers this season (Figure 30, Table 10, Appendix 8).

Colony size varied from one breeding pair to as many as 79 breeding pairs, with an average colony size of 15 breeding pairs (Appendix 8).

The highest known number of terns breeding in a single colony during the previously monitored season (since 2012) was in the 2018/19 season where a colony of 105 pairs was monitored along the upper Waiau Toa/Clarence River (Bell & Harborne 2019).

A total of 259 nests were active at the peak of the 2022/23 breeding season, which is equivalent to 518 birds breeding at any one time (Table 10). The maximum number of active nests counted throughout the 2022/23 season reached 310 equating to a maximum of 620 breeding birds on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers (Table 11). Of this, more birds (199 breeding pairs) were recorded on the upper Waiau Toa/Clarence than on the Wakaputawatea/Acheron River (111 breeding pairs) throughout the season.

Within Phase 2, during the 2021/22 season, 241 nests were recorded (Table 11, Figure 31). There was a 28.6% increase in recorded nests in 2022/23 compared to the previous monitoring season (Figure 31).

***Table 10.*** *Highest active nest and black-fronted tern counts of monitored colonies on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers during the 2022/23 breeding season. Note: Colonies that are located adjacent to each other at the same site have one combined 'highest BFT count' due to it being impossible to differentiate which airborne birds belong to which colony. This is noted with an * next to grouped BFT counts.*

| Zone | Colony Location | River | Colony Code | Highest Active Nest Count | Nest Date | Highest Count of BFT | Count Date |
|---|---|---|---|---|---|---|---|
| Treatment | Natural Island | Waiau Toa/Clarence River | CA1 | 5 | 2-Nov | *48 | 2-Nov |
| | | | CB | 8 | 6-Jan | 16 | 20-Dec |
| | Enhanced Island | | CA2 | 13 | 17 & 29 Nov | *Included in CA1's count | 2-Nov |
| | | | CD | 16 | 15-Dec | 40 | 13-Dec |
| | | | CE | 4 | 27-Oct | 25 | 27-Oct |
| | Enhanced Island/ Mainland | | CI1 | 1 | 10-Nov | 3 | 12-Nov |
| | Mainland | | CA3 | 8 | 2-Nov | *Included in CA1's count | 2-Nov |
| | | | CC | 24 | 10-Nov | 50 | 10-Nov |
| | | | CI2 | 5 | 24-Nov | 8 | 24-Nov |
| Non-Treatment | Natural Island | Waiau Toa/Clarence River | CF | 13 | 2-Dec | 25 | 30-Dec |
| | | | CG1 | 22 | 15-Nov | 50 | 15-Nov |
| | | | CG3 | 6 | 17-Dec | 15 | 17-Dec |
| | | | CH1 | 13 | 17-Dec | **34 | 13-Dec |
| | | | CJ1 | 11 | 16-Dec | 22 | 22-Nov |
| | | Wakaputawatea/Acheron River | AA | 70 | 15-Dec | 130+ | 16-Nov |
| | | | AB1 | 3 | 30-Nov | ***Included in AB2's count | 30-Nov |
| | | | AC | 10 | 24-Nov | 30 | 15-Nov |
| | Enhanced Island | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Enhanced Island/ Mainland | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Mainland | Waiau Toa/ Clarence River | CG2 | 4 | 17-Dec | 12 | 17-Dec |
| | | | CH2 | 4 | 17-Dec | **Included in CH1's count | 13-Dec |
| | | | CJ2 | 3 | 16-Dec | 4 | 16-Dec |
| | | Wakaputawatea/Acheron River | AB2 | 16 | 8-Dec | ***30 | 30-Nov |
| **Combined Total** | | | **21** | **259** | | **542** | |

***Table 11.*** *Maximum number of nests and adult birds present on the Waiau Toa/Upper Clarence and Wakaputawatea/Acheron Rivers during each breeding season, 2012/13 to 2022/23. Note: 2020/21 has been excluded due to no monitoring being carried out this season. The darker shade of blue marks the beginning of the second 5-year study.*

| Season | Max number of active nests (Waiau Toa/Clarence River) | Max number of active nests (Wakaputawatea/Acheron River) | Combined max number of active nests | Max number of breeding birds (No. of nests x 2) |
|---|---|---|---|---|
| 2012/13 | 177 | 202 | 379 | 758 |
| 2013/14 | 151 | 209 | 360 | 720 |
| 2014/15 | 154 | 149 | 303 | 606 |
| 2015/16 | 92 | 93 | 185 | 370 |
| 2016/17 | 275 | 118 | 393 | 786 |
| 2017/18 | 170 | 137 | 307 | 614 |
| 2018/19 | 211 | 52 | 263 | 526 |
| 2019/20 | 180 | 32 | 212 | 424 |
| 2021/22 | 185 | 56 | 241 | 482 |
| 2022/23 | 199 | 111 | 310 | 620 |

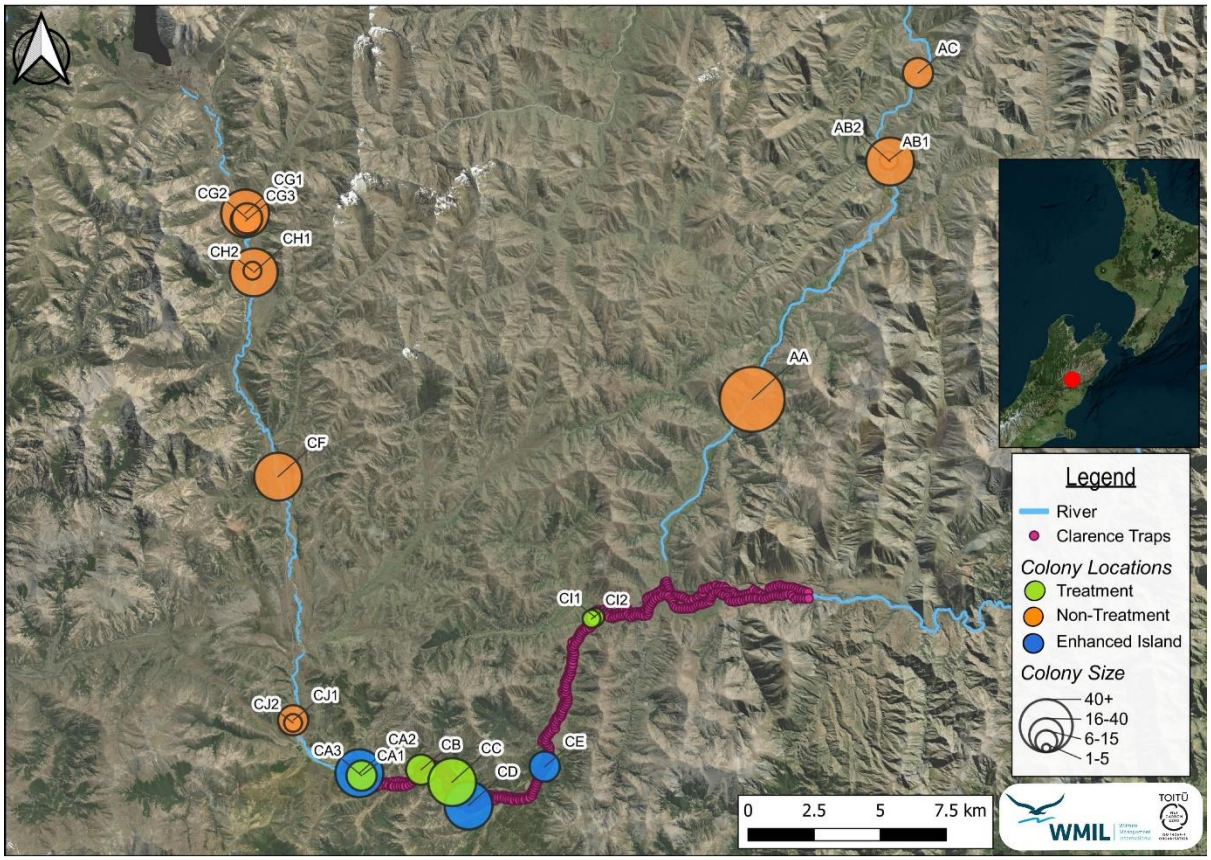


***Figure 30.*** *Black-fronted tern colonies and population size along the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers during the 2022/23 breeding season.*

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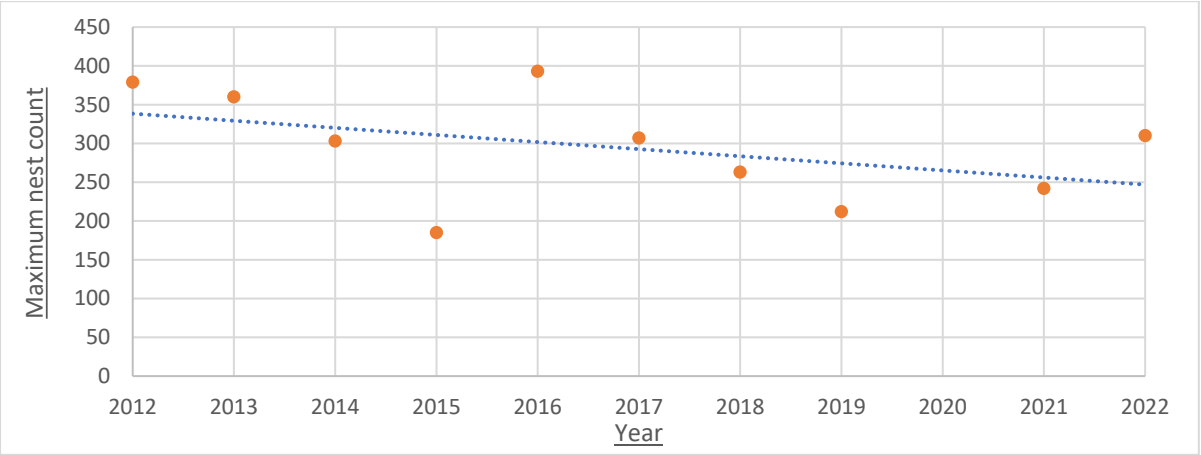


***Figure 31.*** *Maximum nest counts from 2012/13 to 2022/23 on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers combined (Correlation = -0.436)*

When viewing maximum nest data separated by river, trends over time display a gradual increase in nesting pairs on the Waiau Toa/Clarence River ($P$ = 0.385; correlation coefficient = 0.309) whereas a steep decline in nesting pairs is visible on the Wakaputawatea/Acheron River ($P$ > 0.05; correlation coefficient = -0.746) (Figure 32 & Figure 33).

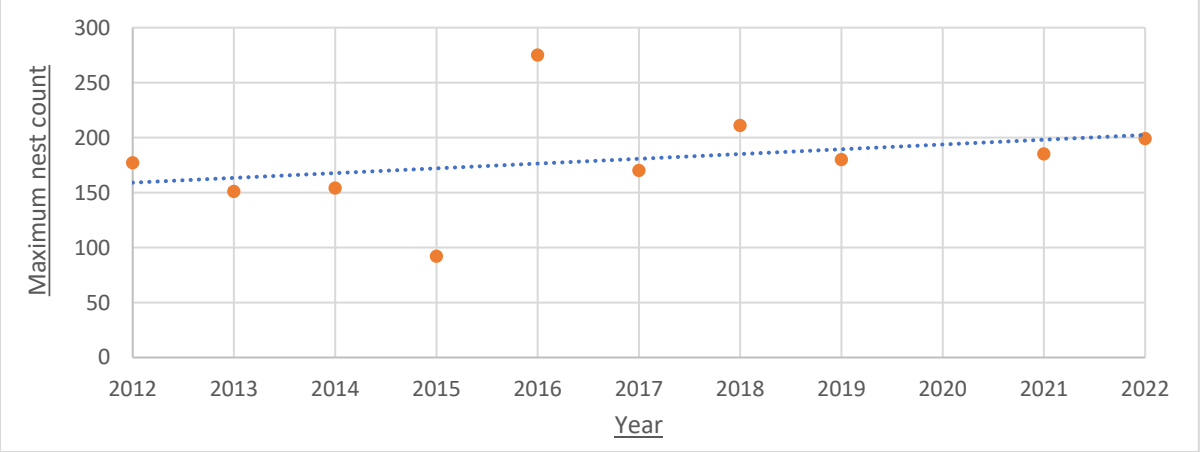


***Figure 32.*** *Maximum nest counts from 2012/13 to 2022/23 on the Waiau Toa/Clarence River (Correlation = 0.309).*

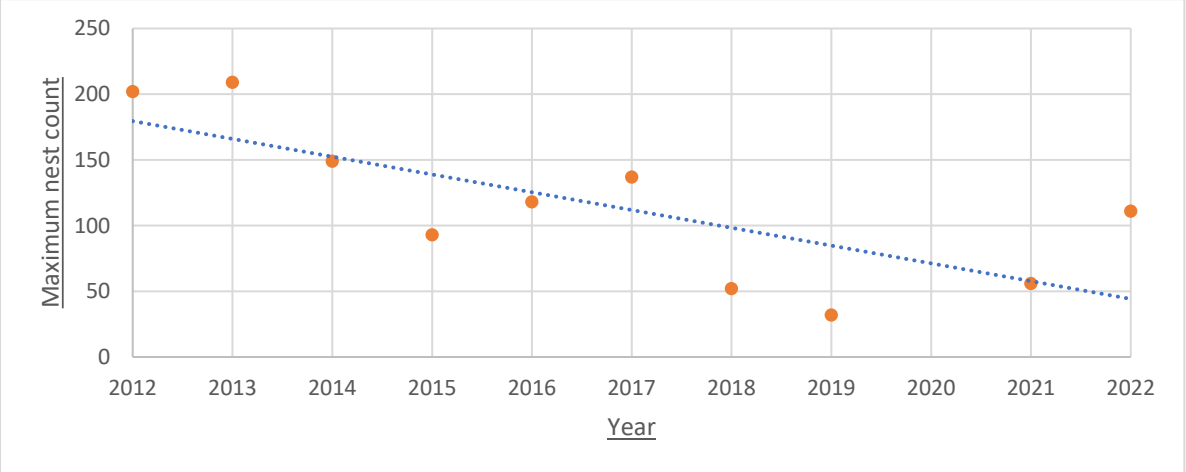


***Figure 33.*** *Maximum nest counts from 2012/13 to 2022/23 on the Wakaputawatea/Acheron River (Correlation = -0.746).*

### 3.4.3 Use of enhanced islands

Throughout the 2022/23 season, four of the seven enhanced islands (Upper Swimming Hole, Cow Island, Mitchell's, and Bridge Island) remained as raised, non-heavily vegetated islands, with suitable surrounding river channels.

Terns attempted to nest on four of the seven previously enhanced islands. This included large, successful colonies on both Upper Swimming Hole and Cow Island which both remained enhanced throughout the season. Several pairs nested on Mitchell's which, although remaining enhanced, was subjected to early failure due to southern black-backed gull predation. One pair nesting on Upper Bush Gully which eventually became connected to the mainland.

### 3.4.4 Breeding Success

#### 3.4.4.1 Waiau Toa/Clarence and Wakaputawatea/Acheron rivers hatching success

##### 3.4.4.1.1 Enhanced Island hatching success

A total of 310 tern nests were monitored during the 2022/23 breeding season. Of these, 49 nests were located on three surviving enhanced islands, one was located on an enhanced island where the river channel dried up mid-season and became connected to the mainland, and the remaining 260 nests were situated on non-enhanced islands/mainland areas (Table 12).

***Table 12.*** *Apparent black-fronted tern hatching success of known-fate nests on enhanced and non-enhanced colonies on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers during the 2022/23 breeding season. Note that no enhanced island or enhanced island/mainland colonies occurred in the non-treatment zone.*

| River | Zone | Colony Location | Colony Code | Nest Count | Hatching | |
|---|---|---|---|---|---|---|
| | | | | | Number | % |
| Waiau Toa/ Clarence | Treatment | Natural Island | CA1 | 5 | 2 | 40% |
| | | | CB | 8 | 6 | 75% |
| | | Enhanced Island | CA2 | 23 | 13 | 57% |
| | | | CD | 16 | 15 | 94% |
| | | | CE | 10 | 2 | 20% |
| | | Enhanced Island/ Mainland | CI1 | 1 | 0 | 0% |
| | | Mainland | CA3 | 9 | 6 | 67% |
| | | | CC | 28 | 7 | 25% |
| | | | CI2 | 5 | 4 | 80% |
| | Non-Treatment | Natural Island | CF | 17 | 10 | 59% |
| | | | CG1 | 22 | 13 | 59% |
| | | | CG3 | 9 | 6 | 67% |
| | | | CH1 | 17 | 7 | 41% |
| | | | CJ1 | 12 | 10 | 83% |
| | | Mainland | CG2 | 8 | 1 | 13% |
| | | | CH2 | 4 | 2 | 50% |
| | | | CJ2 | 5 | 3 | 60% |
| Wakaputawatea/ Acheron | Non-Treatment | Natural Island | AA | 79 | 69 | 87% |
| | | | AB1 | 3 | 2 | 67% |
| | | | AC | 11 | 2 | 18% |
| | | Mainland | AB2 | 18 | 8 | 44% |
| **Combined Total** | | | **21** | **310** | **188** | **61%** |

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A total of 61% (30 of 49 nests) of monitored enhanced island nests hatched one or more chicks (Table 12, Figure 34). The one nest on the failed enhanced island was predated once the island became connected to the mainland. Out of the 260 nests monitored on non-enhanced islands, 158 nests hatched (61%) (Table 12, Figure 34).


***Figure 34.*** *Observed hatched chicks on the Waiau Toa/Clarence River, 2022/23.*

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#### 3.4.4.1.2 Treatment zone colony hatching success

Colonies situated on islands within the treatment zone (active trapping and chick shelter placements) resulted in a 61% hatching success (Table 13). Colonies established on islands within the non-treatment zone (no trapping or chick shelter placement) resulted in a 70% hatching success.

The 17 mainland nests within the treatment zone and 14 within the non-treatment zone both had a 40% hatching success rate (Table 13).

***Table 13.*** *Combined hatching success of black-fronted tern nests situated on islands and the mainland within and outside of trapping zones on the Waiau Toa/Clarence River during the 2022/23 breeding season. Note: nest hatching success is determined by at least one egg from the nest hatching.*

| Zone | Location | Known-fate Nests | Hatching* | |
|---|---|---|---|---|
| | | | Number | % |
| Treatment | Island | 62 | 38 | 61% |
| | Mainland | 43 | 17 | 40% |
| | **Total** | **105** | **55** | **52%** |
| Non-Treatment | Island | 170 | 119 | 70% |
| | Mainland | 35 | 14 | 40% |
| | **Total** | **205** | **133** | **65%** |

*Hatched nests = nests which successfully managed to hatch one or more eggs.

### 3.4.5 Cause of nest failure

Of the 310 monitored nests, a total of 122 nests failed to hatch (92 on the Waiau Toa/Clarence River and 30 on the Wakaputawatea/Acheron River). Overall, predation was the leading cause of failure with 23% (71 od 310) of all nests across both rivers being depredated (Appendix 9: Nest Outcome 2022/23. 9; Figure 35).

Abandonment was the second highest cause of failure, accounting for 13% (42 of 310) of nest failures across both rivers (Appendix 9: Nest Outcome 2022/23. 9; Figure 35). In most cases, abandonment was directly linked to nocturnal predator activity within the colony.

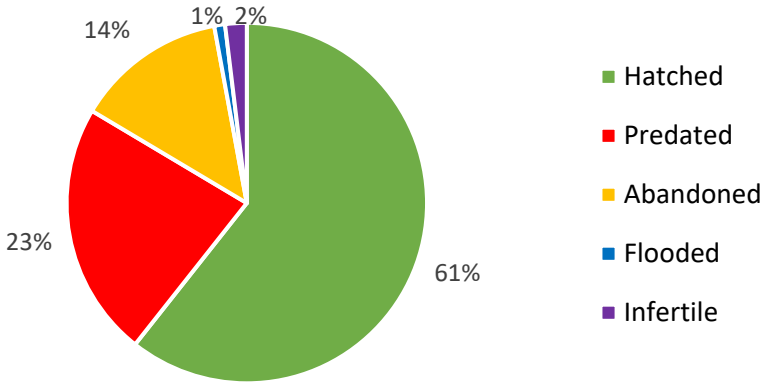


***Figure 35.*** *Overall summary of known nesting outcomes for black-fronted terns on Waiau Toa/Clarence and Wakaputawatea/Acheron rivers, 2022/23.*

The third highest cause of nest failure was due to infertility (2%; 6 of 310) followed closely by flooding (1%; 3 of 310) (Appendix 9; Figure 35). Both had very minimal impact within the season. Weather conditions for egg laying and hatching were very favourable this season with minimal flooding events

and an average flow rate of 8.4 $m^3$ from October 1 to February 10 which was the date the last remaining colony finished (Figure 36).

