Clarence River black-fronted tern restoration project – 2017/2018 operational report.

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Clarence River black-fronted tern restoration project – 2017/2018 operational report.

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Cover Image: Adult black-fronted tern (*Chlidonias albostriatus*) photographed October 2017.

EXECUTIVE SUMMARY

This report summarises the results of the third year of a five-year collaborative project to test a new conservation management regime aimed at improving the nesting success of black-fronted terns on the upper Clarence and Acheron Rivers in Canterbury, New Zealand. The habitat enhancement actions carried out last season at three treatment colonies remained sufficient for the 2017/2018 season, with good flowing channels around the islands as well as clear of woody vegetation. Two significant flood events in September 2017, formed many natural islands clear of vegetation, creating areas of improved black-fronted tern breeding habitat throughout the river system. Predator trapping using a combination of kill traps and leg-hold traps was carried out at these three black-fronted tern colonies, resulting in 492 predators being caught. These included 233 hedgehogs, 83 Australasian harriers, 69 possums, 33 weasels, 30 ferrets, 27 stoats and 17 cats. There was an observed improvement in the breeding success of black-fronted tern at the non-treatment colonies. With the hatching success similar between the treatment (44%) and non-treatment colonies (45%), the treatment colonies fledged significantly more chicks (0.58 chicks/nest), compared to non-treatment colonies (0.24 chicks/nest). In total, 162 black-fronted tern chicks fledged from nests on the upper Clarence and Acheron Rivers during the 2017/2018 season, 58 from treatment colonies and 104 from non-treatment colonies. This stands in contrast to the 31 chicks that fledged from nests during the 2015/2016 breeding season and is only slightly down on the number of chicks that fledged last season. This result may indicate that the combination of predator control and habitat enhancement being carried out at treatment colonies is improving the survival of black-fronted tern chicks. This season two of the three project outcome targets for the project were met, and the combination of island enhancement and predator control being tested in this experiment has led to an improvement in black-fronted tern productivity on the upper Clarence River.

Keywords: Black-fronted tern, *Chlidonias albostriatus,* predator trapping, nest success, MARK, daily nest survival, model selection, trail cameras.

1. INTRODUCTION

The black-fronted tern (*Chlidonias albostriatus*) is ranked as Nationally Endangered under the New Zealand Threat Classification System, with an estimated population of between 5000 and 10000 mature individuals and a predicted rate of decline of around 50% over the next three decades (Townsend et al, 2008; O'Donnell and Hoare, 2011; Robertson et al, 2012).

This ongoing decline is the result of several interacting threats, including depredation by introduced mammals (particularly cats, ferrets and hedgehogs) and habitat loss as a consequence of the invasion of braided river beds by woody weeds (Balneaves and Hughey 1990; Keedwell et al, 2002; Sanders and Moloney, 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 and Hoare, 2011). Several of these 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. These include the Clarence/Acheron/Saxton River system, the Waiau, Hurunui, Ashley, Waimakariri, Rakaia, Ashburton, Rangitata, Tasman, Godley, Cass and Ahuriri Rivers (Forest & Bird, 2014; Forest & Bird 2015).

Between 2012 and 2016 the Department of Conservation and Wildlife Management International Ltd have been monitoring the population trends and breeding success of black-fronted terns on the upper Clarence and Acheron Rivers in the Canterbury region. Over the 2012, 2013 and 2014 breeding seasons, black-fronted tern productivity was very low with the primary reason being predation by introduced mammals (Bell, 2017).

A combined total of 1,510 nests were monitored over the three seasons 2012, 2013 and 2014. During these three seasons the apparent (observed) hatching success was poor with only 42.7% of nests hatching at least one egg. The average fledging productivity was extremely low with 0.13 chicks fledging per nest each year (Bell, 2017). Each season a sample of nests were filmed using motion-activated trail cameras and this work showed that the majority of nest failures were caused by eggs or chicks being depredated by introduced mammalian predators, particularly cats, ferrets and hedgehogs (Bell, 2017).

In response to these results, an intensive 5-year programme of predator trapping, and habitat enhancement has been instigated at three colony sites on the upper Clarence River. Co-funded by the Department of Conservation, Environment Canterbury and the Canterbury Water Management Strategy Kaikoura Zone Committee, this project aims to test whether or not a new combination of localised predator control, weed control and physical habitat enhancement can significantly improve the breeding success of black-fronted terns at island colonies that receive this management (Brown, 2015).

Predator trapping grids were established at three colonies on the upper Clarence River prior to the 2015/2016 season. Habitat enhancement work was carried out prior to the following season, to better form islands at these same three colony sites. Results from the 2016/2017 season observed an improvement in both the hatching success and fledging success between treatment and non-treatment colonies (Bell and McArthur, 2017). This improvement in black-fronted tern's productivity

is a direct reflection of the combined management of pest trapping and habitat enhancement actions carried out.

This report provides a summary of the results of the third season of fieldwork for this project. We report the results of habitat enhancement and predator control work carried out at treatment colonies over the past 12 months, together with black-fronted tern breeding success results for the 2017/2018 breeding season. We also provide a number of recommendations for the 2018/2019 breeding season.

2. METHODS

2.1 Habitat enhancement

In March 2016, a bulldozer was used to carry out a number of tasks aimed at improving breeding habitat for black-fronted terns at each of the three treatment colony sites. This work was carried out under the Resource Consent CRC160509 granted to the Department of Conservation under Section 104 of the Resource Management Act (1991).

Bulldozer work was carried out at Bush Gully and Mitchell's Cutting sites to increase the depth and width of channels, increase the height of the islands and to bury woody vegetation growing on the islands. At the Swimming Hole site, which already had relatively deep and fast flowing channels on either side of the breeding island, the bulldozer work was restricted to removing a heavy infestation of broom (*Cytisus scoparius*) (Bell and McArthur, 2017).

This season no further bulldozer work needed to be carried out on the three treatment colony sites, as they were still sufficient breeding islands from the 2016/2017 season. This included being weed free and having wide and deep surrounding water channels.

Further details and photographic documentation of this habitat enhancement work can be found in previously-circulated reports (McArthur, 2016), and (Bell and McArthur, 2017).

2.2 Predator trapping

2.2.1 Kill trapping

Three black-fronted tern colonies (Swimming Hole, Mitchell's Cutting and Bush Gully) on the upper Clarence River have a network of kill traps set within a 500 metre radius of the breeding islands (Figure 1). Double-set DOC 150 traps and double-set SA cat traps are deployed at every second trap site and a single-set DOC 250 trap is deployed at each alternating trap site within each grid. In addition to the 500 metre grid, a further 500 metre 'tail' of traps spaced 100 metres apart has been established along both banks of the Clarence River, extending both upstream and downstream of each trapping grid (Figure 1).

