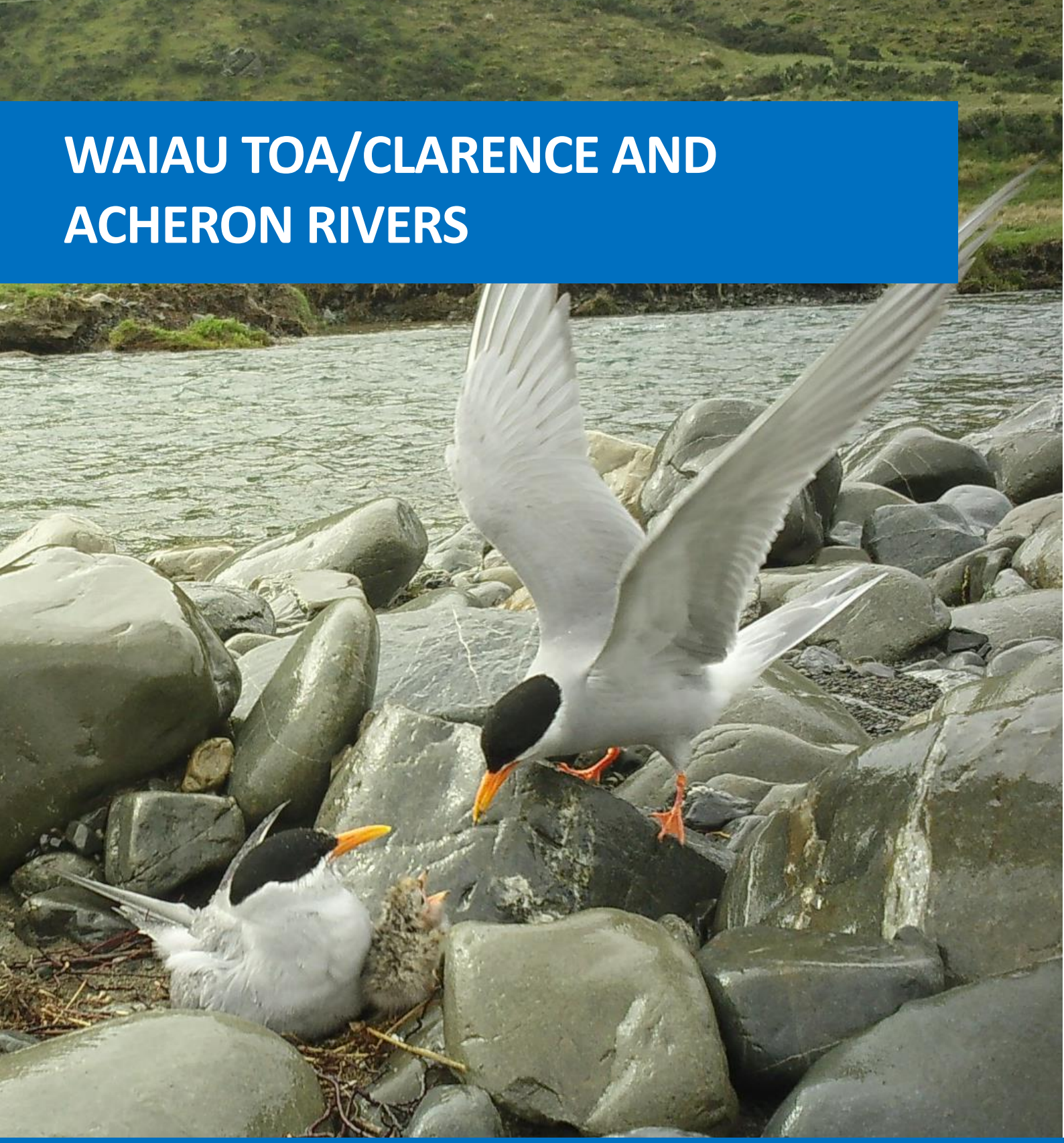
WAIAU TOA/CLARENCE AND ACHERON RIVERS



Waiau Toa/Clarence River black-fronted tern monitoring project - 2021/2022 operational report.

WMIL Wildlife Management International

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Waiau Toa/Clarence River black-fronted tern monitoring project- 2021/2022 operational report.

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This report was prepared by Wildlife Management International Limited (WMIL) for the Department of Conservation in fulfilment of contracts DOC-6744957 BFT Outcome monitoring dated 12 August 2021 and DOC-6703486 BFT Predator Control dated 5 July 2021.

7 June 2022

Version History:

Version	Date	Author	Reason for change
1	17 May 2022	WMIL: Connor-McClean et al.	WMIL First Draft
2	7 June 2022	WMIL: Connor-McClean et al.	WMIL Second Draft
2b	29 July 2022	WMIL: Connor-McClean et al.	Minor edits

Citation:

This report should be cited as:

Connor-McClean, B.; Lamb, S. & Bell, E. 2022. *Waiau Toa/Clarence River black-fronted tern monitoring project- 2021/2022 operational report*. Client report prepared for the Department of Conservation by Wildlife Management International Ltd, Blenheim.

Cover Image: Adult black-fronted tern (*Chlidonias albostriatus*) pair caring for chick during 2021/2022 season, photographed using remote trail camera, December 2021.

CONTENTS

EXECUTIVE SUMMARY

This report summarises the results of the first 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 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. 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 included at colonies within the treatment zone, both on island and mainland colonies.

Habitat enhancement actions were carried out in March 2021 at five islands within the treatment zone where island heights were raised, smoothed over, and channels surrounding these islands were widened, deepened, and cleared. However, major flooding during winter months damaged many of these enhanced islands reducing their effectiveness for the 2021/2022 season.

Predator trapping using a combination of DOC150, DOC200, DOC250, SA1 and SA2 kill traps was carried out in a 52 km trapping line along both sides of the Waiau Toa/Clarence River, resulting in 487 predators being caught. This included 334 hedgehogs (*Erinaceus europaeus*), 17 possums (*Trichosurus vulpecula*), 29 weasels (*Mustela nivalis*), 5 ferrets (*Mustela furo*), 19 stoats (*Mustela erminea*), and 19 cats (*Felis catus*).

There was an observed increase in the breeding success of black-fronted terns at both treatment and non-treatment colonies throughout the 2021/2022 season compared to previously monitored seasons. Hatching success was slightly less in treatment sites, partially due to a high percentage nesting on the mainland (43% hatching success) in comparison to nesting on islands (67% hatching success) while colonies on non-treatment islands had a hatching success of 78%. Observed fledging success was the second highest recorded over the last five monitored seasons. The treatment colonies resulted in having lower fledging rates (0.33 chicks/nest), compared to non-treatment colonies (0.62 chicks/nest). This was likely due to the robustness of islands colonised in non-treatment areas compared to mainland areas being colonised in the treatment zone.

In total, 123 black-fronted tern chicks were observed to have fledged from monitored colonies along the upper Waiau Toa/Clarence and Acheron Rivers during the 2021/2022 season, 30 from treatment colonies and 93 from non-treatment colonies. This stands in contrast to the 14 chicks that fledged from nests during the 2019/2020 breeding season. This highlights the importance of island enhancements to maximise breeding efforts, along with predator control to minimize predation events, particularly for terns that nest on mainland areas.

Waiau Toa/Clarence River black-fronted tern monitoring project - 2021/2022 operational report.

1. INTRODUCTION

The black-fronted tern/tarapirohe (*Chlidonias albostriatus*) is ranked as Nationally Endangered under the New Zealand Threat Classification System, with an estimated population of between 5,000 and 10,000 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 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 black-fronted terns including the Waiau Toa/Clarence/Acheron/Saxton River system, and the Waiau, Hurunui, Ashley, Waimakariri, Rakaia, Ashburton, Rangitata, Tasman, Godley, Cass, and Ahuriri Rivers (Forest & Bird 2016).

Between 2012 and 2020 the Department of Conservation and Wildlife Management International Ltd. (WMIL) have been monitoring the population trends and breeding success of black-fronted terns on the upper Waiau Toa/Clarence and Acheron Rivers in the Canterbury region. Over the 2012/2013, 2013/2014, and 2014/2015 breeding seasons, black-fronted tern productivity was low primarily due to predation by introduced mammals (Bell 2017).

A five-year intensive programme of predator trapping and habitat enhancement was instigated at three colony sites on the upper Waiau Toa/Clarence River between 2015/2016 and 2019/2020 with the goal of increasing black-fronted 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 were filmed using motion-activated trail cameras. Footage showed that majority of nest failures were either caused by flooding, or by eggs or chicks being depredated by introduced mammalian predators, particularly kāhu/Australasian swamp harriers *Circus approximans*, cats, ferrets, 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 black-fronted tern productivity at treatment sites is a direct reflection of the combined management of pest trapping 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 trapping and habitat enhancement has been instigated on a 26 kilometre 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

the Department of Conservation (DOC), Environment Canterbury (eCan), Land Information New Zealand (LINZ, manged by Boffa Miskell) and the Canterbury Water Management Strategy Kaikoura 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 black-fronted terns on an increased number of colonies that receive this management.

Work began on the second five-year management programme in winter 2020 and 2021. A new predator trapping regime was designed in 2020 and implemented in June 2021, which covered both sides of a 26km stretch of river (treatment zone). Habitat enhancement work was carried out prior to the start of the tern nesting season, to better form six different colony sites within the treatment zone. Enhancements included increasing island height, clearing broom and other weeds, increasing channel width, depth, and maintaining the disconnection between colony islands and mainland. These enhancements aim 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 the island. Two additional islands previously enhanced in other seasons required no further maintenance this season resulting in eight enhanced islands available for black-fronted tern use within the treatment zone for the start of the 2021/2022 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 first monitoring season of the new five-year black-fronted tern project. The results of various habitat enhancement and predator control work carried out at treatment colonies over the past 12 months are reported, together with black-fronted tern breeding success results for the 2021/2022 breeding season. Recommendations for future black-fronted tern conservation efforts are provided.

2. METHODS

2.1 Habitat enhancement

2.1.1 Modification of islands and weed control

Using the knowledge gained from monitoring across five breeding seasons, six islands on the Waiau Toa/Clarence River, within the 20km stretch of river managed by predator control, were chosen for island enhancements (Figure 1). Island priority selection was based on available access, native riverbed flora growing on islands, enhancement work required, and previous favourability to nesting black-fronted terns. Modification of islands was based on the guidelines *A quick guide to creating bird nesting islands* produced by ECan and DOC (Appendix 1).

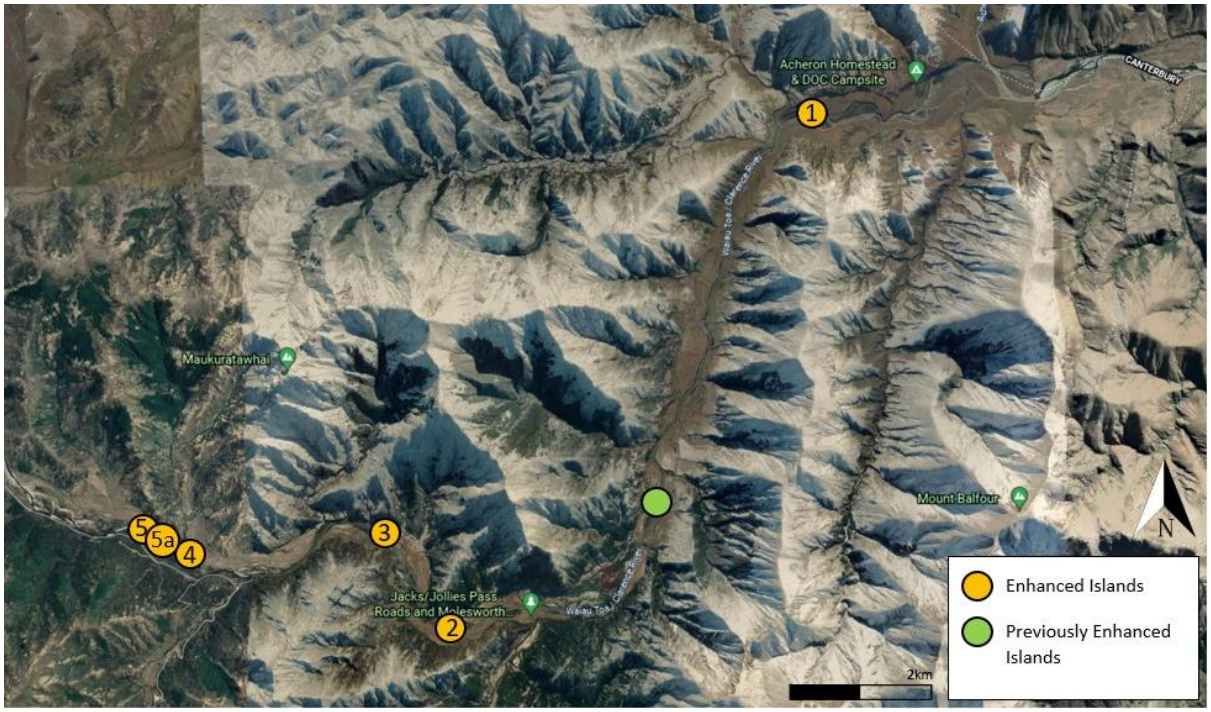

Figure 1. Location of enhanced islands along the Waiau Toa/Clarence River 2021/2022. Green circle marks the location of Mitchell's where further island enhancement was not necessary.

From 23 to 26 March 2021, Bill Lott (Lott Contractors Ltd), Baylee Connor-McClean (WMIL) and Clint McConchie (Te Rūnanga o Ngāi Tahu) carried out some mechanical excavation work at six 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 the removal of weeds and woody debris (see example in Figure 2).

Enhanced island location coordinates and details on each islands works are presented in Appendix 2. A detailed report on the March 2021 island enhancement was provided to DOC and eCan by WMIL (Connor-McClean & Bell 2021).

Figure 2. Before and after enhancing Fisherman's "island" (C4) channel on the Waiau Toa/Clarence River, 2021. Left: Old channel pre-existing before enhancement works - very overgrown and patchy. Right: Channel being cleared, widened, and strengthened by bulldozer.

2.2 Predator trapping

2.2.1 Kill trapping

In June 2020 a trapping line was constructed which followed a 26km stretch of the Waiau Toa/Clarence River. In previous years, the trapping regime was localised at three black-fronted tern colonies (Swimming Hole, Mitchell's Cutting and Bush Gully) with kill traps set within a 500 m radius centred around each of these breeding islands (Connor-McClean & Bell 2020). Changes to the trapping regime saw these localised traps pulled in and spaced along both sides of the riverbank. Double-set DOC150 traps and double-set Steve Allen 1 (SA1) cat traps were deployed at every second trap site and a single-set DOC250 trap was deployed at each alternating trap site along the line on both side of the river with 100m spacings. In March 2021, the remaining gaps in the trapping line were filled and the end of the line was extended downstream with double-set DOC200 traps and Steve Allen 2 (SA2) cat traps alternating with DOC250 traps to fill these sections (Figure 3). The trapping network was completed at a length of approximately 52km long (26km on each side of the river) (Figure 3).

In total, 296 DOC150 traps, 214 DOC200 traps, 296 SA1 traps, 107 SA2 traps, and 262 DOC 250 traps were in operation along the upper Waiau Toa/Clarence River during the 2021/2022 season. During the 2021/2022 season, there were 1175 traps in situ, arranged in three different trap type combinations (DOC150 + SA1; DOC200 + SA2; DOC 250).

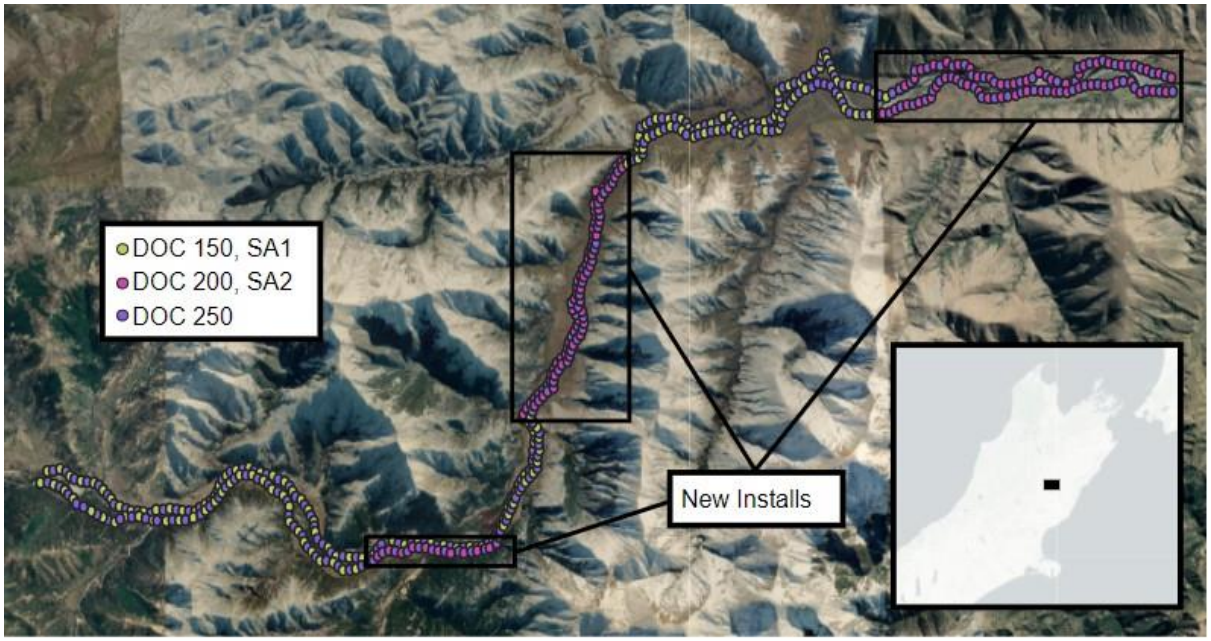

Figure 3. Location of extended trapping line situated along the upper Waiau Toa/Clarence River, March 2021. Locations of newly installed traps are shown by the boxed areas. Different combinations of traps (DOC150 + SA1; DOC200 + SA2; DOC250) at the same location are indicated by their different colours.

Traps were baited from 5 July 2021, prior to the onset of the black-fronted tern breeding season. Once traps were set, trap monitoring and re-baiting (with fresh rabbit meat or chicken necks) occurred approximately once every fortnight until 20 January 2022 when traps were shut down.

The number of days between checks varied from 9 to 46 days (mean = 16.4 days ± 8.25 days SD). Note: the maximum 46 day check range occurred to the nationwide August 2021 COVID-19 lockdown, otherwise the maximum check date was 22 days.

The trapping network was altered following an incident that occurred between 24 and 28 December 2021 when one of the Hossack farm manager's dogs was caught in a SA2 trap on the true left side of the river [Trap CL238] (Figure 4).

On 7 January 2022, all SA2 traps (12 in total, CR233 to CR255) extending into the Hossack's farm were removed from this property (Figure 4). All other traps on this property (DOC200 and DOC250's; CR233 to CR256) were also closed on 7 January 2022 (i.e., two weeks earlier than the rest of the trapping network).

There are ongoing discussions with the farm manager and other stakeholders on this event in regard to forward planning for the 2022/2023 season.

An additional change in the 2021/2022 season trapping regime from the previous monitored seasons is the absence of leg-hold traps. In all previously monitored seasons (except for the 2020/2021 season), two 10-day pulses of leg-hold traps were utilised to target feral cats (see Connor-McClean & Bell 2020 for details).

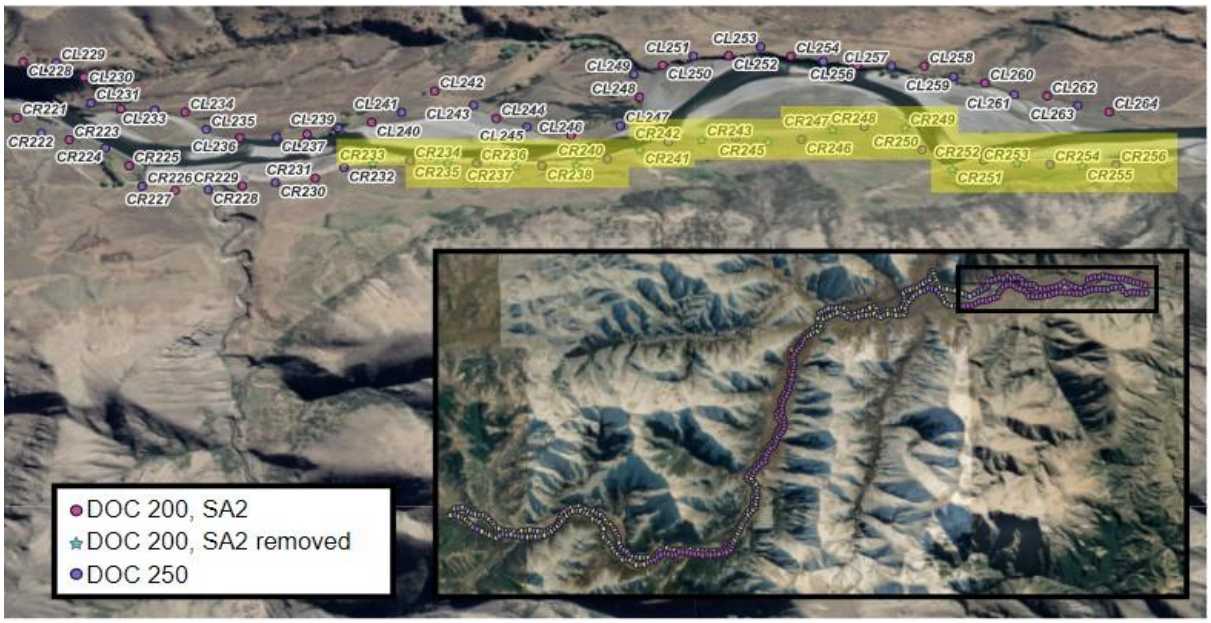

Figure 4. Down-stream section of the upper Waiau Toa/Clarence trapping network. Traps highlighted in yellow indicate those traps in the Hossack's property (CR233 to CR256 – on the true right side of the river). These traps were closed earlier (7 January 2022) than the rest of the trapping network (17-20 January 2022). Green stars indicate where the SA2 traps were removed from the property (DOC200 and DOC250 traps remain in place).

