Final report: Upper Waiau Toa/ Clarence River black-fronted tern project 2015/16 – 2019/20.

WMIL Wildlife Management International

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Final report: Upper Waiau Toa/ Clarence River black-fronted tern project 2015/16 – 2019/20.

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Cover Image: Adult black-fronted tern (*Chlidonias albostriatus*) during December flood, photographed December 2019

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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 5,000 and 10,000 mature individuals and a predicted rate of decline of around 50% over the next three decades (O'Donnell and Hoare 2011, Robertson *et al.* 2017).

This ongoing decline is the result of several interacting threats, including depredation by introduced mammals (particularly cats, ferrets and hedgehogs), habitat loss as a consequence of the invasion of braided river beds by woody weeds and flooding (Balneaves and Hughey 1990, Keedwell *et al.* 2002, Sanders and Moloney 2002, Keedwell 2005, Bell 2017).

The braided rivers of Canterbury are 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, Lower Waiatki, Tasman, Godley, Cass and Ahuriri Rivers (Forest & Bird 2014, Forest & Bird 2015).

Since 2012 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 Waiau Toa and Acheron Rivers in the Canterbury region. Over the 2012, 2013 and 2014 breeding seasons, black-fronted tern productivity was low, primarily due to predation by introduced mammals (Bell 2017).

A combined total of 1,510 nests were monitored over the three seasons 2012, 2013 and 2014 in at least 20 colonies per year. During these three seasons the apparent (observed) hatching success was low with 42.7% of nests hatching at least one egg. The average fledging productivity was very 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 which showed that 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 was instigated at three colony sites on the upper Clarence River in 2015. Co-funded by the Department of Conservation, Environment Canterbury's Braided River Regional Initiative fund 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 breeding success of black-fronted terns at island colonies that receive this management (Brown 2015).

This report provides a summary of this 5-year project. We report the results of habitat enhancement and predator control work carried out at treatment colonies over this time, together with black-fronted tern breeding success throughout the project period. We provide several recommendations for future black-fronted tern conservation efforts.

2. METHODS

2.1 Naming locations

In order to differentiate between the entire catchment and the upper reaches of the Clarence River in this report when referring to the entire catchment, which includes the Acheron River, we use "Upper Waiau Toa/ Clarence River Catchment". When referring only to the upper reaches of the Clarence River we use "Upper Waiau Toa".

2.2 Habitat enhancement

Following three years research (2012, 2013 and 2014) on black-fronted tern in the Upper Waiau Toa, three sites where terns had repeatedly nested (Bell 2017) were selected for habitat enhancement. This enhancement included deepening and widening channels to improve flows around islands to prevent mammalian predator access, and mechanically clearing woody weeds from islands to provide clear gravels for nesting habitat. 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).

The three selected "treatment sites" are further referred to in this report as Swimming Hole, Mitchell's Cutting and Bush Gully.