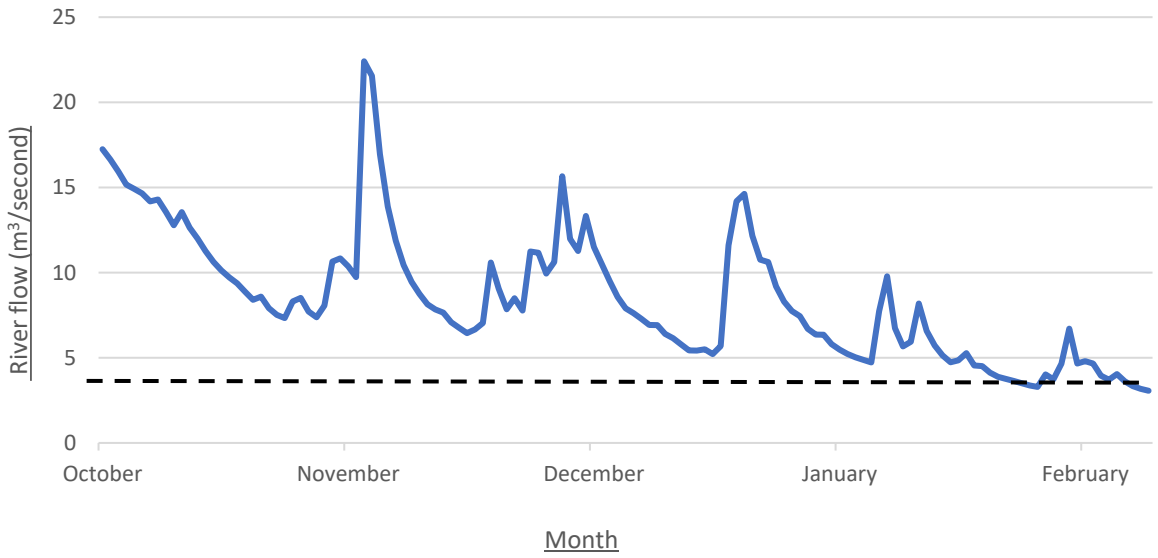


***Figure 36.*** *Waiau Toa/Clarence River flow rates at Jollies (NIWA) from 1 October 2022 to 10 February 2023 (date the last colony finished). Note: Average River flow rate for the 2022/23 season illustrated by black line.*

In comparison, flow rates from the same time period on the Waiau Toa/Clarence River during the last monitored season in 2021/2022 averaged at 12.8 $m^3$/second (Figure 37). Whilst there were large flow rate peaks in 2021/2022 in October and December, this breeding season's conditions were still considered to be suitable compared to previous seasons flooding events (Figure 37). This highlights how low average river flow rates were during the 2022/23 breeding season.

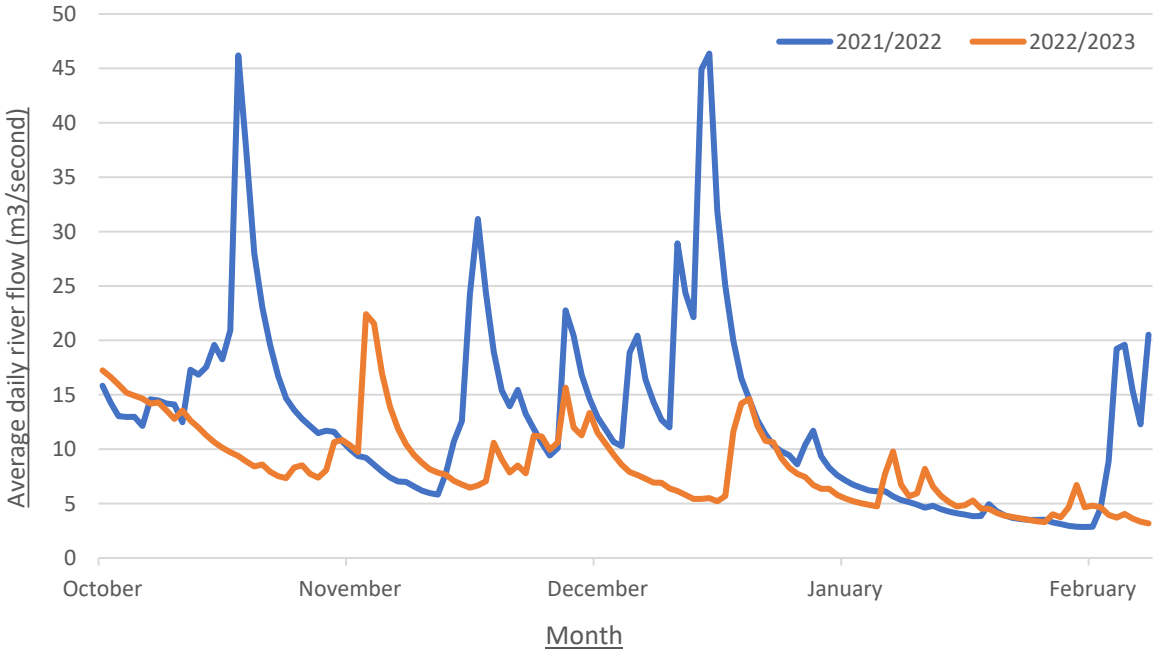


***Figure 37.*** *Waiau Toa/Clarence River daily average flow rates at Jollies between 1 October and 10 February during the 2021/22 and 2022/23 seasons.*

A breakdown of total nest outcomes situated on differing colony locations can be found in Figure 38. Hatching success was high across all islands (both within the treatment and non-treatment zones) ranging between 60-70% hatching success (Figure 38). Predation was evident across all location groups with a larger rate of predation occurring on mainland colonies, both treatment and non-treatment averaging at 37-44% (Figure 38). Abandonment was also prevalent across all location groups ranging between 8-23%.

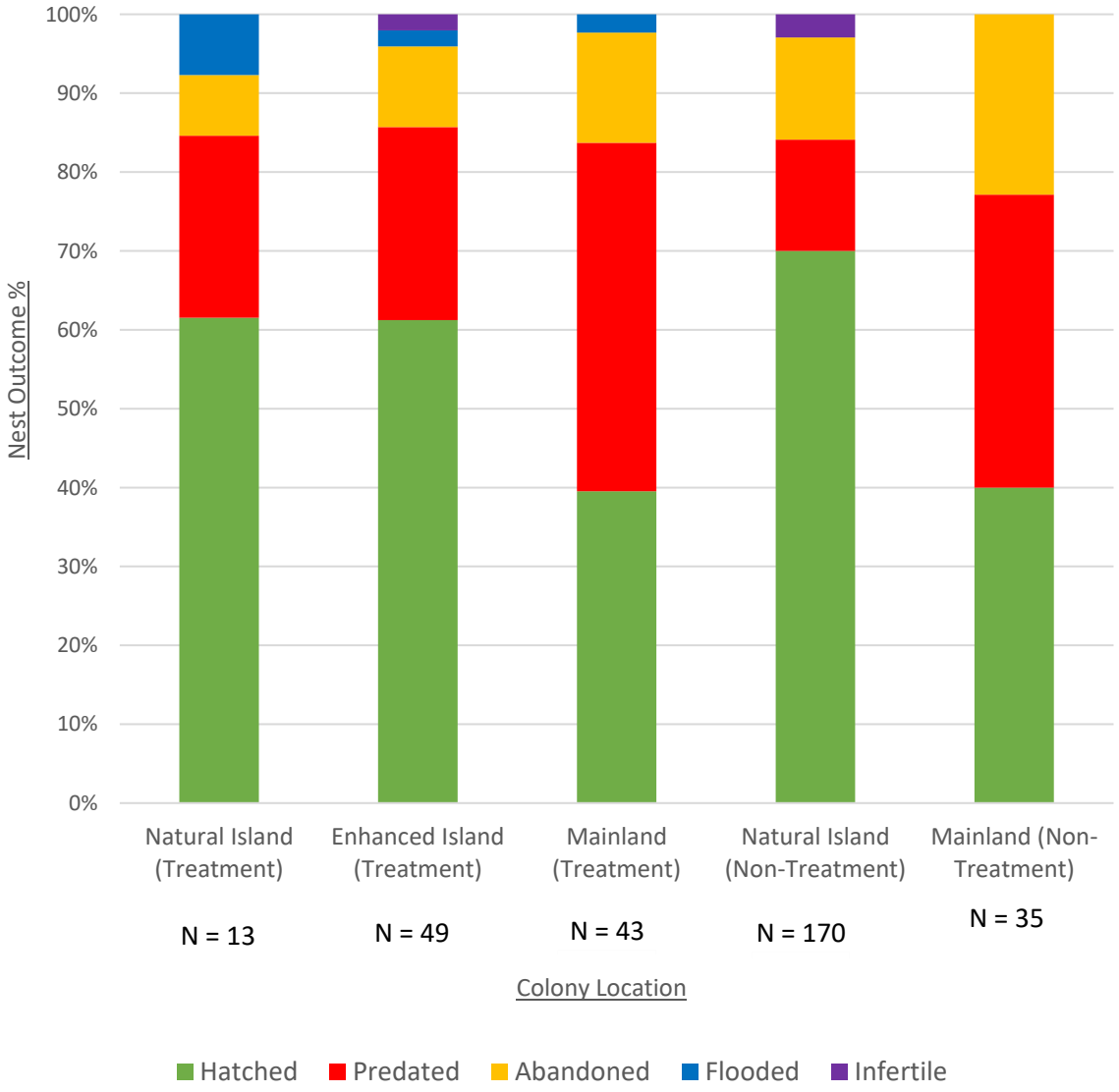


***Figure 38.*** *Overall nest outcome percentages for black-fronted tern colonies situated in different locations on the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers during the 2022/23 season (see Appendix 9) where 'failed enhanced islands' are included in the 'Mainland (Treatment) section and N = total nest count.*

### 3.4.6 Camera monitoring of nests

This season 92 nests were monitored by cameras. Surveillance coverage of nests varied between colonies depending on their location, accessibility, and date of discovery. Between 11-100% of nests at each colony were monitored by nest cameras (Table 14) with an exception to CG3 and CJ2 which were discovered later in the season and failed/hatched before cameras were deployed.

***Table 14.*** *Total camera coverage of black-fronted tern colonies along the Waiau Toa/Upper Clarence and Wakaputawatea/Acheron Rivers, 2022/23.*

| River | Colony | Total nests | Nest cameras | Coverage % |
|---|---|---|---|---|
| Waiau Toa/ Clarence River | CA1 | 5 | 2 | 40% |
| | CA2 | 23 | 6 | 26% |
| | CA3 | 9 | 5 | 56% |
| | CB | 8 | 3 | 38% |
| | CC | 28 | 12 | 43% |
| | CD | 16 | 7 | 44% |
| | CE | 10 | 3 | 30% |
| | CF | 17 | 8 | 47% |
| | CG1 | 22 | 8 | 36% |
| | CG2 | 8 | 4 | 50% |
| | CG3 | 9 | 0 | 0% |
| | CH1 | 17 | 7 | 41% |
| | CH2 | 4 | 2 | 50% |
| | CI1 | 1 | 1 | 100% |
| | CI2 | 5 | 2 | 40% |
| | CJ1 | 12 | 5 | 42% |
| | CJ2 | 5 | 0 | 0% |
| | **Total** | **199** | **75** | **38%** |
| Wakaputawatea/Acheron River | AA | 79 | 11 | 14% |
| | AB1 | 3 | 1 | 33% |
| | AB2 | 18 | 2 | 11% |
| | AC | 11 | 3 | 27% |
| | **Total** | **111** | **17** | **15%** |
| **Combined Total** | | **310** | **92** | **30%** |

Cameras were distributed evenly across colonies. Nests were chosen for monitoring based on the lack of grasses and other loose material that might trigger the cameras in light to severe wind conditions. By choosing nests predominantly situated on gravels, the lack of additional motion saved storage space on SD cards throughout the week. Nest clusters were also targeted with camera monitoring due to the chance of cameras picking up on nests being predated nearby or determining a singular mass predation event causing all nests in the same area to be predated.

The deployment of motion activated cameras enabled the identification of two predator species predating 15 different nests (Table 15). Six other predator species were detected across 16 different nests; however, no predation events were recorded at these nests. It is suspected that these predators caused nest failure due to predation and abandonment events which occurred at unmonitored nests within the same colony.

The predator species responsible for the largest number of predated nests were southern black-backed gulls which were recorded preying on nine nests at six colony sites on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers (Figure 39). Cats were the only other predator recorded predating nests on camera and were responsible for six nest predations over three colonies on the Waiau Toa/Clarence River (Table 15, Figure 39).

These predation events were spread across all colony location types, however, only avian predation events were recorded on islands, whereas both avian and mammalian predation occurred on the mainland within the treatment and non-treatment zone (Table 15).


***Figure 39.*** *Observed nest predation events and predator detection captured during the 2022/23 breeding season at black-fronted tern colony sites along the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers. Above show nest predations by cats and southern black-backed gull, along with detections of a hedgehog, possum, and stoat presence at colonies (no nest predation captured).*

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***Table 15.*** *Camera monitoring outcomes of black-fronted tern nests in colonies within the treatment zone and non- treatment zone on the Waiau Toa/Clarence and Wakaputawatea/Acheron River, 2022/23. Note that no enhanced island or enhanced island/mainland colonies occurred in the non-treatment zone.*

| Zone | Colony Location | Monitored nest outcome | | | | |
|---|---|---|---|---|---|---|
| | | Predation | | Abandonment | Flooded | Hatched |
| | | Southern black-backed gull | Cat | | | |
| Treatment | Natural Island | 1 | | | | 4 |
| | Enhanced Island | 2 | | | | 12 |
| | Enhanced Island/ Mainland | | 1 | | | |
| | Mainland | 1 | 3 | 4 | | 13 |
| Non-Treatment | Natural Island | 4 | | 3 | | 27 |
| | Enhanced Island | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Enhanced Island/ Mainland | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Mainland | 1 | 2 | 1 | | 4 |
| **Combined Total** | | **9** | **6** | **8** | **0** | **60** |

### 3.4.7 Fledging success

Establishing the fledging success of black-fronted terns can be problematic as chicks often move out of the nest at a few days of age. Once out of the immediate nesting area it is not possible to confirm which nest a chick is from unless they are banded. Furthermore, as chicks are highly camouflaged and will freeze when approached they can be difficult to locate even with a considerable search effort. For this reason, while a count of fledglings was undertaken during each monitoring visit, this count should be treated as the minimum number of successful fledglings.

The 310 nests spread over 21 monitored colonies managed to successfully hatch 325 chicks (Table 16). Of these, 142 fledglings were confirmed. A further 70 chicks were estimated to have fledged as they were seen several days before they would have been old enough to fledge with no flooding or predation events recorded to have impacted their success. This brings the maximum number of chicks estimated to have fledged to 212.

Colony CA2 (Upper Swimming Hole) was the most successful colony in fledging chicks with 19 out of 25 hatched chicks observed to have fledged (Table 16). This was followed closely by a second enhanced island where 64-96% of hatched chicks were estimated to have fledged. Colony AA on the Acheron had the largest individual fledgling count with 80 out of 118 chicks observed to have fledged and another 29 estimated to have fledged bringing the colonies fledging success range to total 68-92% (Table 16).

Chicks that hatched on islands within the treatment zone had the greatest chance of fledging with 55 - 81% of chicks estimated to have fledged (Table 17). A larger number of chicks fledged on islands outside of the treatment zone this season (N = 104 - 148). On mainland colonies, both within the treatment and non-treatment zones, no chicks were observed to have fledged out of the 54 chicks that hatched. Only eight were estimated to have fledged as a maximum count (Table 17). The overall combined productivity of fledglings per nest was 0.46 – 0.68 fledglings/nest (Table 17). Productivity between islands in the treatment and non-treatment zone were almost identical where both zones had a minimum productivity of 0.61 fledglings/nest on islands. The highest estimates of fledgling

productivity per nest on islands was 0.9 fledglings/nest in the treatment zone and 0.87 fledglings/nest in the non-treatment zone (Table 17).

***Table 16.*** *Black-fronted tern hatched chicks and confirmed and estimated maximum fledgling success on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers in 2022/23. Note that no enhanced island or enhanced island/mainland colonies occurred in the non-treatment zone.*

| Zone | Colony Location | Colony Code | Hatched Nests | Hatched Individual chicks | Fledging success | | |
|---|---|---|---|---|---|---|---|
| | | | | | Fledglings observed | Max estimated to have fledged | Fledging success range |
| Treatment | Natural Island | CA1 | 2 | 4 | 0 | 0 | 0% |
| | | CB | 6 | 11 | 2 | 5 | 18-45% |
| | Enhanced Island | CA2 | 13 | 25 | 19 | 25 | 76-100% |
| | | CD | 15 | 25 | 16 | 24 | 64-96% |
| | | CE | 2 | 4 | 1 | 2 | 25-50% |
| | Enhanced Island/ Mainland | CI1 | 0 | 0 | 0 | 0 | 0% |
| | Mainland | CA3 | 6 | 8 | 0 | 0 | 0% |
| | | CC | 7 | 12 | 0 | 0 | 0% |
| | | CI2 | 4 | 8 | 0 | 0 | 0% |
| **Total** | | | **55** | **97** | **38** | **56** | **39-58%** |
| Non-Treatment | Natural Island | CF | 10 | 16 | 5 | 11 | 31-69% |
| | | CG1 | 13 | 22 | 0 | 0 | 0% |
| | | CG3 | 6 | 10 | 2 | 6 | 20-60% |
| | | CH1 | 7 | 13 | 2 | 5 | 15-38% |
| | | CJ1 | 10 | 17 | 14 | 16 | 82-94% |
| | | AA | 69 | 118 | 80 | 109 | 68-92% |
| | | AB1 | 2 | 4 | 0 | 0 | 0% |
| | | AC | 2 | 2 | 1 | 1 | 50% |
| | Enhanced Island | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Enhanced Island/ Mainland | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Mainland | CG2 | 1 | 2 | 0 | 0 | 0% |
| | | CH2 | 2 | 4 | 0 | 2 | 0-50% |
| | | CJ2 | 3 | 5 | 0 | 0 | 0% |
| | | AB2 | 8 | 15 | 0 | 6 | 0-40% |
| **Total** | | | **133** | **228** | **104** | **156** | **46-68%** |
| **Combined Total** | | | **188** | **325** | **142** | **212** | **44-65%** |

WMIL: Connor-McClean et al. 2023

***Table 17.*** *Black-fronted tern hatched chick/fledging success and productivity per nest within island and mainland colonies in the treatment and non-treatment zones on the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers in 2022/23. *Nest hatching success refers to number of nests that hatched one or more eggs.*

| Zone | Colony location | Known-fate nests | Nest hatching success* | | Individual chicks hatched | Fledglings seen | | Fledglings/chicks hatched | | Fledglings/nest | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Number | % | | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| Treatment | Island | 62 | 38 | 61% | 69 | 38 | 56 | 55% | 81% | 0.61 | 0.9 |
| | Mainland | 43 | 17 | 40% | 28 | 0 | 0 | 0% | 0% | 0 | 0 |
| **Total** | | **105** | **55** | **52%** | **97** | **38** | **56** | **39%** | **58%** | **0.36** | **0.53** |
| Non-Treatment | Island | 170 | 119 | 70% | 202 | 104 | 148 | 51% | 73% | 0.61 | 0.87 |
| | Mainland | 35 | 14 | 40% | 26 | 0 | 8 | 0% | 31% | 0 | 0.23 |
| **Total** | | **205** | **133** | **65%** | **228** | **104** | **156** | **46%** | **68%** | **0.51** | **0.76** |
| **Combined Total** | | **310** | **188** | **61%** | **325** | **142** | **212** | **44%** | **65%** | **0.46** | **0.68** |

Of the 325 chicks that hatched, 15 chick fatalities were observed (Table 18).

On island colonies within the treatment zone, the only observed chick death was due to being born lame and weak. This chick hatched a day after the first chick and over three days wasn't fed once. On mainland colonies within the treatment zone, chick fatalities were due to a cat predation event on one colony which was caught on camera. Two chicks were found dead at their nesting site in the same colony. The cause of their death is unknown; however, one stoat was detected on camera at the colony around a similar time (Figure 40).

Within the non-treatment zone, five chicks were subjected to predation while another five died of heat exhaustion (Table 18). Heat exhaustion fatalities were determined by chick behaviour captured on monitoring cameras or in person, along with taking into consideration weather temperatures within the week (recorded on nest cameras), and the state/ location of the dead chicks.

***Table 18.*** *Reasons for chick fatalities within treatment and non-treatment zones throughout the 2022/23 breeding season on the Waiau Toa/Clarence River.*

| Zone | Colony Location | Individual Chicks Hatched | Causes of chick mortality | | | | |
|---|---|---|---|---|---|---|---|
| | | | Predation | | Heat exhaustion | Hatched with disability | Other |
| | | | Cat | Southern black-backed gull | | | |
| Treatment | Natural Island | 15 | | | | 1 | |
| | Enhanced Island | 54 | | | | | |
| | Enhanced Island/ Mainland | 0 | | | | | |
| | Mainland | 28 | 2 | | | | 2 |
| | **Total** | **97** | **2** | **0** | **0** | **1** | **2** |
| Non-Treatment | Natural Island | 202 | | 3 | 5 | | |
| | Enhanced Island | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Enhanced Island/ Mainland | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* | *No Data* |
| | Mainland | 26 | 1 | 1 | | | |
| | **Total** | **228** | **1** | **4** | **5** | **0** | **0** |
| **Combined Total** | | **325** | **3** | **4** | **5** | **1** | **2** |

Whilst many complete colony chick disappearances were not caught on camera, nest cameras detected stoat, cat, and southern black-backed gull presence at these colonies during the time of chick disappearance. Estimations can be drawn that many of these chicks were predated or flushed down the river in an escape response (Figure 40).


***Figure 40.*** *Observed chick predation events and predator detection/disturbance captured during the 2022/23 breeding season at black-fronted tern colony sites along the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers. Above images show chick predations by cats and southern black-backed gull, along with detections of a stoat, 4WD vehicle, and cows present at colonies with hatched chicks (no nest predation/fatalities captured).*

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## 3.5 Chick shelter use

Approximately 60 chick shelters were distributed across island and mainland colonies within the treatment zone on the Waiau Toa/Clarence River.

Nest cameras showed chicks continuously using the shelters from the day of hatching, through to leaving the nest (Figure 42). Larger chicks were also seen occasionally coming in to use the shelters during the day.

Chick shelters that did not have cameras monitoring their use often had remaining chick poo underneath the shelter upon removal, implying that the shelters were being used.