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 upper Waiau Toa/Clarence and Acheron Rivers during mid-October to early November 2021, to locate black-fronted 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.

2.3.1.2 River-based surveys

Pack-rafts were used to survey sections of river and to reach colonies on islands that were challenging to access on foot, particularly post flooding events.

An observer rafted sections of the river, scanning gravel beaches and islands for black-fronted terns. Each time a concentration of black-fronted terns was found, the observer would disembark and walk through the area they were frequenting following the methodology outlined for walk-through surveys.

Pack-rafts were particularly used to cross large, deep river channels to access colonies on islands not crossable by foot. This enabled large colonies detected on the Acheron River during 2021/2022 season to be monitored.

2.3.1.3 Helicopter surveys

A helicopter survey was carried out along the upper Waiau Toa/Clarence and Acheron Rivers on 8 November 2021. The survey began from Lake Tennyson and travelled towards the end of the trapping line downstream of the Waiau Toa/Clarence/Acheron confluence, then surveyed up the Acheron River till the shelter where the road diverts from the river. The helicopter flew 20-30 metres above the ground at a speed of 30 knots to flush black-fronted terns from their nests along the braided river. During this survey two observers counted the number of black-fronted terns seen flying along the river along with a population count at each colony. Each observer covered one side of the helicopter, 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, its location recorded using a handheld GPS unit and a small rock cairn erected approximately one metre 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. Nests were re-checked until they either failed, or the chicks had wandered away from the nest site.

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 small sample of nests were chosen for camera surveillance in order to identify the causes of any failures that occurred at these nests, and to quantify the relative impacts of various predators on black-fronted tern hatching success. A minimum 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 metre tall wooden stand approximately 1 metre from the nest. 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 3). Cameras were programmed to record both day and night, with a 30 second interval between consecutive activations (Appendix 3). 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.

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 black-fronted 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), and has continued to be used so that comparisons with previous seasons' results can be made. Apparent nest success has also been reported as a measure of shorebird breeding success in previous studies (e.g., Rebergen et al. 1998, Sanders & Maloney 2002).

2.4 Banding and resighting

2.4.1 Kāhu/Australasian swamp harrier banding

Nest predation by kāhu/Australasian swamp harriers is known to have a significant impact on breeding black-fronted terns (Bell & Harborne 2019). However, little is known on the population of harriers 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 black-fronted tern nests a capture and banding scheme was organised.

From 13 to 16 September 2021, a total of 18 funnelled harrier 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 colonies to the Waiau Toa/Clarence and Acheron River confluence (Figure 5). Traps were spaced approximately 2 km apart from each other and about 30-100m from the roadside and baited with possum or rabbit carcasses (Figure 6). The 40 km stretch of river with harrier traps was driven up to 6 times per day. Where traps were thought to be ineffective, they were moved to other potentially more suitable locations.

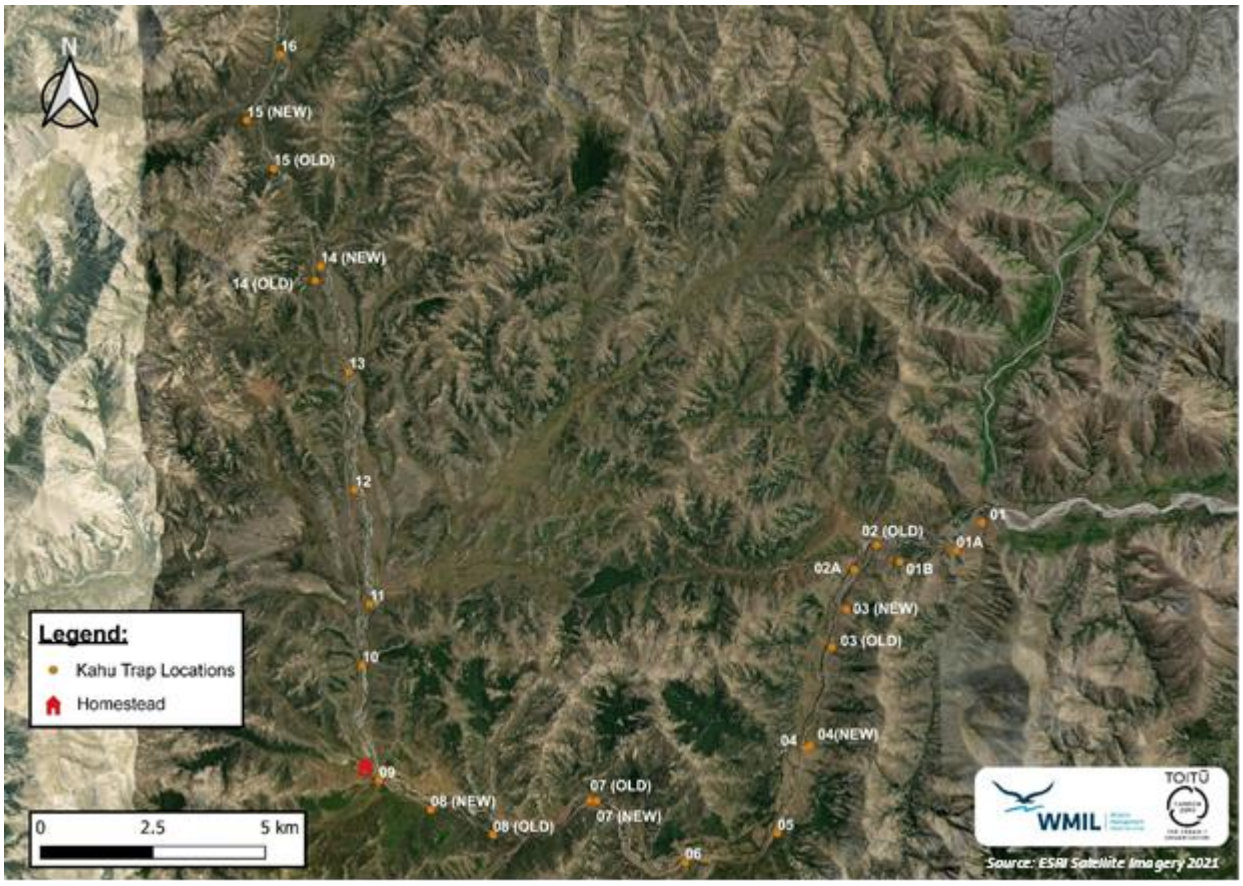

Figure 5. Kāhu/Australasian swamp harrier *Circus approximans* trap locations along Waiau Toa/Clarence River, 13-16 September 2021.

Figure 6. Baited kāhu/Australasian swamp harrier *Circus approximans* trap setup on the Waiau Toa/Clarence River, 13-16 September 2021.

Captured harriers 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 7). Harriers 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).

Figure 7. Darvic and metal bands on kāhu/Australasian swamp harrier *Circus approximans* on the Waiau Toa/Clarence River, 13-16 September 2021. (Photo © Dan Burgin).

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

2.4.2 Black-fronted tern banding

2.4.2.1 Adults

From 20 to 21 November 2021, black-fronted tern banding took place at several large colonies along the upper Waiau Toa/Clarence River under permit through the DOC contract DOC-6744957. All banding was supervised by a certified level three bander (Mike Bell, Toroa Consulting).

Terns were captured using drop traps. At any one time, a maximum of four drop traps were set over nests with two eggs (Figure 8). When a bird was captured (Figure 9), an observer instantly collected the bird, placed it into a bird bag, and carried it to the banding station. The bird was banded with a metal band and yellow flag with an ID code, then weighed and released.

Figure 8. Two styles of drop traps set up over black-fronted tern nests used on the Waiau Toa/Clarence River, 20-21 November 2021. Left: drop trap set with thin, clear, nylon string attached to one out of two wooden leg halves stacked carefully on top of each other; Right: remote controlled drop-trap.

Figure 9. Drop-trap successfully catching an adult black-fronted tern on the Waiau Toa/Clarence River, 20-21 November 2021.

2.4.2.2 Chick banding

Between 21 and 23 December 2021, all colonies were visited for chick banding under permit through the DOC contract DOC-6744957. All banding was supervised by a level three bander (Patrick Crowe, DOC).

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 downstream. Any chicks found were caught by hand or with nets and were banded with metal bands. Chicks were then released back under a large rock to shelter, or safely away from the river's edge ensuring no chicks were tempted to run into the fast-flowing water.

2.4.3 Band resighting

2.4.3.1 Black-fronted terns

At the beginning of the breeding season (early October), clusters of black-fronted 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 (Figure 10). Many banded black-fronted terns were recaptured during adult black-fronted tern banding trips in November 2021.

Figure 10. Yellow flag resighting (BE) shown in enlarged photograph at upper Bush Gully (CC), 23/10/2021, Waiau Toa/Clarence River. This bird was previously banded in 2012 at Bush Gully Colony on the Waiau Toa/Clarence River as a 2+ year old bird.

2.4.3.2 Kāhu/Australasian swamp harriers

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

Future harrier cage trapping trips is likely to also be 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 30 flat-roof chick shelter designs were built and distributed throughout treatment colonies during the 2021/2022 season (Figure 11).

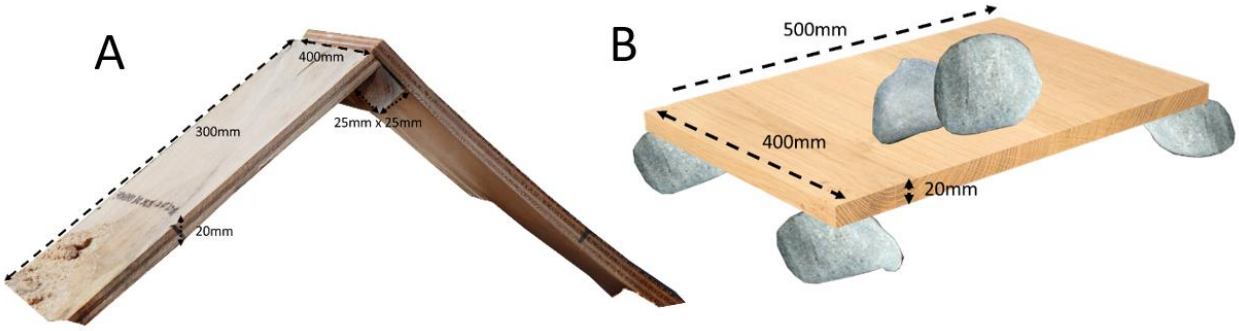

Figure 11. Chick shelter designs incorporated into 2021/2022 black-fronted tern breeding season on the upper Waiau Toa/Clarence River. Shelter A shows the A-frame design and measurements used. Shelter B shows the flat-roof design and measurements used.

Once a black-fronted 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 12). 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 12. 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 2021/2022 breeding season.

3. RESULTS

3.1 Enhanced islands

Leading up to the start of the 2021/2022 season, only three of the seven available enhanced islands were suitable breeding islands (this includes Mitchell's Island which had no enhancement work carried out in March 2021).

During the winter of 2021, river flow rates peaked three times to extremely high levels (Figure 13). Normal river flow on the Waiau Toa/Clarence River would sit at around 20 m^3/sec with occasional spikes reaching around 50 m^3/sec as demonstrated during the 2020 winter period (Figure 13). However, on 31 May 2021, river flow rates averaged at 150 m^3/sec. Furthermore, river flow rates averaged at 170 m^3/sec on 21 June 2021 and 205 m^3/sec on 17 July 2021 (Figure 13). These peaks are significantly higher than most flooding events on the Waiau Toa/Clarence River putting extreme pressure on the braided river formation and drastically changing the geography of the Waiau Toa/Clarence River.

A comparison over the last seven wintering periods (2015-2021) showed that winter 2021 had the second, fourth and fifth highest flooding events recorded (Appendix 4).

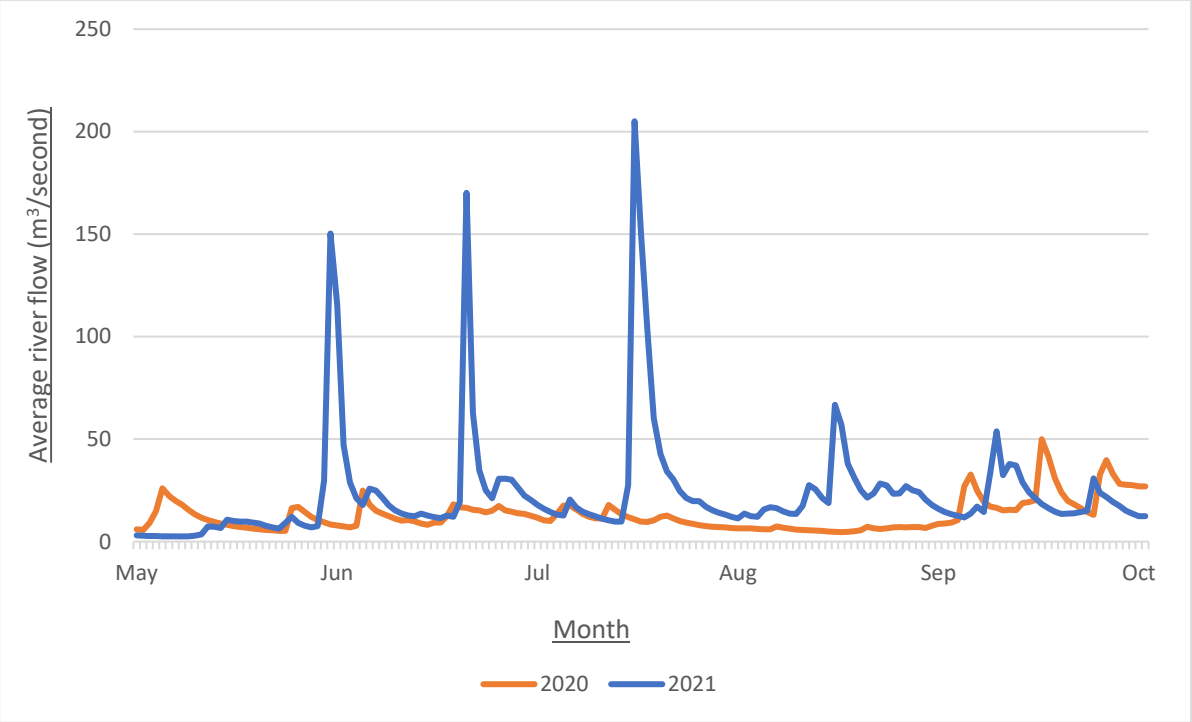

Figure 13. Comparison of average daily river flow rates on the Waiau Toa/Clarence River during the months of April to October in 2020 and 2021.

By the end of the July 2021 flood, many of the previously enhanced islands along the Waiau Toa/Clarence River were dramatically changed (see examples in Figure 14 and Figure 15). Consecutive flooding caused many islands to be flattened into the mainland, lowered in height and channels to be blocked off and diverted (Table 1, see example in Figure 15).

Table 1. Condition of enhanced islands on the Waiau Toa/Clarence River at the end of the 2021/2022 season and maintenance required.

River	Code	Site	Condition at end of 2021/2022 season	Maintenance Required
Waiau Toa/Clarence River	C1	Bush Gully	Island remains in good condition. Wide, deep channels on either side keep island separated from the mainland. Vegetation starting to grow but currently not preventing the availability of ideal nesting habitat. Island raised above medium flooding levels. River gravels quite large throughout island reducing available nesting areas.	Requires vegetation control depending on growth. Top layer of large river gravels could be scraped to uncover smaller, more suitable nesting gravels below (needs to be confirmed).
	C2	Cow Island	Large winter flooding caused island land mass to be spread out further and flattened. Inner enhanced channel now broken up and filled in with river gravels causing channel to be shallow and slow flowing. Connected to mainland at low river flow.	Inner channel needs to be widened and deepened to separate island from mainland. Island height to be raised to avoid flooding damage.
	C3	Fisherman's	Main entrance to the true left enhanced channel of island blocked up after winter flooding. "Island" remains connected to the mainland.	Due to channel being easily blocked up and a large amount of native riverbed flora on the island, no island enhancements are recommended to be continued.
	C4	Swimming Hole	Island remains in good condition. Wide, deep channels on either side keep island separated from the mainland. Thick broom and grasses on the outer perimeter of island blocking access to parts of the river.	Requires vegetation control, however vegetation was attempted to be covered in March 2021 by bulldozer however this just uncovered a layer of topsoil, removing suitable nesting gravels, and instead providing more land area for weeds to grow.
	C5	Upper Swimming Hole Island	Winter flooding caused island to be flattened and pushed into the mainland, blocking off true left river flow. Land area still fairly raised in parts.	Discontinued
	C5a	Upper Swimming Hole	Channel has been cut off from river flow and passage is no longer cleared. Land area is still connected to mainland.	Channel needs to be cleared and deepened to allow river flow through. Channel entry point needs to be deepened/widened to allow a greater river flow into channel.

Figure 14. Before and after-flood shots of Upper Swimming Hole Island (no. 5) pon the Waiau Toa/Clarence River. Above: Final outcome of enhanced island with wide channel flowing down true left side of island, March 2021. Below: Winter floods (June-August 2021) have flattened "island" and pushed material up to mainland. No channel flowing down true left side. Initial island shapefile shown by yellow dotted line. Material has also blocked entrance to water flow down the enhanced channel of Upper Swimming Hole (no.5a). Historic river flow route marked by blue arrows.

Figure 15. Before and after-flood shots of Cow Island (no. 3) on the Waiau Toa/Clarence River Above: Bulldozer deepening, widening, and clearing channel of Cow Island down the middle of split river channel (true left of island). Below: Cow Island after the winter floods with the channel down the middle has filled in along with island being flattened, widened, and connected to the mainland.

3.2 Predator trapping

Over the course of 207,065 trap nights, a total of 487 predators were caught in kill traps along the upper Waiau Toa/Clarence River during the 2021/2022 field season including 19 cats, 5 ferrets, 334 hedgehogs, 17 possums (*Trichosurus vulpecula*), 19 stoats (*M. erminea*), 29 weasel (*M. nivalis*) and 94 mice (*Mus musculus/domesticus*) (Table 2 and Table 3).

Each trap type caught a mixture of predator species (Table 2). More predators were caught in DOC250 traps, followed by double-set DOC200 and double-set DOC150. Double-set SA1 and SA2 traps caught substantially less than all other traps (Table 2), but as expected caught more cats (which these traps are designed to target). Both SA-1 and SA-2 traps performed similarly for cat catches.

Table 2. Total number of mammalian predators caught in kill traps along the Waiau Toa/Clarence River during 2021/2022. The total number of traps deployed follows in brackets.

Predator	Trap type					
	DOC150 (296)	DOC200 (214)	DOC250 (262)	Steve Allen 1 (296)	Steve Allen 2 (107)	Total (1175)
Cat	2	2	2	6	7	**19**
Ferret	2	-	2	-	1	**5**
Hedgehog	65	98	112	50	9	**334**
Possum	-	3	5	1	8	**17**
Stoat	8	3	8	-	-	**19**
Weasel	12	3	14	-	-	**29**
Mouse	17		46	1	-	**94**
Rat	-	-	-	-	-	**0**
Total	**106**	**109**	**189**	**58**	**25**	**487**

Predators were caught approximately even numbers on either side of the river, except for possums, stoats and weasels which were caught at almost double the rate on the true right compared to the true left (Table 3).

Table 3. Total number of mammalian predators caught in kill traps during the 2021/2022 on either side of the upper Waiau Toa/Clarence River (true left and true right).

Predator	True Left	True Right
Cat	9	10
Ferret	1	4
Hedgehog	172	162
Possum	2	15
Stoat	6	13
Weasel	10	19
Mouse	46	48
Rat	-	-
Total	246	271

The total number of predators caught during the 2021/2022 season is slightly higher to that of the previous season (440 predators caught in 2020/2021; Table 4). However, the composition of predators caught across trapping network show notable difference compared to the previous year. Mustelid catches have dropped considerably, in particular ferrets and stoats, which are approximately a third (15 caught in 2020/2021) and a fifth (92 caught in 2020/2021) the number caught in the previous season, respectively. Weasel catches are also slightly lower, but reasonably similar to the previous season (32 caught in 2020/2021; Table 4).