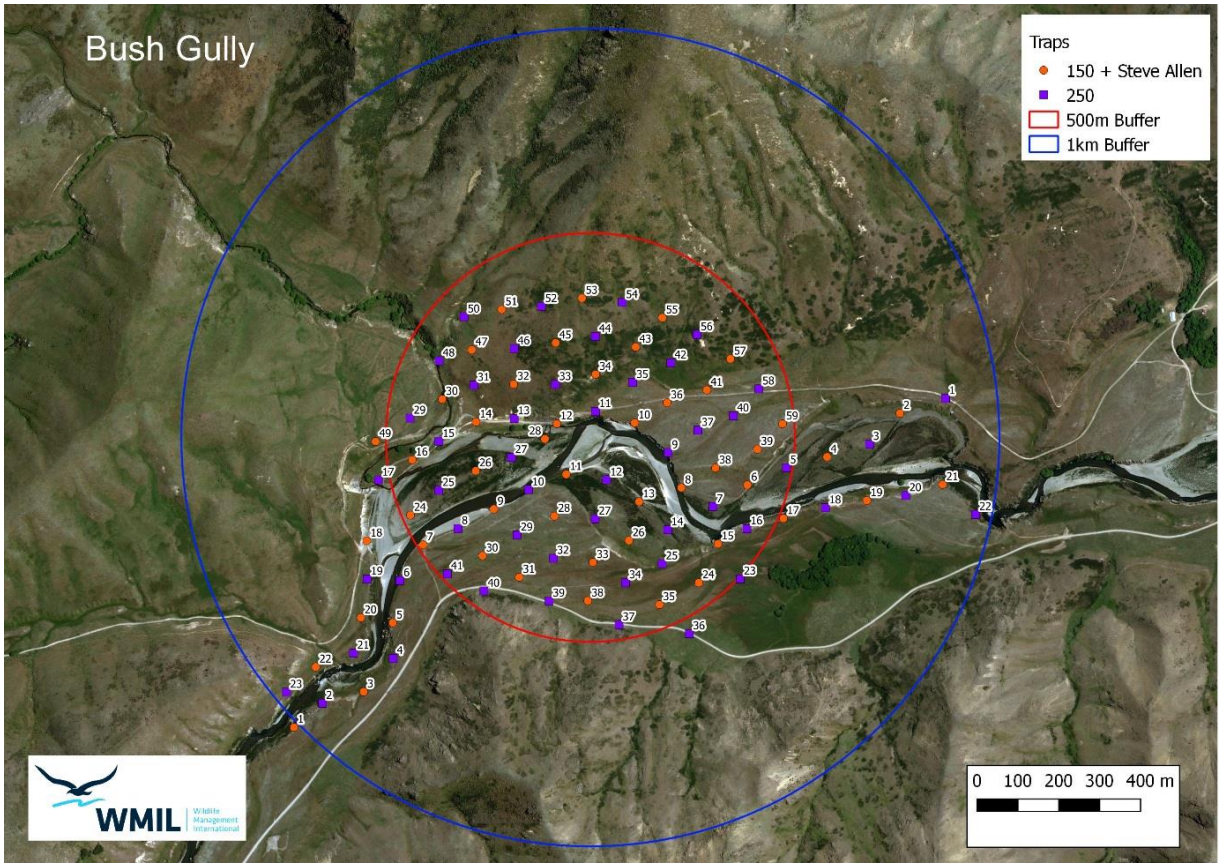
2.3 Predator trapping

2.3.1 Kill trapping

The three treatment black-fronted tern colonies (Swimming Hole, Mitchell's Cutting and Bush Gully) on the Upper Waiau Toa had a network of kill traps set within a 500 metre radius of the breeding islands (Figure 3). Double-set DOC 150 traps and double-set SA cat traps (Figure 1) are deployed at every second trap site and a single-set DOC 250 trap was 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 2).

Figure 1. Field staff setting a SA cat trap in the Bush Gully treatment site, October 20015.

Figure 2. Example of a predator trapping grid established on the Upper Waiau Toa. 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 blue circle denotes a 1 km radius.



The traps were baited and set for the first time each season during the first week of well prior to the onset of the black-fronted tern breeding season. Once traps were set, trapping continued through to the middle of January when the last traps were shut down once there were no active nests left on the treatment colonies. During this time, all traps were checked and re-baited once per fortnight with fresh or dry rabbit meat, and the results of each check were recorded and entered into a Microsoft™ Access database.

2.3.2 Leg-hold trapping

Two 10-day leg-hold trapping sessions were run each season; once just prior to egg laying (usually the last two weeks in September) and during early chick hatching (early November to early December). During each trapping session, 90-100 1.5 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 Waiau Toa/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 leg-hold trap was checked daily, and any animals caught were humanely euthanised. Each season, leghold trapping prior to the onset of breeding was always carried out at all treatment sites. However, if black-fronted tern breeding was not occurring (or the colony had already failed) by late November or early December, the second session of leg-hold trapping was not carried out.

2.4 Natural events

2.4.1 Flooding

Flooding is a significant risk to braided river shorebirds, and conservation management projects. NIWA maintain a flow gauge on the Upper Waiau Toa at Jollies Pass, and data from this was downloaded via the NIWA website to use for in analysis.

2.4.2 Snow Fall

The Upper Waiau Toa/ Clarence Catchment lies above 800m a.s.l. and as such is routinely having significant snow fall events each winter and spring. Such events can prevent trap checks as snow completely covers traps up to 1m deep. This is to be expected with a high-country trapping project and is unlikely to have significant impacts on capture rate. Late snow falls during spring, at the start of the black-fronted tern breeding season has likely caused delays in the onset of breeding in some seasons.

2.4.3 Kaikoura Earthquake

The magnitude 7.8 Kaikoura Earthquake on the 14th November, 2016 caused significant disruption to the black-fronted tern monitoring work during the 2016 breeding season. Immediately following the earthquake, access to the upper Waiau Toa and Acheron Rivers was impossible due to extensive road closures in the Marlborough and Canterbury Regions. For an eight-day period between the 14th and 21st of November, WMIL field staff were unable to access the Upper Waiau Toa to check on black-fronted tern nests. Access to the Acheron River was even more seriously affected, due to the risk of flash-flooding caused by the failure of landslide dams that had formed in the headwaters of the Acheron River following the earthquake. As a result, WMIL field staff were unable to access and monitor black-fronted tern nests on the Acheron River for almost three weeks between November 14th and December 1st 2016.