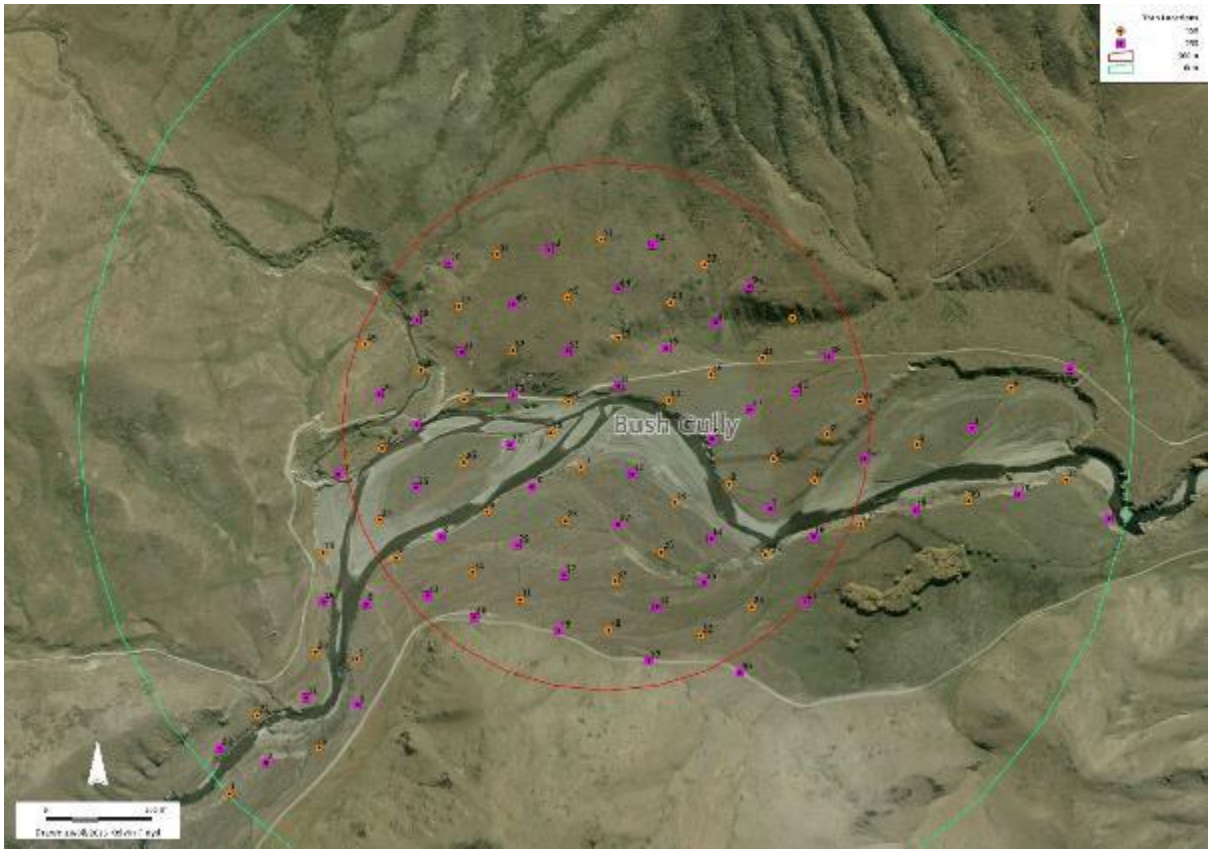

Figure 1: Example of a predator trapping grid established on the upper Clarence River. Orange dots mark the locations of DOC150 and SA cat traps, purple squares show the locations of DOC250 traps. The red circle denotes a 500 metre radius around the tern colony and the green circle denotes a 1 km radius.

The first traps were baited and set on the 5th of July 2017, prior to the onset of the black-fronted tern breeding season. Once traps were set, trapping continued through to the 20th of January 2018 where the last traps were shut down once the last chicks had fledged from the three treatment colonies. During this time, all traps were checked and re-baited once per fortnight with fresh rabbit meat and the results of each check were recorded and entered into a Microsoft™ Access database.

2.2.2 Leg-hold trapping

Two 10-day leg-hold trapping sessions were run between the 13th and 29th of September, and the 1st and 11th of November 2017. During each trapping session, 90-100 No. 1½ soft-catch Oneida Victor™ leg-hold traps were deployed in the vicinity of the three treatment tern colonies, with a short loop of 15 traps deployed at approximately 100-300 metre intervals on each bank of the Clarence River in the vicinity of each colony. Each leg-hold trap was baited with fresh rabbit meat that was replaced every two or three days or more frequently when required. Each trap was checked leg-hold daily, and any animals caught were humanely euthanised.

Due to the substantial amount of rain during the September leg-hold trapping session, the upper Clarence River levels prevented access to the true left banks of the three treatment sites (see below for further details). To compensate for the loss of access, an increase in leg-hold traps (20-30 traps) were implemented on the true right banks of the treatment sites during this period.

2.3 Black-fronted tern monitoring

2.3.1 River surveys

A walk-through survey was carried out along the upper Clarence and Acheron Rivers during mid October 2017 to locate black-fronted tern nesting colonies. The 44 km of the Clarence River, between Lake Tennyson and the Acheron River confluence was surveyed, as well as a further 44 km of the Acheron River, between Ward's Pass and the Clarence River confluence. This was done between the 17th and 20th of October 2017. 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 or not 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.

2.3.2 Nest and chick monitoring

Once a nesting colony had been located, it was then re-visited 1-2 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, it's location recorded using a handheld GPS unit and a small rock cairn erected approximately 1 metre away in an upstream 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. Where time allowed, chicks were caught by hand and banded at approximately 3-4 weeks of age, or once their primary wing feathers were >⅔ grown. Each chick was banded with a metal band on the left leg, and a yellow flag inscribed with a two-letter combination on the right leg. This banding work was carried out under Wildlife Act Authority No. 2009003 as an extension to a longer-term investigation into black-fronted tern survival rates and movements being carried out by Wildlife Management International Ltd staff.

2.3.3 Video surveillance

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 filmed nests and to quantify the relative impacts of various

predators on black-fronted tern hatching success. A minimum of two cameras were deployed at each non-treatment colony and at least four cameras were deployed at each treatment colony. Within colonies, the nests at which cameras were set up were arbitrarily selected, with some preference 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. At each selected nest, an LTL Acorn™ 5310A trail camera was mounted on a 0.5 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 eight AA batteries and an external LTL Sun™ solar charger and was equipped with a 16 GB SD memory card. These cameras were programmed to record 10 seconds of video footage each time the cameras' motion sensors were activated in response to movement around the nest. Cameras were programmed to record both day and night, with a 1 minute interval between consecutive recordings. Cameras were checked at least 1-2 times per week and usually remained at the nest until it either failed or hatched. 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.