Hedgehogs continue to dominate the number of catches throughout the trapping network, with an approximate 49% increase compared to the previous season (244 caught in 2020/2021). Other increases in the number caught were observed in possums and mice, which are approximately triple the number caught in the previous season (6 and 31 caught in 2021/22, respectively). The number of cats caught was similar to the previous season and no rats were caught during the 2021/2022 season. There was an additionally four kāhu/ Australian harriers caught as bycatch throughout the season, two were caught in DOC200 traps and two were caught in SA2 traps.

Table 4. Total number of predators caught in kill traps along the upper Waiau Toa/Clarence River each season between the 2015/2016 and 2021/2022 seasons. 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. Current season is in bold and highlighted in blue. Note: all seasons excluding the 2020/2021 and 2021/2022 season utilised two 10-day pulses of leg-hold traps to target feral cats in addition to kill traps (kāhu were bycaught in these leg-hold traps).

	2015/2016	**2016/2017**	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**	**2021/22**	**Total**
No. Trap Nights	*101,446*	*151,134*	*146,943*	*137,825*	*120,356*	*144,908*	*207,065*	***1,009,677***
Harrier	58	82 (+41%)	83 (+1%)	82 (-1%)	67 (-18%)	0 (-100%)	4	**376**
Cat	26	29 (+11%)	17 (-41%)	16 (-6%)	17 (+6%)	18 (+6%)	19 (+6%)	**142**
Ferret	41	33 (-20%)	30 (-9%)	17 (-43%)	4 (-76%)	15 (+275%)	5 (-66.7%)	**145**
Hedgehog	102	221 (+117%)	233 (5%)	134 (-42%)	137 (+2%)	244 (+78%)	334 (+49%)	**1405**
Possum	19	36 (+89%)	69 (+92%)	68 (-1%)	55 (-19%)	6 (-89%)	17 (+183%)	**270**
Stoat	34	57 (+67%)	27 (-53%)	66 (+144%)	35 (+47%)	92 (+163%)	19 (-79%)	**330**
Weasel	16	20 (+25%)	33 (+65%)	8 (-75%)	26 (+225%)	32 (+23%)	29 (-9%)	**164**
Rat	0	0	0	0	23	2 (-91%)	0 (-100%)	**25**
Mice	12	152 (+1167%)	58 (-62%)	16 (-72%)	70 (+338%)	31 (56%)	94 (+203%)	**433**
Total	**308**	**630**	**550**	**407**	**434**	**440**	**487**	**3256**

Trapping captures fluctuated with the change in season (Figure 16). Overall, predator captures during winter (July and August) were exceptionally low (in particular stoats and weasels) when compared to the previous season (Appendix 8), except for cats which followed the same pattern as 2021/2022 and for possums which increased in capture rate throughout the year due to the introduction of SA2 traps into the trapping network.

Stoat, weasel, and ferret catches all peaked in September before dropping to zero during November and December (stoats and weasels) or remained at zero catches thereafter (ferrets; Figure 16). Whilst a lower rate of capture during these months has been found in previous years for mustelids, the drop to zero catches has not been observed before (Appendix 8). Stoat and weasels catch numbers rebounded thereafter during January.

Hedgehog captures peaked in October, likely due to their emergence from hibernation in the spring (Figure 16). This pattern corresponds to all previous years except for the 2020/2021 season where hedgehog numbers peaked in December. In comparison to the previous year, December had the lowest catch rate during the season (excluding July and August when hedgehogs were still hibernating).

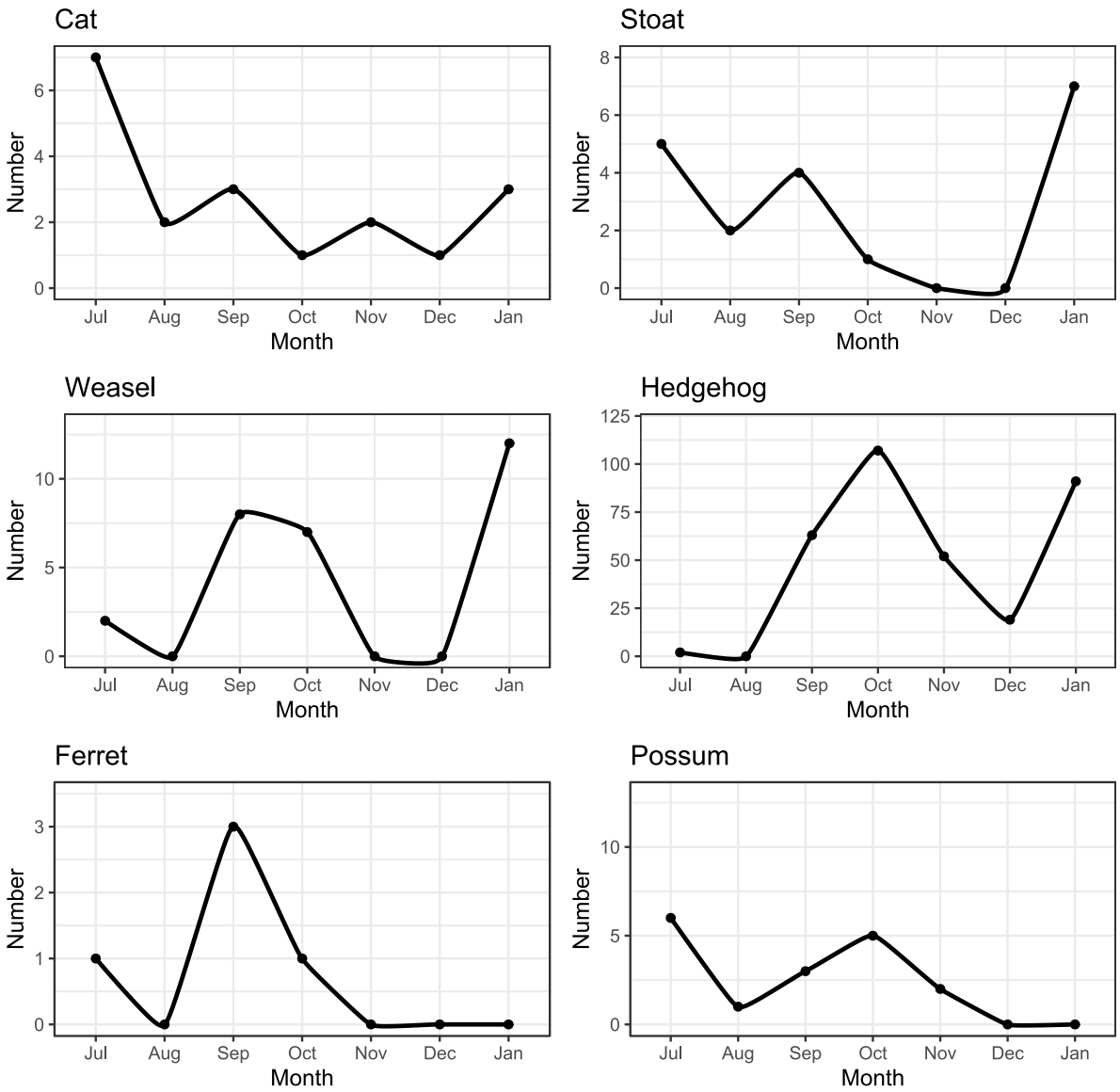

Figure 16. Total number of predators caught per month on the Waiau Toa/Clarence River between July 2021 and January 2022.

Predators were caught throughout the trapping network however the spatial distribution of catches was dependent on each species (Figure 17). Some species were caught uniformly throughout the network, including cats, hedgehogs, and possums, with no apparent spatial structuring in their catches (Figure 17).

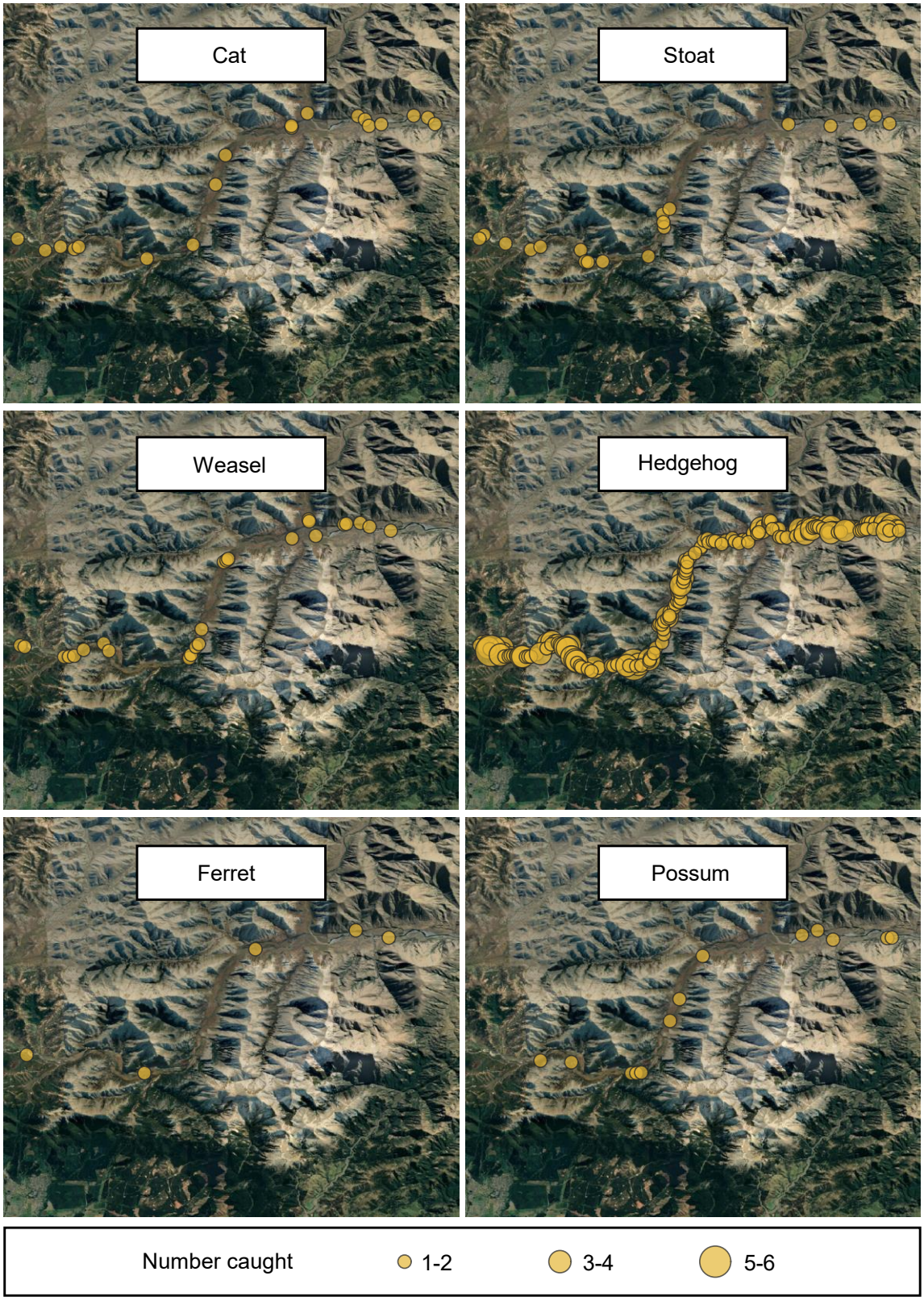

Figure 17. The spatial distribution of predators caught along the upper Waiau Toa/Clarence River, 2021/2022. The size of point indicates the number caught at the same trap site. Points are slightly transparent to indicate concentration of captures.

The distribution of weasel catches was also relatively even but exhibited some clustering in sections, in particular in the middle section. Mice also tended to be caught throughout the middle section of the network. Stoat catches were more unevenly distributed and tended to be caught at either the upstream or downstream sections of the network. In contrast to all other predators, ferrets tended to be caught more on the periphery of the trapping network (Figure 17).

3.3 Kāhu/Australasian harrier banding

A total of total of 41 birds were caught (Table 5). The majority of birds caught were female. Interestingly most female birds caught were young first year birds (Table 5 and Figure 19). In total, 10 second year, and 13 third year (or older) birds were caught (Table 1). A total of eight birds were recaptured, with catches split evenly over September 15 and 16. Most recaptures were 2-year birds.

Table 5. Total catch and recapture totals of kāhu/Australasian swamp harrier *Circus approximans* on the Waiau Toa/Clarence River, 13-16 September 2021.

Date	Female			Male			Total	Recaptures
	Adult (3+ Yr)	2 Yr	1 Yr	Adult (3+ Yr)	2 Yr	1 Yr		
13/9/2021	0	2	1	0	0	2	**5**	0
14/9/2021	2	2	4	3	0	1	**12**	0
15/9/2021	2	2	3	1	2	1	**11**	4
16/9/2021	2	1	5	3	1	1	**13**	4
Total	**6**	**7**	**13**	**7**	**3**	**5**	**41**	**8**
	26			**15**				

3.3.1 Total Catch by Trap

Catch totals per trap are shown in Figure 18 and Table 5 & Table 6. Not all traps caught kāhu. Certain locations picked up more individuals than others. Traps were moved when the traps were not being effective, or an extra trap added in-between if it was a successful site. These additional trap locations are represented with ‘A’ or ‘B’ after the trap number (Figure 18).

Table 6. Total kāhu/Australasian swamp harrier *Circus approximans* captures for each trap, including recaptures on the Waiau Toa/Clarence River, 13-16 September 2021.

Trap Number	New Captures	Recaptures	Total Catch
1	6	0	**6**
2	1	0	**1**
4	1	0	**1**
5	2	0	**2**
7	1	0	**1**
9	6	0	**6**
12	8	1	**9**
14	3	1	**4**
16	5	0	**5**
14A	2	0	**2**
1A	3	3	**6**
1B	0	2	**2**
2A	2	1	**3**
4A	1	0	**1**
Totals	**41**	**8**	**49**

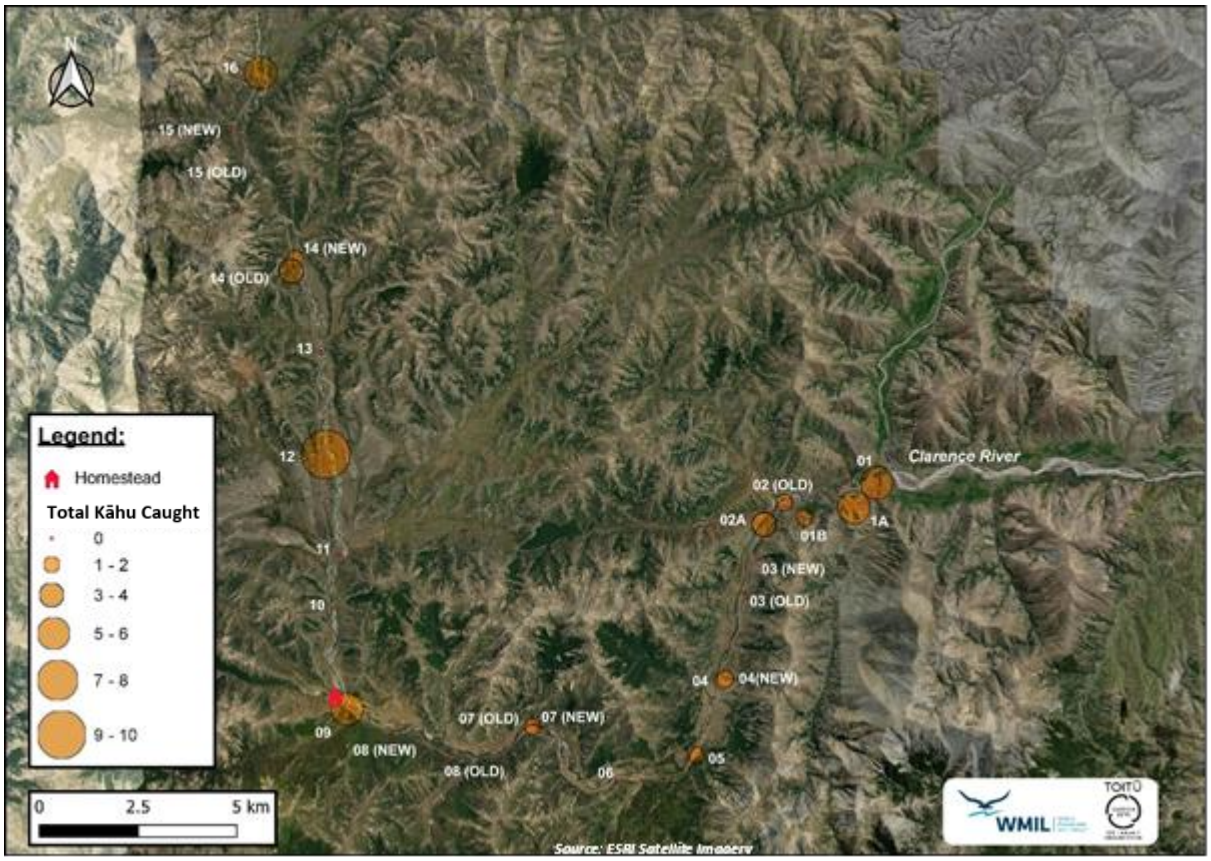

Figure 18. Kāhu/Australasian swamp harrier *Circus approximans* trap capture numbers for each trap on the Waiau Toa/Clarence River, 13-16 September 2021.

Figure 19. Two female kāhu/Australasian swamp harriers *Circus approximans* caught on the Waiau Toa/Clarence River, 13-16 September 2021. Left: 3+ year old female kāhu; Right: 1 year old female kāhu.

3.4 Black- fronted terns

3.4.1 Clarence and Acheron River Surveys

3.4.1.1 Initial walk-through surveys

The first walk-through surveys were conducted on 22 October 2021 on the Waiau Toa/Clarence River. Sections of river with black-fronted terns sighted nearby were surveyed intensively. During this survey, 12-13 active nests on Upper Swimming hole colony (CA) and Upper Bush Gully (CC) were found with over 40 birds counted at each site. The Acheron River and sections of the Waiau Toa/Clarence River were again surveyed on 27 October 2021 with two new colonies found (one on the Acheron, one on the Waiau Toa/Clarence River).

Subsequent surveys were conducted along the Waiau Toa/Clarence River during early November. Four new colonies ranging between two to six nests, were discovered on this sweep.

3.4.1.2 Helicopter survey

On 8 November 2021, a helicopter survey was undertaken. This survey covered from Lake Tennyson to the end of the trapping line, past the Acheron and Waiau Toa/Clarence River confluence and covered the Acheron River up until the river diverted from the road past a shelter (Figure 20). During the helicopter survey, 15 black-fronted tern colonies were found, and estimated populations were counted (Table 7). Of these 15 colonies, seven had not been found before due to their location and difficulty to access. A total of 341 black-fronted terns were counted along the Waiau Toa/Clarence and Acheron River with the largest colony count reaching 60 estimated birds (Table 7). For location coordinates of all colonies found, refer to Appendix 5.

Table 7. Black-fronted tern colonies and population counts during helicopter survey along the upper Waiau Toa/Clarence and Acheron Rivers during the 2021/2022 breeding season. Note: original monitored colony codes are represented in bold. Separate numbers and letters represent the GPS code during the helicopter survey.

River	Colony Name	Colony Code	Estimated bird count
Waiau Toa/Clarence River	Top colony	**CH** (1)	60
	Upper Fowlers	**CE** (2)	18
	Heli Colony	**CI** (3)	35
	Middle Braid	**CD** (4)	3
	3-4th Pilon	5	4
	Upper Lookout Hill	6	5
	Upper Swimming Hole	**CA** (7)	20
	Swimming Hole	**CB** (8)	20
	Mitchell's	**CG** (9)	6
	Eddy's Inlet	**CF** (10)	15
	Upper Bush Gully	**CC** (11)	20
	Confluence	12	20
Acheron River	Grader Island	**AA** (A)	40
	Beginner braid	B	6
	Acheron Island	**AB** (C)	15
Other birds seen away from colonies			54
Combined Count			**341**

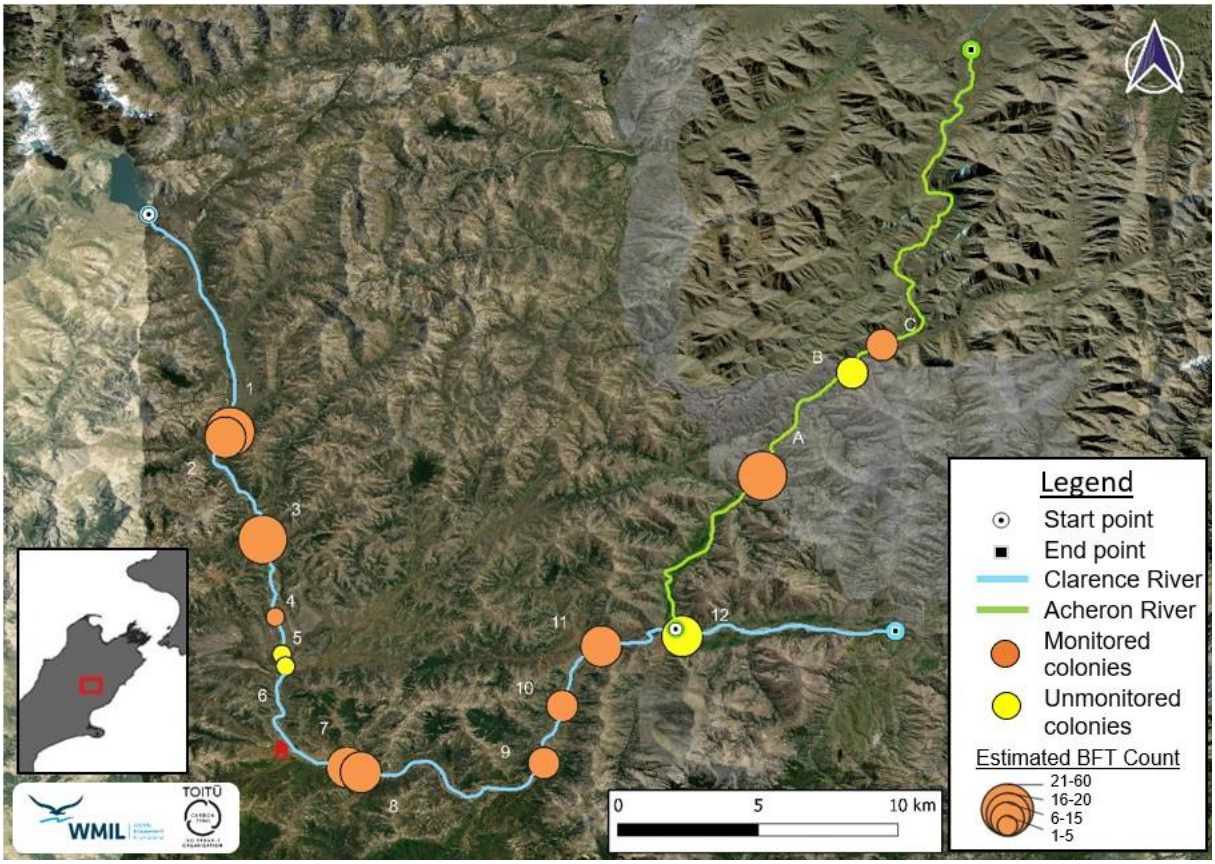

Figure 20. Helicopter survey route and location of colonies found along the Waiau Toa/Clarence and Acheron Rivers including monitored and unmonitored colonies, 8 November, 2021. Note: Unmonitored colonies represent those sighted on the helicopter, however a nest count could not be taken before the colony had failed.