The main reason for chicks to utilize these shelters was to escape extreme heat, even whilst a parent bird was sitting at the nesting site close by. Nest cameras on the Waiau Toa/Clarence and Acheron rivers recorded ground temperatures of 40+°C on consecutive days in December and January. Chicks were also seen using the shelters during heavy rain at temperatures around 1-8°C.

One video observation was made where a chick ran to the shade of the chick shelter to hide when sounds of a southern black-back gull being dive bombed by adult black-fronted terns were heard in the background of the video. This is the only observation of a chick using the shelter to escape a predator.

Other species including tuturiwhatu/banded dotterel (*Charadrius bicinctus*) and pīhoihoi/pipit (*Anthus novaeseelandiae*) chicks were also seen using these shelters on occasion to escape extreme weather conditions (Figure 43).

Other chicks that hatched on non-treatment colonies without chick shelters were observed sheltering under vegetation or woody debris or wedging themselves into rocks in an attempt to cool down (Figure 41).


***Figure 41.*** *Black-fronted tern chicks using driftwood to shelter from 36°C temperatures on the Waiau Toa/Clarence River, 12/14/2022.*


***Figure 42.*** *Observed chick shelter use (both A-frame and flat-roof design) in treatment colonies during the 2022/23 breeding season at black-fronted tern colony sites along the Waiau Toa/Clarence River.*

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***Figure 43.*** *Detections of banded dotterel and pipit use of unoccupied chick shelters during extreme weather events and temperatures on the Waiau Toa/Clarence River, 2022/23.*

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## 3.6 Comparison of tern breeding seasons between 2015/16 to 2022/23

A comparison between the seven previously monitored tern seasons on the upper Waiau Toa/Clarence and Wakaputawatea/Acheron rivers has been made. This comparison involves small changes to keep data consistencies over the years. These changes include removing all mainland nests from treatment results (trapped island colonies) and combining them into non-treatment results (no trapping). This comparison takes into consideration all the outcomes of known egg-fate nests between October 2015 and January 2023 (excluding 2020/21 due to no monitoring being carried out that season).

The percentage of unknown nest outcomes for each season have been excluded from the overall data analysis. This removes bias and the potential to skew the data in favour of an outcome that doesn't correctly represent tern breeding success. For this reason, these results should be determined as minimum percentages for each outcome.

Throughout the previous seven monitored seasons, locations of colonies along the rivers are relatively spread throughout the study area with several sites evidently being used in consecutive years (Figure 44 and Figure 45).

In comparison to all seven seasons, the 2022/23 season has been one of the most successful seasons for treatment and non-treatment colony successes. At treatment colonies 61% of nests hatched (5% lower than the 2021/22 season), and 60% of nests hatched at non-treatment colonies (second most successful season after 69% in 2021/22) (Table 19).

The 2022/23 season also had the second highest number of fledglings observed at treatment colonies (38 fledglings; 0.59 fledglings/nest) and the second highest fledgling productivity (0.42) at non-treatment colonies (Table 20; Figure 46).

Across all seasons, 2016/17 had the highest fledgling productivity (1.06 fledglings/nest) within treatment colonies where 147 fledglings were counted (Table 20; Figure 46).

***Table 19.*** *Comparison of hatching success of black-fronted terns from 2015/16 to 2022/23 on the Waiau Toa/Upper Clarence and Wakaputawatea/Acheron rivers. Note: 2020/21 excluded due to no monitoring being carried out that season. Blue shading marks the the second 5-year study. For this comparison, all mainland nests have been included in the "Non-Treatment" section to keep data consistent throughout each season.*

| | | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2021/22 | 2022/23 |
|---|---|---|---|---|---|---|---|---|
| **Treatment (excl mainland nests)** | Known-fate nest total | 45 | 139 | 82 | 43 | 18 | 38 | 62 |
| | Hatching probability | 44% | 61% | 40% | 21% | 44% | 66% | 61% |
| **Non-treatment + Mainland nests** | Known-fate nest total | 420 | 240 | 427 | 506 | 271 | 204 | 248 |
| | Hatching probability | 31% | 39% | 46% | 30% | 27% | 69% | 60% |

***Table 20.*** *Minimum fledging success of black-fronted terns on the Waiau Toa/Upper Clarence and Wakaputawatea/Acheron rivers, 2015-2023. Note: 2020/21 excluded due to no monitoring being carried out that season. Blue shading marks the second five-year study period. For this comparison, all mainland nests/fledglings have been included in the "Non-Treatment" section to keep data consistent throughout each season.*

| | | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2021/22 | 2022/23 |
|---|---|---|---|---|---|---|---|---|
| **Treatment (excl mainland nests/ fledglings)** | Number of nests monitored | 45 | 139 | 82 | 43 | 18 | 38 | 62 |
| | Fledglings seen | 7 | 147 | 25 | 13 | 4 | 22 | 38 |
| | Productivity | 0.16 | 1.06 | 0.3 | 0.3 | 0.22 | 0.58 | 0.59 |
| **Non-treatment + Mainland nests/ fledglings** | Number of nests monitored | 420 | 240 | 427 | 506 | 271 | 204 | 248 |
| | Fledglings seen | 24 | 55 | 137 | 129 | 10 | 101 | 104 |
| | Productivity | 0.06 | 0.23 | 0.32 | 0.25 | 0.04 | 0.50 | 0.42 |

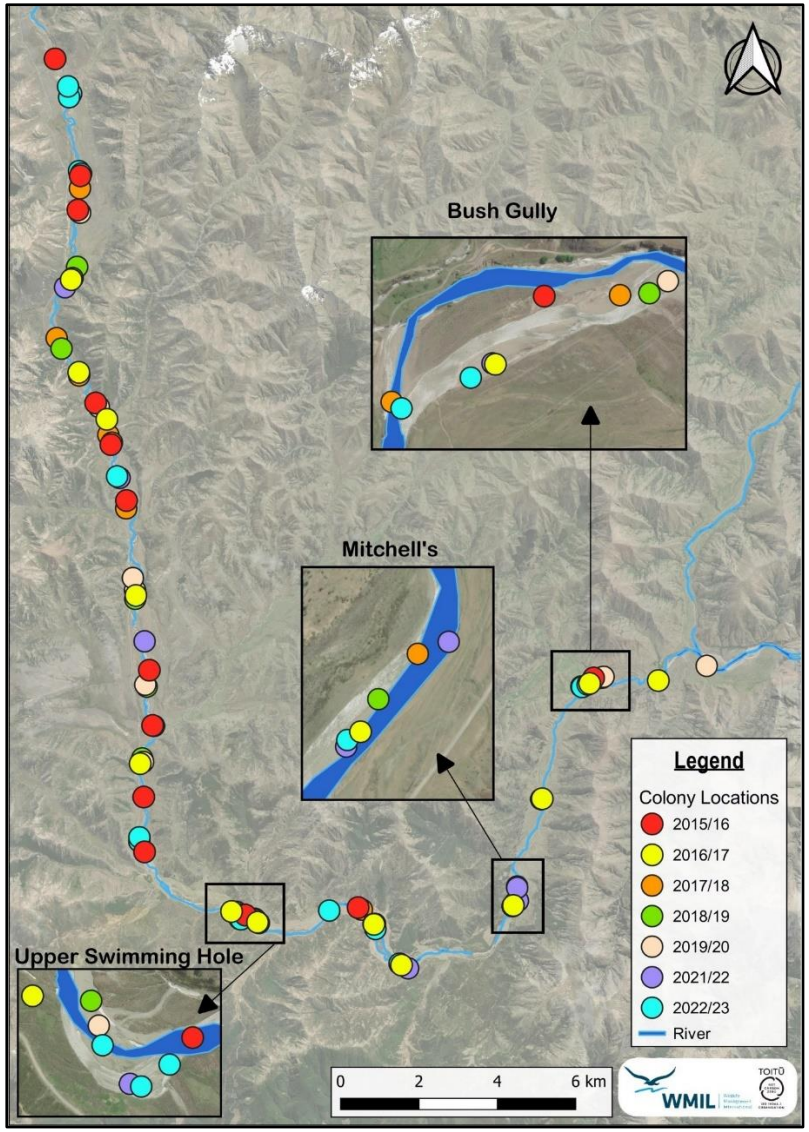


***Figure 44.*** *All locations of black fronted tern colonies from 2015/16 to 2022/23 along the Waiau Toa/Clarence River.*

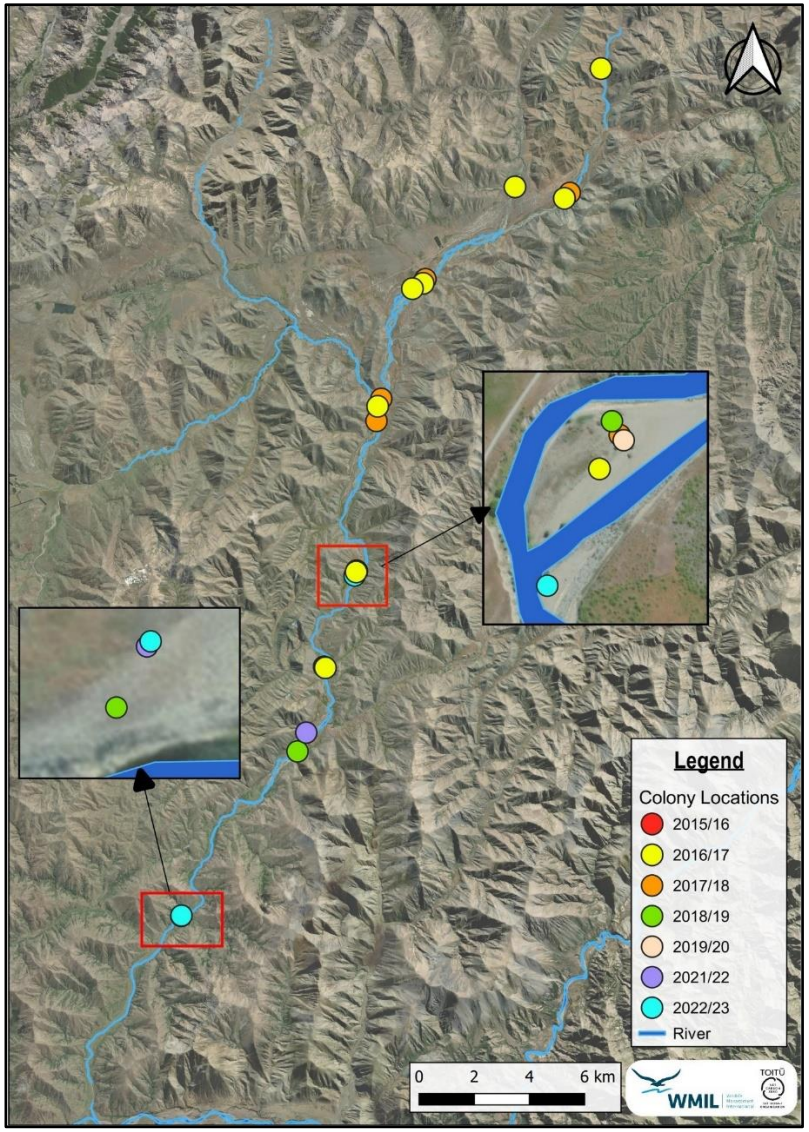


***Figure 45.*** *All locations of black fronted tern colonies from 2015/16 to 2022/23 along the Wakaputawatea/Acheron River.*

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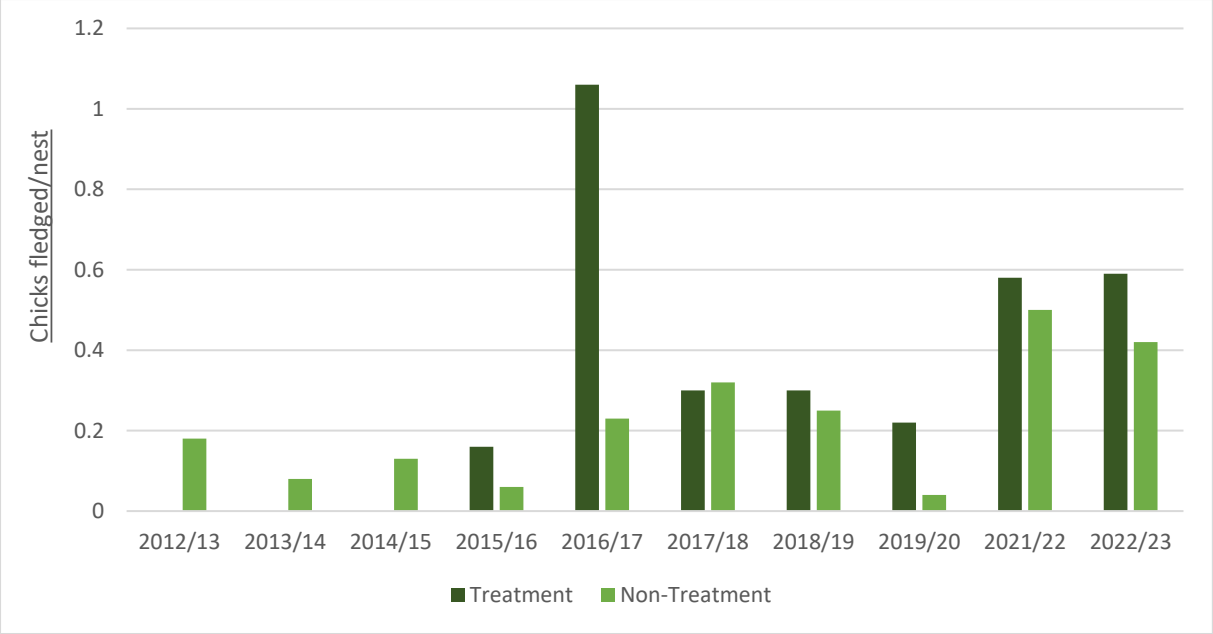


***Figure 46.*** *Comparison of fledging success between treatment and non-treatment colonies on the upper Waiau Toa/Clarence and Wakaputawatea/Acheron rivers 2012-2023. Note: trapping grids were fully established and baited by early November 2015 while island enhancements were carried out in March 2016. For this comparison, treatment includes trapped islands only, whereas non-treatment includes all mainland nests and non-trapped islands.*

The main cause of failure across all seasons on both treatment and non-treatment colonies was predation, except during the 2021/22 season where failure due to abandonment was 7% higher than failure due to predation on treatment colonies (Figure 47 & Appendix 10).

Abandonment was the second highest cause of failure with fairly even rates between treatment and non-treatment colonies. Flooding was the lowest cause of failure in most years, with an exception in 2019/20 when 28% of non-treatment nests were flooded. Flooding on non-treatment nests was more significant on four out of six years compared to treatment colonies where 2018/19 was the only year where flooding of treatment nests outweighed non-treatment colony nests (Figure 47 & Appendix 10).

Throughout the seven monitored seasons, predation by cats have been the largest observed cause of nest failure (Appendix 11). Within the treatment zone on islands, cats, southern black-backed gulls, and black-fronted terns have been the most common cause of nest failure due to predation. Each of these species has been observed predating upon nests in multiple seasons (Appendix 11). Hedgehogs and cats have been the main observed predator on mainland nests within the treatment zone. Within the non-treatment zone, three times more nests were predated (n=168) than within the treatment zone (n=56) (Appendix 11). Kāhu, cats, ferrets, and southern black-backed gulls were the top predators caught on camera throughout non-treatment colonies. No ferret or stoat predations have been recorded on camera or by observers on treatment colonies thus far (Appendix 11).

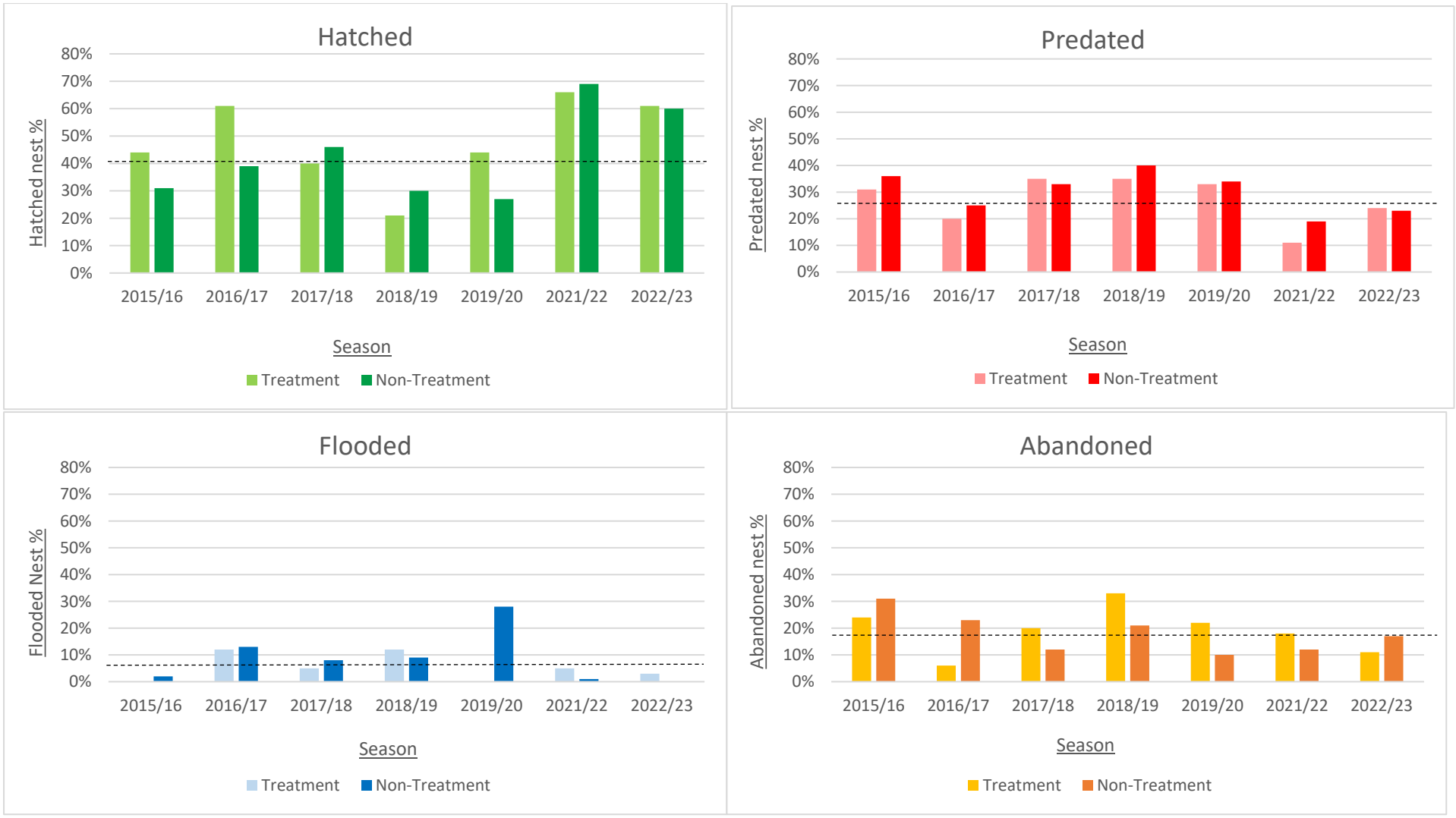


***Figure 47.*** *Comparison of combined known-nest outcome percentages from 2015/16 to 2022/23 on the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers. Black dotted horizontal lines indicate the overall average percentage for each outcome. Note that treatment nests here include all trapped island nests. Non-treatment includes non-trapped island nests and all mainland nests.*

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### 3.6.1 Spatial difference in breeding success

Within the colonies on the Waiau Toa/Clarence River there is a weak, negative correlation (correlation coefficent = -0.097) between hatching success and distance from the trapping line (Figure 48). Pooling data from all seven seasons, hatching success at colonies within 10km of a trapping area (mean= 43%, n= 44) is higher than at colonies further than 10km from a trapping site (mean= 36%, n= 28).

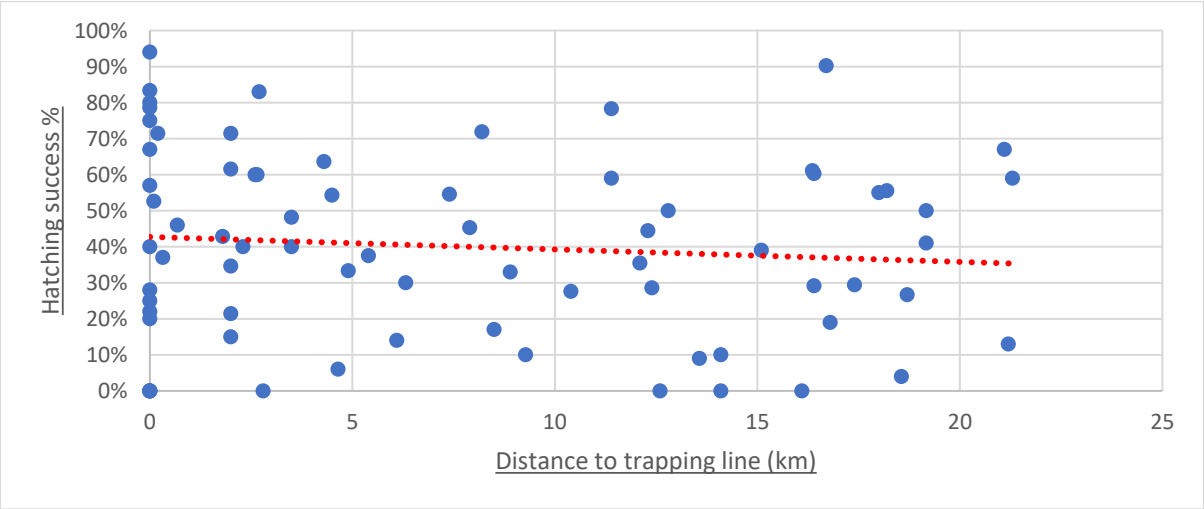



***Figure 48.*** *The relationship between hatching success (proportion of all nests in a colony that hatched at least one egg) and distance to nearest trapping networks in black-fronted tern colonies on the upper Waiau Toa/Clarence River 2015-2023 (Cor = -0.097).*

Results gathered from each of the five seasons (2015 – 2023) show a positive relationship between the distance from trapping networks and percentage of nests predated at various colonies (Figure 49). Out of the six colonies that were further than 25 km from the nearest trapping network, all of them had predation rates between 50 – 100%. Of the 48 colonies less than 10 km from the nearest trapping network, 36 had nest predation rates less than 40% (Figure 49).