2.3.4 Nest success analysis

Nest success (defined here as the proportion of clutches laid that hatched chicks) was calculated in two different ways. Apparent (observed) nest success 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 and Mischler 2014; Bell, 2015), so we've continued to use this measure to allow us to make comparisons with the results from previous seasons. Apparent nest success has also been reported as a measure of shorebird breeding success in previous studies, for example Rebergen et al (1998) and, Sanders and Moloney (2002).

Apparent nest success has been recognised for some time as being a somewhat unreliable measure of nest success, however. Apparent nest success is often positively biased in relation to true nest success because unsuccessful nests are on average less likely to be found and monitored than successful nests (Mayfield 1961, 1975). Furthermore, because this positive bias can vary in relation to true nest success rates, the frequency of visits and total effort invested into searching for nests and other spatial and temporal factors, apparent nest success estimates cannot usually be reliably compared with one another (Armstrong et al, 2002).

This problem was solved by Mayfield (1961) who created an *ad hoc* estimator of nest success that overcomes this bias by calculating a daily survival probability for the days that nests are under observation. Nest success is then calculated as (daily nest survival)^n where n is the length of the incubation period (in the case of precocial species such as most shorebirds). This 'Mayfield' method of calculating nest success has also been used in New Zealand shorebird studies (e.g. Rebergen et al, 1998; Kearvell, 2011). Inherent in this method is an assumption that daily nest survival is constant over time, removing any opportunity for researchers to examine temporal patterns in nest success, or the influence of time-specific or nest-specific covariates on nest success (Dinsmore et al, 2002).

The software package MARK (White and Burnham, 1999) is an excellent tool for estimating daily nest survival probabilities as unlike the Mayfield method, it allows the user to build and evaluate

alternative models of daily nest survival, reflecting alternative hypotheses concerning sources of both temporal and spatial variation in nest survival (Dinsmore et al, 2002; Rotella et al, 2004). MARK uses Akaike's Information Criterion (AIC) to rigorously evaluate support for competing models, enabling the selection of the most parsimonious model from which to estimate daily nest survival probabilities (Burnham and Anderson 2002).

In addition to reporting apparent nest success therefore, we also used MARK to model daily nest survival rates for black-fronted terns on the upper Clarence and Acheron Rivers. We first built an 'encounter history' for each known-fate nest that we monitored during the 2015/2016 field season, using the method described in Dinsmore et al, (2002). We then assigned our nests to one of eight groups, depending on whether or not nests were located within treatment or non-treatment colonies, on gravel islands or on gravel beaches connected to the mainland, or whether they were filmed with trail cameras during at least part of the incubation period or not. We then built a series of candidate models to test various hypotheses concerning whether or not nest success varied according to nest location (island or mainland; treatment or non-treatment colony) or whether a nest was filmed or not. Because the key question being asked by this project is whether the conservation management regime being implemented at treatment colonies improves black-fronted tern nest success rates, all of the candidate models we considered included a treatment/non-treatment variable. These candidate models were fitted to the nest survival data and ranked using Akaike's Information Criterion in order to choose the optimum model from which to derive daily nest survival probabilities.

2.4 Weather events

2.4.1 Pre-season snow

After the first traps were baited and set on July 5th 2017, prior to the onset of the black-fronted tern breeding season, a large snow event struck the Clarence disrupting all trapping checks in July. Due to the several substantial dumping's of snow the fortnightly checks were unable to be carried out until the 4th of August. These trapping checks however only consisted on the true right banks of the two of the three treatment sites, as high river levels from the melted snow prevented access across the upper Clarence River. This six-week disruption reduced the predator management control as full trapping checks could not continue until the 28th of August 2017.

2.4.2 Flooding

During the 2017/2018 breeding season two significant rainfall events caused the Clarence River to flood mid-September (Figure 3). This restricted access to the true left banks of the upper Clarence River, which limited predator trapping during this event. This significant flood washed out the Clarence River bridge at Acheron, as well as having an impact on the treatment colonies physical features (Figure 2).

The heavy rainfall caused treatment islands to flood over, clearing off excess vegetation and slightly reducing the size of all treatment colonies. At Swimming Hole, the floods prompted a heavier flow to run down the true left channel. This impacted the true right channel of the colony later in the breeding

season, causing it to dry out during the late summer as river levels fell. Consequently, this connected the breeding island to the mainland which exposed the black-fronted tern nests to land predators.

Across the rest of the river system, the September floods altered the river, forming new channels and creating new islands. Many of these were clear of all vegetation but were relatively low lying. This created plenty of good black-fronted tern breeding habitat across the river system outside of the treatment sites.