3.4.2 Local population size and distribution of breeding colonies

A total of 14 black-fronted tern nesting colonies were located on the upper Waiau Toa/Clarence and Acheron Rivers this season (Figure 21, Appendix 6). Colony size varied from one breeding pair to as many as 55 breeding pairs, with an average colony size of 17 breeding pairs.

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

A total of 172 nests were active at the peak of the 2021/2022 breeding season, which is equivalent to 344 birds breeding at any one time (Table 8). The maximum number of active nests counted throughout the 2021/2022 season reached 241 equating to a maximum of 482 breeding birds on the Waiau Toa/Clarence and Acheron River (Table 9). Of this, more birds (185 breeding pairs) were recorded on the upper Waiau Toa/Clarence than on the Acheron River (56 breeding pairs) throughout the season.

During the 2019/2020 season 212 nests were recorded, and 263 nests in 2018 (Figure 22); indicating a 12% increase in nests from the previously monitored season and an 11% decrease in nests over the past five monitored seasons (Figure 22).

Table 8. Number of nests and adult birds present on the upper Waiau Toa/Clarence and Acheron at the peak of each breeding season, 2021/2022.

River	Colony Code	Highest Active Nest Count	Nest Date	Highest Count of BFT	Count Date
Waiau Toa/Clarence River	CA	16	7-Nov	40+	22-Oct & 28-Oct
	CB	10	15-Nov	23	15-Nov
	CC	12	26-Oct	40+	22-Oct & 19-Nov
	CD	5	14-Nov	17	1-Dec
	CE	9	20-Nov	26	20-Nov
	CF	11	13-Nov	25	9-Dec
	CG	11	19-Nov	24	1-Dec
	CH	34	19-Nov	50+	13-Nov
	CI	14	19-Nov	50+	19-Nov & 14-Dec
	CJ	1	3-Dec	6	2-Dec
	CK	6	13-Dec	18	13-Dec
	CL	2	13-Dec	8	13-Dec
	Total	**131**		**147**	
Acheron River	AA	39	23-Nov	70+	23-Nov
	AB	2	23-Nov	15	8-Nov
	Total	**41**		**85+**	
Combined Total		**172**		**232**	

Table 9. Maximum number of active nests and breeding birds on the Waiau Toa/Clarence and Acheron rivers during the 2021/2022 season.

Season	Max number of active nests **(Waiau Toa/Clarence River)**	Max number of active nests **(Acheron River)**	Combined max number of active nests	Max number of breeding birds **(No. of nests x2)**
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

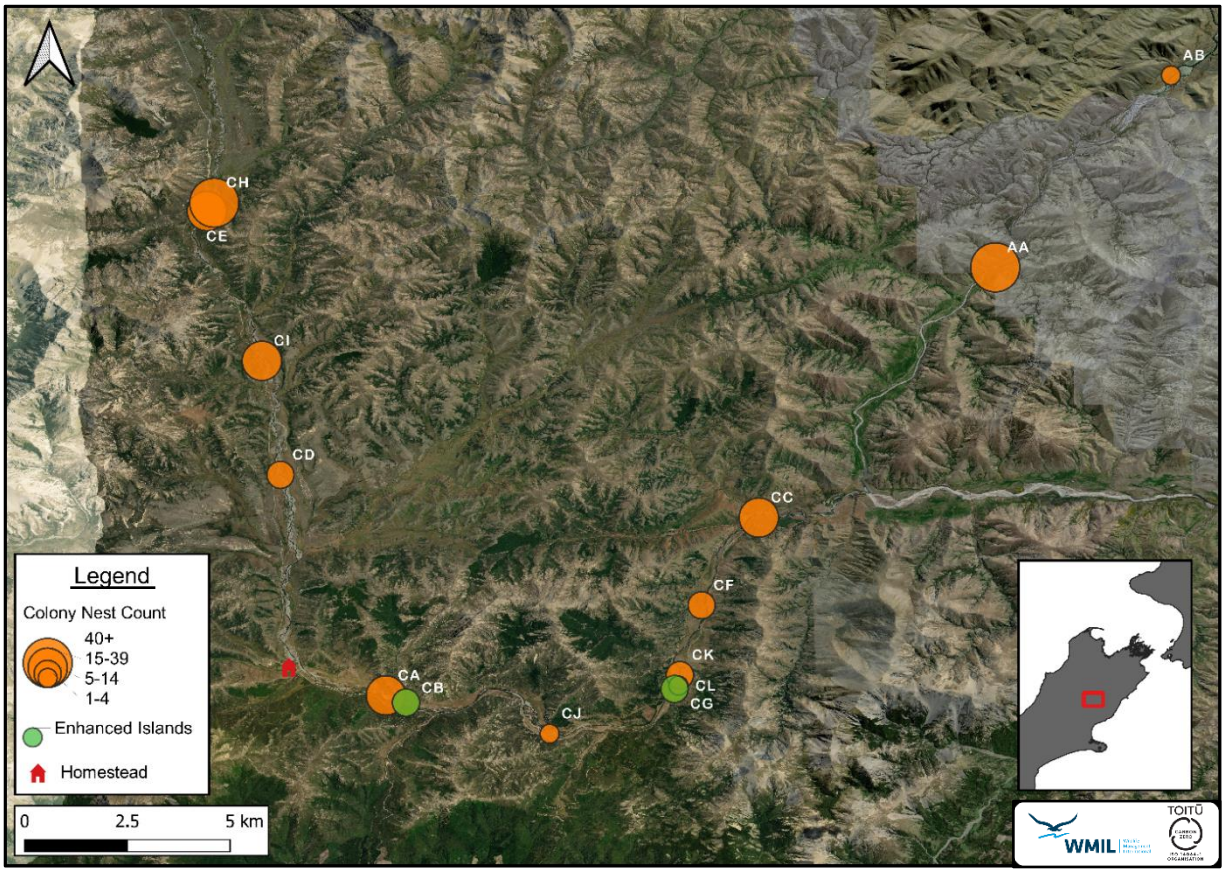

Figure 21. Locations and relative size of black-fronted tern colonies monitored on the upper Waiau Toa/Clarence and Acheron Rivers during the 2021/2022 breeding season.

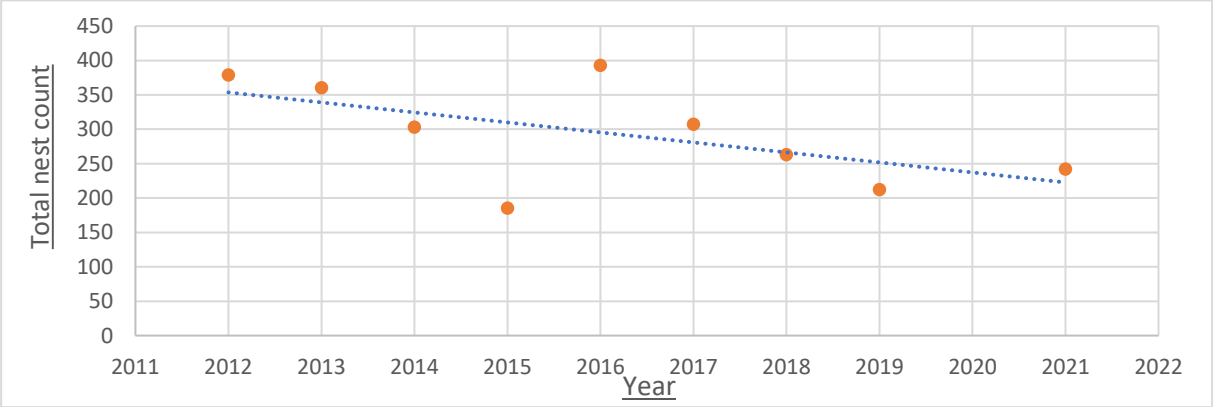

Figure 22. Maximum number of active black-fronted tern nests during the past nine breeding seasons from 2012/13 to 2021/2022 along the Waiau Toa/ Clarence and Acheron Rivers. Note: no monitoring or counts took place during 2020/2021.

3.4.3 Use of enhanced islands

Throughout the 2021/2022 season, only three of the previously enhanced islands (Swimming Hole, Mitchell's, and Bush Gully) remained as raised islands with suitable surrounding channels. Black-fronted terns attempted to nest on five of the seven previously enhanced islands. This included medium-large colonies on upper Swimming Hole (enhanced island 5a), Swimming Hole (enhanced island 4) and Mitchell's (previously enhanced island with no extra work needed). One nest was laid on upper Swimming Hole "island" (enhanced island 5); however, this nest was predated. One nest was monitored and hatched on Cow Island (enhanced island 2). No nesting attempts were made on

Fisherman's (enhanced island 3) or Bush Gully (enhanced island 1). A large colony established 150 m upstream of Bush Gully on river gravels that were formed after the winter flooding, however this colony was largely connected to the mainland.

3.4.4 Breeding success

3.4.4.1 Waiau Toa/Clarence and Acheron hatching success

Enhanced Island hatching success

A total of 241 black-fronted tern nests were monitored during the 2021/2022 breeding season. Of these, 27 nests were located on two surviving enhanced islands, 20 nests were located on two previously enhanced islands that had flooded/failed before October 2021 and were now mostly connected to the mainland, and the remaining 194 nests were situated on non-enhanced islands/ mainland areas (Table 10).

Table 10. Apparent black-fronted tern hatching success of known-fate nests on enhanced and non-enhanced colonies on the Waiau Toa/Clarence and Acheron rivers during the 2021/2022 breeding season.

	Colony Code	Known-fate nests	Hatching	
			Number	%
Enhanced Island	CB	14	10	71%
	CG	13	11	85%
	Total	**27**	**21**	**78%**
Flooded/Failed Enhanced "Island"	CA	19	10	53%
	CJ	1	1	100%
	Total	**20**	**11**	**55%**
Non-Enhanced Colonies	CC	25	7	28%
	CD	11	6	55%
	CE	18	11	61%
	CF	12	10	83%
	CH	41	37	90%
	CI	23	18	78%
	CK	6	0	0%
	CL	2	0	0%
	AA	55	43	78%
	AB	1	0	0%
	Total	**194**	**132**	**68%**
Combined Total		**241**	**164**	**68%**

A total of 78% of monitored enhanced island nests hatched one or more chicks (Table 10, Figure 23) while previously enhanced islands which were altered and shifted by winter floods prior to the start of the season had a 55% hatching success. Out of the 194 nests monitored at non-enhanced islands, 132 nests hatched with a hatching probability of 68% (Table 10, Figure 23).

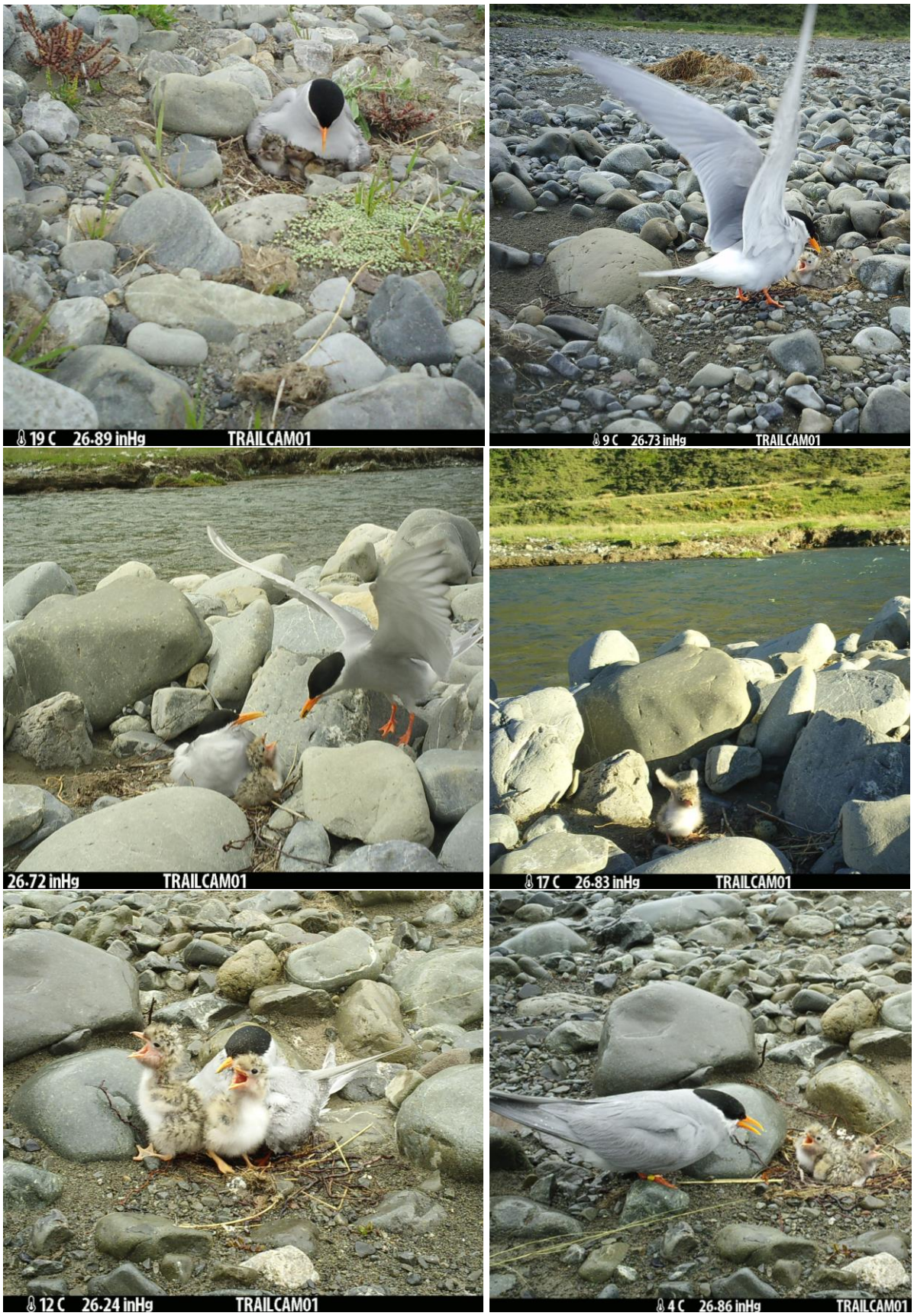

Figure 23. Observed hatched chicks on the Waiau Toa/Clarence River, 2021/2022.

Treatment colony hatching success

Colonies situated on islands within the active trapping zone (treatment zone) resulted in a 67% hatching success (Table 11). Colonies established on islands outside of the trapping zone (non-treatment zone) resulted in a 78% hatching success.

More than half of nests within the trapping zone were situated on the mainland, whereas only 3 nests outside of the trapping zone were on the mainland. This resulted in a 43% hatching success rate of mainland nests within the trapping zone compared the non-trapped zones where two out of three nests hatched (Table 11).

Table 11. 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 2021/2022 breeding season.

Zone	Colony Location	Known-fate nests	Hatching	
			Number	%
Trapping	Island	39	26	67%
	Mainland	53	23	43%
	Total	**92**	**49**	**53%**
No Trapping	Island	146	114	78%
	Mainland	3	2	67%
	Total	**149**	**116**	**78%**

3.4.5 Cause of nest failure

Of the 241 nests with known outcomes, a total of 76 nests failed to hatch (63 on the Waiau Toa/Clarence River and 13 on the Acheron River). Overall, predation was the leading cause of failure with 17% of all monitored nests across both rivers being depredated (Table 12; Figure 24).

Table 12. Outcome of black-fronted tern nests along the Waiau Toa/Clarence and Acheron River during the 2021/2022 breeding season.

River	Colony Code	Known-nest outcomes	Predated		Abandoned		Flooded		Hatched	
			Nests	%	Nests	%	Nests	%	Nests	%
Clarence River	CA	19	4	21%	5	26%			10	53%
	CB	14	1	7%	3	21%			10	71%
	CC	25	8	32%	9	36%	1	4%	7	28%
	CD	11	4	36%	1	9%			6	55%
	CE	18	5	28%	1	6%			12	67%
	CF	12			2	17%			10	83%
	CG	13			2	15%			11	85%
	CH	41	3	7%			1	2%	37	90%
	CI	23	3	13%	2	9%			18	78%
	CJ	1							1	100%
	CK	6	4	67%			2	33%		
	CL	2					2	100%		
	Total	185	32	17%	25	14%	6	3%	122	66%
Acheron River	AA	55	8	15%	4	7%			43	78%
	AB	1	1	100%						
	Total	56	9	16%	4	7%	0	0%	43	77%
Combined Total		**241**	**41**	**17%**	**29**	**12%**	**6**	**3%**	**165**	**68%**

Abandonment was the second highest cause of failure, accounting for 12% of nest failures across both rivers (Waiau Toa/Clarence River 14%, Acheron River 7%) (Table 12, Figure 23). In all cases, abandonment was directly linked to predation or flooding events. For example, at colony CC, there were 17 remaining active nests on 25 November 2021. By 13 December 2021, all 17 nests had failed, or previously hatched chicks were predated. Footage of a cat predating four different nests was caught on camera. It is highly probable that this nocturnal disturbance resulted in the abandonment of the remaining nine nests.

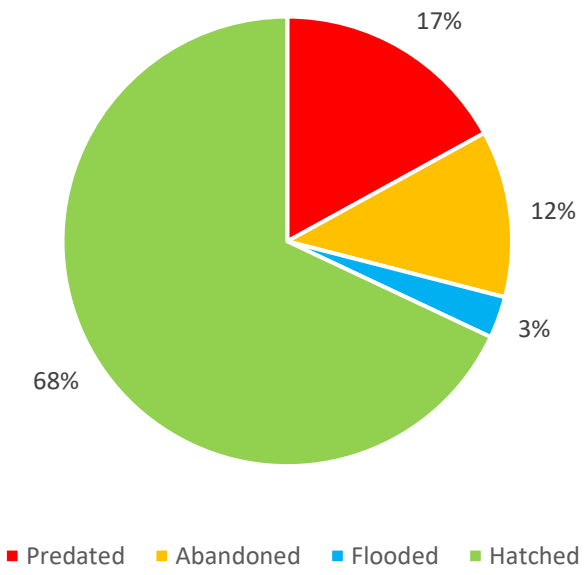

Figure 24. Overall summary of known nesting outcomes for black-fronted terns on Waiau Toa/Clarence and Acheron River, 2021/2022.

The third highest cause of nest failure was due to flooding which was very minimal this season with only 3% of nests being flooded (six nests) (Table 12, Figure 23). Conditions for egg laying and hatching were very favourable this season with a period of 24 days (23 October to 16 November 2021) consisting of flow rates below the seasonal average of 15 m^3/sec (Figure 25). This allowed majority of eggs to be laid without the risk of flooding. Whilst 17 November saw river flow rates peak at 30 m^3/sec, the large majority of nests remained safe out of proximity to the rising waters. Such low river flow rates allowed chicks to safely hatch and grow large enough to easily be able to head to higher ground during one flood which peaked at 45 m^3/sec on the Clarence River (16 December 2021) (Figure 25).