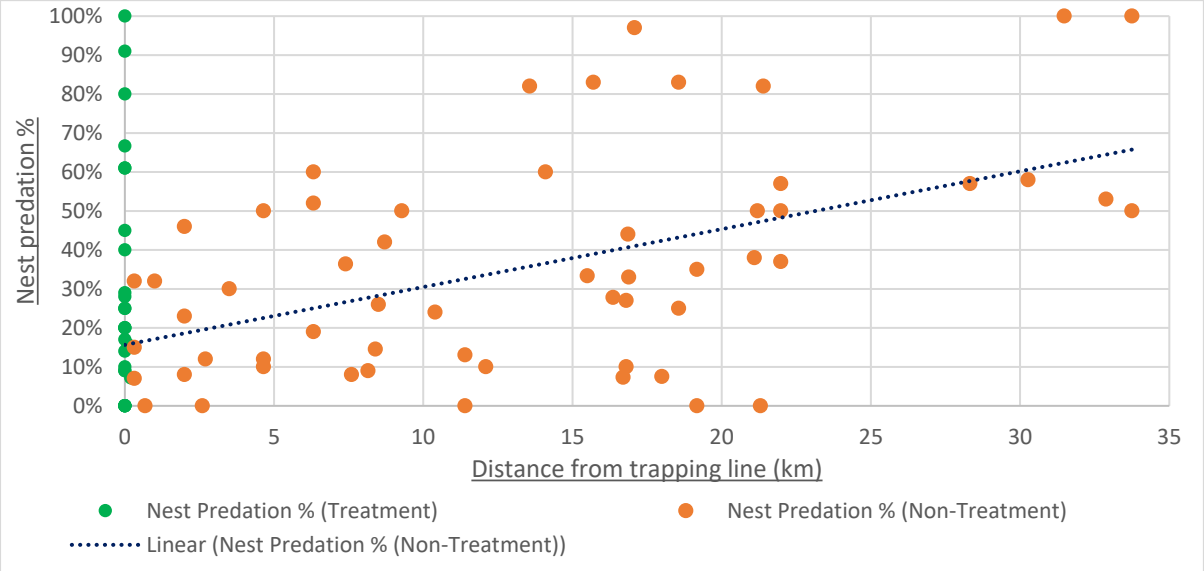



***Figure 49.*** *The relationship between the percentage of nests predated and distance to nearest trapping network in black-fronted tern colonies from 2015/16 to 2022/23 along Waiau Toa/Clarence and Wakaputawatea/Acheron rivers (Cor = 0.389). Note: treatment colonies within the second phase of monitoring include mainland colonies.*

## 3.7 Banding and resighting

### 3.7.1 Adult banding

Across several days throughout November and December 2022, adult banding took place at seven different colonies on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers. Over these days, a total of 20 birds were caught and banded (Table 21; Figure 50).

***Table 21.*** *Number and location of newly banded black-fronted tern adults on the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers during the 2022/23 season.*

| Colony Code | Month of banding | |
|---|---|---|
| | November | December |
| CA | 1 | 1 |
| CC | 2 | |
| CD | | 3 |
| CF | 1 | 1 |
| CG | 1 | |
| CH | | 4 |
| AA | 3 | 3 |
| Total | 8 | 12 |
| Combined Total | 20 | |

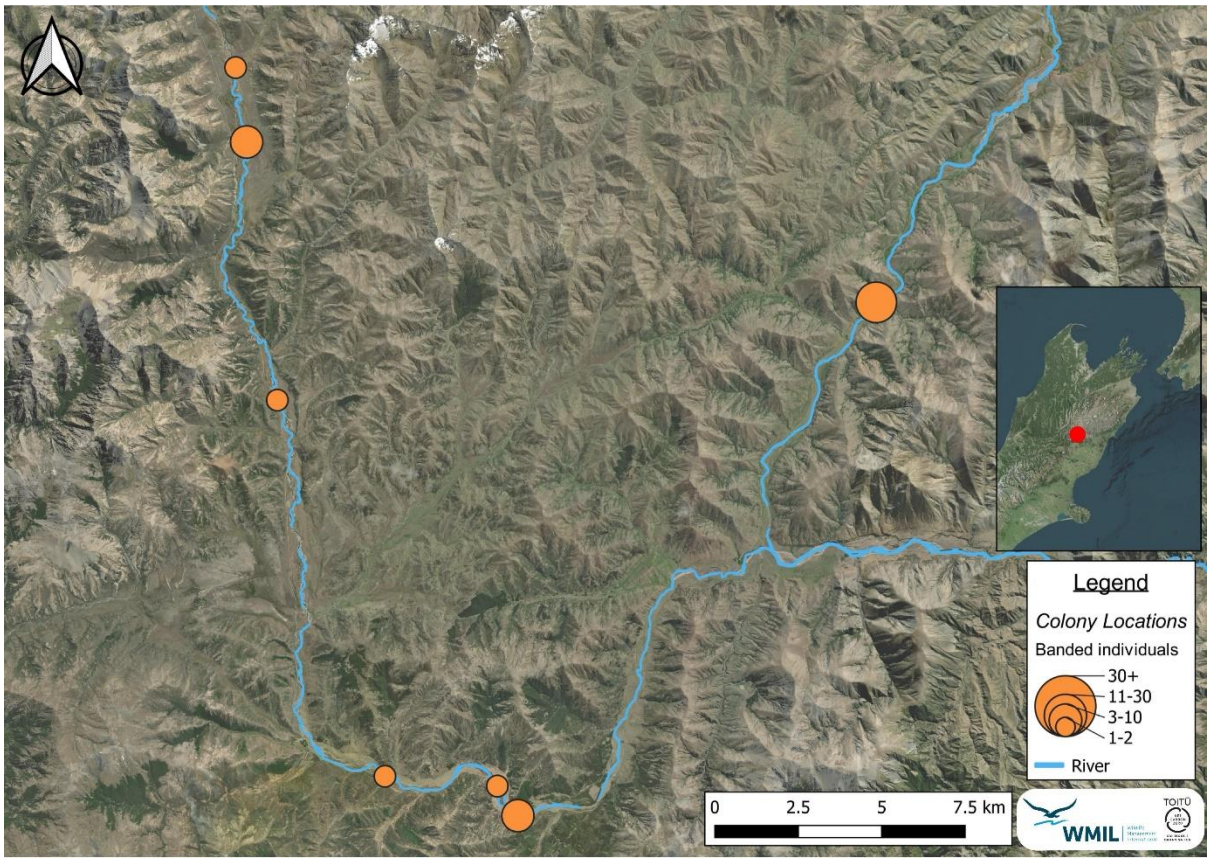



***Figure 50.*** *Location and count of black-fronted tern adults banded during the 2022/23 breeding season on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers.*

WMIL: Connor-McClean et al. 2023

### 3.7.2 Chick banding

Between 15-17 December 2022, a joint effort to band as many chicks was carried out. During these three days, 88 chicks were caught and banded at eight different colony sites (Table 22; Figure 51).

A further five chicks were banded in January during colony checks, bringing the overall total to 93 chicks banded over ten colonies during the 2022/23 season (Table 22; Figure 52).

***Table 22.*** *Number and location of newly banded black-fronted tern chicks on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers during the 2022/23 season.*

| Colony Code | Month of banding | |
|---|---|---|
| | December | January |
| CA | 13 | 1 |
| CD | | 2 |
| CE | | 1 |
| CF | 3 | |
| CG1 | 1 | |
| CG2 | 2 | |
| CG3 | 2 | |
| CH | 1 | |
| CJ | 10 | 1 |
| AA | 56 | |
| Total | 88 | 5 |
| Combined Total | 93 | |

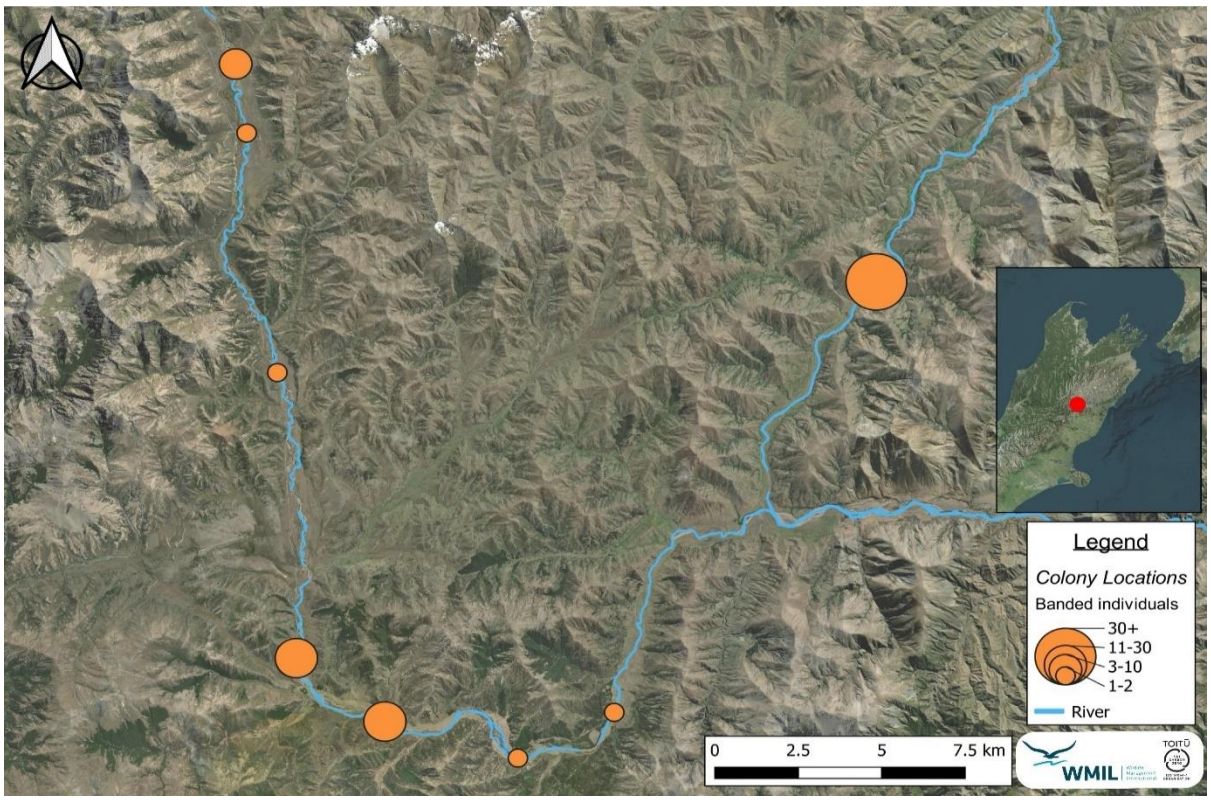



***Figure 51.*** *Location and count of black-fronted tern chicks banded during the 2022/23 breeding season on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers.*

WMIL: Connor-McClean et al. 2023

***Figure 52.*** *Black-fronted tern chicks being banded at CG3 colony (top) and an almost fledged chick banded at CA colony (bottom) on the Waiau Toa/Clarence River.*

## 3.7.3 Band resightings

### 3.7.3.1 Black-fronted terns

Throughout the 2022/23 season, 36 previously banded black-fronted terns were resighted (Figure 53). These birds were predominantly nesting on the Waiau Toa/Clarence (eight different colonies), and five birds were resighted at one colony on the Wakaputawatea/Acheron River.

Data on the tern banding and resighting history can be found on the FALCON database (https://app.birdbanding.doc.govt.nz/) under the *Black-fronted tern study* project.


***Figure 53.*** *Band resightings (PB, NK, and KE) caught on nest cameras during the 2022/23 breeding season on the Waiau Toa/Clarence River.*

#### 3.7.3.2 Kāhu

Throughout the 2022/23 tern breeding season, no banded kāhu were resighted. Furthermore, no kāhu predation events were caught on camera this season resulting in 2022/23 being the first breeding season since 2015/16 to have no nest predations by kāhu recorded.

# 4. DISCUSSION

This is the second year of the second five-year study on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers black-fronted tern population. The previous five-year monitoring project involved carrying out localised predator control in the vicinity of three islands on which terns nested, as well as improving habitat quality on each island by removing woody weeds and 'engineering' islands to be both more resistant to flooding and less accessible to predators. Upon the completion of the original five-year project, the successful results of terns breeding on enhanced islands highlighted the importance of engineering more islands along the Waiau Toa/Clarence River (Connor-McClean & Bell 2020). This would allow more suitable nesting habitat and a higher chance at deterring threats. Extending the predator trapping network would also target predators along a longer stretch of the Waiau Toa/Clarence River supporting an increase in productivity of terns in conjunction with enhanced islands.

Within the first year (2021/22) of the second five-year study, a larger portion of the Waiau Toa/Clarence River was trapped on both sides (26 km stretch of river) which formed the new treatment zone area (Connor-McClean et al. 2022). In 2021 and 2022, five to seven islands were enhanced within the trapped treatment zone, with the goal of facilitating more successful black-fronted tern nesting. Chick shelters were also added in the second five-year study and were distributed across all colonies within the treatment zone throughout the season one week before chicks were due to hatch. This was to assist with higher fledgling rates and less chick fatalities due to heat exhaustion and aerial predation.

## 4.1 Island enhancement

To prepare for the start of the 2022/23 season, island enhancement work was carried out in March-April 2022 on five different islands on the Waiau Toa/Clarence River. Two other previously enhanced islands were still in good condition for nesting terns.

Of the seven available islands, four were suitable for a safe nesting environment. Of these four remaining enhanced islands, three were colonised (CA2, CD, CE). Two colonies (CA2 & CD) had successful hatching and fledgling success (Appendix 9). Colony CE was subjected to southern black-backed gull predation early in the season. This island was recolonised mid-season, but again was wiped out by southern black-backed gull predation/disturbance.

Weed growth was problematic on one island (Swimming Hole Island) which, in spring, produced dense vegetation over the island making it an unfavourable nesting site for terns this season. This is the first-time during Phase 1 or 2 where no terns have nested on Swimming Hole. Previous island enhancements in 2021 attempted to clear woody vegetation around the perimeter of the island, however it was discovered that the island possessed a thin layer of gravels with silt and soil uncovered underneath. This resulted in enhancement works being stopped to prevent the uncovering of soil and nesting gravels to be lost. An emphasis on weed control by hand will need to be applied for the following season.

We now know that enhancement efforts can be easily undone by large winter flooding events that occur prior to the start of the nesting season. These extreme floods have the potential to completely change the geography of the islands. During the winter 2022 winter period on the Waiau Toa/Clarence River, maximum flood levels reached 107 $m^3$/sec on 7 August 2022 (Figure 15).

Despite the high rainfall, most of the enhanced islands suffered little to no damage with only two islands having their channels filled in with gravels causing them to dry up and re-connect to the mainland during low river flow in the December to February. To maintain strong islands which can withstand high river flow levels, islands need to be raised and surrounding channels deepened to protect these nesting areas. These channels also need to be designed in a way that they can support the flow of water during droughts and low river flow (e.g.: 5 $m^3$/sec on the Waiau Toa/Clarence River). Enhancement work success would also be improved by carrying out bulldozer work closer to the start of the tern breeding season in August or early September after the large winter flash flood period.

Two of the early enhanced islands carried out in 2016 have maintained their robust structure and have not needed further enhancement work during any of the consecutive years. This shows the cost-effective benefits of using island enhancements to create robust islands which can last for successive years and provide favourable, safe nesting habitat for returning terns.

## 4.2 Predator control

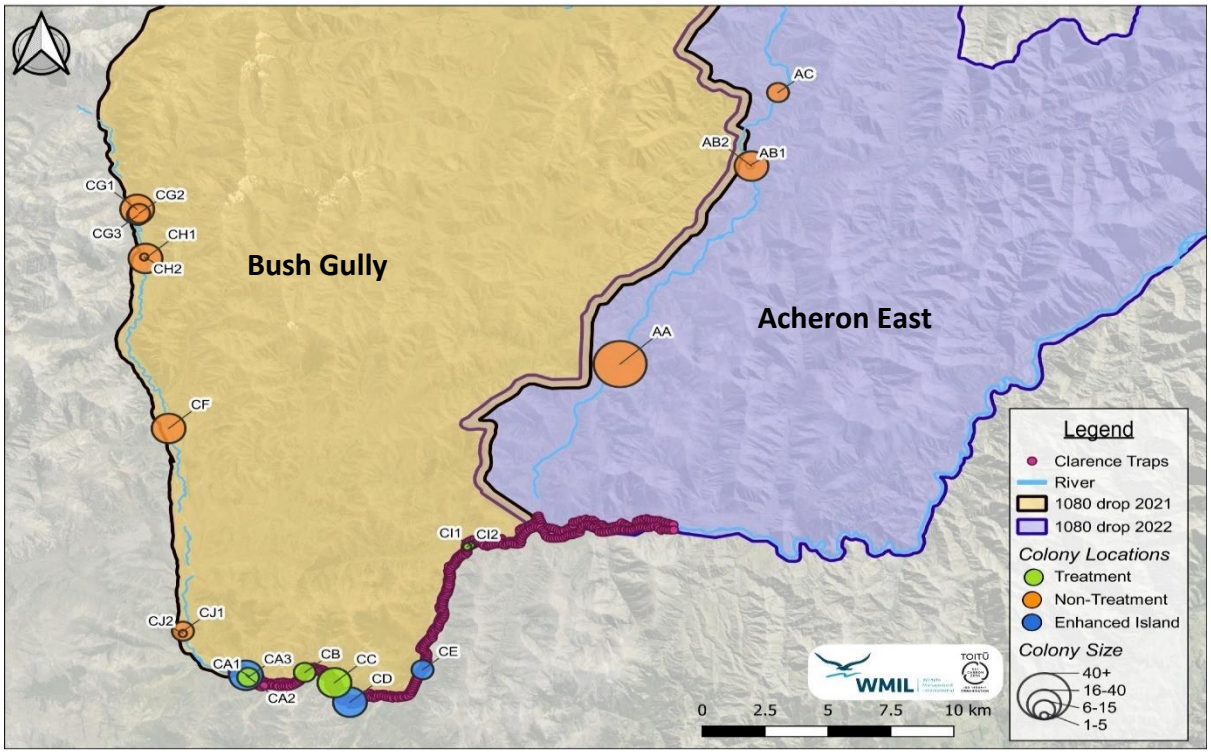
### 4.2.1 1080 operation

In June 2021, OSPRI conducted an aerial 1080 operation over 21,500 ha around Bush Gully and 40,000 ha over Tarndale to eradicate possums carrying bovine tuberculosis (OSPRI 2020). This aerial operation bordered the true left of the Waiau Toa/Clarence River from Lake Tennyson to the confluence, and the true right of the Wakaputawatea/Acheron River to the confluence (

Figure *54*).

In October 2022, another 1080 operation occurred over a 62,500 area; bordered from the confluence, downstream along the true left side of the Waiau Toa/Clarence River and along the true left of the Wakaputawatea/Acheron River, covering areas monitored for tern nesting behaviour (

Figure *54*) (OSPRI 2023).




WMIL: Connor-McClean et al. 2023

***Figure 54.*** *The 2021 and 2022 1080 operation zones in comparison to black-fronted tern colonies and trap line during the 2022/23 season along the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers.*

Based on the comparison between opposing sides of the river, this 1080 operation did not appear to have a major impact on reducing mammalian predator captures within the trapped area. It was expected that primary and secondary poisoning could lead to an acute reduction in the number of species caught within the ariel application zone. Apart from hedgehog captures which were almost half the number caught in the months following the 1080 drop, all other mammalian pests were caught in similar numbers post-operation compared to the traps on the opposing side of the river.

After enquiring to OSPRI about information regarding their final course of operation, it was discovered that the operation area was slightly reduced near the trapped area and around the surrounding water ways (Figure 55). The updated operation area tracks show that the operation never overlapped with the trap line with operation distances ranging from 250 m to 1,300 m away from the trap line (Figure 55).