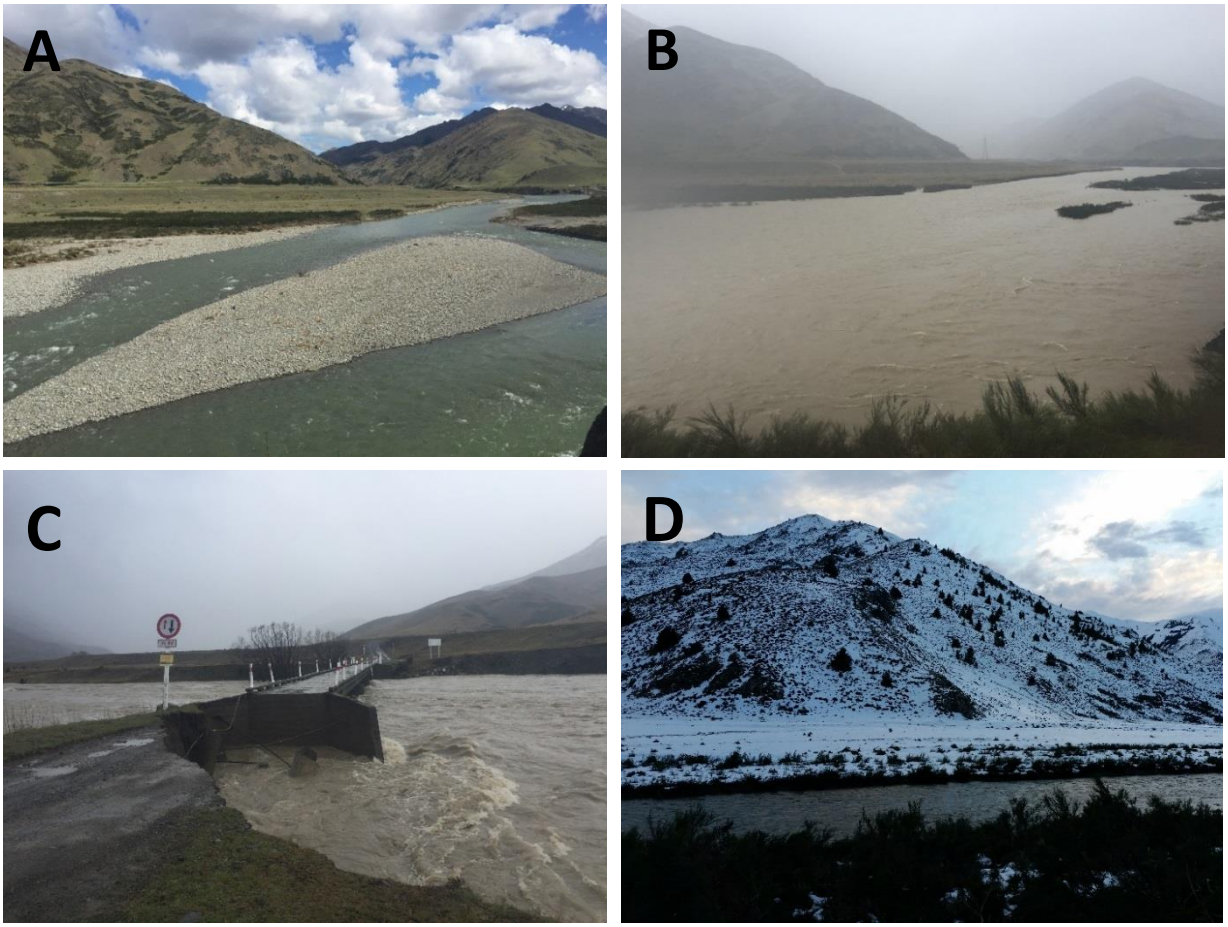

Figure 2: Impacts of weather events on the Clarence during the 2017/2018 season A) Bush Gully treatment colony prior to flooding B) Bush Gully treatment colony during September flood; C) Clarence River bridge at Acheron wash out September; D) Heavy snow up to 1m thick at Swimming Hole site July 2017.

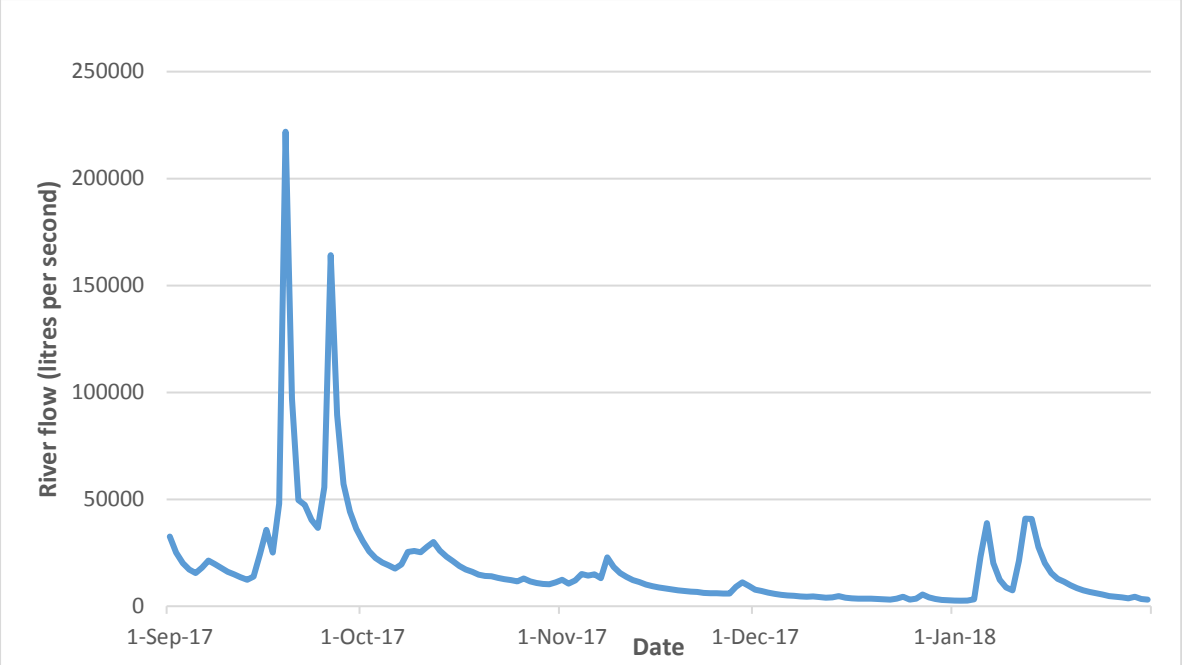

Figure 3: Upper Clarence river flow rates between September 2017 and January 2018, showing the 19th and 26th September flood events (https://www.ecan.govt.nz/data/riverflow/sitedetails/62105; retrieved 28/02/2018)

3. RESULTS

3.1 Local population size and distribution of breeding colonies

A total of 21 black-fronted tern nesting colonies were located on the upper Clarence and Acheron Rivers during the walk-through surveys (Figure 4). Colonies sizes varied from 3 breeding pairs to as many as 73 breeding pairs, with an average colony size of 25 breeding pairs.

A total of 307 nests were active at the peak of the breeding season, which is equivalent to 614 pairs breeding at one time (Table 1). Of this more birds (170 breeding pairs) were recorded on the upper Clarence River than on the Acheron River (137 breeding pairs) during peak nesting in the 2017/2018 breeding season (Figure 4).

Table 1: Number of nests and adult birds present on the upper Clarence and Acheron Rivers at the peak of each breeding season, 2012-2018.

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Max number of active nests	379	360	303	181	393	307
Max number of breeding birds (No. of nests x 2)	758	720	606	362	786	614