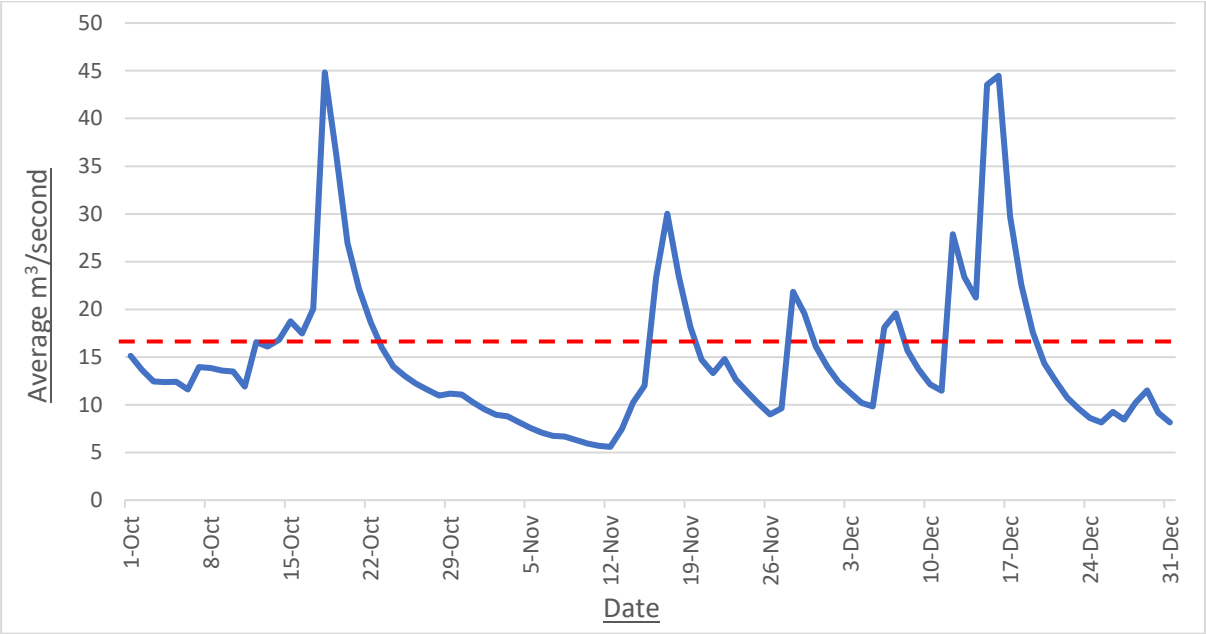

Figure 25. Waiau Toa/Clarence River flow rates at Jollies (NIWA) from 1 October 2021 to 1 January 2022. Note: Average River flow rates for the 2021/2022 season illustrated by red line.

In comparison, flow rates from the same time period on the Waiau Toa/Clarence River during the last monitored season in 2019/2020 averaged at 18 m^3/sec (Figure 26). Large peaks on 11 November 2019 (51 m^3/sec) and 4 December 2019 (47 m^3/sec) largely disrupted nesting and chick fledging rates and both floods were large enough to fully submerge islands where colonies had formed (Figure 26). This illustrates how optimal river flow rates are crucial for chick productivity.

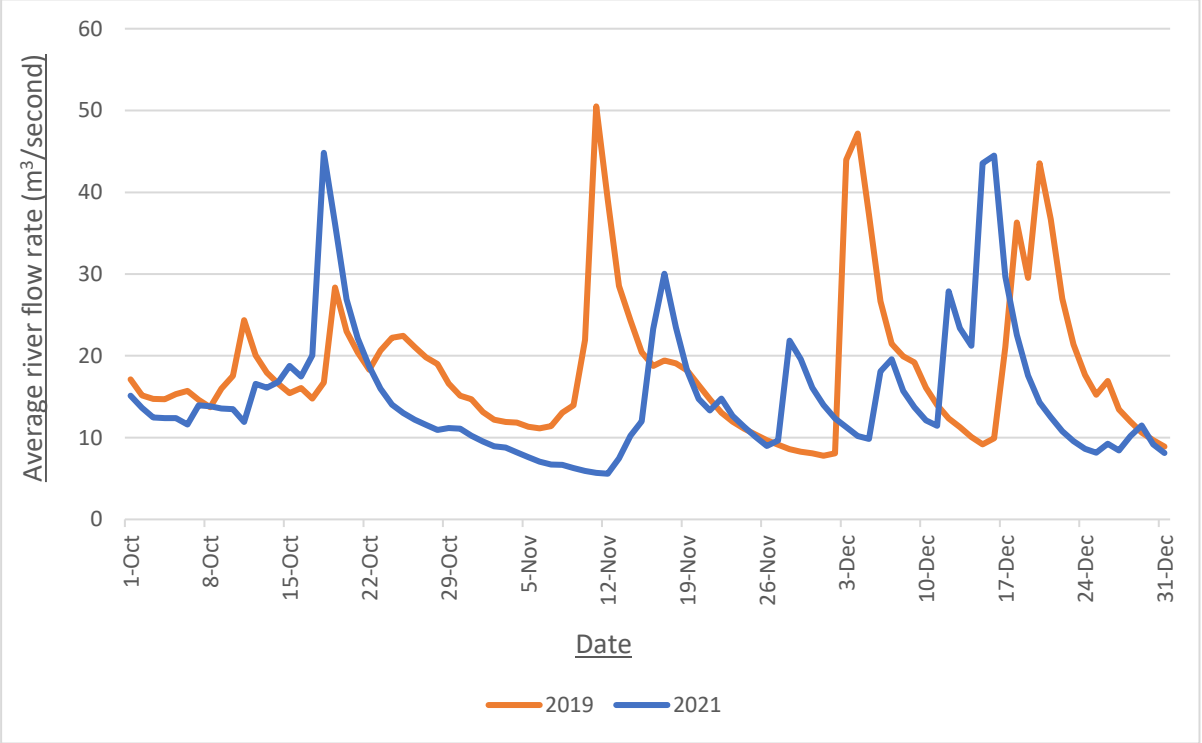

Figure 26. Waiau Toa/Clarence River flow rates at Jollies between 1 October and 1 January during the 2019/2020 and 2021/2022 seasons.

A breakdown of the total nest outcome between enhanced islands, colonies within the treatment zone (including enhanced islands), and non-treatment colonies can be found in Figure 27. Hatching success was high across enhanced islands and non-treatment colonies (78% hatching success). Hatching

success on treatment colonies was at 53% which was largely successful with consideration that almost half of these nests were situated on the mainland (Table 11). Taking this into consideration, only 18% of nests were predated within the treatment zone and 16% of nests were predated on non-treatment colonies (Figure 27).

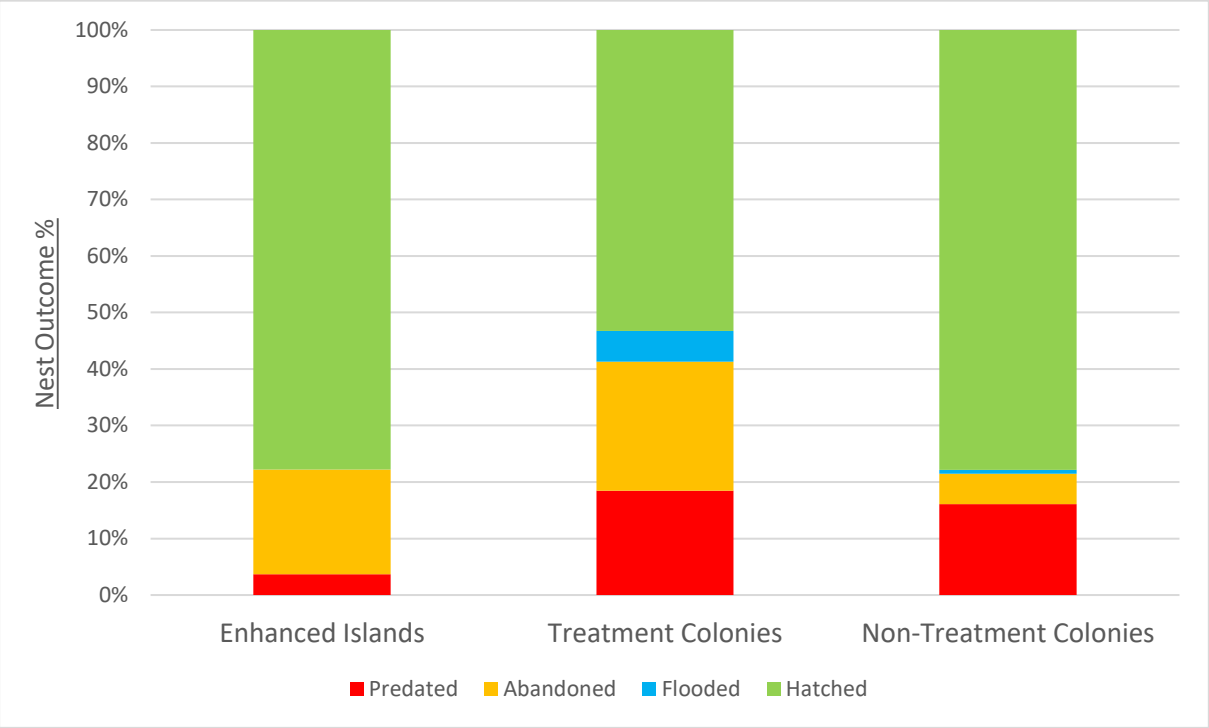

Figure 27. Overall nest outcome percentages for colonies on enhanced islands (27 nests), within the treatment zone (92 nests) (including enhanced islands), and within the non-treatment zone (149 nests) on the Waiau Toa/Clarence and Acheron Rivers during the 2021/2022 season.

3.4.6 Camera monitoring of nests

This season, 73 nests were monitored by cameras. Surveillance coverage of nests varied between colonies, with between 16% to 50% of nests at a colony being monitored by cameras (Table 13).

Low coverage rates can be attributed to difficulty of reaching islands and transporting cameras to the site. For example, colony AA was mostly accessible by pack raft resulting in only four cameras being deployed on site and rotated to nine different nests.

Table 13. Total camera coverage of colonies along the Waiau Toa/Clarence and Acheron River, 2021/2022.

River	Colony	Total nests	Nest cameras	Coverage %
Waiau Toa/ Clarence River	CA	19	8	42%
	CB	14	7	50%
	CC	25	8	32%
	CD	11	4	36%
	CE	18	7	39%
	CF	12	5	42%
	CG	13	5	38%
	CH	41	12	29%
	CI	23	8	35%

River	Colony	Total nests	Nest cameras	Coverage %
	CJ	1	0	0%
	CK	6	0	0%
	CL	2	0	0%
	Total	**185**	64	35%
Acheron River	AA	55	9	16%
	AB	3	0	0%
	Total	**57**	9	16%
Combined Total		**242**	73	30%

Cameras were distributed evenly across nested areas of the island/mainland areas colonised. 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 five predator species at seven of the 42 predated nests (Figure 28).

The predator species responsible for the largest number of predated nests were cats which was recorded preying on four nests at one colony site on the Waiau Toa/Clarence River (Table 14, Figure 28). Colony CC (25 nests) was estimated to have been wiped out by a single cat over the space of several days after four cameras picked up cat predations of eggs, chicks, and adult black-fronted terns on consecutive nights. Other predators recorded on the Waiau Toa/Clarence and Acheron River included harrier, ferret, hedgehog, and Southern black-backed gulls (Table 14; Figure 28).

Of these predation events, no predators were filmed predating nests on islands within the treatment zone, while only harrier predations were recorded on non-treatment islands (Table 14). Mainland colonies within the treatment zone and those outside of the treatment zone both had two different predator species predate nests on camera (Table 14).

Table 14. Camera monitoring outcomes of black-fronted tern nests in colonies within the treatment zone and outside of the treatment zone on the Waiau Toa/Clarence and Acheron River, 2021/2022.

Monitored nest outcome	Treatment colonies		Non-treatment colonies	
	Island nests	Mainland nests	Island nests	Mainland nests
Predation				
Australasian harrier			2	
Cat		4		
Ferret				1
Hedgehog				1
SBBG		1		
Abandonment	4	17	8	
Flooding	2	1	1	
Hatched	13	10	33	
Combined total	**19**	**33**	**44**	**2**

Figure 28. Observed nest predation events filmed during the 2021/2022 breeding season at black-fronted tern colony sites along the Waiau Toa/Clarence and Acheron Rivers. Above show nest predations by feral cats, ferrets, Southern black-backed gull, kāhu/Australian swamp harrier and hedgehogs.

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 164 nests spread over 11 monitored colonies managed to successfully hatch 267 chicks. Of these, 123 fledglings were confirmed. Another 67 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 (Table 15). This brings the maximum number of chicks estimated to have fledged to 190.

Colony CB (Swimming Hole) was the most successful colony in fledging chicks with 14 out of the 19 hatched chicks observed to have fledged (Table 15). Colony AA on the Acheron had the largest individual fledgling count with 43 out of 63 fledglings observed to have fledged and another 17 estimated to have fledged bringing the fledgling success range of AA colony to 68-95% (Table 15).

Table 15. Black-fronted tern confirmed and theoretical maximum fledgling success on the Waiau Toa/Clarence and Acheron Rivers in 2021/2022.

River	Colony Code	Hatched Nests	Individual chicks hatched	Fledging success		
				Fledglings seen	Max number estimated to have fledged	Fledging success range
Waiau Toa/Clarence River	CA	10	18	0	1	0-6%
	CB	10	19	14	15	74-79%
	CC	7	13	0	2	0-15%
	CD	6	10	6	8	60-80%
	CE	11	19	2	6	11-32%
	CF	10	16	8	15	50-94%
	CG	11	19	8	15	42-79%
	CH	37	60	25	40	42-67%
	CI	18	29	17	27	59-93%
	CJ	1	1	0	1	0-100%
	CK	0	0	0	0	0%
	CL	0	0	0	0	0%
Acheron River	AA	43	63	43	60	68-95%
	AB	0	0	0	0	0%
Combined total		**164**	**267**	**123**	**190**	**46-71%**

Chicks that hatched on islands had the greatest chance of fledging with 115 chicks observed to have fledge both within and out of the treatment zone (Table 16) . A larger percentage of chicks fledged on islands outside of the treatment zone this season. However, chicks that hatched on the mainland within the treatment zone, had a 17-42% higher chance of fledging compared to outside of the treatment zone where zero chicks hatched/fledged (Table 16).

Table 16. Black-fronted tern fledging success on island and mainland colonies within and out of the treatment zone on the Waiau Toa/Clarence and Acheron Rivers in 2021/2022.

Zone	Colony Location	Individual Chicks Hatched	Fledging success		
			Fledglings seen	Max number estimated to have fledged	Fledging success range
Trapping	Island	46	22	30	48-65%
	Mainland	59	10	25	17-42%
	Total	**105**	**32**	**55**	**30-52%**
No Trapping	Island	181	93	141	51-78%
	Mainland	0	0	0	0%
	Total	**181**	**93**	**141**	**51-78%**

Of the 265 chicks that hatched, 15 chick fatalities were observed (Table 17).

On island colonies within the treatment zone, the only observed cause of chick death was heat exhaustion where two newly hatched chicks were found dead in their nest. On mainland colonies within the treatment zone, chick fatalities were due to a cat predation event on one colony which was caught on camera. One other chick was observed on camera to hatch with lame legs and was unable to correct itself after falling over on its back.

Outside of the treatment zone (non-treatment zone), three chicks were subjected to predation while another three died of heat exhaustion. Two other chicks were seen running into the river during a colony check and were unable to be saved before being washed down the rapids and beyond.

Table 17. Reasons for chick fatalities within treatment and non-treatment zones throughout the 2021/2022 breeding season on the Waiau Toa/Clarence River.

Zones	Individual chicks hatched	Causes of chick death		
		Predation	Heat exhaustion	Other
Treatment Island colonies	44		2	
Treatment Mainland colonies	40	4		1
Non-treatment colonies	181	3	3	2
Combined Total	**265**	**7**	**5**	**3**

3.5 Chick shelter use

Approximately 30 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 29). Larger chicks were also seen coming in to use the shelters throughout the day.

Chick shelters that did not have cameras monitoring their use, often instead had remaining chick poo underneath the shelter upon removal, implying that the shelters were being used (Figure 30).

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 River recorded ground temperatures of 40+°C on consecutive days in December and January with the highest known temperature reaching 49°C on the Acheron River at colony AA. Large chicks were also seen using the chick shelters during heavy rain at temperatures of around 8°C.

No observations were made of chicks using shelters to escape predators; however this would be hard to capture without the use of video footage. Throughout this season, cameras were set to take 3 photos at each trigger to save space on camera cards.

Other species including banded dotterels and pipit chicks were also seen using these shelters on occasion (Figure 31).

Figure 29. Nest camera shots of chick shelters (both A-frame design and flat-roof design) in use on the Waiau Toa/Clarence River, 2021/2022.

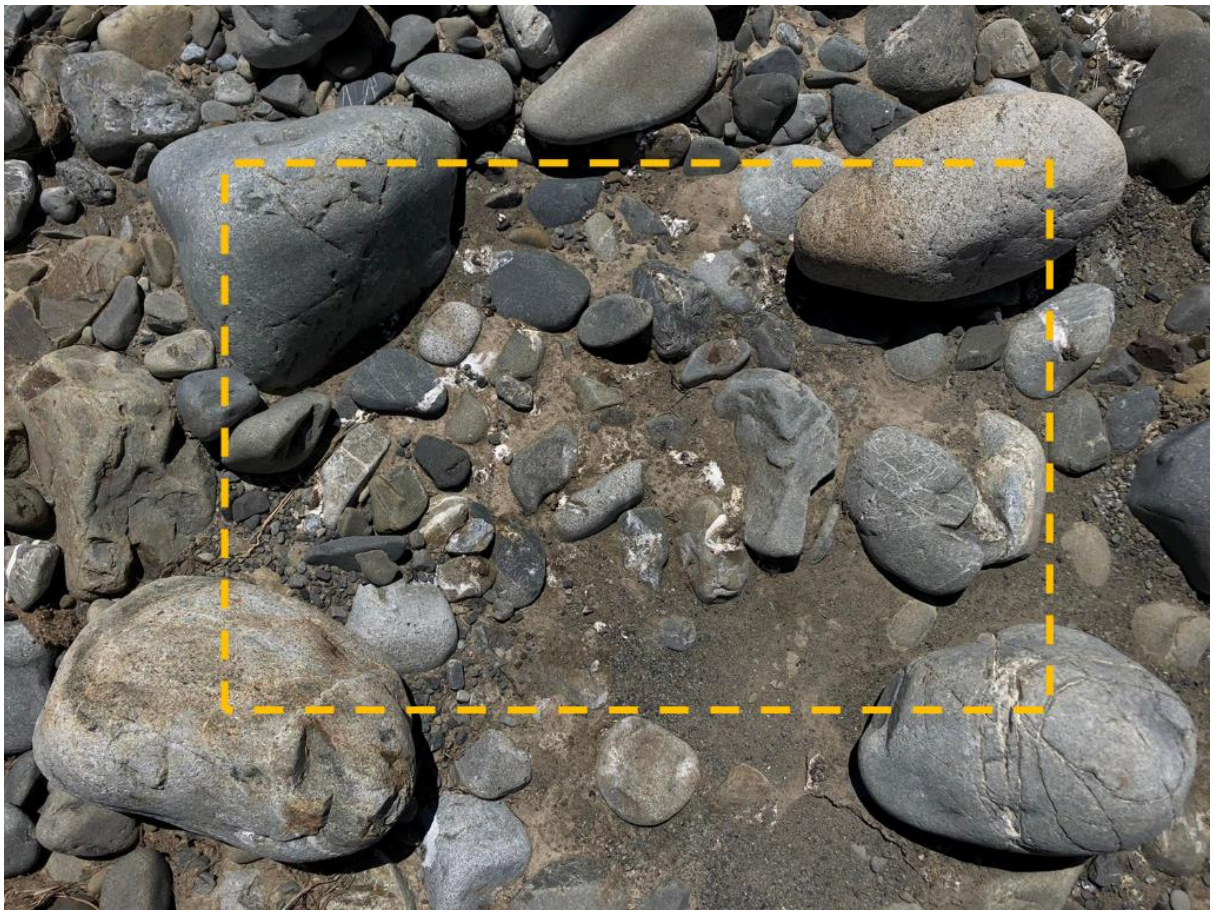

Figure 30. Evidence of black-fronted tern chick droppings underneath previously established flat-roof chick shelter on Waiau Toa/Clarence River, 2021/2022. Note: Initial chick shelter set up is shown by dotted orange lines.

Figure 31. A pipit (left) and banded-dotterel chick (right) also using the unoccupied chick shelter during high temperatures on the Waiau Toa/Clarence River, 2021/2022.

Other chicks that hatched on non-treatment colonies without chick shelters were observed to hide under vegetation or wedge themselves in under rocks in an attempt to cool down (Figure 32).

Figure 32. Black-fronted tern chicks seek shade under woody debris close to nesting site on the Waiau Toa/Clarence River, 2021/2022 (chick in centre of yellow circle).

3.6 Comparison of black-fronted tern breeding seasons between 2015/2016 to 2021/2022

A comparison between the previously monitored black-fronted tern seasons on the upper Waiau Toa/Clarence and Acheron Rivers has been made. This takes into consideration all the outcomes of known egg-fate nests on Waiau Toa/Clarence and Acheron Rivers between October 2015 and January 2022 (excluding 2020/2021 due to no monitoring being carried out).