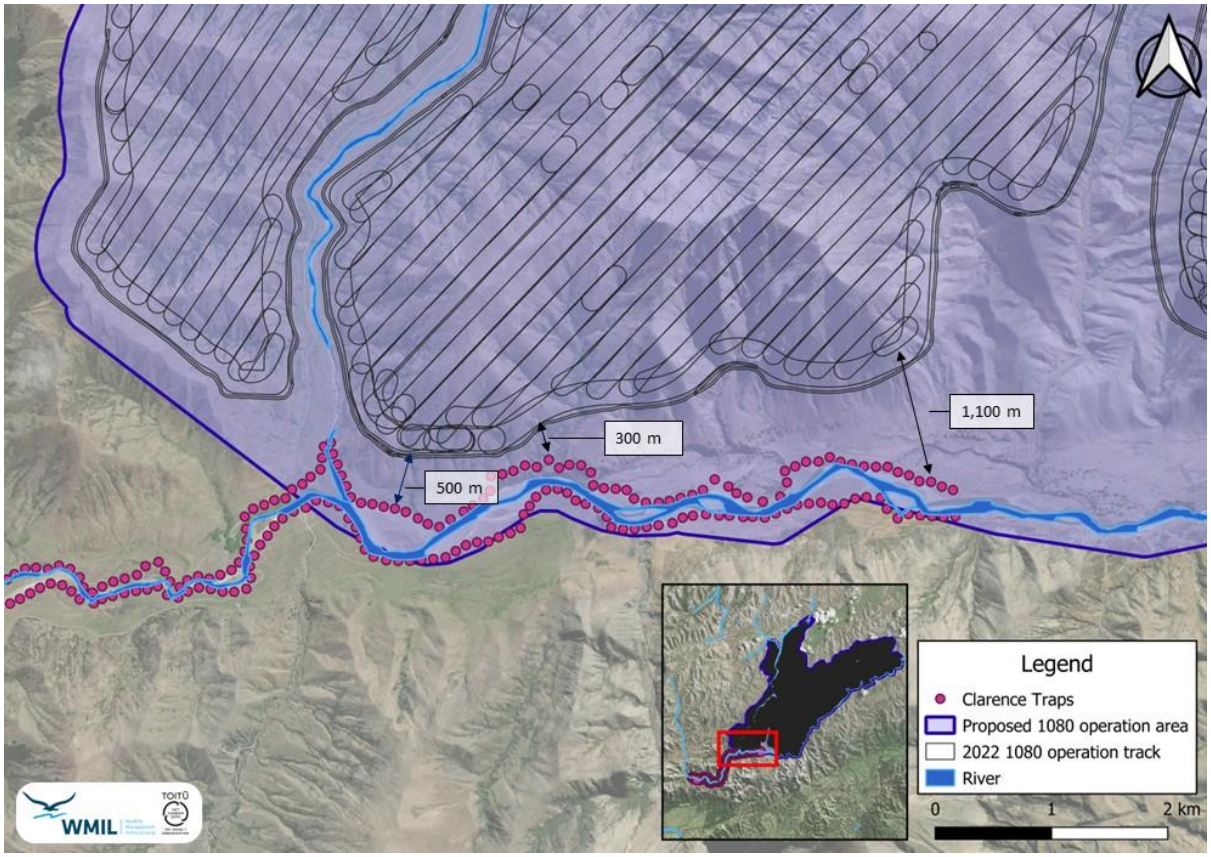



***Figure 55.*** *Helicopter tracks from the 2022 OSPRI 1080 operation within the Wakaputawatea/Acheron East Area in conjunction with the trapping line, Waiau Toa/Clarence River.*

These gaps increase validation as to why trap catches remained relatively unchanged. Additionally, the river may not have acted as a strong enough barrier to deter predators from crossing and could be another reason underlying the similar numbers. Without additional monitoring in place the ability to draw conclusions is limited.

After the 1080 operations in 2021 and 2022 (despite no change in catch numbers, except for hedgehogs), the most recent two seasons following on from these operations have seen the lowest nest predation percentages in non-treatment zones in the past seven years (2021/22: 19%; 2022/23:

23%) (Appendix 10). The average nest predation percentage in non-treatment colonies during Phase 2 (21%) is 12.6% lower than the Phase 1 average (33.6%) (Appendix 10).

During the 2022/23 season, only one mainland colony was situated in the 1080 operational zone (AB2). Of this colony 44% hatched. However, 44% of nests were also predated. Whilst no predation events were caught on camera, there was one southern black-backed gull captured on camera at a nest where chicks had hatched and recently left the nest. It is possible that the predator of these nests was avian. Colonies close by AA and AC have evidence of southern black-backed gulls also predating nests and chicks.

This result partially follows the previous 2021/22 season where colony (CF) within the treatment zone and 2021 1080 operation zone was fully attached to the mainland on the true left side and was successful in hatching 83% of nests with the other 17% of nests being abandoned. Colony CF also obtained a 50-94% fledging success rate. In comparison, mainland colonies on the true right side of the river were largely predated before nests were able to hatch, or before chicks were able to fledge.

The reduced number of kāhu predations throughout the 2021/22 and 2022/23 seasons compared to previous monitored seasons may also be attributed to the effects of secondary poisoning of 1080.

### 4.2.2 Predator trapping

Trapping for mammalian predators in the upper Waiau Toa/Clarence River was established in July 2015 and has been carried out each season from July to January-February. Kill trapping continues to be successful at removing large numbers of target mammalian predators that had previously accounted for a large proportion of observed nest failures at black-fronted tern colonies (Connor-McClean & Bell 2020).

For most mammalian pest species, the numbers and capture rates are much higher compared to the previous season. Moreover, the peak rate of species caught (except for possums) were substantially higher than the previous season.

Whilst increases in numbers caught may not necessarily be reflective or indicative of the true local abundance or changes in population size of these pest species, a higher rate could indicate an increase in efficiency of the trapping network. Changes to the trapping network throughout the field such as changing to a longer-lasting bait, and a re-calibration of the traps may have contributed to the higher catch rate. However, complementary monitoring of predators (e.g., tracking tunnels or camera monitoring) inside/outside the trapped would increase the understanding of predator populations within the site as a whole and the effect of the trapping regime on the population structure.

#### 4.2.2.1 Trapping regime changes

Following the change in bait type (from fresh meat to dehydrated Muste-Bait and accompanying cat-mustelid lure spray) and trapping check regime (fortnightly to monthly), that occurred from November onwards (i.e., bait switch occurred during the November check, results are thus from December onwards), there was no apparent slowdown in capture rates; indeed, the majority of species were caught at higher rates from December onwards relative to the previous season. Despite the increase in catch-rate from December onwards, without an indication of pest abundances within the local area it is difficult to distinguish between whether the trapping regime caught more or whether there was a higher abundance of target animals relative to the previous season. Nonetheless, the lack of a marked decline in capture rates following the change in bait and check regime suggest that pest species are unlikely to be avoiding the new bait type and that monthly checks were sufficient to maintain a buffer of reduced predation pressure around the black-fronted tern colonies.

#### 4.2.2.2 Trapping impacts on treatment colonies

At the local scale the trapping network appears to be sufficient in suppressing predation pressure on tern colonies within the network for the duration of the breeding season. During the 2022/23 season, tern hatching success within the treatment zone was 52%, with predation pressure encompassing 32% of nest failure and around 67% of known fledging mortality (Table 18; Appendix 9). However, over half of these nest predations were attributed to avian predation which are not targeted by any active trap types.

Mainland colonies in the treatment area were still subject to mammalian predations including cat and stoat predations (44% of nests predated). These mammalian predators are also estimated to be the cause of all 28 hatched chick predations resulting in a 100% chick fatality rate. Whilst a fair number of stoats and cats were captured along the trap line, there still seems to be a problem with trap shyness, particularly in cats. This makes it challenging for mainland nests to survive a full season and reach fledging. It was noticed that many cats captured were juveniles (62.5% of the eight cats that were aged), occurring towards the end of the season. Adult cats were much harder to lure into a trap during tern nesting season.

At a broader landscape level, the trap network is unlikely to be able to reduce the population sizes of mammalian pest species due to its relatively small footprint compared to the rest of the wider environment in which it sits. Continued trapping through the non-breeding season may alleviate some additional predation pressure faced in the following breeding season, but the surrounding landscape will continue to act as a reservoir for immigration and population growth regardless of the effect of the singular trapping line.

The most influencing factor of colony success is evidently based on how robust the island they nest on is. An island with strong, wide channels surrounding the whole perimeter of the island is the most effective predator buffer in the treatment and non-treatment zones. Predator trapping continues to aid in suppressing mammalian predator numbers within the treatment zone which enables colonies to have the best chance in breeding success.

#### 4.2.2.3 Increasing rat presence

The presence and the high number of rats caught in the trapping network was an unanticipated and a concerning result during the 2022/23 field season. Rats have been seen in high numbers in one other field season. In the 2019/20 field season 23 rats were caught in the network, but rats were either completely absent or in low numbers (i.e., two rats caught in 2020/21) in every other field season where trapping took place. Rats, in particular Norway rats (*R. norvegicus*) can have devastating effects on tern breeding. For example, at a tern colony located on the Hurunui River, a single rat over five successive nights caused all tern nests to fail (Connor-McClean & Bell 2021a).

All rats found within the Waiau Toa/Clarence River trapping network were ship rats (*R. rattus*). It is thought that the high elevation and harsher environment of the site (c. 600 m a.s.l.) would dissuade rats from inhabiting the landscape, but this does not appear to be the case. Outside of the trapping network rats were also found to be present at farm buildings located within the same landscape (Ward, J., DOC., pers. comm.). If the site trends towards increasingly favourable conditions for rats to persist, they may become a more prevalent predator that terns would have to contend with. Along with the 2019/20 season having the highest trapped rats, it was also the only season to have recorded nest predations by rats with three rats caught predating nests on camera (Connor-McClean & Bell 2021a).

It will also be important to continue to monitor for the presence of rats in the trapping network as a tool for climate modellers to understand species responses to ongoing climatic changes.

#### 4.2.2.4 Trap calibration

The trap calibration sessions undertaken in late June and July prior to the opening of the traps were designed to provide maintenance and to re-calibrate traps to appropriate firing weights to reduce catches of non-target species (e.g., mice). Despite the calibration sessions, the catch rate of mice was higher compared to the previous season. The catch rate was relatively low up until October, and then continued to increase from then on. Additional monitoring in the future on the occurrence of tussock masting (i.e., the mass production of seeds by members of the same species), during the field season may help to explain mice captures in the future as this process can cause rapid changes in the mice population (Wilson & Lee 2010). Despite mice being caught at higher rates than expected (and thus diverting potential trapping effort away from targeted species), the overall rate of capture for targeted species remained high.

## 4.3 Black-fronted tern breeding success

The 2022/23 breeding season has added another successful season to the second five-year study instigated on the rivers. The initial nesting phase of the tern season started off rather late with peak nest laying occurring in early to mid-November (n = 182). This may have been due to late snow events in the season and cool weather leading up to the spring season.

Two colonies that had predation events early in the season were forced to relocate and re-nest on an enhanced island downstream (CD) which resulted in a much more successful outcome for these birds (64 - 96% fledging success) (Chicks that hatched on islands within the treatment zone had the greatest chance of fledging with 55 - 81% of chicks estimated to have fledged (Table 17). A larger number of chicks fledged on islands outside of the treatment zone this season (N = 104 - 148). On mainland colonies, both within the treatment and non-treatment zones, no chicks were observed to have fledged out of the 54 chicks that hatched. Only eight were estimated to have fledged as a maximum count (Table 17). The overall combined productivity of fledglings per nest was 0.46 – 0.68 fledglings/nest (Table 17). Productivity between islands in the treatment and non-treatment zone were almost identical where both zones had a minimum productivity of 0.61 fledglings/nest on islands. The highest estimates of fledgling productivity per nest on islands was 0.9 fledglings/nest in the treatment zone and 0.87 fledglings/nest in the non-treatment zone (Table 17).

***Table 16***).

Flooding had no impact on the outcome of the tern nesting and fledging success with the highest river flow rates during the season peaking at 24 $m^3$/sec. The end of February finished with a 71$m^3$/sec flood; however, all remaining chicks had fledged by this stage. In contrast, the low water flow rates throughout the season caused many channels to thin out or dry out altogether. This created access for mammalian predators into the colonies along with channel sections thinning to less than 3 m wide which is accessible by cats and some mustelids to jump across.

In September, a stoat was seen swimming across the Waiau Toa/Clarence River from Upper Bush Gully true right to the true left side at 15 $m^3$/sec. The average river flow rate of the 2022/23 breeding season was 8.4 $m^3$/second from 1 October to 10 February which was the date the last remaining colony finished. This shows how manoeuvrable mustelids can be between the mainland, to islands, to the other side of the channel and how at risk any colony can be from mustelid predation.

Despite the challenges faced by nesting terns this season, fledgling success continued to be satisfactory within the treatment zone with a productivity of 0.59 fledglings per nest. Fledgling productivity in the non-treatment zone was almost double the seven-year average (0.26 fledglings per nest) with a productivity of 0.42 fledglings per nest (Table 20).

### 4.3.1 2015/16 to 2022/23 comparisons

The definition of "treatment zone" differs between the two five-year studies and this made comparisons between the two studies misleading and inaccurate. To mitigate these differences, data from the last seven seasons was recalculated to allow for comparison; this included separating treatment colonies to include only trapped island nests while non-treatment colonies included all non-trapped island nests along with all mainland nests. Historic colony data of "upper Swimming hole" was also shifted into the non-treatment category for Phase 1 (Table 19 and Appendix 10).

Hatching success within non-treatment zones was the second highest in comparison to previously monitored seasons with a 60% hatching success rate (19% higher than the seven-year average) (Appendix 10). Non-treatment colonies also had the second lowest nest predations rates (23%) and lowest number of flooded nests (0%). This was largely due to the low river flow rates during the 2022/23 season, along with the largest colony establishing on a very robust, natural island within the non-treatment zone (Grader Island, AA). This island had raised heights and strong river channels surrounding the islands allowing nests to avoid mammalian predation and flooding.

Grader Island was colonised by large numbers of breeding pairs in both 2021/22 (55 nests; Connor-McClean & Bell 2022) and 2022/23 (79 nests) (Table 12). Both seasons had a high hatching success rate (2021/22 = 78% (Connor-McClean & Bell 2022), 2022/23 = 87%; Table 12) along with high fledgling success rates (2021/22 = 68 – 95% (Connor-McClean & Bell 2022), 2022/23 = 68 – 92%; Table 16Chicks that hatched on islands within the treatment zone had the greatest chance of fledging with 55 - 81% of chicks estimated to have fledged (Table 17). A larger number of chicks fledged on islands outside of the treatment zone this season (N = 104 - 148). On mainland colonies, both within the treatment and non-treatment zones, no chicks were observed to have fledged out of the 54 chicks that hatched. Only eight were estimated to have fledged as a maximum count (Table 17). The overall combined productivity of fledglings per nest was 0.46 – 0.68 fledglings/nest (Table 17). Productivity between islands in the treatment and non-treatment zone were almost identical where both zones had a minimum productivity of 0.61 fledglings/nest on islands. The highest estimates of fledgling productivity per nest on islands was 0.9 fledglings/nest in the treatment zone and 0.87 fledglings/nest in the non-treatment zone (Table 17).

***Table 16***). These numbers largely influenced the success of overall non-treatment breeding success.

Fledgling success within non-treatment zones followed a similar pattern of success with a productivity of 0.51/nest (0.22 higher than the seven-year average).

The largest number of fledglings were produced from a non-treatment natural island (AA) where 80-109 fledglings were estimated to have fledged. This can be attributed to the strong, wide river channels surrounding the island, raised island height, suitable nesting gravels and enough low-lying vegetation for shelter and shade.

Below is an example of where colony checks were too dangerous to continue during peak chick hatching-fledging season due to chicks fleeing to the water and being washed downstream. During early stages, a total of seven chicks had to be rescued and returned to the island from the water. Whilst carrying out chick banding on this island, our team had to rescue 22 chicks from the water including wading to the other side of the channel to retrieve chicks that had swam across and climbed out onto the mainland (Figure 56). During this time, it was not safe to conduct weekly nest checks with only one observer.

***Figure 56.*** *Retrieval of a black-fronted tern chick that had swam across the channel during the December banding trip on the Wakaputawatea/Acheron River, 2022.*

### 4.3.2 Historic robust island use in non-treatment zones

In recent years within the Phase 2 project, overall non-treatment zone hatching and fledging success has increased to substantial levels. This raises the question of if these "robust, suitable" breeding islands have been used in Phase 1 and whether or not they had the same effect as they have in Phase 2 non-treatment nest and fledgling success.

Within the previous five monitored years (Phase 1), Grader Island (AA) was only nested on once during the 2018/19 season (Parry Duck Island colony [AP]) (Appendix 12) with 12 known nests achieving a 58% hatching success rate (Bell & Harborne 2019b). The remaining 42% of nests were predated with suspected kāhu predation being the cause of failure due to the state of the eggshell and neighbouring colony predations also by kāhu (Bell & Harborne 2019b).

St James Colony (CJ1) was also a very robust island in the non-treatment zone during the 2022/23 season which achieved an 83% hatching success rate and fledged 82 – 94% of those chicks (Table 12; Table 16). This was the first year this island was colonised during any monitored season (Appendix 13). Fluctuations in river flow over the last 10 years are suspected to have changed the shape of the river system, creating stronger channels around this island, making it more favourable than it may have been in previous seasons.

The most successful island on the Waiau Toa/Clarence River in the non-treatment zone in 2021/22 was Top Colony (CH) (Connor-McClean et al. 2022). This robust island achieved a 90% hatching success rate (n = 37) and fledged 42 – 67 % of chicks (Connor-McClean et al. 2022). This island has only been used one other time during the 2017/18 season where 73 nests were monitored on this island (CF) (Bell et al. 2018b; Appendix 14). The 2017/18 season was recorded to have the highest hatching success of all non-treatment colonies during the five monitored years of Phase 1 and also maintained the second highest fledgling productivity on non-treatment colonies throughout Phase 1 (Bell et al. 2018). Bell et al. (2018) stated that the success of the non-treatment zone "is likely due to both islands having good breeding habitats with excellent channels…which highlights the importance of well-formed breeding islands for black-fronted terns."

The success of these non-treatment colonies on robust islands, particularly in recent years, highlights the importance and effectiveness of enhanced island equivalents, and the drastic impact site suitability can have on colonies, particularly where no predator control has been initiated.

### 4.3.3 Colony size correlation to breeding success

An observation that was noted throughout the 2021/22 and 2022/23 seasons was the effectiveness of larger colonies at scaring away avian predators. Throughout each season, southern black-backed gulls have been observed to fly up and down the rivers looking for nests to predate. Kāhu have also been seen hovering around nesting colonies.

During this time, it has been noticed that smaller colonies have less success at scaring away these avian predators. However, colonies that have more than 30 tern pairs attacking these threats appear to have more success in driving the predator away. Results from the previous two seasons (2021/22 and 2022/23) show a moderate, positive correlation between the colony size and hatching success in non-treatment zone colonies (correlation coefficient = 0.57) whilst treatment zone colonies had a weak correlation (correlation coefficient = 0.053) (Figure 57).

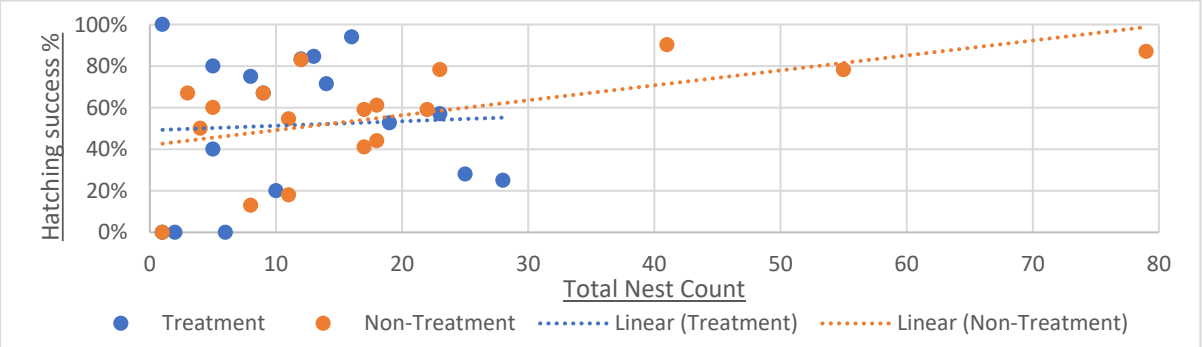



***Figure 57.*** *Relationship between colony size (total nest count) and hatching success % in colonies along the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers during the 2021/22 and 2022/23 breeding seasons (Cor [treatment = 0.053; non-treatment = 0.570]).*

It was also observed that nesting tōrea/South Island pied oystercatchers (SIPO, *Haematopus finschi*) were very successful in chasing off avian predators in the area, benefitting tern colonies that were also nesting in the same area as these birds.

### 4.3.4 Black-fronted tern nest predation

Another unusual observation that was caught on camera throughout the 2022/23 season was the predation of abandoned nests by first-year terns (Figure 58). There were also accounts of adults in breeding plumage predating abandoned nests. This raises a question of what nutritional needs aren't being met for the birds to predate these nests along with other potential causes or behaviours.

Amongst all the exotic grassland (Figure 3), Molesworth is also heavily vegetated by native tussock grasslands. This ecosystem provides habitat for many native invertebrates and lizards (Mark et al. 2013) which are a food source to terns (O'Donnell & Hoare 2009). However, the invasion of conifers into tussock land can result in increased soil acidity as well as reduced carbon sequestration (Dickie et al. 2011, Emson 2022, Yeates & Saggar 1998). As a result, invaded systems can show a significant decrease in invertebrate and lizard diversity (Dickie et al. 2011).

It could also be possible that eggs form a natural (but small portion, hence their low rate of being recorded) part of the tern diet or represents an opportunistic nest predation event. A clear understanding of a tern's diet is needed to understand whether egg predation is an opportunistic event, natural behaviour or whether it represents a decline (and thus a switching of resources) of their regular prey species (e.g., invertebrates).


***Figure 58.*** *Camera observations of abandoned nest predations by black-fronted terns and South Island pied oystercatcher on the Waiau Toa/Clarence River, 2022/23.*

WMIL: Connor-McClean et al. 2023

These hypotheses could all separately explain the behaviour of breeding terns predating nests. Black-fronted terns are thought to be mainly 'income breeders,' acquiring most of their energy and nutrients required for egg production from current and cumulative dietary intake (as opposed to stored nutrient reserves i.e., 'capital breeders'; Moore et al. 2000). Cost of egg production in terns is particularly high with two eggs weighing almost 50% of their body weight (around 20g per egg; 41 x 28mm in size) (Bell 2022, Moore et al. 2000, British Trust for Ornithology 2022). If terns are not gaining enough nutrients to re-stock their nutritional supplies after laying eggs, these birds may be inclined to predate eggs in order to quickly replenish their protein, lipid, and calcium stocks (Lafeber 2022).