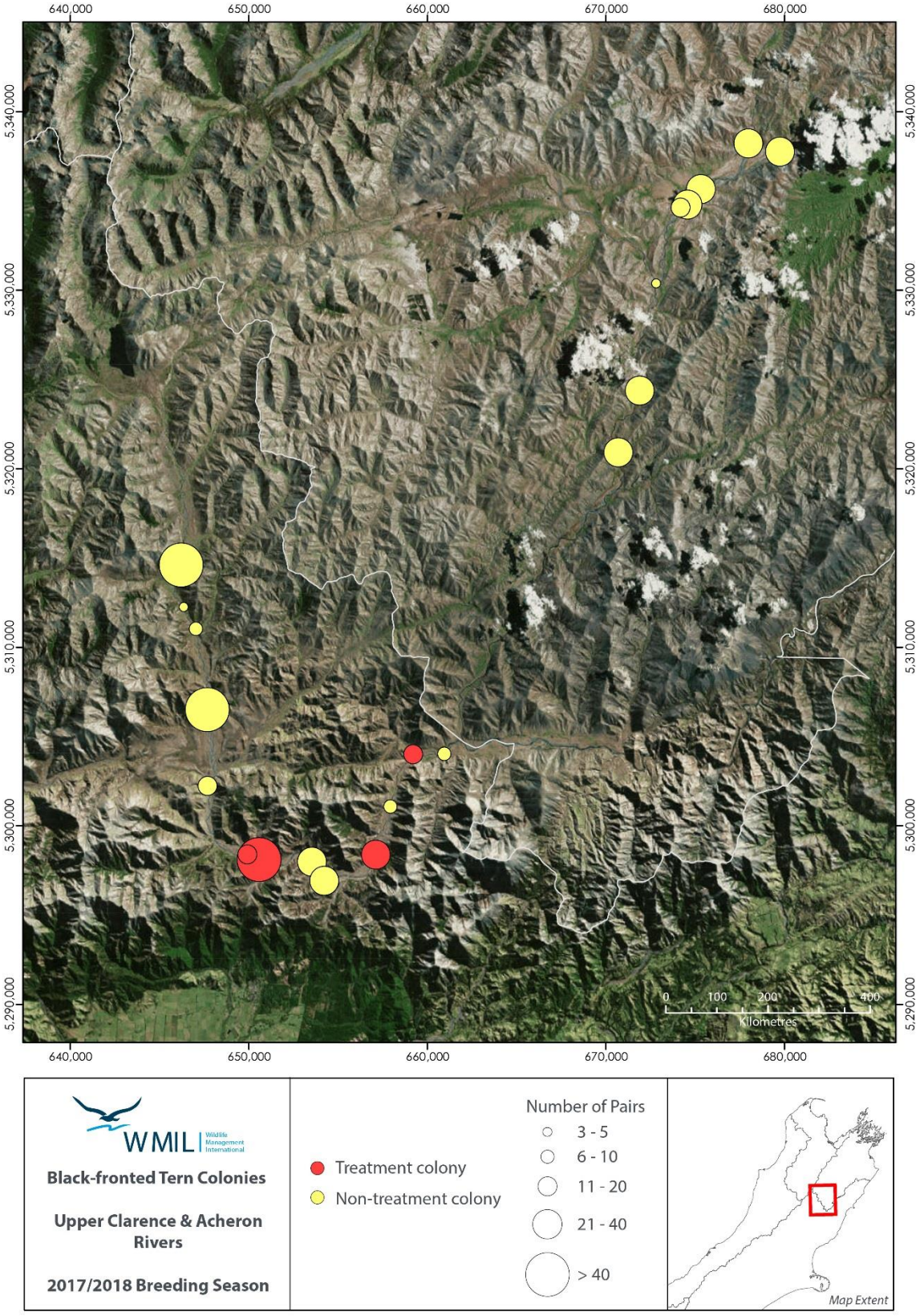

Figure 4: Locations and relative size of black-fronted tern colonies monitored on the upper Clarence and Acheron Rivers during the 2017/2018 breeding season.

3.2 Predator trapping

A total of 222 predators were caught in kill traps at the three treatment sites during the 2017/2018 field season. This includes 122 hedgehogs, 31 weasels, 27 stoats, 22 ferrets, 14 possums, and 6 cats (Table 2). A substantially greater number of stoats and weasels were caught at the Swimming Hole site than at either Mitchell's Cutting or Bush Gully treatment sites (Table 2).

Table 2: Total number of predators caught in kill traps at treatment colonies on the upper Clarence River during the 2017/2018 season.

	Swimming Hole	Mitchell's Cutting	Bush Gully	Total
No. Trap Nights	48,734	47,052	49,634	145,420
Cat	2	3	1	6
Ferret	7	6	9	22
Hedgehog	45	34	43	122
Possum	5	5	4	14
Stoat	17	7	3	27
Weasel	17	3	11	31

The number of cats and stoats caught (both the number of individuals and the capture rate) have halved between this season compared to 2016/2017 (Table 3). Capture rates for hedgehogs and ferrets is slightly lower in 2017/2018 than that recorded the previous season. Whereas capture rates for weasels and possums have significantly increased this season compared to 2016/2017 (Table 3).

Only this and last season's trapping results have been presented, as due to trap cover modifications carried out last season. Therefore, only the 2016/17 and 2017/18 trapping results are directly comparable.

Table 3: Total number of predators caught and trapping rates (in brackets; expressed as captures per 1000 trap nights) at treatment colonies on the upper Clarence River, 2016-2018.

Trap type	SA		DOC250		DOC150		Total	
Year	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
Trap Nights	59,350	57,774	30,429	29,604	59,720	58,042	149,499	145,420
Cat	9(0.15)	4(0.07)	3(0.10)	0(0.00)	3(0.05)	2(0.03)	15(0.10)	6(0.04)
Ferret	12(0.20)	9(0.16)	10(0.33)	8(0.27)	7(0.12)	5(0.09)	29(0.19)	22(0.15)
Hedgehog	45(0.76)	53(0.92)	59(1.94)	38(1.28)	53(0.89)	31(0.53)	157(1.05)	122(0.84)
Stoat	6(0.10)	1(0.02)	21(0.69)	13(0.44)	30(0.50)	13(0.22)	57(0.38)	27(0.19)
Possum	2(0.03)	1(0.02)	0(0.00)	11(0.37)	0(0.00)	2(0.03)	2(0.01)	14(0.10)
Weasel	0(0.00)	3(0.05)	4(0.13)	13(0.44)	16(0.27)	15(0.26)	20(0.13)	31(0.21)

A further 270 predators were caught during the two leg-hold trapping sessions run in September and November during the 2017/2018 season. This includes 111 hedgehogs, 83 Australasian harriers, 55 possums, 11 cats, 8 ferrets and 2 weasels (Table 4).

Results from September's leg-hold trapping session are only inclusive from the true right banks of the three treatment sites. This is due to the substantial amount of rain during September (and the Clarence bridge at Acheron wash out), preventing access to the true left of the upper Clarence River (Figure 4). An increased number of leg-holds were implemented on the true right banks of the treatment sites during this period to compensate for the loss of access.

Table 4: Total number of animals caught and trapping rates (in brackets; expressed as captures per 100 trap nights) in leg-hold traps deployed at treatment colonies on the upper Clarence River during the 2017/2018 season.