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 black-fronted tern breeding success. For this reason, these results should be determined as minimum percentages for each outcome.

In comparison to all six seasons, the 2021/2022 season has been most successful for non-treatment colonies with the highest hatching percentage (78%) and observed fledging productivity (0.62) on non-treatment colonies (Table 18, Table 19 & Figure 33).

The 2021/2022 season also had the second highest hatching success percentage (53%) but third lowest observed fledgling success (0.33) (Table 18, Table 19 & Figure 33).

Across all seasons, 2016/2017 saw the highest hatching success (56%) and observed fledgling success (0.96) within treatment colonies where 145 fledglings were counted (Table 18 & Table 19).

Table 18. Apparent (observed) black-fronted tern nest success rates on the upper Waiau Toa/Clarence and Acheron Rivers, 2015-2022 (Note: 2016/17 season data includes only upper Waiau Toa/Clarence nests due to the Kaikoura earthquake). Blue season colouring represents the start of the second five-year study.

		2015/16	2016/17	2017/18	2018/19	2019/20	2021/22
Treatment	Known-fate nest total	91	151	98	106	18	92
	Hatching probability	26%	56%	45%	23%	44%	53%
Non-treatment	Known-fate nest total	286	227	411	442	249	149
	Hatching probability	44%	40%	45%	31%	27%	78%

Table 19. Fledging success of black-fronted terns on upper Waiau Toa/Clarence and Acheron Rivers 2015-2022. Blue season colouring represents the start of the second five-year study.

		2015/16	2016/17	2017/18	2018/19	2019/20	2021/22
Treatment	Number of nests monitored	91	151	98	106	18	92
	Fledglings seen	7	145	58	22	4	30
	Productivity	0.08	0.96	0.6	0.59	0.22	0.33
Non-treatment	Number of nests monitored	286	227	411	442	249	149
	Fledglings seen	24	55	104	120	10	93
	Productivity	0.08	0.24	0.25	0.27	0.04	0.62

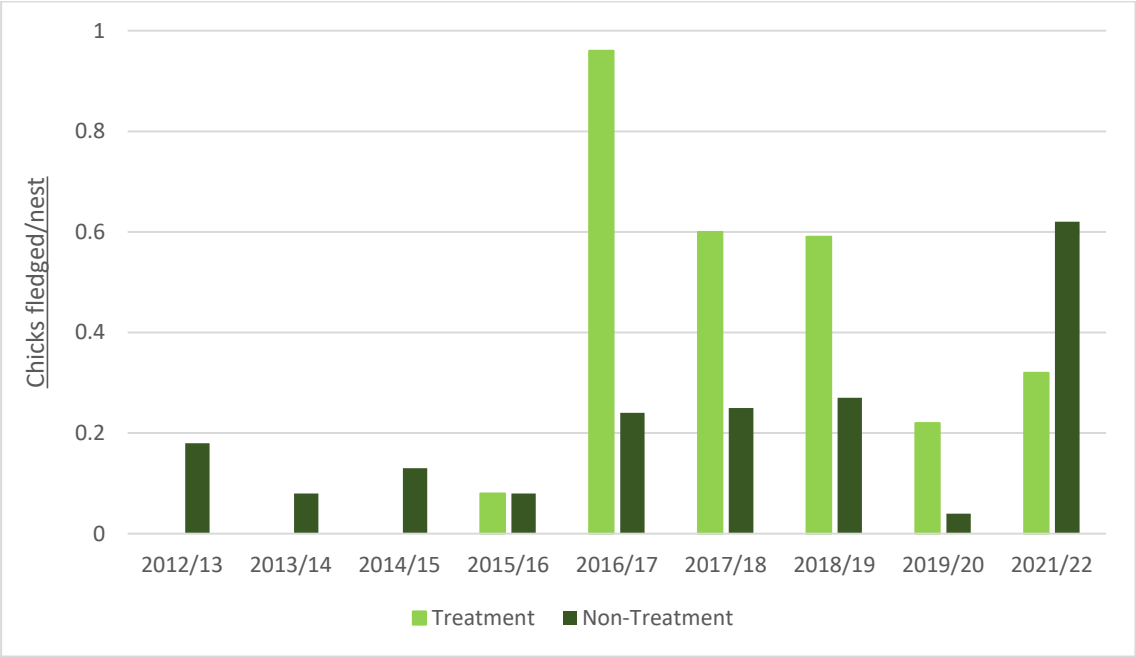

Figure 33. Comparison of fledging success between treatment and non-treatment colonies on the upper Waiau Toa/Clarence and Acheron Rivers 2012-2022.

The main cause of failure across all seasons on both treatment and non-treatment colonies was predation, except during the 2015/2016 and 2020/2021 seasons where failure due to abandonment was 1-4% higher than failure due to predation on treatment colonies (Figure 34 & Appendix 7). 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 2019/2020 where 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 2018/2019 was the only year where flooding of treatment nests greatly outweighed non-treatment colony nests (Figure 34 & Appendix 7).

Throughout the six monitored seasons, predation by kāhu/Australasian swamp harriers was the largest observed cause of nest failure (Appendix 8). Within the treatment zone on islands, feral cats, southern black-backed gulls and black-fronted terns have been the most common nest predators. Each of these species has been observed predating upon nests in multiple seasons (Appendix 8). Hedgehogs and feral cats have been the main observed predator on mainland nests within the treatment zone. Within the non-treatment zone, almost four times more nests were predated (n=163) than within the treatment zone (n=48) (Appendix 8). Kāhu/Australasian swamp harriers, feral 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 8).

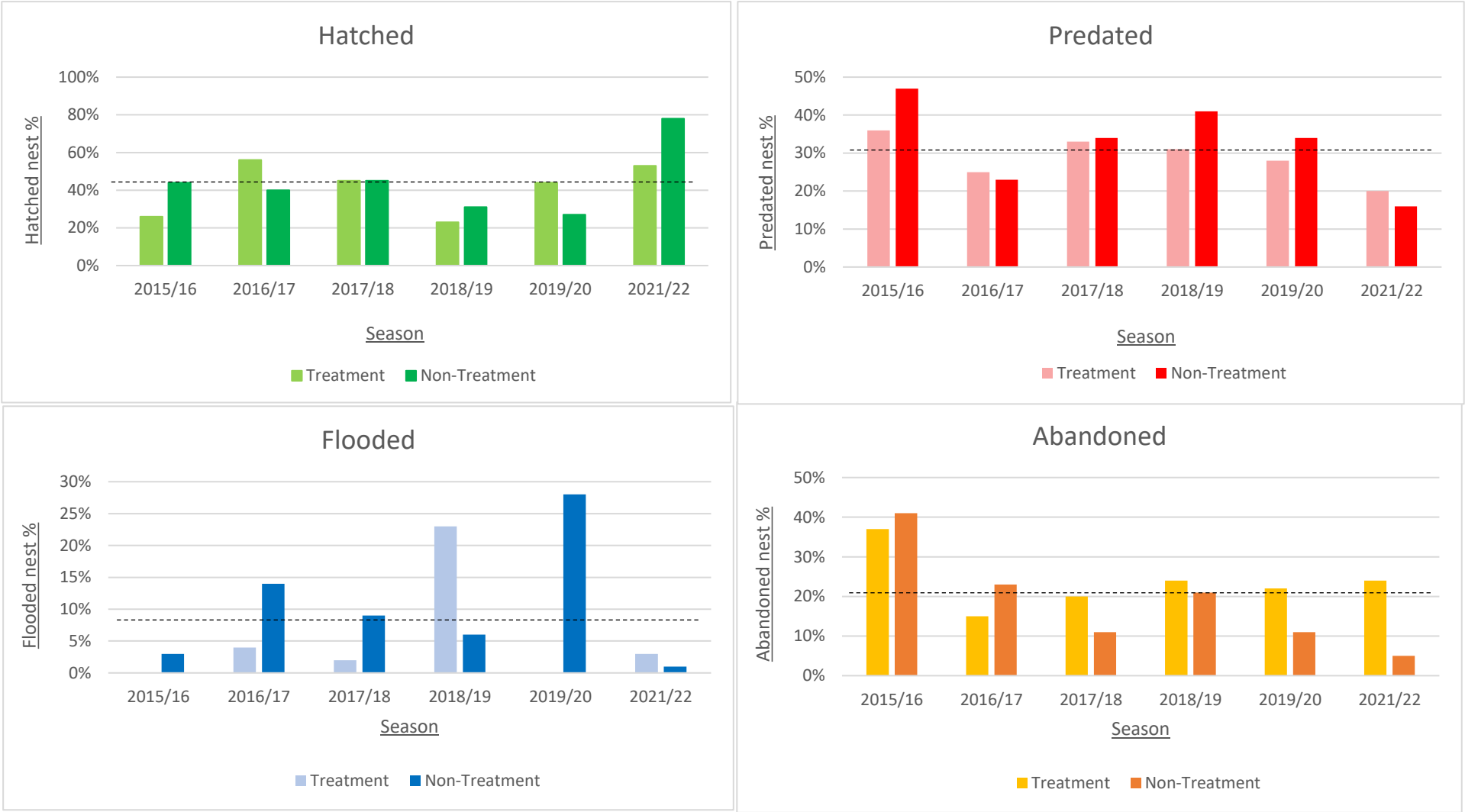

Figure 34. Comparison of combined known-nest outcome percentages from 2015/16 to 2021/22 on the Waiau Toa/Clarence and Acheron Rivers. Black dotted horizontal line indicates the overall average percentage for each outcome.

3.6.1 Spatial difference in breeding success

Within the colonies on the Waiau Toa/Clarence River there is a correlation between hatching success and distance from the trapping line (Figure 35). Pooling data from all seasons, hatching success at colonies within 10 km of a trapping area (mean 39%, n=33) is higher than at colonies further than 10 km from a trapping site (mean 33%, n=22).

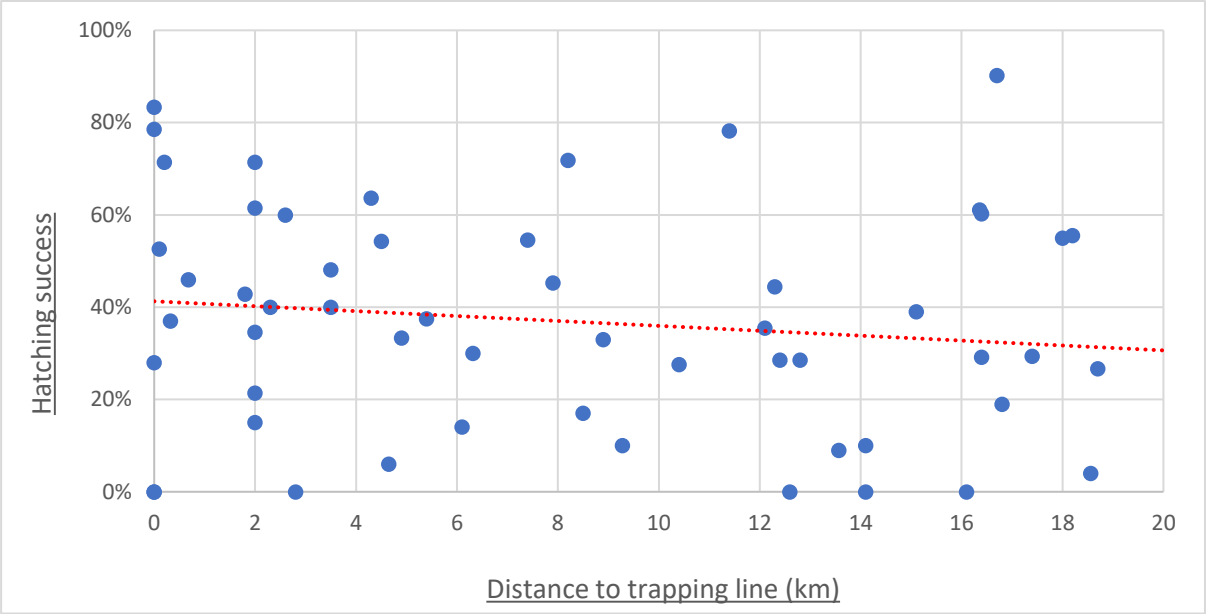

Figure 35. The relationship between hatching success and distance to nearest trapping networks in black-fronted tern colonies on the upper Waiau Toa/Clarence River 2015-2022.

Results gathered from each of the five seasons (2015 – 2022) show a positive relationship between the distance from trapping networks and percentage of nests predated on at various colonies (Figure 36). Out of the six colonies that were further than 28km from the nearest trapping network, all of them had predation rates between and including 50 – 100%. Of the 40 colonies less than 10km from the nearest trapping network, 30 had nest predation rates less than 40% (Figure 36).

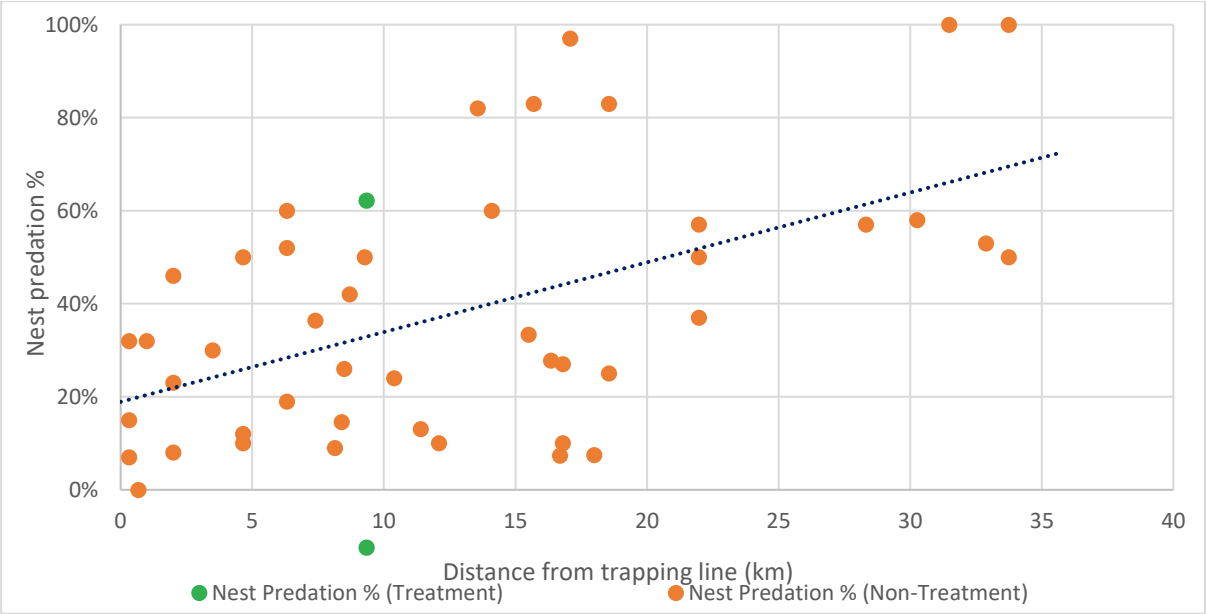

Figure 36. The relationship between the percentage of nests predated and distance to nearest trapping networks in a proportion of black-fronted tern colonies from 2015/2016 to 2021/2022 along the upper Waiau Toa/Clarence and Acheron Rivers.

3.7 Banding and resighting

3.7.1 Adult banding

During the weekend 20-21 November 2021, banding at five different colonies on the Waiau Toa/Clarence River took place. Over these two days, a total of 28 birds were caught and banded (Table 20, Figure 37). Another three birds were caught and banded on the Acheron during the chick banding trip on 22 December 2021.

Table 20. Number and location of newly banded black-fronted terns on the Waiau Toa/Clarence and Acheron Rivers during the 2021/2022 season.

Colony Code	Date of banding		
	20-Nov	21-Nov	22-Dec
CH	11		
CE	9		
CI	2		
CG		4	
CC		2	
AA			3
Total	**22**	**6**	**3**
Combined Total	**31**		

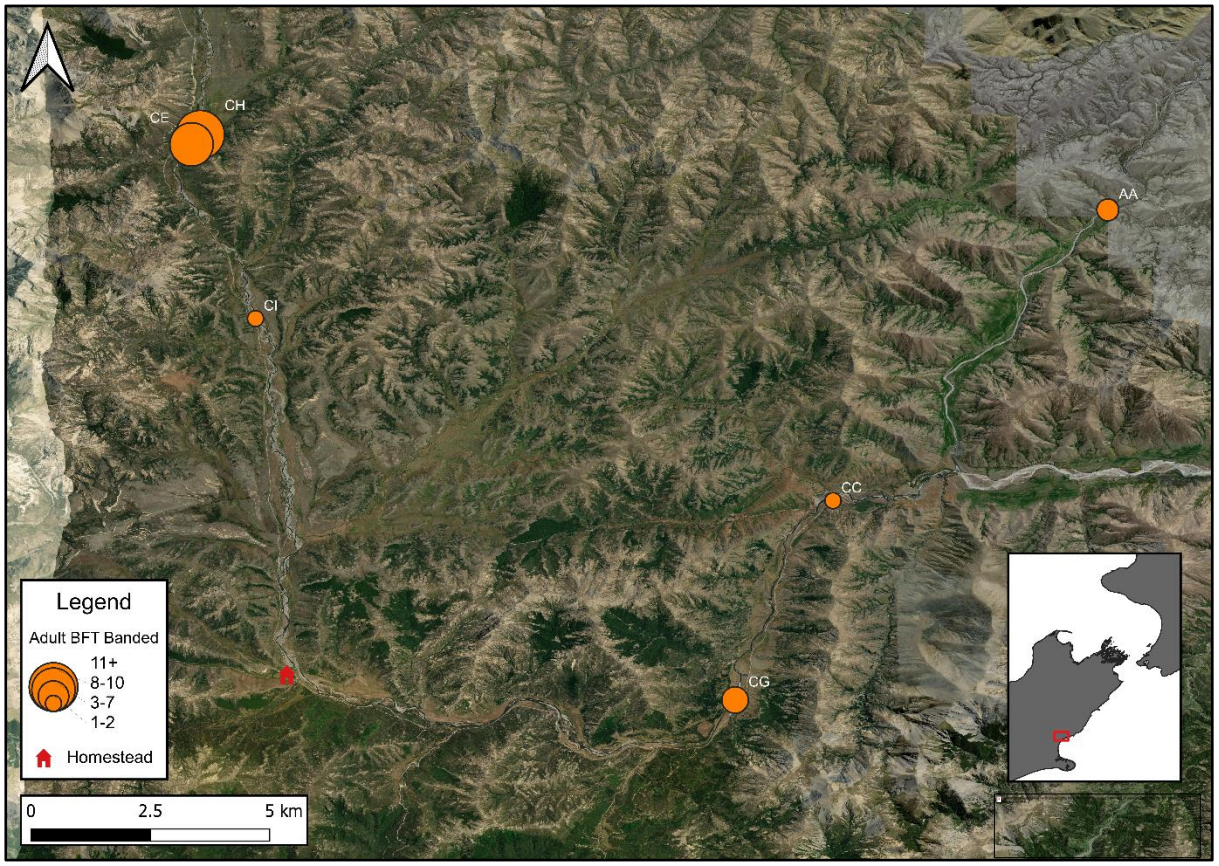

Figure 37. Location and number of black-fronted tern adults banded on the Waiau Toa/Clarence and Acheron River, 20-21 November and 22 December 2021.

3.7.2 Chick banding

Between 21 to 23 December 2021, 18 chicks were caught and banded at four different colony sites (Table 21; Figure 38).

All colonies were checked during this trip, however due to previous chick banding trips being cancelled due to unfavourable conditions and flooding, most chicks had fledged by this stage.

Table 21. Number and location of newly banded chicks during the 2021/2022 breeding season.

Colony Code	Date of banding	
	21-Dec	22-Dec
CI	7	1
CB	4	
CF		2
AA		4
Total	**11**	**7**
Combined Total	**18**	

Figure 38. Black-fronted tern chick being banded at CI colony on the Waiau Toa/Clarence River (left) and the new band on the left tarsus of chick (right).

3.7.3 Band resightings

3.7.3.1 Black-fronted terns

Throughout the 2021/2022 season, 23 previously banded black-fronted terns were resighted with a total of 29 band resightings made (Figure 39). These birds were predominantly nesting on the upper Waiau Toa/Clarence River with three sightings made on the Acheron River and one resighting made on the Waiau River.

Figure 39. Band resightings (EA, NU & TK) caught on nest cameras during the 2021/2022 breeding season on the Waiau Toa/Clarence River.

3.7.3.2 Kāhu/Australasian swamp harriers

Throughout the 2021/2022 black-fronted tern breeding season, no banded kāhu were resighted. Only two kāhu predation events were caught on camera this season, both predations taking place by the same adult kāhu (unbanded). These predation events occurred between Harrier Traps 15 and 16 where five kāhu were captured and banded.

4. DISCUSSION

This is the first year of a second five-year study on the Waiau Toa/Clarence and Acheron River black-fronted tern population. The previous five-year monitoring project involved carrying out localised predator control in the vicinity of three islands on which black-fronted 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 this original five-year project, the successful results of black-fronted terns breeding on enhanced islands highlighted the importance of engineering more islands along the Waiau Toa/Clarence River. This would allow more suitable nesting habitat and a higher chance at deterring threats. The extended predator trapping line will also minimise predators along a longer stretch of the Waiau Toa/Clarence River.