Further research will need to be obtained to fully understand the nutritional health of terns in the study area and to determine if there are any impacts on the prey species abundances and composition, particularly the presence of invasive conifers and their subsequent management. A study into the diet derived compounds into tern eggs may be useful.

## 4.4 Chick shelters

### 4.4.1 Heat exhaustion

An issue that has been noted in previous tern studies (Connor-McClean & Bell 2021a, Miskimmin et al. 2022) is the effects of heat exhaustion on chick survival rates.

Large rocky islands and sections of mainland exposed to solar radiation causes intense heat to be generated from these rocks in colonies along the rivers (Mitchell et al. 1996). On clear, sunny days river gravel temperatures rise due to conduction causing heat energy to slowly be released from each rock into the atmosphere, forming pockets of warmer air (National Weather Service undated). With daily temperatures frequently reaching more than 30°C, ground temperatures on rocky islands along the Wakaputawatea/Acheron were regularly reaching 40+°C throughout late December/early January (Figure 59). This caused extreme heat conditions for young, exposed chicks on the ground. Young chicks cannot thermoregulate and are vulnerable to overheating in hot weather conditions (Babcock & Booth 2020).


***Figure 59.*** *Adult black-fronted tern trying to cool down during 41°C ground temperatures on the Wakaputawatea/Acheron River on 17 December 2022.*

Chick shelters were put in place on colonies within the treatment zone for the second five-year study to trial their use by chicks over the season. Nest camera footage showed that chick shelters were frequently being used throughout the 2022/23 season by chicks during a variety of weather conditions and temperatures (Figure 60).

Whilst temperatures remained below extreme levels until late December/January, chick shelters were still used throughout the season for shade, shelter from wind, and also shelter from rain which was a more frequent occurrence.


***Figure 60.*** *Black-fronted tern chicks using chick shelter to shelter from rain during the 2022/23 breeding season on the Waiau Toa/Clarence River.*

Of the 15 observed chick deaths, five were a result of heat exhaustion all situated on non-treatment colonies. This was determined due to nest camera footage, the observed state of the bird, lack of vegetation near nesting sites, and all five chicks hatching late in December/early January when ground temperatures were reaching 40+°C.

A study of tern nesting success on the Hurunui and Waiau-Uwha rivers (Connor-McClean & Bell 2021b) saw one colony (HJ) lose 26 out of 54 chicks over the period of 19 days (17 December 2020 to 5 January 2021) due to heat exhaustion. This island was unvegetated, so chicks were left exposed to the severe temperatures. This highlights the importance of shade availability.

### 4.4.2 Predator avoidance

Throughout the 2022/23 season, one chick was seen using the chick shelter to actively hide from a predator on the island. This chick was observed for two days prior to the event on nest camera. With one unhatched egg still being incubated, the hatched chick was spending every moment in the nest site with or without a parent bird incubating the second egg. In one video, the adult has left the chick at the nest site. In the background alarmed terns can be heard screeching and divebombing a southern black-backed gull which was also heard. The chick in the nest runs towards the shelter for the first time where it hunkers down in the shade of the shelter and stays frozen for ten minutes until the calling dies off and an adult returns to the nest.

There are other examples of chicks using shelters during non-extreme temperatures with no wind or rain events occurring. This suggests that these chicks could also be using the shelter to keep safe from danger while both parents are away from the nesting site.

Two chicks in a treatment colony were predated by a cat, however, this occurred during the night when the chicks were in the nest under the adult with no time to use the chick shelter. Cats were detected on camera smelling the chick shelter edges during the night after checking the nest site.

The first two chicks of the season located in nests within 15 m of each other were both found dead in the nest site. At this time there were no chick shelters placed due to these nests hatching earlier than expected. The reason for this chick mortality is unclear as temperatures around this time were still mild. However, speculation arose later in the season when a stoat was seen on a nest camera running around this colony at the time of all the other hatched chick disappearances. No chick predation from this stoat was caught on camera.

## 4.5 Bird banding and resighting

### 4.5.1 Banding

#### 4.5.1.1 Black-fronted terns

A total of 113 terns (20 adults, 93 chicks) were banded on the rivers during the 2022/23 season. Adult banding was found to be quite time consuming sometimes taking an hour before a bird was captured (this includes moving traps between nests every 15-20 minutes to prevent too much disruption of adults incubating nests). The only time frame adults can be caught in drop traps is during the nesting phase, however, this is also the busiest period of the season and often there is not enough time to carry out weekly nest checks at colonies and spend hours banding adults. Where there were assisting helpers on site, nest checks and banding could be carried out more efficiently.

#### 4.5.1.2 Kāhu

A total of 21 birds were captured over three days of banding; an average of seven birds per day. Speculations due to such low numbers were formed, however it was thought that due to the continuous snowstorm events that occurred throughout the 2022 winter, many kāhu may have migrated to areas of lower altitude with a warmer climate. Kāhu tracked in Tasmania, Australia were recorded to make a regular migration to escape the rigours of the Tasmanian winter, much like the winters occurring in the Molesworth (Birdlife Australia 2017). These kāhu only returned to breed in late winter and spring.

Low numbers could also be attributed to a lag effect of secondary poisoning during the 2021 1080 operation.

To have the most success capturing higher numbers of kāhu in the area, trapping and banding should occur within the months of October to January when the black-fronted tern season is underway.

### 4.5.2 Band resighting

Throughout the 2022/23 season, 36 tern band resightings were made (excluding all newly banded birds throughout the season). No banded kāhu were resighted.

Band resightings were nearly impossible by binoculars unless the bird was rested on a surface nearby. At the very beginning of the season, photographs could be used to resight bands when birds were resting on gravel beaches, as they were not flighty so photographers could get close enough to take a clear shot. The most effective way to resight birds was through nest cameras, which required flicking through camera photos until both adults were in the shot with a clear view of legs to ensure that either no birds were banded, or one/both birds were banded. Photos were then continually flicked through until a band reading was clear and readable. Towards the end of the season, another way to capture band readings was trialled which was for the observer to hold a phone up with a

recording function while protective black-fronted terns were swooping them during nest checks. By replaying these videos back on slow motion, several band readings were identified.

Whilst no banded kāhu were resighted, readings would also be easily obtained by nest cameras which were recording nests being predated by kāhu. Many kāhu were spotted resting on fence posts; however, these were all non-banded birds.

## 4.6 Observations and trends

Over the seven breeding seasons monitored, a collection of observations and possible trends have been identified:

- To date, trapping appears to have prevented ferret and stoat predation within treatment areas. This suggests that these predators can be suppressed to levels which positively benefit black-fronted terns. [Note: One stoat was seen on camera at a mainland colony, however no predations were recorded.]
- Within the second five-year project, the new trapping line design has increased hedgehog numbers caught in traps annually and decreased hedgehog nest predation on the mainland within treatment sites.
- Monitoring over the last seven years has shown that nest predation by hedgehogs can be eliminated if breeding occurs on an island (regardless of treatment).
- Cat predation has occurred on treatment island/mainland nests along with enhanced islands. This highlights that cats are the most difficult predator to suppress with the current trapping regime to levels which positively benefit black-fronted terns.
- Single predator incursions can have major negative impacts. In two separate seasons a cat reaching the islands has caused numerous nest failures highlighting the impacts that a single predator which avoids traps can have.
- There is uncertainty around why kāhu predation has drastically reduced over the 2021/22 and 2022/23 seasons. One link could be attributed to the application of 1080 along the Waiau Toa/Clarence and Wakaputawatea/Acheron River boundaries. Only one kāhu was caught on camera predating two different nests in the past two seasons. However, there was also a 1080 aerial operation in October 2017 which had no effect on predation numbers during the 2017/18 season where 16 kāhu predation events on nests were caught on camera.
- Whilst 56 kāhu have been banded in 2021 and 2022, most (n=39) were juveniles or less than 2 years old. Throughout the last two seasons, only one un-banded adult kāhu was observed predating nests suggesting that a change in the population structure (and age composition) within the area
- Another assumption is that kāhu nest predation is a learned behaviour that has been picked up over the last few years as no younger kāhu were observed predating tern nests.
- Chicks regularly used chick shelters to escape extreme temperatures and rain. No chicks in nests with chick shelters on site died of heat exhaustion.
- One chick was observed using the shelter as an attempt to hide from a predator on the island. Other chicks used shelters throughout the day while waiting for their parents to return with food. This included days with non-extreme weather which suggests the shelters do provide a sense of safety to the chicks.
- A decline in mammalian predation in the non-treatment area has been observed over the last two seasons. This corresponds to the use of robust islands surrounded by wide, flowing channels along with the OSPRI 1080 operations around the project sites. It appears that while

there are good channels and a strong river flow around islands, they are less likely to be predated on by mammalian predators and less likely to be susceptible to incursions. It is also likely that the 1080 program occurring has had some positive benefits on reducing the mammalian population in favour of tern nesting success.

- Southern black-backed gulls are becoming more prevalent on the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers and are predicted to become an increasing issue for the nesting and fledging success of terns with this learnt behaviour expanding.
- It has been noticed that the same individual southern black-backed gull has been observed predating nests at different colonies along the Waiau Toa/Clarence River over consecutive years. This suggests that these nest predations have also become a learnt behaviour by a few individual gulls that are routinely seen cruising up and down the river.
- Colonies larger in size have a greater success in deterring avian predators and having a more successful breeding season.
- Colonies with SIPO nesting in the same colony are estimated to have a greater success in deterring avian predators.
- Juvenile terns and SIPO have been seen in more recent years predating on abandoned tern nests suggesting a lack of nutrients or availability of their food source. This could also be a natural behaviour of the species, however, with little evidence-based research on the matter, this remains speculation.

## 4.7 Recommendations

Based on the results over the last seven years monitoring of the terns breeding on the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers, for future tern conservation it is recommended that:

### 4.7.1 Island Enhancement

- Island Enhancement should be prioritised each season to create islands that will withstand flooding and possess wide, deep channels surrounding the island. This is the most effective way to maximise tern breeding success.
- Island enhancement surveys and work by bulldozer should be carried out in late August/early September. Previously, island enhancement works were carried out by April for the season ahead due to consent restraints. However, large flooding events throughout winter cause these costly enhancement works to be significantly altered or erased. Island enhancements should be carried out towards the end of the winter period, prior to 15 September to maximise the success and survival of terns.
- Weed control is carried out on suitable islands prior to the onset of the breeding season to ensure that the islands are kept clear of weeds and are favourable to arriving terns. Weed control should consist of either mechanical or manual removal of any woody weeds rather than herbicide spraying to avoid leaving dead, standing vegetation on the islands.
- Chick shelters should be placed on islands to provide shelter and shade from extreme temperatures that would have been provided by cleared vegetation. Chick shelters should only be placed near active nests that are a couple of weeks away from hatching, to prevent adults being deterred from areas due to previously placed chick shelters, or from abandoning their nests early on.

### 4.7.2 Black-fronted tern monitoring

- A helicopter survey is carried out during the peak of the breeding season to provide a best estimate tern population count, increasing the likelihood that all colonies along the Waiau Toa/Clarence and Wakaputawatea/Acheron rivers have been found.
- Rack rafts are used to access islands/colonies that are not accessible on foot. Surveys by pack raft should also be used to investigate sections of river throughout the season if there are colony failures and changes in colony locations.
- The monitoring of tern nesting is continued to determine breeding success and population estimates.
- Signage should be erected near colony sites, particularly near vehicle access points, to deter 4WD vehicles on colonies.

### 4.7.3 Banding and resighting

- Kāhu banding is continued to target a larger population with emphasis in areas that are previously known to have kāhu predations. This should be carried out in spring and/or summer to ensure resident kāhu are captured and banded, and migratory birds have returned.
- Tern banding should be continued to help achieve more information on distribution patterns and pairings.
- Tern chick banding should be continued to help gauge fledgling survival rates in future years.
- Additional help is recommended during adult banding to allow more time to be put towards banding and resighting adults whilst weekly colony checks can still occur.
- Additional help is recommended during chick banding to minimise birds fleeing to the water. This will also make colony visits more efficient to create less disturbance time.
- Additional nest cameras are established at each colony and rotated through the area to re-sight a larger percentage of banded birds (both terns and kāhu) within the colonies.

### 4.7.4 Predator suppression

- Spotlight shooting to be carried out to target cats, and other nocturnal species, especially trap shy predators with the assistance of thermal technology.
- Nocturnal-only ten-day leg hold trapping periods to target cats be carried out once a month during the season (October- January) where traps are opened in the evening and checked/closed in the morning each day when kāhu are less active and less likely to be captured.
- Continue monthly trap checks year-round to maximise captures of kittens/juvenile cats and mustelids (as well as hedgehogs) throughout February, March, and April. This could help reduce the abundance of predators, and the impacts of cat predations on terns in future seasons.
- Residual pest monitoring is recommended to be set up along areas approximate to the trap line.
- To continue using the Mustebait as a lure for predator control year-round.

## 5. LIMITATIONS

- It was deemed too risky to carry out weekly colony checks at large colonies with a high percentage of hatched chicks with just one person due to a high rate of chicks fleeing to the water. Therefore, regular colony checks couldn't be obtained during peak chick season

(primarily colony AA) and the outcome of several remaining nests was unknown due to the amount of time that passed before the colony was safe to revisit (most chicks fledged).

- Nests with chicks were not prioritised with camera monitoring, however this made some predation events unexplained such as a small colony of hatched chicks on an island/mainland being completely wiped out with no evidence of predation or chick outcome.
- Adult tern banding was too time consuming to carry out with just one or two people, as weeks were spent prioritising colony checks and camera servicing. To band more adults, one person would need to be focused on colony checks whilst a second or third person focused on banding adults during that time on a separate colony.

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Predator trapping, including calibration, trap repair, and fortnightly-monthly checks between July and February was completed by several WMIL personnel.

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# 8. APPENDICES

## 8.1 Appendix 1: Island Enhancement Guidelines

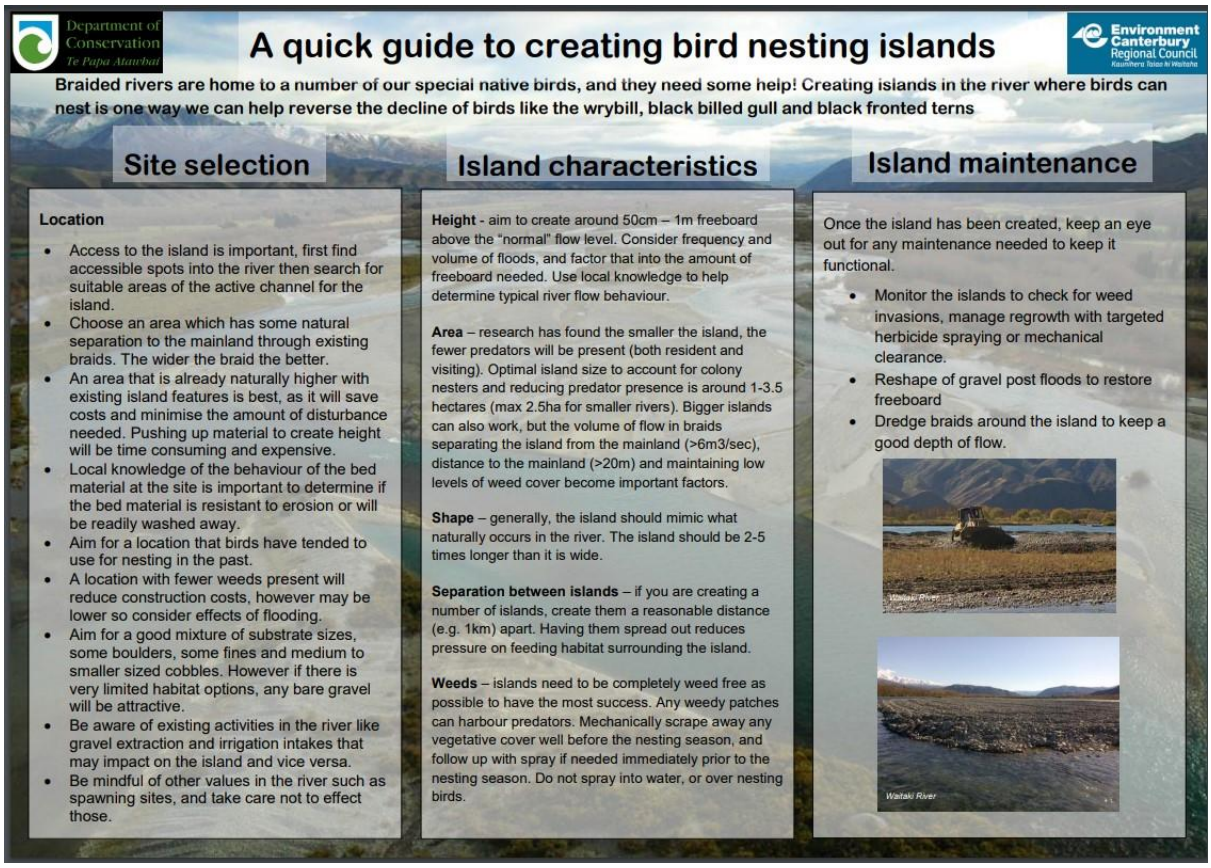


***Figure 61.*** *Island Enhancement Guidelines; A quick guide to creating bird nesting islands, retrieved from https://braidedrivers.org/wp-content/uploads/Bird-Island-creation-guidance.pdf*

## 8.2 Appendix 2: Enhanced Island descriptions

***Table 23.*** *Location and size of enhanced islands, and works that took place along the Waiau Toa/Clarence River, 2022.*

| River | Code | Site | Easting | Northing | Area ($m^2$) | Island Enhancement Works |
|---|---|---|---|---|---|---|
| Waiau Toa/Clarence River | C1 | Upper Swimming Hole | E1594957 | N5305985 | 15,000 | Channel was cleared and opened to allow river flow through previously dried up channel. Material from the channel was used to raise the height of the island slightly and stabilise the bank on the opposite side. |
| | C2 | Cow Island | E1589716 | N5298708 | 12,000 | Pre-existing channel was cleared and widened. Material from channel was pushed onto island to raise the height along its banks. River channel was diverted further upstream to allow river flow to travel around the true left side of the channel again. |
| | C3 | Eddy's Inlet | E1593387 | N5302867 | 2,700 | Large natural channel dried up around the true left side of island was deepened, widened, and opened to allow water flow to surround the island. |
| | C4 | Upper Bush Gully | E1594597 | N5305816 | 4,000 | Channel around true right side of island was cleared, widened, and deepened to allow river flow around island. River was directed down true right side of island. Gravels from the channel were pushed onto island to slightly raise the island height. |
| | C5 | Bridge Island | E1596531 | N5305946 | 22,000 | Island was mostly cleared of broom and other vegetation. Small pockets of vegetation were left around the edges on the island to provide a level of shade. Natural riverbed vegetation was left untouched. Channels were cleared and diverted to create an even flow around the island as part of the bridge support works. |
| | A | Swimming Hole | E1586108 | N5299755 | 8,500 | No further Island enhancements were required |
| | B | Mitchell's | E1592640 | N5300137 | 4,300 | No further Island enhancements were required |

## 8.3 Appendix 3: Predator capture comparison

***Table 24.*** *Total number of predators caught in kill traps along the upper Waiau Toa/Clarence River each season between 2015/16 and 2022/23. In brackets following raw numbers details the percentage increase/decrease in captures from the previous season with all percentages are rounded to the nearest integer. Seasons within the second five-year study are shaded blue. Note: all seasons excluding the 2020/21, 2021/22 and 2022/23 season utilised two 10-day pulses of leg-hold traps to target cats in addition to kill traps (kāhu were bycaught in these leg-hold traps). Additionally note that trap nights for 2021/22 and 2022/23 are calculated slightly differently to all other field seasons (denoted by *; i.e., for the current and previous field season, the time interval of a sprung trap is halved whereas in the other seasons the time interval for a sprung trap was assumed to be zero.*

| | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | Total |
|---|---|---|---|---|---|---|---|---|---|
| ***No. Trap Nights*** | *101,446** | *151,134** | *146,943** | *137,825** | *120,356** | *144,908** | *205,177.5* | *202185* | ***1,065,067*** |
| **Kāhu** | 58 | 82 (+41%) | 83 (+1%) | 82 (-1%) | 67 (-18%) | 0 (-100%) | 4 | 3 (-25%) | **379** |
| **Cat** | 26 | 29 (+11%) | 17 (-41%) | 16 (-6%) | 17 (+6%) | 18 (+6%) | 19 (+6%) | 17 (-10.5%) | **159** |
| **Ferret** | 41 | 33 (-20%) | 30 (-9%) | 17 (-43%) | 4 (-76%) | 15 (+275%) | 5 (-66.7%) | 11 (+120%) | **156** |
| **Hedgehog** | 102 | 221 (+117%) | 233 (5%) | 134 (-42%) | 137 (+2%) | 244 (+78%) | 334 (+49%) | 520 (55.7%) | **1925** |
| **Possum** | 19 | 36 (+89%) | 69 (+92%) | 68 (-1%) | 55 (-19%) | 6 (-89%) | 17 (+183%) | 11 (-35.3%) | **281** |
| **Rat** | 0 | 0 | 0 | 0 | 23 | 2 (-91%) | 0 (-100%) | 18 | **43** |
| **Stoat** | 34 | 57 (+67%) | 27 (-53%) | 66 (+144%) | 35 (+47%) | 92 (+163%) | 19 (-79%) | 38 (+100%) | **368** |
| **Weasel** | 16 | 20 (+25%) | 33 (+65%) | 8 (-75%) | 26 (+225%) | 32 (+23%) | 29 (-9%) | 74 (+155.2%) | **164** |
| **Mice** | 12 | 152 (+1167%) | 58 (-62%) | 16 (-72%) | 70 (+338%) | 31 (56%) | 94 (+203%) | 77 (18%) | **510** |
| **Total** | **308** | **630** | **550** | **407** | **434** | **440** | **487** | **766** | **4,022** |