	Swimming Hole		Mitchell's Cutting		Bush Gully		Total
	Sep	Nov	Sep	Nov	Sep	Nov	
Trap nights	220	320	223	300	160	300	1,523
Australasian harrier	12 (5.45)	15 (4.69)	19 (8.52)	11 (3.67)	13 (8.13)	13 (4.33)	83 (5.45)
Cat	3 (1.36)	2 (0.63)	1 (0.45)	2 (0.67)	2 (1.25)	1 (0.33)	11 (0.72)
Ferret	1 (0.45)	2 (0.63)	0 (0.00)	3 (1.00)	0 (0.00)	2 (0.67)	8 (0.53)
Hedgehog	5 (2.27)	38(11.88)	11 (4.93)	15 (5.00)	8 (5.00)	34(11.33)	111(7.29)
Possum	9 (4.09)	11 (3.44)	12 (5.38)	7 (2.33)	5 (3.13)	11 (3.67)	55 (3.61)
Weasel	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.67)	0 (0.00)	0 (0.00)	2 (0.13)

3.3 Black-fronted tern nesting success

A total of 525 black-fronted tern nests were monitored during the 2017/2018 breeding season. Of these, 100 nests were located in the three treatment colonies and the remaining 425 nests were situated in non-treatment colonies. A total of 44% of monitored treatment colony nests successfully hatched one or more chicks (Table 5). With 190 nests out of the 425 nests monitored among non-treatment colonies successfully hatched resulting in a hatching probability of 45%. This apparent (observed) hatching success rate for non-treatment colony nests is the highest recorded on the Acheron and Clarence Rivers during this project (Table 5).

Table 5: Apparent (observed) black-fronted tern nest success rates on the upper Clarence and Acheron Rivers, 2015-2018 (Note: 2016/17 season data includes only upper Clarence River nests).

	Treatment colonies	Non-treatment colonies	Treatment colonies	Non-treatment colonies	Treatment colonies	Non-treatment colonies
	2015/16	2015/16	2016/17	2016/17	2017/18	2017/18
Number of known-fate nests monitored	79	377	152	230	100	425
Hatching probability	29.1%	31.6%	57.2%	41.7%	44%	45%

During the 2017/2018 breeding season, only three nests were located on the 'mainland' in treatment colonies. Due to a lack of encounter history data for mainland, treatment colony nests therefore, we were unable to build and compare models that quantified the influence that nest 'site' (mainland vs island) had on daily nest survival probabilities. For this reason, the most parsimonious model of daily nest survival for the 2017/2018 breeding season was the model that assumed that daily survival rates varied according to whether nests were situated in treatment or non-treatment colonies ('Treatment'), and whether or not nests were filmed with trail cameras ('Filmed'; Table 6). This model was 3.74 AICc units better than the second-best model, which assumed that daily nest survival did not vary according to whether or not it was situated in a treatment colony or was filmed.

Based on daily nest survival probabilities generated from the most parsimonious model, black-fronted tern nests that were situated in treatment colonies did not have a significantly higher hatching probability than those situated in non-treatment colonies (Figure 5). Similarly, there was no significant difference in hatching success between filmed and non-filmed nests.

Table 6: Candidate nest success models ranked by AIC values

Model	Deviance	AICc	ΔAICc	Number of parameters	Model weight
{Treatment*Filmed}	1606.52	1614.52	0.00	4	1.00
{.}	1616.27	1618.27	3.74	1	0.15
{Treatment}	1616.26	1620.27	5.74	2	0.06

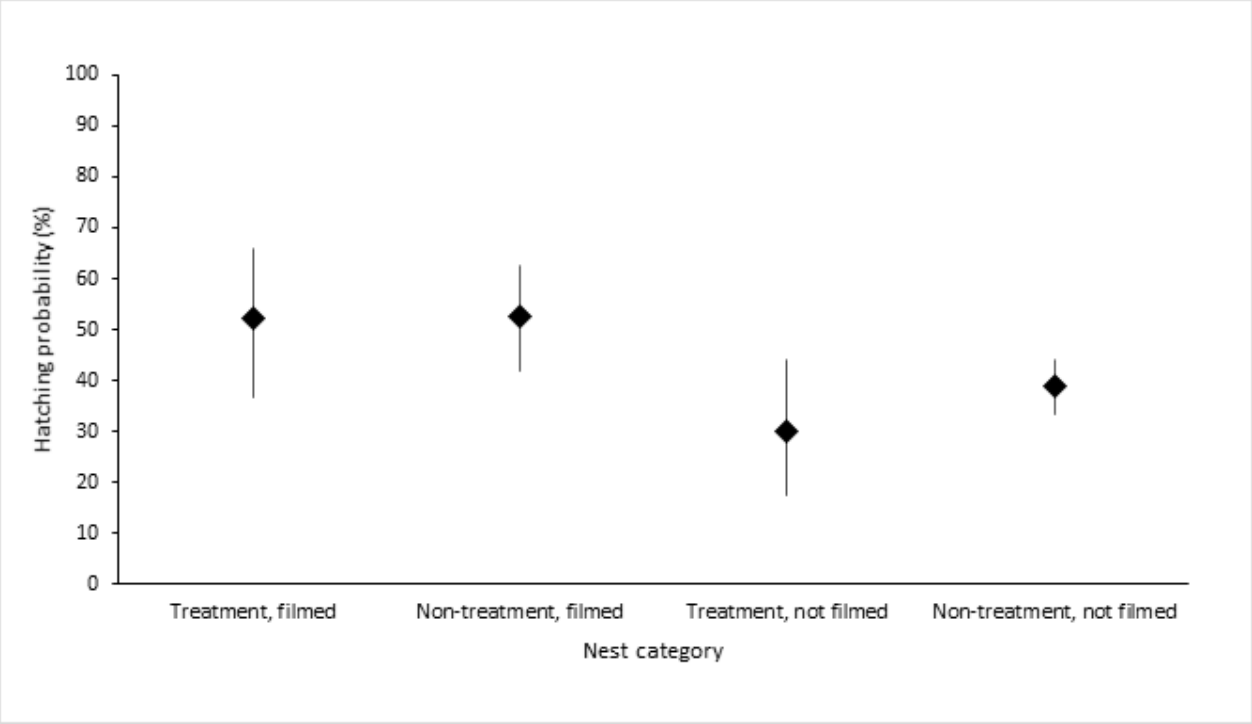

Figure 5: True nest success estimates for black-fronted tern nests on the upper Clarence River during the 2017/2018 breeding season (error bars represent 95% confidence limits).

A minimum of 162 chicks successfully fledged from the upper Clarence and Acheron River colonies during the 2017/2018 breeding season. This includes 58 chicks that fledged from treatment colonies and 104 chicks that fledged from non-treatment colonies. Compared to last season, in total 40 less fledglings were recorded, however this is the greatest number of fledglings from non-treatment colonies produced in a single season on the upper Clarence and Acheron Rivers (Table 7).

During the 2017/2018 season, the mean number of fledglings produced per nest in treatment colonies (0.58 fledglings/nest) was significantly higher than in non-treatment colonies (0.24 fledglings/nest; U=12; P<0.05; Mann-Whitney U Test; Table 7).