Within the first year (2021/2022) of the second five-year study, a larger portion of the Waiau Toa/Clarence River was trapped on both sides (26km stretch of river) which formed the new treatment zone area. Six islands were enhanced within the trapped treatment zone, with the goal of facilitating more successful black-fronted tern nesting. Chick shelters were also distributed across all colonies within the treatment zone throughout the season one week before chicks were due to start hatching 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 2021/2022 season, island enhancement work was carried out in March 2021 on six different islands on the Waiau Toa/Clarence River (Connor-McClean 2021). This work consisted of clearing, deepening, and widening channels to allow river flow to surround each island, so as to prevent easy access to the islands for predators. Island heights were raised to prevent islands being submerged under high river flow levels during floods, and unnatural material mounds and ridges were levelled out. Each island enhancement was successfully completed and looked favourable for the 2021/2022 breeding season. An additional two islands remained in good condition from previous season enhancements resulting in eight enhanced islands available for the 2021/2022 season.

During the winter period the Waiau Toa/Clarence River was hit with heavy rainfall causing the river flow to spike on three separate occasions. On 31 May 2021 river levels averaged at 150 m^3/sec and 21 June 2021 saw river levels average at 170 m^3/sec. Winter levels peaked on 17 July 2021 with an average of 205 m^3/sec (Figure 13). These river flow rates were the second, fourth and fifth largest flooding

events seen on the Waiau Toa/Clarence River over the past seven years (Appendix 4). The Waiau Toa/Clarence braided river system was drastically changed three times throughout the 2021 winter which also included a complete change in many of the newly enhanced islands.

By the time black-fronted terns started arriving to the Waiau Toa/Clarence River around October 2021, only two of the eight previously enhanced islands remained in good condition. Other islands had been completely flattened and excess material had been pushed into the banks, which connected these "islands" to the mainland. This resulted in majority of nesting habitat within the treatment zone being largely connected to the mainland and thus remaining vulnerable to predation events. Whilst one mainland colony (CC) had a 28% hatching success, the whole island was later predated by a feral cat leaving no surviving chicks or active nests. Both remaining enhanced islands (CB & CG) had high rates of hatching success (71-79%), with only one nest predation between the two islands.

4.2 Predator control

4.2.1 1080 drop

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

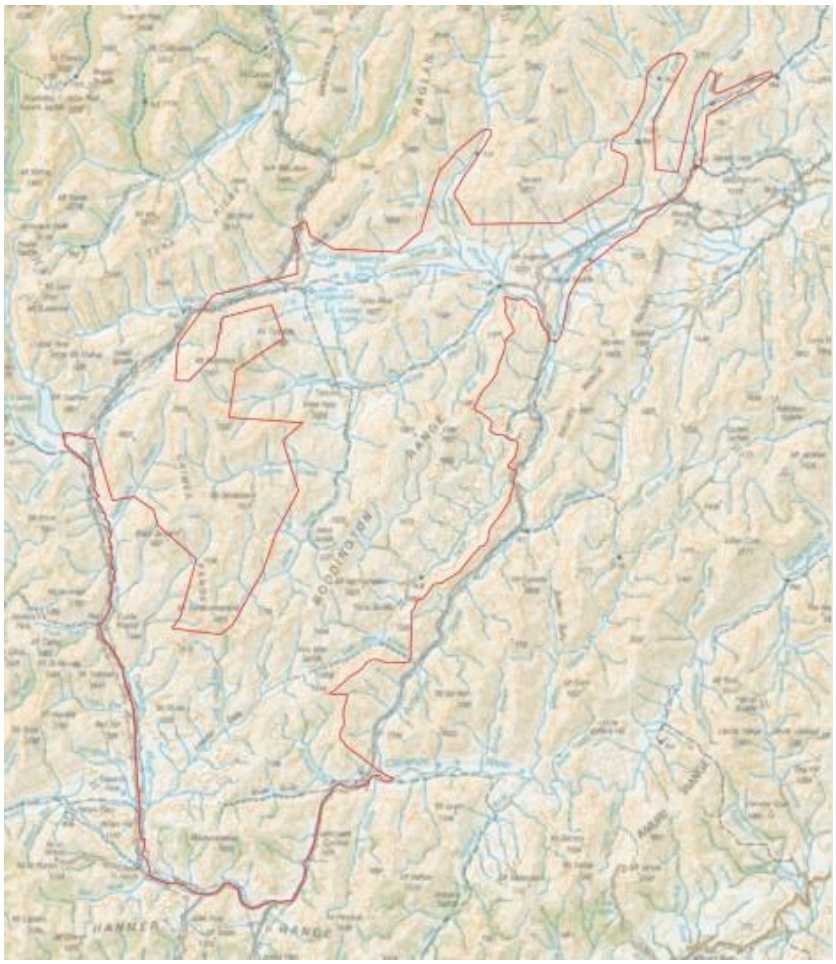

Figure 40. Screenshot of Bush Gully/Tarndale area treated with aerial 1080 on the true left of the Waiau Toa/Clarence River, June 2021. Retrieved from OSPRI 2020.

This 1080 drop may largely have contributed to reduced predator numbers on the true left side of the Waiau Toa/Clarence River and therefore, reduced numbers of nest predations on treatment colonies and non-treatment colonies. For example, colony (CF) within the treatment 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/harrier predations throughout the season compared to previous monitored seasons may also be attributed to the effects of secondary poisoning of 1080.

4.2.2 Predator Trapping

Predation is a significant issue for the long-term survival of black-fronted terns. Trapping for mammalian predators in the upper Waiau Toa/Clarence was established in July 2015 and has been carried out each season from July to January. Kill trapping continues to be successful at removing relatively large number 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).

Prior to the start of the current season, approximately 20 km of traps was installed into the network closing the gap between the previous, 'up-stream' and 'down-stream' sections of the river and extending the network further down-stream. Following the trapping network extension, as expected, the overall total number of mammalian predators caught were higher compared to the previous years (11% increase). However, these numbers were largely dominated by hedgehogs rather than other key predators whereas, captures of mustelids, particularly stoats, were far lower than the previous season (Table 4). Reasons for the drop in mustelid captures might have been due to the 1080 drop that occurred bordering sections of the true left side of the river in June 2021 (see Section 4.2.1). Indeed, captures of stoats, possums, weasels, and ferrets were far lower along the true left side of the trapping network when compared to the true right (Table 3). Furthermore, black-fronted tern colonies occurring on islands connected to the mainland on the true left side of the river (e.g., colony CF) experienced a far higher breeding success. Catch numbers for several key predators typically experience a spike when traps are first opened and checked in July (Appendix 8). This pattern was largely absent across species (Figure 16) pointing to further circumstantial evidence of an effect of the 1080 drop on overall number of predators within the surrounding environs.

Steve Allen 2 traps were incorporated into the trapping network for the first time. Overall, both SA1 and SA2 traps lag behind the DOC series traps (DOC150, DOC200, and DOC250) in overall capture numbers, however, they are still key for targeting larger mammals such as cats, ferrets, and possums (Table 2). Capture rates of SA2 traps were approximately half compared to SA1 traps; however, this discrepancy was largely due to the number of hedgehogs caught by SA1 traps. Whilst accounting for hedgehog captures, SA2 traps were largely on par with the SA1 traps in terms of larger mammals (cats, possums, and ferrets) caught (Table 2).

4.3 Black-fronted tern breeding success

The 2021/2022 breeding season has been a very successful start to the second five-year study instigated on the Waiau Toa/Clarence/Acheron Rivers. The initial nesting phase of the black-fronted tern season started off smoothly with the majority of nests being laid between 22 October and 14 November following a spring flood with peaked on 18 October 2021. This laying period was consistent with no further flooding events until 17 November where the river flow rate averaged at 30 m^3/second. This flooding event had no effect on nest outcome and chicks continued to hatch around this period with most nests having hatched by December. One flooding event over 15-16 December reached an average river flow rate of 44.5 m^3/sec, however by this stage, many chicks were large enough to get to higher ground away from the water's edge and mostly survived the flood. This largely undisturbed period of nest laying, and hatching, saw chicks having fledged as early as 14 December 2021.

While the definition of "treatment zone" differs between the two five-year studies (refer to introduction), the rate of hatching success within the treatment zone during the 2021/22 season was still the second highest (53% hatching success) out of the previous five monitored seasons. This was a

surprising result considering over half of these nests were situated on the mainland whereas in previous seasons, treatment islands only included three enhanced islands surrounded by a trapping grid (Connor-McClean & Bell, 2019/20). The 2021/22 season also saw nests within the treatment zone having the lowest nest predation outcomes (20%) which is 9% lower that the six year nest predation average (Appendix 7).

Fledgling success within the treatment zone was moderate in comparison to other season outcomes, with a productivity of only 0.33/nest. This was largely due to the change in "treatment zone" definitions between the two 5-year projects colonies where mainland colonies within the trapped zone are now included. Fledging outcomes on the mainland were rather unsuccessful this season as a result of predation events that occurred after nests had hatched.

Hatching success within non-treatment zones was the highest in comparison to previously monitored seasons with a 78% hatching success rate. The second highest hatching success rate occurred in 2017/2018 at a rate of 45%. Non-treatment colonies also had the lowest nest predations rates (16%) and lowest number of flooded nests (1%). This was largely due to non-treatment colonies establishing on very robust, suitable islands with raised heights and strong river channels surrounding the islands allowing nests to avoid predation and flooding. This 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.[1]

Fledgling success within non-treatment zones followed a similar pattern with a productivity of 0.62/nest. This doubles the second highest productivity outcome of 0.27/nest which occurred in 2018/2019.

One factor to make note of was the number of chicks at the water's edge during checks. If chicks were not already at the water's edge feeding upon arrival, many would run to the water's edge at the presence of the observer. Many chicks would get in the water as the observer carried out nest checks (even at 20+ meters away). Depending on the river flow strength, many would be carried downstream in the currents and light rapids and had to be chased and rescued before they hit the rapids. This could also scare other unseen chicks within the area, causing them to also jump into the water. A total of nine large chicks were seen being carried downstream. Of these, six were rescued and released away from the water's edge, two were seen getting out on the mainland side and scurrying off into the long grasses, and one could not be saved before being whisked down the larger rapids and away downstream. Upon arriving to some colonies, large chicks were found congregating at the water's edge (13+) and therefore the decision was made to postpone the colony check to ensure that the presence of the observer would not scare this large number of chicks into the water and cause them to be washed away before fledging. By this stage there were only a few remaining active nests with cameras.

4.4 Chick shelters

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

Large rocky islands and sections of mainland exposed to the suns radiation cause intense heat to be generated from these rocks in colonies along the Clarence and Acheron 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 Acheron were regularly reaching 40+°C throughout late December/early January (Figure 43). 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).

[1] Note: a 1080 operation occurred earlier in the year on true left side of the Waiau Toa/Clarence River (see Section 4.2.1).

Chick shelters were put in place on colonies within the treatment zone to trial their use by chicks over the season. Nest camera footage showed that chick shelters were frequently being used throughout the season by chicks (Figure 41) as early as one day old to large chicks with their adult feathers using the shelters on occasion when ground temperatures became too high.

Figure 41. Black fronted tern chick enters shelter 3 hours after hatching as ground temperature reaches 32°C on the Waiau Toa/Clarence River, 2021/2022.

Of the 15 observed chick deaths, five were a result of heat exhaustion. No observed chick fatalities occurred at nests with chick shelters. It was also noted that majority of chick fatalities as a result of heat exhaustion occurred towards the end of the season (10-11 January). By this stage, many chicks had fledged. A large proportion of chicks hatched in earlier months (November), when temperatures were milder and more manageable. Many chicks managed to escape the harsh temperature conditions that occurred towards the end of the season or found enough shade to cool down (Figure 42). A study of black-fronted tern nesting success on the Hurunui and Waiau River (Connor-McClean & Bell 2021b) saw one colony (HJ) lose 26 out of 54 chicks over the period of 19 days (17 December to 5 January) due to heat exhaustion. This is the same time period of when ground temperatures peaked consistently throughout the 2021/2022 season and highlights the importance of available shade to chicks.

Figure 42. Black-fronted tern chick trying to cool down in the shade of a rock cairn during 38°C temperatures on the Acheron River, 2021/2022.

Figure 43. High nest camera temperatures recorded in the Acheron at colony AA on different days during the 2021/2022 season. A high of 49°C was reached on 10 January 2022.

4.5 Bird banding and resighting

4.5.1 Banding

A total of 49 black-fronted terns (31 adults, 18 chicks) were banded on the Waiau Toa/Clarence and Acheron Rivers during 2021/2022. This occurred over 4 days. Banding was limited this season due to a lack of suitably qualified personnel (i.e. Level 3 trainers) and weather windows. In upcoming seasons, monitoring staff will be appropriately qualified so that black-fronted tern banding can be carried out throughout the season during colony checks, allowing a larger proportion of birds to be caught and banded.

4.5.2 Band resighting

Throughout the 2021/2022 season, 29 black-fronted tern band resightings were made (excluding all newly banded birds throughout the season). No banded kāhu/harriers 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/harriers 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. Further kāhu banding should be carried out in order to increase the sample size focusing particularly in areas where black-fronted tern nest predations by kāhu are known to occur. Banding kāhu between July and October could also allow for a more localised population present throughout the winter and summer season to be captured and banded.

4.6 Observations and trends

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

- To date, trapping has prevented ferret and stoat predation on treatment islands/mainland. This suggests that these predators can be suppressed to levels which positively benefit black-fronted terns.
- Within the second 5-year project, the new trapping line design has successfully prevented island and mainland hedgehog nest predations, and has increased hedgehog numbers caught in traps annually. In the past six monitored years, whilst mainland nest predations have occurred, no nests on islands have been predated by hedgehogs, suggesting that the trapping alone may not completely eliminate the impacts of hedgehogs on the mainland, but island creation does.
- Feral cat predation has occurred on treatment island/mainland nests along with enhanced islands. This highlights that feral 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 feral cat reaching the islands have caused numerous nest failure events highlighting the impacts that a single predator which avoids traps can have on the overall success of a treatment site.
- Kāhu/Australasian swamp harrier predation drastically reduced this season after the application of 1080 along the Waiau Toa/Clarence River. Only one kāhu was caught on camera predating two nests this season. This compares to 2017/2018 where 16 kāhu predation events on nests were caught on camera.
- Whilst 41 kāhu were banded in 2021, most (n=27) were juveniles or less than 2 years old. During the 2021/2022 season, only one un-banded adult kāhu was observed predating nests. This suggests that kāhu predating nests is a learned behaviour that has been picked up over the last few years as no younger harriers were observed predating black-fronted tern nests.

- Chicks regularly used chick shelters to escape extreme temperatures and rain. No chicks in nests with chick shelters nearby died of heat exhaustion.
- No observations were made of chicks using shelters to escape avian or mammalian predation, however they would wedge themselves into the nearest rock or vegetation during nest checks.
- A decline in mammalian predation has been observed over the last three seasons. This corresponds to a steady increase in river flow or robust island use surrounded by wide, flowing channels. 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.
- Nests that are still active towards the end of the season (December- January) have a large risk of predation by southern black-backed gulls. In 2019/2020 and 2021/2022, it was noticed that southern black-backed gull predation began to occur in December and a few birds were seen flying up and down the Waiau Toa/Clarence River searching for eggs. Colonies that hatched chicks earlier in the season appeared safer from predation by southern black-backed gulls. Southern black-backed gulls were the top observed predator in 2019/2020 despite only being observed predating nests towards the end of the breeding season.
- 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. This suggests that these nest predations have also become a learnt behaviour by a few southern black-backed gulls that are seen cruising up and down the Waiau Toa/Clarence River around December- January, after a typical southern black-backed gull breeding season has finished.

4.7 Recommendations

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

4.7.1 Island Enhancement

- 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 the winter cause these enhancement works to be significantly altered or completely destroyed. Island enhancements should be carried out towards the end of the winter period, prior to 15 September to maximise the success and survival of black-fronted 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 in order to avoid leaving dead, standing vegetation on the islands.
- Chick shelters should be placed in 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 an accurate complete black-fronted tern population count, and certainty that all colonies along the Waiau Toa/Clarence and Acheron Rivers have been found.

- The use of a pack raft is continued to get to islands/colonies that are not crossable 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 black-fronted tern nesting success is continued to determine breeding success and population estimates.

4.7.3 Banding and resighting

- This project continues to collaborate with and work in conjunction with the DOC black-fronted tern tracking project (Project Lead: Emma Williams) to gain a greater understanding of black-fronted tern feeding patterns throughout the season, and roosting locations along with wintering destinations.
- Kāhu/Australasian swamp harrier 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 winter and summer to ensure localised kāhu are captured and banded.
- Black-fronted tern banding should be continued to help achieve more information on distribution patterns and pairings.
- Black-fronted tern chick banding should be continued to help gauge fledgling survival rates in future years.
- Additional nest cameras are established at each colony and rotated through the area in order to re-sight a larger percentage of banded birds (both black-fronted terns and kāhu) within the colonies.

4.7.4 Predator suppression

- Consideration for the use of 1080 drops on both sides of river to reduce predators within proximity to the Waiau Toa/Clarence River prior to the black-fronted tern breeding season.
- Nocturnal-only 10-day leg hold trapping periods to target feral 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.
- Extend trapping checks into February when increased numbers of kittens/young cats and mustelids (as well as hedgehogs) are being caught. This could help reduce impacts of cat and mustelid predations on black-fronted terns in future seasons.

5. LIMITATIONS

- Pack rafting required a second safety person to be on site which wasn't always easy to organise due to a lack of available personnel. This made planning for river surveys and island commute trips difficult to keep consistent and a couple of colonies could not be regularly surveyed because of this.
- Observers assigned to this project only obtained a Level 1 banding license for this season, so all banding had to be monitored by a Level 3 bander which was difficult to find over the busy summer season. A minimal number of chicks were banded as most had fledged by the time a Level 3 bander could attend.
- 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 being completely wiped out with the only remaining monitored nest being untouched.

6. ACKNOWLEDGMENTS

Thanks to Environment Canterbury (ECan), Department of Conservation (DOC) and Land Information New Zealand (LINZ) for funding this project. We also appreciate the contributions and proactive efforts of DOC, especially Patrick Crowe and Ellery Mayence and Boffa Miskell especially Sian Reynolds for effectively co-managing this project.

Field work and monitoring of nests was able to run smoothly with the assistance of other WMIL staff members and several volunteers.

Predator trapping, including establishing the extended trap lines and fortnightly checks between July and January was completed by a number of WMIL personnel.

Thanks to Mike Bell (Toroa Consulting) and Patrick Crowe (DOC) who gave their time to help supervise black-fronted tern banding and kāhu banding.

Thanks to Jim Ward (Molesworth Station) and Kelvin (Baldy) Jones (Hossack's Station) for permission to carry out this project and placement of traps on Hossack's Station.

Amuri Helicopters assisted with trap establishment (bulk trap movements) and the black-fronted tern nest survey along the rivers.

Bill Lott assisted with the island enhancement work.