WMIL: Connor-McClean et al. 2023

## 8.4 Appendix 4: Monthly catches for mammalian predators 2015/2016 to 2020/2021

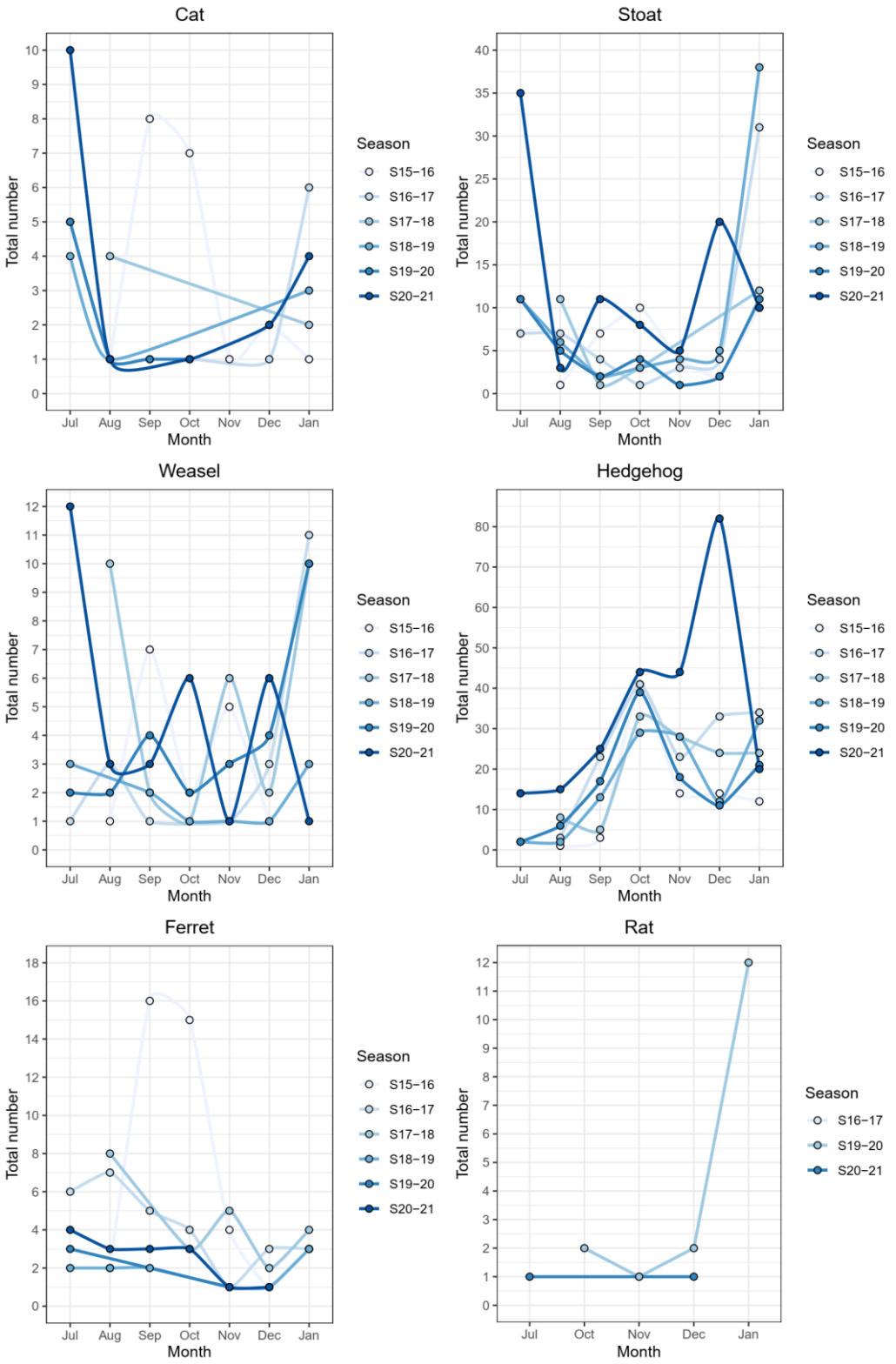


*Figure 62.* *Total number of predators caught per month between July and January each season on the Waiau Toa/Clarence River (2015/16 to 2020/21). Points and lines are coloured from light blue to dark blue to visually indicate the change in field season from 2015/16 to 2020/21.*

## 8.5 Appendix 5: Mergin Maps App

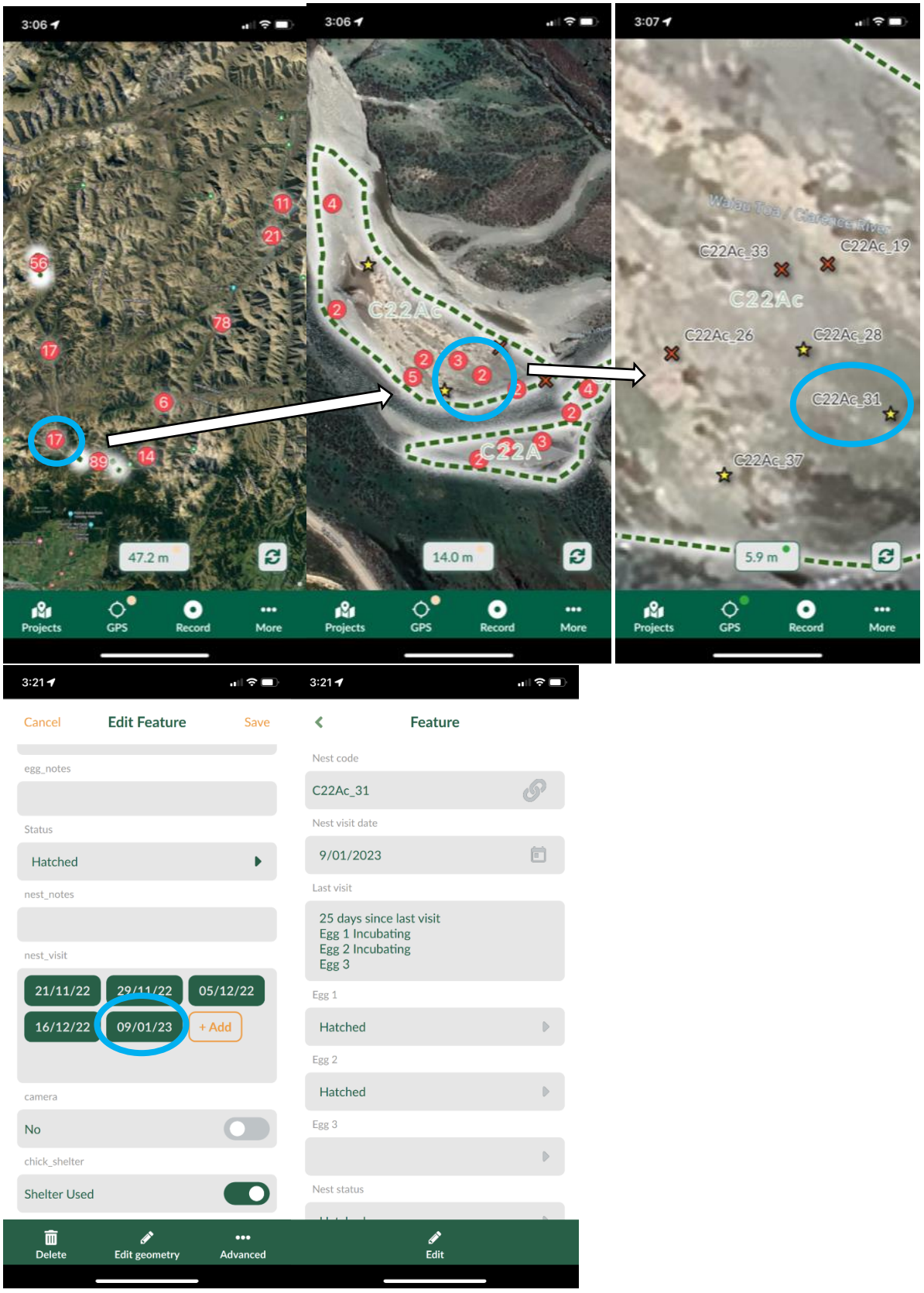


***Figure 63.*** *Screenshots of "Mergin Maps" app used to collect and store nest data throughout the 2022/23 black-fronted tern season.*

WMIL: Connor-McClean et al. 2023

## 8.6 Appendix 6: Browning Dark Ops Pro XD (BTC-6PXD) trail camera settings.

***Table 25.*** *Browning Dark Ops Pro XD (BTC-6PXD) trail camera settings used for black-fronted tern nest monitoring, 2022/23.*

| Camera Settings | | | |
|---|---|---|---|
| Time & Date | Set to correct time and date | | |
| Mode | TRAIL | ... | VIDEO |
| Capture Delay | 20s | | |
| Picture Size | High 12 MP | ... | N/A |
| Multishot | RPF- 3 SHOT | ... | N/A |
| Video quality | N/A | ... | High |
| Video length | N/A | ... | 10s |
| Smart IR video | OFF | | |
| Night Exposure | Power save | | |
| Temperature units | Celsius | | |
| Info strip | ON | | |
| SD card management | ON | | |
| Motion Detect | Normal | | |

## 8.7 Appendix 7: Locations of colonies found during helicopter survey

***Table 26.*** *Locations of black-fronted tern colonies found within the helicopter survey carried out on 8 November 2022 along the Waiau Toa/ Clarence and Wakaputawatea/Acheron rivers. Included are the start and end locations of the survey. Note: absent breeding colony codes (NA) refer to colonies that weren't monitored during the season.*

| River | Survey GPS Code | Colony Code | Co-ordinates | |
|---|---|---|---|---|
| | | | Latitude | Longitude |
| **Waiau Toa/ Clarence River** | **Start Location** | **-** | **-42.212301** | **172.739745** |
| | 1 | CG | -42.2625470 | 172.7734029 |
| | 2 | CH | -42.2826503 | 172.7771261 |
| | 3 | CF | -42.3522302 | 172.7884678 |
| | 4 | CJ | -42.4349339 | 172.795035 |
| | 5 | CA | -42.4532861 | 172.825526 |
| | 6 | CB | -42.4520902 | 172.8536374 |
| | 7 | CC | -42.4561777 | 172.8680576 |
| | 8 | CD | -42.4643163 | 172.8756687 |
| | 9 | CE | -42.4510522 | 172.9104953 |
| | 10 | CI | -42.4001682 | 172.9338334 |
| | 11 | NA | -42.3988178 | 172.9567289 |
| | **End Location** | **-** | **-42.3967290** | **173.073228** |
| **Wakaputawatea/Acheron River** | **Start Location** | **-** | **-42.3924850** | **172.9682016** |
| | A | AC | -42.3260490 | 173.0059623 |
| | B | AB | -42.2450938 | 173.068991 |
| | C | AA | -42.2148087 | 173.0819845 |
| | **End Location** | **-** | **-42.1536370** | **173.09615** |

## 8.8 Appendix 8: Monitored colony details, descriptions, and locations, 2022/23.

***Table 27.*** *Monitored colony details, descriptions, and locations on the Waiau Toa/Clarence (WTC) and Wakaputawatea/Acheron (W/A) Rivers, 2022/23.*

| Colony Name | Colony Code | River | Zone | Location | Co-ordinates | | Start Date | End Date | Description/ Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Latitude | Longitude | | | |
| Upper Swimming Hole | CA1 | WTC | Treatment | Natural Island | -42.45358886 | 172.8269518 | 2-Nov | 15-Dec | Small, thin raised island with no vegetation. Strong flow surrounding island. |
| Upper Swimming Hole | CA2 | WTC | Treatment | Enhanced Island | -42.4534169 | 172.825473 | 2-Nov | 19-Jan | Island remained separated from the mainland throughout the whole season, thin flow on true left, but adequate protection from predators. More than 50% of island covered in vegetation including grasses and riverbed plants. This area was still favourable to nest in. Island raised enough to escape flooding. |
| Upper Swimming Hole | CA3 | WTC | Treatment | Mainland | -42.4540473 | 172.8262011 | 2-Nov | 9-Jan | Large, flat gravelled island that joined the mainland halfway through the season when water levels dropped. Channel on the true right quite narrow with a small steppingstone island. Easily accessible to land predators. |
| Mike's Rock | CB | WTC | Treatment | Natural Island | -42.4520902 | 172.8536374 | 20-Dec | 24-Jan | Low lying island, with little vegetation. River levels very low around island but managed to stay disconnected from the mainland for the whole season. |
| Fisherman's | CC | WTC | Treatment | Mainland | -42.4561777 | 172.8680576 | 10-Nov | 30-Dec | Large, gravelled area with a high percentage of vegetated area consisting of grasses and small riverbed plants. The whole length of the true left side of colony connected to mainland. |
| Cow Island | CD | WTC | Treatment | Enhanced Island | -42.4643163 | 172.8756687 | 13-Dec | 9-Feb | Main enhanced island separated from mainland throughout whole season. Sections of island raised enough to avoid floods. Small section of vegetated area which was used by large chicks to hide and shelter in. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mitchell's | CE | WTC | Treatment | Enhanced Island | -42.4510522 | 172.9104953 | 27-Oct | 28-Dec | Long, thin, raised island with strong channels around island and a strip of vegetation on the downstream end. Otherwise, good nesting gravels. |
| Heli Colony | CF | WTC | Non-Treatment | Natural Island | -42.3522302 | 172.7884678 | 7-Nov | 12-Jan | Large, raised island with good percentages of nesting gravels to vegetation, surrounded by water flow however some channels are narrow and others low flowing. |
| Nightingale | CG1 | WTC | Non-Treatment | Natural Island | -42.2624820 | 172.7733305 | 9-Nov | 17-Jan | Main island contained suitable nesting habitat. Island was raised with wide channels surrounding island. Some sections were low flow. |
| Nightingale | CG2 | WTC | Non-Treatment | Mainland | -42.2641313 | 172.7741779 | 14-Dec | 17-Jan | Large, gravelled area connected to the mainland. Raised to avoid flooding. |
| Nightingale | CG3 | WTC | Non-Treatment | Natural Island | -42.2649123 | 172.7735262 | 14-Dec | 17-Jan | Smaller islands grouped close together. Raised enough to avoid medium floods. No vegetation on island. |
| Seymour Island | CH1 | WTC | Non-Treatment | Natural Island | -42.2825004 | 172.7771473 | 9-Nov | 12-Jan | Network of 6 islands nested on. Sections of some channels thinned out during low flow creating access for land predators. Little to no vegetation on islands. |
| Seymour Island | CH2 | WTC | Non-Treatment | Mainland | -42.2820073 | 172.7765737 | 15-Nov | 5-Jan | Raised section of gravels and vegetation. Connected to the mainland. |
| Upper Bush Gully | CI1 | WTC | Treatment | Enhanced Island/ Mainland | -42.4001729 | 172.9339156 | 10-Nov | 8-Dec | Large, gravelled island with little vegetation. True right channel dries up when river flow drops below 8m^3. Island edges low and subjected to flooding, however the mid sections and true right side of the island built up higher. |
| Upper Bush Gully | CI2 | WTC | Treatment | Mainland | -42.4006722 | 172.9320097 | 24-Nov | 28-Dec | Gravelled section connected to the mainland. Half of the nests situated on a slightly raised bank. |
| St James Island | CJ1 | WTC | Non-Treatment | Natural Island | -42.4349447 | 172.7950151 | 15-Nov | 20-Jan | An effective island with strong, wide channels surrounding the island. Island raised high to avoid flooding. About 15% vegetation coverage up high which was used by large chicks for shelter. |
| St James Island | CJ2 | WTC | Non-Treatment | Mainland | -42.4359509 | 172.7947542 | 16-Dec | 12-Jan | A section of gravel at the edge of a vegetated area. Will flood during higher river flow. |
| Grader Island | AA | W/A | Non-Treatment | Natural Island | -42.2148087 | 173.0819845 | 11-Nov | 2-Feb | Very good island! Large, raised gravelled island with long grasses in the middle and strong river |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | flow surrounding island. Willow tree at far end with a sandy base, good shade provided- only accessible on foot during low flow, otherwise a pack raft is required. |
| The Zoo | AB1 | W/A | Non-Treatment | Natural Island | -42.2447263 | 173.0685510 | 14-Nov | 4-Jan | A long, thin strip of gravels isolated by wide channels surrounding island. Relatively raised. |
| The Zoo | AB2 | W/A | Non-Treatment | Mainland | -42.2452296 | 173.0690048 | 14-Nov | 4-Jan | Large, raised area of gravels connected to the mainland. |
| Acheron Island | AC | W/A | Non-Treatment | Natural Island | -42.3260490 | 173.0059623 | 15-Nov | 4-Jan | Large, vegetated island with gravelled sections, surrounded by river flow. A smaller, raised gravel island situated adjacent with strong flow surrounding the island. |

## 8.9 Appendix 9: Nest Outcome 2022/23.

***Table 28.*** *Outcome of black-fronted tern nests along the Upper Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers during the 2022/23 breeding season. Treatment zones represent colonies with surrounding predator control and chick shelter placements.*

| Zone | Colony Location | Colony Code | Hatched | | Predated | | Abandoned | | Flooded | | Infertile | | Total Nests |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Number | % | Number | % | Number | % | Number | % | Number | % | |
| Treatment | Natural Island | CA1 | 2 | 40% | 1 | 20% | 1 | 20% | 1 | 20% | 0 | 0% | 5 |
| | | CB | 6 | 75% | 2 | 25% | 0 | 0% | 0 | 0% | 0 | 0% | 8 |
| | Enhanced Island | CA2 | 13 | 57% | 4 | 17% | 5 | 22% | 1 | 4% | 0 | 0% | 23 |
| | | CD | 15 | 94% | 0 | 0% | 0 | 0% | 0 | 0% | 1 | 6% | 16 |
| | | CE | 2 | 20% | 8 | 80% | 0 | 0% | 0 | 0% | 0 | 0% | 10 |
| | Enhanced Island/ Mainland | CI1 | 0 | 0% | 1 | 100% | 0 | 0% | 0 | 0% | 0 | 0% | 1 |
| | Mainland | CA3 | 6 | 67% | 0 | 0% | 2 | 22% | 1 | 11% | 0 | 0% | 9 |
| | | CC | 7 | 25% | 17 | 61% | 4 | 14% | 0 | 0% | 0 | 0% | 28 |
| | | CI2 | 4 | 80% | 1 | 20% | 0 | 0% | 0 | 0% | 0 | 0% | 5 |
| **Total** | | | **55** | **52%** | **34** | **32%** | **12** | **12%** | **3** | **3%** | **1** | **1%** | **105** |
| Non-Treatment | Natural Island | CF | 10 | 59% | 2 | 12% | 5 | 29% | 0 | 0% | 0 | 0% | 17 |
| | | CG1 | 13 | 59% | 0 | 0% | 7 | 32% | 0 | 0% | 2 | 9% | 22 |
| | | CG3 | 6 | 67% | 0 | 0% | 3 | 33% | 0 | 0% | 0 | 0% | 9 |
| | | CH1 | 7 | 41% | 6 | 35% | 3 | 18% | 0 | 0% | 1 | 6% | 17 |
| | | CJ1 | 10 | 83% | 0 | 0% | 1 | 8% | 0 | 0% | 1 | 8% | 12 |
| | | AA | 69 | 87% | 6 | 8% | 3 | 4% | 0 | 0% | 1 | 1% | 79 |
| | | AB1 | 2 | 67% | 1 | 33% | 0 | 0% | 0 | 0% | 0 | 0% | 3 |
| | | AC | 2 | 18% | 9 | 82% | 0 | 0% | 0 | 0% | 0 | 0% | 11 |
| | Enhanced Island | *No Data* | | | | | | | | | | | |
| | Enhanced Island/ Mainland | *No Data* | | | | | | | | | | | |
| | Mainland | CG2 | 1 | 13% | 3 | 38% | 4 | 50% | 0 | 0% | 0 | 0% | 8 |
| | | CH2 | 2 | 50% | 2 | 50% | 0 | 0% | 0 | 0% | 0 | 0% | 4 |
| | | CJ2 | 3 | 60% | 0 | 0% | 2 | 40% | 0 | 0% | 0 | 0% | 5 |
| | | AB2 | 8 | 44% | 8 | 44% | 2 | 11% | 0 | 0% | 0 | 0% | 18 |
| **Total** | | | **133** | **65%** | **37** | **18%** | **30** | **15%** | **0** | **0%** | **5** | **2%** | **205** |
| **Combined Total** | | | **188** | **61%** | **71** | **23%** | **42** | **13%** | **3** | **1%** | **6** | **2%** | **310** |

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## 8.10 Appendix 10: Comparison of nest outcomes 2015/16 to 2022/23.