Table 7. Fledging success of black-fronted terns in the upper Clarence and Acheron Rivers 2015-2018.

	Treatment colonies	Non-treatment colonies	Treatment colonies	Non-treatment colonies	Treatment colonies	Non-treatment colonies
	2015/16	**2015/16**	**2016/17**	**2016/17**	**2017/18**	**2017/18**
Number of nests monitored	79	377	152	348	100	425
Fledglings	7	24	147	55	58	104
Productivity	0.09	0.06	0.97	0.16	0.58	0.24

3.4 Causes of nest failure

A total of 82 nest failure events were either filmed or directly observed during the 2017/2018 breeding season. With 18 of these events recorded at nests situated within one of the three treatment colonies, while the remaining 64 failure events occurred at nests in non-treatment colonies.

At treatment colonies, depredation by black-fronted terns was the leading cause of observed nest failures among nests situated on islands, accounting for 46% of observed events (n=17). Other depredation events recorded on a treatment island was observed by feral cats, black-backed gulls and flooding, each responsible for three nests (Table 8). Additional trapping to target the cats observed at the Bush Gully and Swimming Hole treatment colonies was initiated immediately following the depredation events, but neither were caught. During the 2017/2018 season, there was no recorded predation by ferrets, stoats, or possums on treatment islands.

At non-treatment colonies flooding accounted for 59% of the observed nest failures, with southern black-backed gull and Australasian harrier depredation also responsible for a significant number of nest losses (Table 8).

Table 8. Causes of observed nest failure events on the upper Clarence and Acheron Rivers during the 2017/2018 breeding season.

Cause of nest failure	Treatment colony nests		Non-treatment colony nests	
	Island nests	Mainland nests	Island nests	Mainland nests
Feral cat	3 (18%)	0 (0%)	2 (4%)	1 (10%)
Australasian harrier	0 (0%)	0 (0%)	7 (13%)	1 (10%)
Flooding	3 (18%)	0 (0%)	32 (59%)	0 (0%)
Ferret	0 (0%)	0 (0%)	0 (0%)	1 (10%)
Stoat	0 (0%)	0 (0%)	0 (0%)	1 (10%)
Hedgehog	0 (0%)	1 (100%)	1 (2%)	1 (10%)
Black-fronted tern	8 (46%)	0 (0%)	0 (0%)	3 (30%)
Southern black-backed gull	3 (18%)	0 (0%)	9 (16%)	0 (0%)
Pig	0 (0%)	0 (0%)	1 (2%)	0 (0%)
Hare	0 (0%)	0 (0%)	1 (2%)	0 (0%)
Cow	0 (0%)	0 (0%)	0 (0%)	1 (10%)
Rabbit	0 (0%)	0 (0%)	0 (0%)	1 (10%)
Total	17	1	54	10

Over the past three breeding seasons, 202 nest failure events have been observed on black-fronted tern nests at colonies on the upper Clarence and Acheron Rivers. Loss of nests by flooding has been the leading cause of nest failures, accounting for 28% of observed events over this three year period (Table 9). Feral cats have been the second most common cause of nest failures (18% of observed events), and Australasian harriers the third most important predator (9%).

Australasian harriers and ferrets are common predators identified at non-treatment colonies, accounting for a combined 20% of observed nest failures this season (Table 9). These two predators however have only rarely been observed predating black-fronted tern nests at treatment colony sites, with ferrets never once recorded. Flooding has been the second most common cause of nest failure at non-treatment colonies the last two breeding seasons, and the leading cause at non-treatment colonies this season (33%). This has never been a large contributor to nest failures at treatment colonies, likely due to the bulldozer work carried out on treatment islands.

This season 10% of nests were lost as a result of black-fronted tern 'depredation'. It is unclear from the trail camera footage whether the birds responsible are the parents of the depredated nests, or

whether the nests were being attacked by unrelated birds (Table 9). This phenomenon was also recorded during the last breeding season, but not in the 2015/2016 season.

Southern black-backed gulls have been a predator recorded for the first time this season, depredating 6% of observed events.

Table 9: Causes of observed nest failure events on the upper Clarence and Acheron Rivers recorded between 2012 and 2018.

Cause of nest failure	2015/16 treatment	2015/16 non-treatment	2016/17 treatment	2016/17 non-treatment	2017/18 treatment	2017/18 non-treatment	Total treatment	Total non-treatment
Flooding	0	9 (20%)	0	13 (24%)	3 (17%)	32 (50%)	**3 (8%)**	**54 (33%)**
Feral cat	5 (42%)	11 (24%)	1 (14%)	14 (26%)	3 (17%)	3 (5%)	**9 (24%)**	**28 (17%)**
Australasian harrier	0	9 (20%)	1 (14%)	0	0	8 (13%)	**1 (3%)**	**17 (10%)**
Ferret	0	7 (15%)	0	8 (15%)	0	1 (2%)	**0**	**16 (10%)**
Hedgehog	4 (33%)	1 (2%)	1 (14%)	7 (13%)	1 (6%)	2 (3%)	**6 (16%)**	**10 (6%)**
Southern black-backed gull	0	0	0	0	3 (17%)	9 (14%)	**3 (8%)**	**9 (5%)**
Black-fronted tern	0	0	4 (57%)	6 (11%)	8 (44%)	3 (5%)	**12 (32%)**	**9 (5%)**
Stoat	0	5 (11%)	0	1 (2%)	0	1 (2%)	**0**	**7 (4%)**
Possum	3 (25%)	0	0	4 (7%)	0	0	**3 (8%)**	**4 (2%)**
SIPO	0	2 (4%)	0	1 (2%)	0	0	**0**	**3 (2%)**
Rabbit	0	1 (1%)	0	1 (2%)	0	1 (2%)	**0**	**3 (2%)**
Cow	0	0	0	0	0	2 (3%)	**0**	**2 (1%)**
Hare	0	1 (1%)	0	0	0	1 (2%)	**0**	**2 (1%)**
Pig	0	0	0	0	0	1 (2%)	**0**	**1 (1%)**
Total	**12**	**46**	**7**	**55**	**18**	**64**	**37**	**165**

4. DISCUSSION

4.1 Local black-fronted tern population trends

The peak number of 307 active nests recorded during the 2017/2018 breeding season is close to the five year average black-fronted tern population of 323 active nests during peak season, observed 2012-2017 in the Upper Clarence catchment (Bell and McArthur, 2017).

The number of active nests at the peak of each breeding season from 2012/2013 through to 2017/2018 varies each year, suggesting that black-fronted terns are likely to be relatively mobile, and may be shifting between rivers across North Canterbury. Birds banded on the Clarence River were recorded on the Waiau River this season further suggesting that black-fronted terns move between rivers. With this likely mobility, determining meaningful population trends of black-fronted tern on a single river is problematic. Long term datasets with counts every season is likely to be the only way to determine meaningful trends. Carrying out annual aerial surveys of the Acheron and upper Clarence Rivers, counting both black-fronted terns attending colonies and those foraging away from colonies, would likely deliver more accurate estimates of population size and is recommended.