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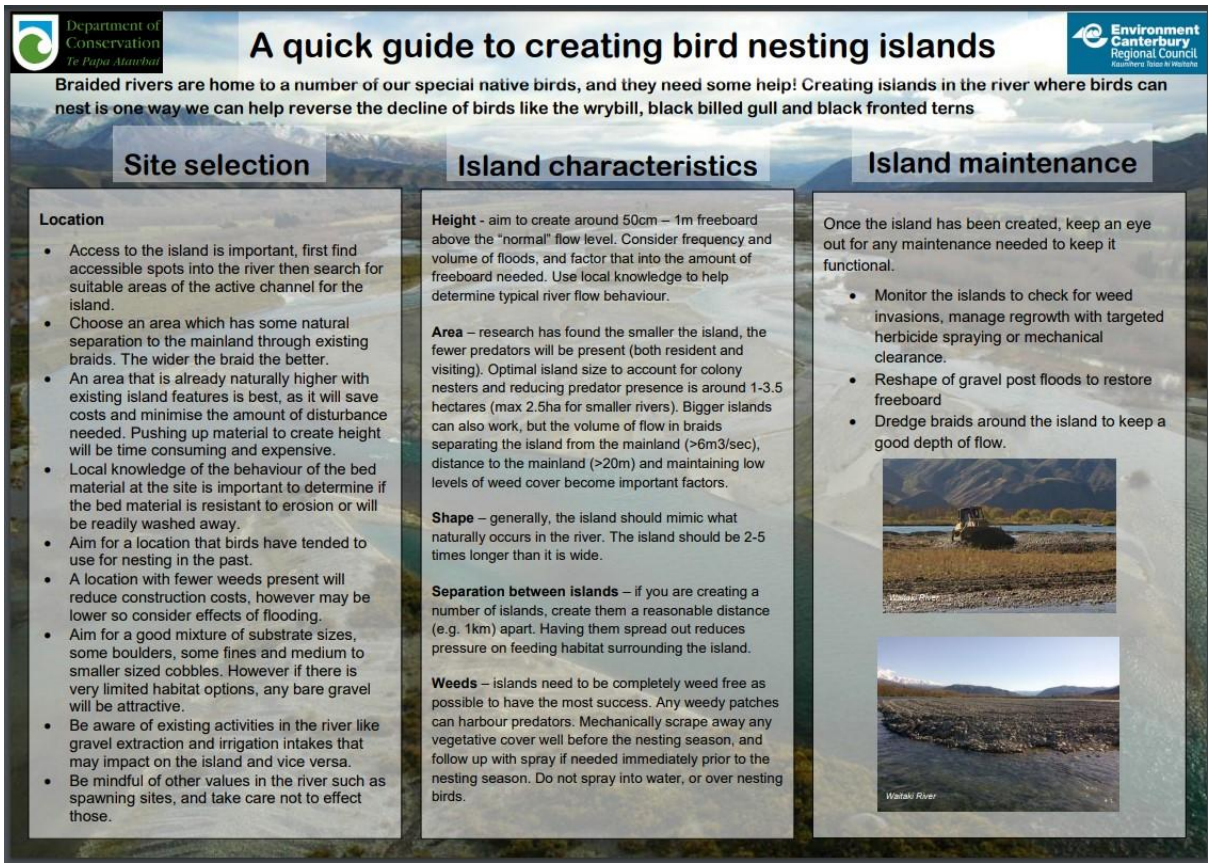
8. APPENDICES

8.1 Appendix 1: Island Enhancement Guidelines



Department of Conservation Te Papa Atawhai

A quick guide to creating bird nesting islands

Environment Canterbury Regional Council Kaunihera Taiao ki Waitaha

Braided rivers are home to a number of our special native birds, and they need some help! Creating islands in the river where birds can nest is one way we can help reverse the decline of birds like the wrybill, black billed gull and black fronted terns

Site selection

Location

- Access to the island is important, first find accessible spots into the river then search for suitable areas of the active channel for the island.
- Choose an area which has some natural separation to the mainland through existing braids. The wider the braid the better.
- An area that is already naturally higher with existing island features is best, as it will save costs and minimise the amount of disturbance needed. Pushing up material to create height will be time consuming and expensive.
- Local knowledge of the behaviour of the bed material at the site is important to determine if the bed material is resistant to erosion or will be readily washed away.
- Aim for a location that birds have tended to use for nesting in the past.
- A location with fewer weeds present will reduce construction costs, however may be lower so consider effects of flooding.
- Aim for a good mixture of substrate sizes, some boulders, some fines and medium to smaller sized cobbles. However if there is very limited habitat options, any bare gravel will be attractive.
- Be aware of existing activities in the river like gravel extraction and irrigation intakes that may impact on the island and vice versa.
- Be mindful of other values in the river such as spawning sites, and take care not to effect those.

Island characteristics

Height - aim to create around 50cm – 1m freeboard above the "normal" flow level. Consider frequency and volume of floods, and factor that into the amount of freeboard needed. Use local knowledge to help determine typical river flow behaviour.

Area – research has found the smaller the island, the fewer predators will be present (both resident and visiting). Optimal island size to account for colony nesters and reducing predator presence is around 1-3.5 hectares (max 2.5ha for smaller rivers). Bigger islands can also work, but the volume of flow in braids separating the island from the mainland (>6m3/sec), distance to the mainland (>20m) and maintaining low levels of weed cover become important factors.

Shape – generally, the island should mimic what naturally occurs in the river. The island should be 2-5 times longer than it is wide.

Separation between islands – if you are creating a number of islands, create them a reasonable distance (e.g. 1km) apart. Having them spread out reduces pressure on feeding habitat surrounding the island.

Weeds – islands need to be completely weed free as possible to have the most success. Any weedy patches can harbour predators. Mechanically scrape away any vegetative cover well before the nesting season, and follow up with spray if needed immediately prior to the nesting season. Do not spray into water, or over nesting birds.

Island maintenance

Once the island has been created, keep an eye out for any maintenance needed to keep it functional.

- Monitor the islands to check for weed invasions, manage regrowth with targeted herbicide spraying or mechanical clearance.
- Reshape of gravel post floods to restore freeboard
- Dredge braids around the island to keep a good depth of flow.

Waitaki River

Figure 44. 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 22. Location and size of enhanced islands, and works that took place along the Waiau Toa/Clarence River, 2021.

River	Code	Site	Easting	Northing	Area (m^2)	Island enhancements
Waiau Toa/Clarence River	C1	Bush Gully	E1585585	N5300229	5,600m^2	Bank of true left side of island raised and strengthen taking material from the channel, ridge mound along true right side of the island was levelled off to look more natural.
	C2	Cow Island	E1585687	N5300076	12,000m^2	Channel along true left side of island was cleared of emerging "stepping-stones," widened and deepened, excavated material used to build up island bank and slightly raise the island in various sections, upper left tip of island was raised.
	C3	Fisherman's	E1586106	N5299762	16,800m^2	True left channel was cleared from obstructions, widened, deepened and unblocked, banks of island were raised and strengthen, banks of mainland stabilised to prevent erosion.
	C4	Swimming Hole	E1589007	N5299776	10,800m^2	Two unnaturally large mounds from previous island enhancement work were levelled out to a more natural height, covering of vegetation was started, however soon stopped due to uncovering sediment and removal of river gravel layer.
	C5	Upper Swimming Hole Island	E1589973	N5298545	1,600m^2	Channel was widened and deepened along true left side of island, material from the channel was used to raise height of island to 1m.
	C5a	Upper Swimming Hole	E1594957	N5305985	16,800m^2	Old pre-existing channel was widened to a minimum of 2m and cleared of large grassy mounds and other obstructions, entrance was widened and deepened.

8.3 Appendix 3: Browning Dark Ops Pro XD (BTC-6PXD) trail camera settings.

Table 23. Browning Dark Ops Pro XD (BTC-6PXD) trail camera settings used for black-fronted tern nest monitoring, 2021/2022.

Camera Settings	
Time & Date	Set to correct time and date
Mode	TRAIL
Capture Delay	20s
Picture Size	Medium 10 MP
Multishot	3-SHOT STANDARD
Video quality	N/A
Video length	N/A
Smart IR video	OFF
Adjustable IR Flash	Power save
Timelapse	OFF
Temperature units	Celsius
Info strip	ON
SD card management	ON
Delete All	Use each time to re-enter cleared SD card ready for use

8.4 Appendix 4: River flow comparison 2015-2021.

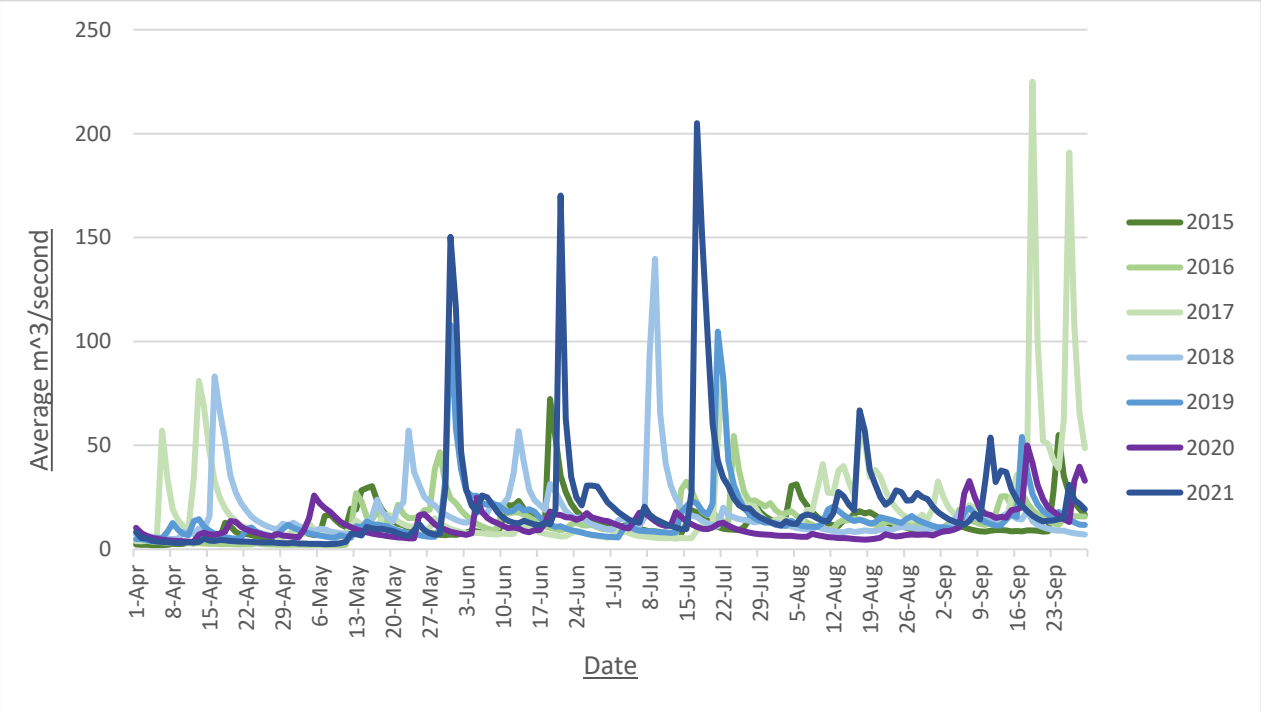


Figure 45. Comparison of average winter daily river flow rate (m^3/second) on the Waiau Toa/Clarence River from 1 April to 30 September each year (2015 to 2021).

8.5 Appendix 5: Locations of colonies found during helicopter survey

Table 24. Locations of black-fronted tern colonies found within the helicopter survey carried out on 8 November 2021 along the Waiau Toa/ Clarence and Acheron Rivers. Included are the start and end locations of the survey. Note, absent breeding colony codes refer to colonies that weren't monitored during the season.

River	Colony GPS Code (Survey)	Active Breeding Colony Code	Co-ordinates	
			Latitude	Longitude
Waiau Toa/ Clarence River	**Start Location**	**-**	**-42.212456**	**172.739154**
	1	CH	-42.306856	172.774631
	2	CE	-42.309326	172.772431
	3	CI	-42.35365	172.788724
	4	CD	-42.387375	172.794212
	5	-	-42.403529	172.797074
	6	-	-42.408734	172.798667
	7	CA	-42.452663	172.825447
	8	CB	-42.454784	172.831413
	9	CG	-42.450755	172.910912
	10	CF	-42.425992	172.918924
	11	CC	-42.400015	172.935868
	12	-	-42.395639	172.971023
	End Location	**-**	**-42.393374**	**173.063736**
Acheron River	**Start Location**	**-**	**-42.392573**	**172.968208**
	A	AA	-42.325981	173.005878
	B	-	-42.281217	173.044901
	C	AB	-42.269131	173.057932
	End Location	**-**	**-42.140908**	**173.096609**

8.6 Appendix 6: Monitored colony details, descriptions, and locations, 2021/2022.

Table 25. Monitored colony details, descriptions, and locations on the Waiau Toa/Clarence and Acheron Rivers, 2021/2022.

Colony name	Colony Code	River	Zone	Island/ Mainland	Enhanced	NZTM Easting	NZTM Northing	Distance from trapping line	Start date	End date	Description/Notes
Upper Swimming Hole	CA	Clarence	Treatment	Island/ Mainland	Yes	E1585685	N5299800	0km	22-Oct	29-Dec	All island enhancements washed away in winter flood. New thin island created which had good channels around but no vegetation. Mainland area had vegetation and a lot of space however, entirely connected to mainland.
Swimming Hole	CB	Clarence	Treatment	Island	Yes	E1586098	N5299773	0km	27-Oct	10-Jan	Good sized island with large, fast flowing channels on both sides, good percentage of vegetation.
Upper Bush Gully	CC	Clarence	Treatment	Mainland	No	E1594597	N5305816	0km	22-Oct	13-Dec	Large area of land with good stony terrain connected to the mainland. A small water channel separated the land mass at 30+ cubic meters/second. No vegetation. High banks border the true right side.
Middle Braid	CD	Clarence	Non-treatment	Island	No	E1583253	N5306889	7.4km	3-Nov	29-Dec	Good long island separated by fast flowing water. Some BFT chose to nest on the mainland nearby.
Upper Fowlers	CE	Clarence	Non-treatment	Island	No	E1581224	N5315924	16.36km	3-Nov	11-Jan	Large island with good water flow around island. Vegetation on half the island

Eddy's Inlet	CF	Clarence	Treatment	Mainland	No	E1593387	N5302867	0km	6-Nov	11-Jan	Medium sized land mass connected to the mainland. A steep bank/ cliff borders colony area. Good river gravel terrain.
Mitchell's	CG	Clarence	Treatment	Island	Yes	E1592638	N5300129	0km	6-Nov	11-Jan	Long, thin, raised island with strong channels around island and a strip of vegetation on the downstream end. Otherwise, good nesting gravels.
Top Island	CH	Clarence	Non-treatment	Island	No	E1581415	N5316159	16.7km	13-Nov	21-Dec	Large, raised, vegetated island with strong, wide water channels surrounding island. Very robust island.
Heli Colony	CI	Clarence	Non-treatment	Island	No	E1582615	N5311059	11.4km	14-Nov	11-Jan	Large, raised island with good percentages of vegetation to nesting gravels, surrounded by water flow however some channels are narrow and others low flowing.
Cow Island	CJ	Clarence	Treatment	Island/ Mainland	Yes	E1589973	N5298545	0km	3-Dec	9-Dec	Large section of river gravels and sand connected to mainland with small trickle of running water down the middle. Subjected to incursions.
Lower Mitchell's	CK	Clarence	Treatment	Mainland	No	E1592755	N5300598	0km	13-Dec	16-Dec	Large, gravelled land mass connected to mainland. Little vegetation.
Pocket island	CL	Clarence	Treatment	Island	No	E1592772	N5300266	0km	13-Dec	18-Dec	Very small island (4m squared) separated from mainland by good channels at 2m wide.
Grader island	AA	Acheron	Non-treatment	Island	No	E1600489	N5314022	8.4km	27-Oct	11-Jan	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 by pack raft.
Acheron island	AB	Acheron	Non-treatment	Island	No	E1605012	N5320658	15.5km	8-Nov	24-Nov	Large, vegetated island with gravelled sections, surrounded by river flow.

8.7 Appendix 7: Comparison of nest outcomes 2015/16 to 2021/22.

Table 26. Comparison of known nest outcomes of black-fronted terns between the 2015/16 to 2021/2022 breeding seasons at treatment and non-treatment colonies. Note: colonies on the Acheron River were excluded from 2016/17 data due to Kaikoura earthquake preventing regular checks from taking place.

Zone	Season	Known-fate nests	Hatched		Failed		Cause of Nest Failure					
							Predation		Flooded		Abandoned	
			Number	%	Number	%	Number	%	Number	%	Number	%
Treatment	2015/16	91	24	26%	67	74%	33	36%	0	0%	34	37%
	2016/17	151	84	56%	67	44%	38	25%	6	4%	23	15%
	2017/18	98	44	45%	52	53%	32	33%	2	2%	20	20%
	2018/19	106	24	23%	82	77%	33	31%	24	23%	25	24%
	2019/20	18	8	44%	10	56%	5	28%	0	0%	4	22%
	2021/22	92	49	53%	43	47%	18	20%	3	3%	22	24%
	Total	**556**	**233**	**42%**	**321**	**58%**	**159**	**29%**	**35**	**6%**	**128**	**23%**
Non-Treatment	2015/16	386	126	44%	260	91%	133	47%	9	3%	118	41%
	2016/17	227	91	40%	136	60%	52	23%	31	14%	53	23%
	2017/18	411	187	45%	224	55%	141	34%	36	9%	47	11%
	2018/19	442	137	31%	305	69%	183	41%	27	6%	95	21%
	2019/20	249	66	27%	182	73%	85	34%	70	28%	27	11%
	2021/22	149	116	78%	33	22%	24	16%	1	1%	8	5%
	Total	**1764**	**723**	**41%**	**1140**	**65%**	**618**	**35%**	**174**	**10%**	**348**	**20%**

8.8 Appendix 8: Comparison of observed cause of nest failure.

Table 27. Comparison of observed causes of black-fronted tern nest failure on treatment (island/mainland) and non-treatment colonies along the Waiau Toa/Clarence and Acheron Rivers from 2015/2016 to 2021/2022.

Cause of Failure	Treatment														Non-Treatment						
	Island							Mainland													
Season	15/16	16/17	17/18	18/19	19/20	21/22	**Total**	15/16	16/17	17/18	18/19	19/20	21/22	**Total**	15/16	16/17	17/18	18/19	19/20	21/22	**Total**
PREDATION																					
Kāhu/harrier		1					**1**					1		**1**	9		8	16	1	2	**36**
Feral cat	4		3				**7**			1			4	**5**	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		**6**						1	**1**			9	1	6		**16**
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**	**30**	**0**	**6**	**2**	**1**	**4**	**5**	**18**	**37**	**42**	**32**	**27**	**21**	**4**	**163**
FLOODING			**3**	**17**		**2**	**22**						**1**	**1**	**9**	**13**	**32**	**35**	**74**	**1**	**164**
ABANDONMENT					**4**	**4**	**8**						**17**	**17**					**24**	**8**	**32**
Combined Total	**6**	**5**	**17**	**20**	**6**	**6**	**60**	**0**	**6**	**2**	**1**	**4**	**23**	**36**	**46**	**55**	**64**	**62**	**119**	**13**	**359**

8.9 Appendix 8: Monthly catches for mammalian predators 2015/2016 to 2020/2021

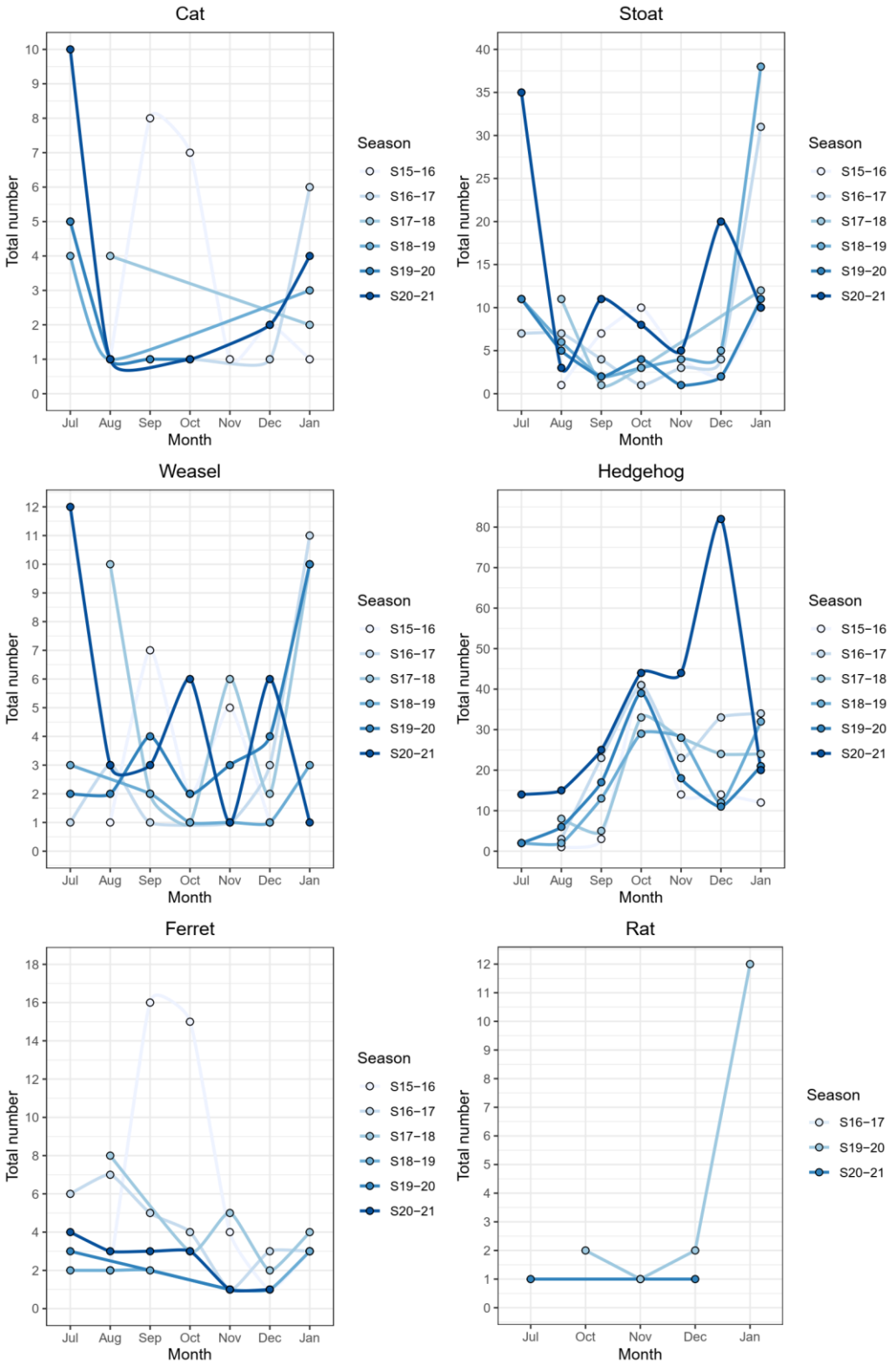


Figure 46. Total number of predators caught per month between July and January each season on the Waiau Toa/Clarence River (2015/2016 to 2020/2021). Points and lines are coloured from light blue to dark blue to visually indicate the change in field season from 2015/2016 to 2020/2021.