***Table 29.*** *Comparison of known nest outcomes of black-fronted terns between the 2015/16 to 2022/23 breeding seasons at trapped island sites and non-trapped island sites including all mainland nests. This keeps data comparable throughout the seasons and differing Phase 1 and 2 changes. Note: colonies on the Wakaputawatea/Acheron River were excluded from 2016/17 data due to Kaikoura earthquake preventing regular checks from taking place. Phase 2 seasons are shaded blue.*

| | Season | Known-fate nests | Hatched | | Failed | | Cause of Nest Failure | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Predation | | Flooded | | Abandoned | |
| | | | Number | % | Number | % | Number | % | Number | % | Number | % |
| **Trapped Islands** | 2015/16 | 45 | 20 | 44% | 25 | 56% | 14 | 31% | 0 | 0% | 11 | 24% |
| | 2016/17 | 139 | 85 | 61% | 54 | 39% | 28 | 20% | 17 | 12% | 9 | 6% |
| | 2017/18 | 82 | 33 | 40% | 49 | 60% | 29 | 35% | 4 | 5% | 16 | 20% |
| | 2018/19 | 43 | 9 | 21% | 34 | 79% | 15 | 35% | 5 | 12% | 14 | 33% |
| | 2019/20 | 18 | 8 | 44% | 10 | 56% | 6 | 33% | 0 | 0% | 4 | 22% |
| | 2021/22 | 38 | 25 | 66% | 13 | 34% | 4 | 11% | 2 | 5% | 7 | 18% |
| | 2022/23 | 62 | 38 | 61% | 24 | 39% | 15 | 24% | 2 | 3% | 7 | 11% |
| | **Total** | **427** | **218** | **51%** | **209** | **49%** | **111** | **26%** | **30** | **7%** | **68** | **16%** |
| **Non-Trapped Islands + Mainland** | 2015/16 | 420 | 130 | 31% | 290 | 69% | 152 | 36% | 9 | 2% | 129 | 31% |
| | 2016/17 | 240 | 93 | 39% | 147 | 61% | 61 | 25% | 31 | 13% | 55 | 23% |
| | 2017/18 | 427 | 198 | 46% | 229 | 54% | 142 | 33% | 36 | 8% | 51 | 12% |
| | 2018/19 | 506 | 153 | 30% | 353 | 70% | 201 | 40% | 45 | 9% | 107 | 21% |
| | 2019/20 | 271 | 74 | 27% | 197 | 73% | 93 | 34% | 77 | 28% | 27 | 10% |
| | 2021/22 | 204 | 140 | 69% | 64 | 31% | 38 | 19% | 2 | 1% | 24 | 12% |
| | 2022/23 | 248 | 150 | 60% | 98 | 40% | 56 | 23% | 1 | 0% | 41 | 17% |
| | **Total** | **2316** | **938** | **41%** | **1378** | **59%** | **743** | **32%** | **201** | **9%** | **434** | **19%** |

## 8.11 Appendix 11: Comparison of observed cause of nest failure.

***Table 30.*** *Comparison of observed causes of black-fronted tern nest failure on treatment (island/mainland) and non-treatment colonies along the Waiau Toa/Clarence and Wakaputawatea/Acheron Rivers from 2015/16 to 2022/23.*

| Cause of Failure | Treatment | | | | | | | | | | | | | | | | Non-Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Island | | | | | | | | Mainland | | | | | | | | | | | | | | | |
| **Season** | **15/16** | **16/17** | **17/18** | **18/19** | **19/20** | **21/22** | **22/ 23** | **Total** | **15/16** | **16/17** | **17/18** | **18/19** | **19/20** | **21/22** | **22/ 23** | **Total** | **15/16** | **16/17** | **17/18** | **18/19** | **19/20** | **21/22** | **22/ 23** | **Total** |
| Kāhu | | 1 | | | | | | **1** | | | | | 1 | | | **1** | 9 | | 8 | 16 | 1 | 2 | | **36** |
| Cat | 4 | | 3 | | | | | **7** | | | 1 | | | 4 | 4 | **9** | 11 | 14 | 3 | | | | | **28** |
| Ferret | | | | | | | | **0** | | | | | | | | **0** | 7 | 8 | 1 | 1 | | 1 | | **18** |
| Hedgehog | | | | | | | | **0** | | 5 | 1 | 1 | 2 | | | **9** | 1 | 7 | 2 | | 2 | 1 | | **13** |
| SBBG | | | 3 | 1 | 2 | | 3 | **9** | | | | | | 1 | 1 | **2** | | | 9 | 1 | 6 | | 5 | **21** |
| Black-fronted tern | | 4 | 8 | 1 | | | | **13** | | | | | 1 | | | **1** | | 6 | 3 | 3 | | | | **12** |
| Stoat | | | | | | | | **0** | | | | | | | | **0** | 5 | 1 | 1 | | | | | **7** |
| Possum | 2 | | | | | | | **2** | | 1 | | | | | | **1** | | 4 | | | | | | **4** |
| SIPO | | | | | | | | **0** | | | | | | | | **0** | 2 | 1 | | | | | | **3** |
| Rabbit | | | | | | | | **0** | | | | | | | | **0** | 1 | 1 | 1 | | 2 | | | **5** |
| Cow | | | | 1 | | | | **1** | | | | | | | | **0** | | | 2 | 5 | 4 | | | **11** |
| Hare | | | | | | | | **0** | | | | | | | | **0** | 1 | | 1 | | | | | **2** |
| Pig | | | | | | | | **0** | | | | | | | | **0** | | | 1 | | | | | **1** |
| Magpie | | | | | | | | **0** | | | | | | | | **0** | | | | 1 | | | | **1** |
| Rat | | | | | | | | **0** | | | | | | | | **0** | | | | | 3 | | | **3** |
| Mouse | | | | | | | | **0** | | | | | | | | **0** | | | | | 3 | | | **3** |
| **PREDATION TOTAL** | **6** | **5** | **14** | **3** | **2** | **0** | **3** | **33** | **0** | **6** | **2** | **1** | **4** | **5** | **5** | **23** | **37** | **42** | **32** | **27** | **21** | **4** | **5** | **168** |
| **FLOODING** | | | **3** | **17** | | **2** | **2** | **24** | | | | | | **1** | **1** | **2** | **9** | **13** | **32** | **35** | **74** | **1** | | **164** |
| **ABANDONMENT** | | | | | **4** | **4** | **6** | **14** | | | | | | **17** | **6** | **23** | | | | | **24** | **8** | **42** | **74** |
| **Combined Total** | **6** | **5** | **17** | **20** | **6** | **6** | **11** | **71** | **0** | **6** | **2** | **1** | **4** | **23** | **12** | **48** | **46** | **55** | **64** | **62** | **119** | **13** | **47** | **406** |

## 8.12 Appendix 12: Map of Historic colonies monitored on Grader Island (AA).

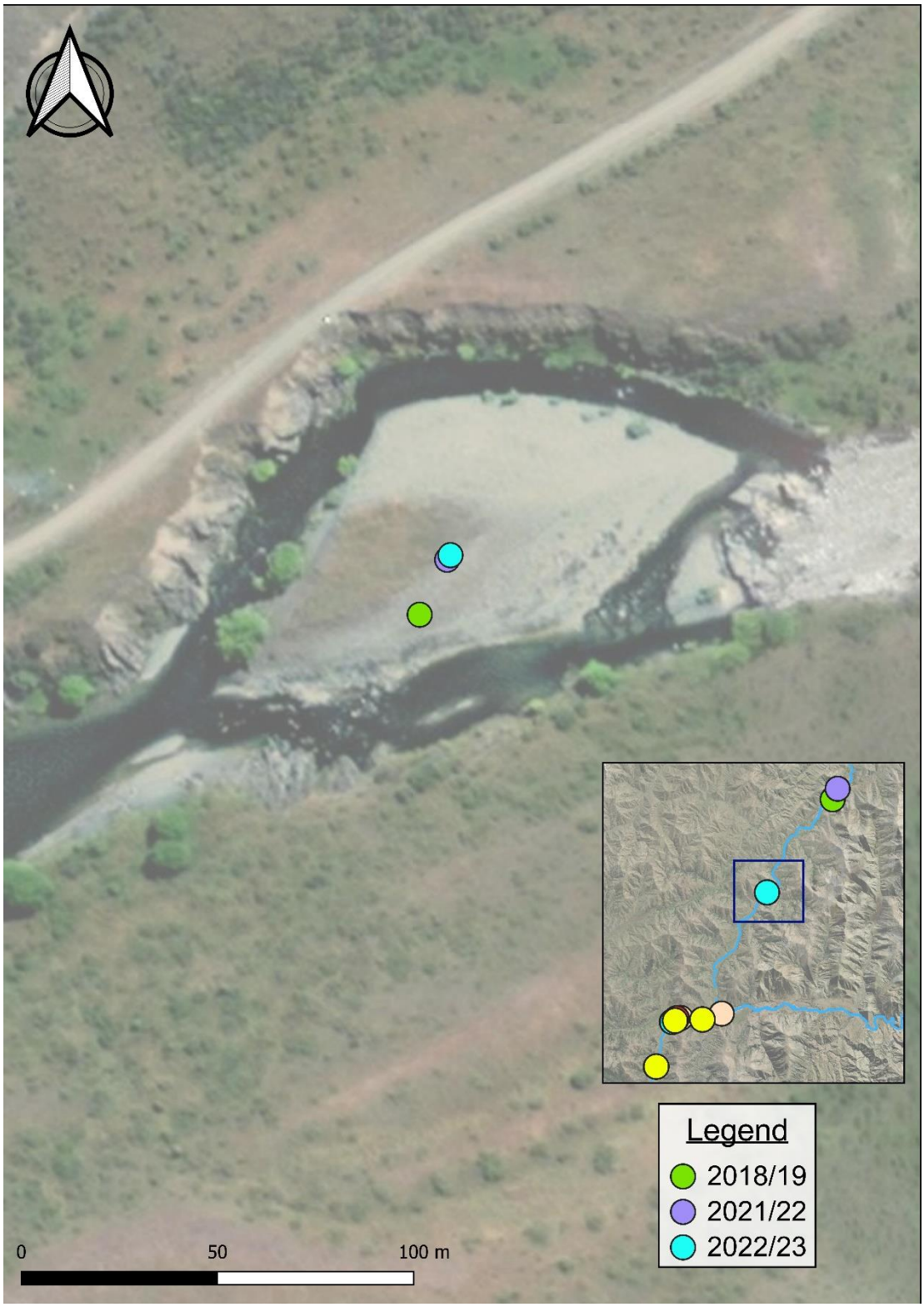


***Figure 64.*** *Historic colonies which formed on Grader Island (AA) on the Wakaputawatea/Acheron River. Note: satellite imagery used does not show the updated strong, river flow channels surrounding island.*

## 8.13 Appendix 13: Map of Historic colonies monitored on St James Colony (CJ).

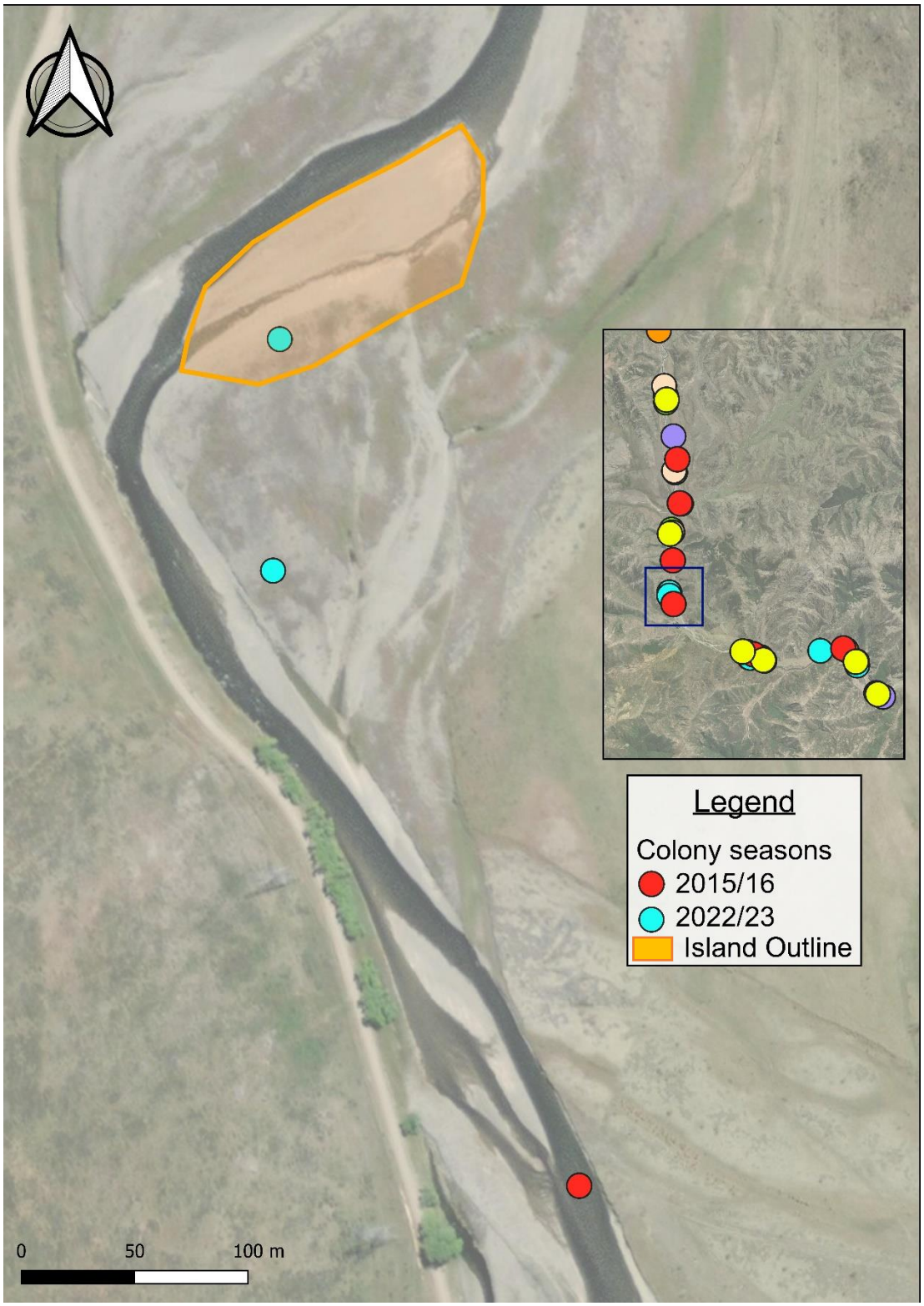


***Figure 65.*** *Historic colonies which formed on St James Island (CJ) on the Waiau Toa/Clarence River. Note: satellite imagery used does not show the updated strong, river flow channels surrounding island. The second colony point outside of the orange island outline represents where the mainland colony established.*

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## 8.14 Appendix 14: Map of Historic colonies monitored on Top Colony (CH).

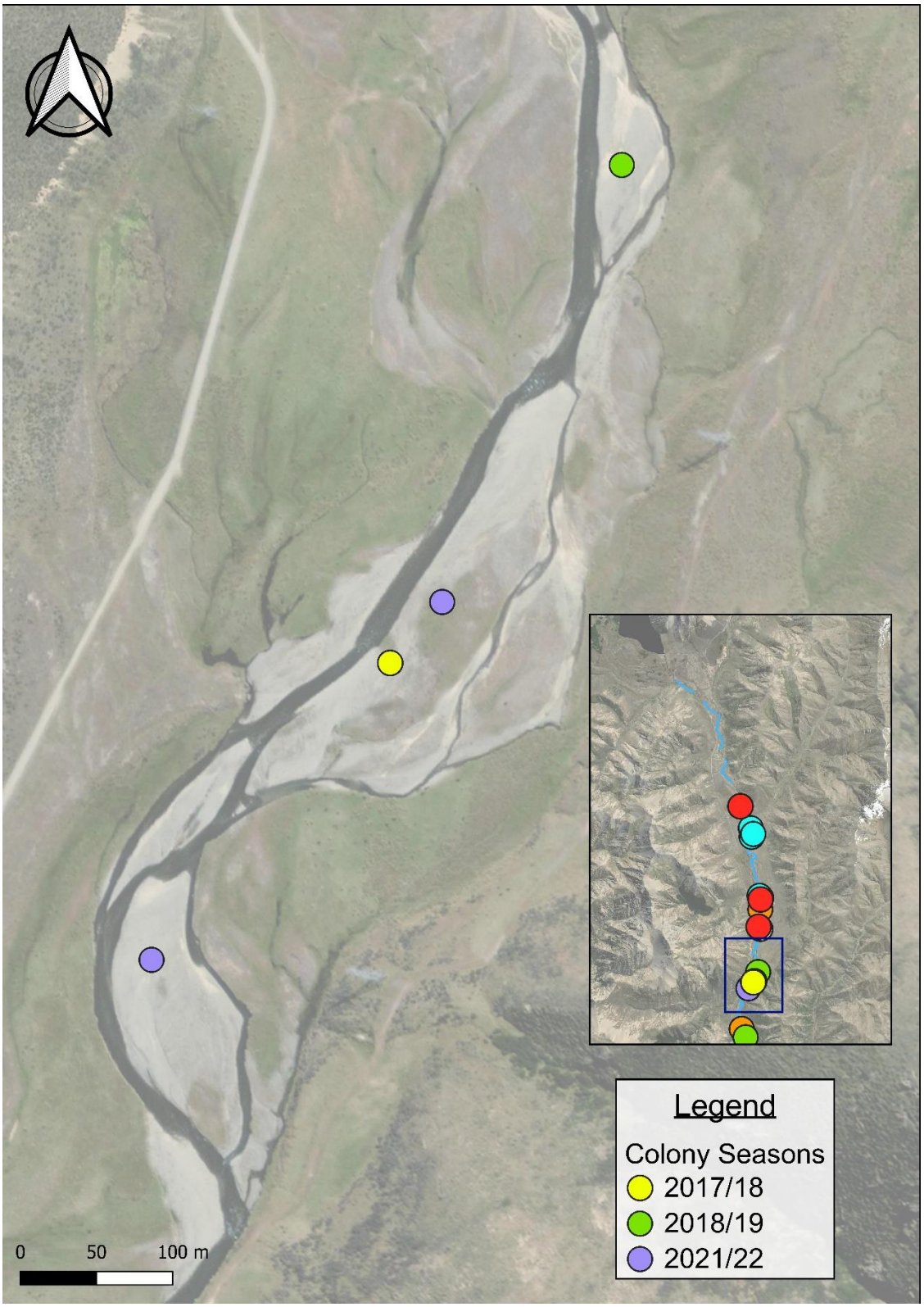


***Figure 66.*** *Historic colonies which formed on Top Colony (CH) on the Waiau Toa/Clarence River. Note: satellite imagery used does not show the updated strong, river flow channels surrounding island.*

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## 8.15 Appendix 15: Map of Upper Swimming Hole Colony sections.

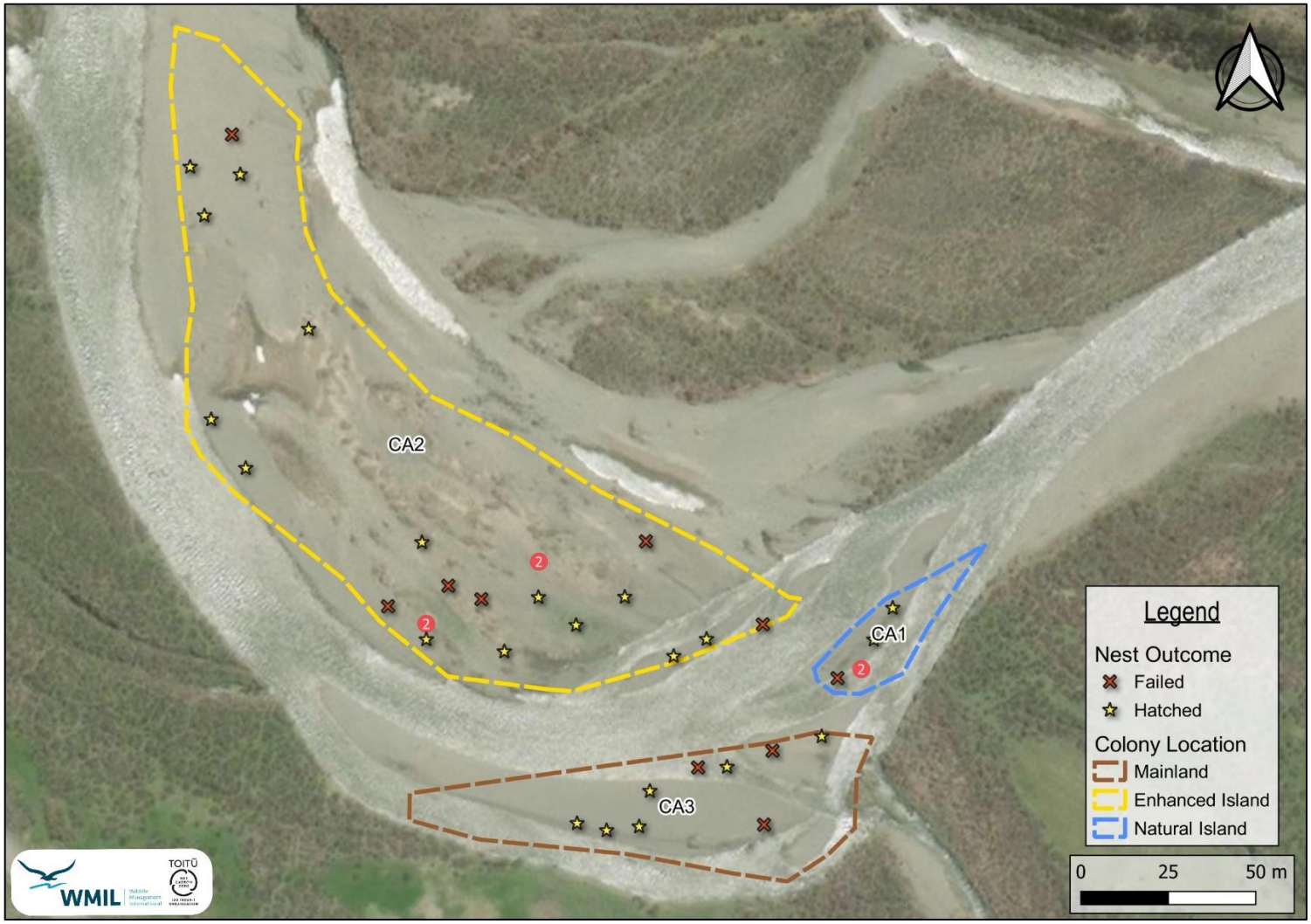


***Figure 67.*** *Split colony sections of Upper Swimming Hole Colony (CA1, CA2 & CA3) on the Waiau Toa/Clarence River during the 2022/23 breeding season.*

WMIL: Connor-McClean et al. 2023