4.2 Habitat enhancement

The bulldozer work carried out in March 2016 was effective in improving breeding habitat for black-fronted terns. Alterations on the three treatment colonies included increasing the depth and width of adjacent river channels, reducing weed vegetation and woody infestations, and raising the height of portions of the Mitchell's Cutting and Bush Gully islands. These modifications remained sufficient throughout the 2017/2018 season despite a number of floods that occurred during winter and spring.

With the Upper Clarence River being a small to medium flow river, enhancing black-fronted tern breeding habitats is a cost effective management action as it appears islands can sufficiently withstand river flows across multiple seasons. With some follow up weed spraying prior to each breeding season, the three treatment islands can effectively continue to be highly suitable and attractive nesting habitats for black-fronted terns.

Fewer black-fronted terns were observed breeding on the treatment islands this season. The September floods created new islands throughout the river system. Several of these in the upper Clarence were good breeding habitats with clear exposed gravels lacking vegetation, and had large colonies established on them. This type of challenge is presented when working in a dynamic system of braided rivers.

Flooding was a significant contributor to poor hatching success from non-treatment colonies. This emphasises the importance of the bulldozers work in mechanically raising the height of treatment islands, where flooding was only a minor issue at these sites. When mechanically enhancing islands, equal importance should be placed on creating good channels around islands and raising islands to better with stand higher river flows.

4.3 Predator trapping

Large numbers of the target mammalian predators that had formerly accounted for a large proportion of observed nest failures at black-fronted tern colonies, have continued to be successfully removed, from the efficient combination of kill trapping and leg-hold trapping.

A significantly higher number of stoats, weasels and hedgehogs were caught in the vicinity of the Swimming Hole colony, compared to at the Mitchell's Cutting and Bush Gully colonies. This is likely due to the site comprising of an almost pure broom (*Cytisus scoparius)* shrubland, which can support a higher density of stoats, weasels and hedgehogs. Whereas vegetation surrounding Mitchell's Cutting and Bush Gully colonies consist of a mosaic of exotic and native grasses, native herbs and shrubs, broom and wildling pines. This trend continues to be observed from past seasons where an increased amount of mammalian predators are caught at the Swimming Hole site. With both broom and wilding pines are starting to expand at Mitchell's Cutting and Bush Gully, the number of predators caught in these areas is likely to increase in the long-term.

In comparison to previous seasons, very few cats and stoats were caught in the kill traps and leg-hold traps during 2017/2018 season. This is likely a reflection of the severe weather events (large snow event in July and flooding in September), decreasing the number of cats and stoats in the vicinity of the treatment areas, leading to decreased predator densities as they didn't survive the winter. Increased hatching and fledging success of black-fronted terns at some upper Clarence non-treatment colonies, also suggests that there were fewer mammalian predators in the system this season.

4.4 Black-fronted tern nesting success

The 2017/2018 breeding season for black-fronted terns was moderately successful. There was no evident difference between the hatching probability in treatment vs non-treatment colonies, fledging productivity was significantly higher from nests located in treatment colonies. From this seasons results, it is observed that the combined management of pest trapping, and habitat enhancement has greatly increased chick survival rates, but has not affected the hatching probability of black-fronted tern eggs.

Two islands situated at non-treatment colonies did specifically well with an average hatching success of 66% and a combined total of 74 recorded fledglings. This is likely due to both islands having good breeding habitats with excellent channels following the September flooding, as well as a reduced predator density from the season's winter conditions. These two colonies results alone, have increased both the hatching probability and fledgling productivity for non-treatment colonies, which highlights the importance of well-formed breeding islands for black-fronted terns.

This season avian predators had more impact than previously, with harrier and southern black-backed gulls predating nests. Although trapping of harriers around the treatment colonies appears to have prevented harrier predation at these sites. An increase in 'depredation' by black-fronted terns has also been observed this season at all three treatment colonies, the cause for this is unknown, meaning mitigating it is impossible at this stage.

One of the three outcome targets, regarding black-fronted tern hatching success at treatment colonies, was not met this season and can be explained by avian depredation (Table 9). Southern black-backed gulls were observed depredating three nests at Mitchell's Cutting colony and were likely

responsible for more, as well as for chick predation which is difficult to monitor (Table 7). This has reduced hatching success and fledging productivity rates significantly for treatment colonies. The incidences of black-fronted terns 'depredating' their own nests has increased at treatment colonies therefore also reducing overall hatching success. Nonetheless, during the 2017/2018 season, two of the three seasonal outcome targets for this project were achieved (Table 10).

Table 10. A comparison of project target outcomes and 2017/2018 season results for the Clarence River black-fronted tern restoration project.

Outcome target*	2017/2018 season result	Outcome target met?
Black-fronted tern hatching success is >60% annually	45%** hatching success at treatment colonies	No
At least 75 black-fronted tern chicks fledge annually from the upper Clarence and Acheron Rivers	At least 162 black-fronted tern chicks successfully fledged	Yes
The number of black-fronted tern nests in early December is increased by >50% to more than 225 by December 2020	307 nests active at the peak of the breeding season	Too early to assess

* Source: Brown, 2015.
** Mean true hatching success for treatment colony nests situated on islands.

5. RECOMMENDATIONS

Based on the results of the first three seasons of black-fronted tern management and monitoring, we make the following recommendations for future seasons' work:

5.1 Island enhancement

- That weed control is carried out on the three treatment colonies prior to the onset of the 2018/2019 breeding season, to ensure that the islands are kept clear of weeds. Weed control can consist of either mechanical or manual removal of any woody weeds, as well herbicide spraying as long as it is carried out at regular intervals.
- That the river channels at the three treatment colonies are checked in March 2018, and any remedial work to deepen and widen channels is carried out by 15th April 2018.

5.2 Black-fronted tern population monitoring

- That aerial helicopter surveys of the upper Clarence and Acheron Rivers be carried out on an annual basis for the duration of this project. Aerial surveys are likely to provide a more accurate and consistent measure of the size and trajectory of the upper Clarence and Acheron Rivers black-fronted tern population, as this survey method isn't as susceptible to errors caused by yearly variation in nesting asynchrony.

5.3 Predator trapping

- That we continue to implement a "responsive" component to the trapping regime whereby additional traps are temporarily deployed in the vicinity of treatment colonies in response to any observed spate in depredation events (potentially caused by a single predator gaining access to the tern colony), or to periods of exceptionally low river flows.
- That resources should be put into controlling the southern black-backed gull colony on the Acheron River.

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