The eight-day disruption to nest monitoring at Upper Waiau Toa colonies had only a relatively minor impact on our ability to determine the outcomes of nesting attempts that were underway on this river at the time of the earthquake. However, the three week disruption to monitoring nesting attempts on the Acheron River greatly reduced our ability to determine outcomes of active nests, to the extent that we could not be certain whether the majority of nests that were active on the Acheron River at the time of the earthquake had hatched or failed. Due to the uncertain fates of these nests, they could not be added to the sample of nests from which hatching success could be estimated. Furthermore, because the remaining known-fate nests from the Acheron River represents a temporally-biased sample of 'non-treatment' site nests (the majority of which are relatively late-season nests), we exclude all Acheron River nests (n=118) from the sample of known-fate nesting attempts used for the 2016 season in this report.

2.5 Black-fronted tern monitoring

2.5.1 River surveys

Walk-through surveys were carried out along the Upper Waiau Toa (Figure 3) and Acheron Rivers during mid-October to early November 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. Following significant flooding events, the entire length of the rivers were surveyed 7-10 days later to locate breeding colonies lost in the flood.

Figure 3. The middle reaches of the Upper Waia Toa which are largely free of woody weeds.

2.5.2 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 died or 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 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.

Figure 4. Black-fronted tern nest with two eggs, and nest with two recently hatched chicks, Upper Waiau Toa November 2016.

2.5.3 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 larger than two nests, and at least four cameras were deployed at the active treatment colony at any one time. 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 (Figure 5). 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 take one photo and 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 one 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 temporarily retrieved if large amounts of rain were predicted to prevent being washed away. 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.

Figure 5. Trail camera set up at a black-fronted tern nest, Acheron River, October 2015.

2.5.4 Nest success analysis

In this report we define hatching success as the proportion of clutches laid that hatched at least one chick. 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), and has continued to be used 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 (Rebergen *et al.* 1998, Sanders and Maloney 2002).

Productivity is the number of chicks fledged per nesting attempt. This will be a lower rate that chicks fledged per pair, as many pairs have multiple breeding attempts. As the Upper Waiau Toa/ Clarence River catchment population is largely unbanded, it would be impossible to be able to determine the number of clutches each pair have laid.

3. RESULTS

3.1 Habitat enhancement

On the 29th and 30th of March 2016 at three treatment colony sites on the Upper Waiau Toa/ Clarence River a bulldozer was used to improve breeding habitat for black-fronted terns. 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). The bulldozer work was carried out after the first breeding season of this study, so it was only the last four breeding seasons where islands had the benefit of enhancement.

At Bush Gully and Mitchell's Cutting, a rock bund was constructed at the upstream end of two small channels to temporarily divert water from those channels whilst excavation work was carried out in the stream bed. As water levels in these channels dropped, stranded fish were rescued and relocate to adjacent river channels. Once the channels were dewatered, the bulldozer increased the depth and width of the channel, and removed any emergent "stepping stone" rocks. Excavated material was spread over the surface of the islands, both to increase the height of the islands above the surrounding water channels and to bury woody vegetation growing on the islands. Once completed the bund was removed and water flow was re-instated to the newly-excavated channel (Figure 6 and 7).

At the Swimming Hole site, which already had relatively deep and fast flowing channels on either side of the breeding island, the bulldozer removed a heavy infestation of broom (*Cytisus scoparius*). To achieve this, the bulldozer scraped off the broom and buried it beneath 0.3-0.5m of mixed gravel and silt, leaving a bare surface composed of a 50:50 mix of silt, soil and gravel. Over the next several months, rainfall washed exposed soil and silt down into the interstices between surface gravels, creating a clean and bare gravel surface to the island by the beginning of the 2016/2017 breeding season.

Figure 6. Map of the Mitchell's Cutting site showing location of temporary bund and areas (bounded by red) where material was excavated from the stream bed and redistributed onto the breeding island.

Figure 7. River works at the Bush Gully site. A) Creating the temporary bund at the upstream end of channel; B) Deepening and widening existing channel, with excess material being deposited on the island; C) Channel prior to works; D) Channel after works and with flow re-instated.

Following each breeding season weed control was carried out at each treatment island. Each January-March seedling broom and other weeds were sprayed to maintain the islands weed free using glyphosate administered with a knapsack sprayer. This work very well at Bush Gully and Mitchell's cutting, were the islands remained almost completely weed free throughout the 5-year project. Swimming Hole was a more consolidated island consisting of a considerable amount of slit, which had significant weed growth each spring. Annual control post black-fronted tern breeding was not enough to keep on top of this weed growth, and although broom was kept off the island, other annual and perennial weeds eventually covered up to 70% of the island three seasons after mechanical clearance.

In April 2019 additional bulldozer work was carried out to maintain treatment site islands, with each island required a different amount of work. At Bush Gully the channel on the true right was widened and deepened to improve flow. Excavated material was again spread over the surface of the islands, weed growth was minimal and widespread scraping across the entire island was not required. At Swimming Hole, the channel on the true right was deepened (but not widened) to improve flow. As this site had a considerable amount of weed growth, the island was scraped to remove these. No maintenance work was required at Mitchell's Cutting, with this island still having good channels and was largely free of weeds.

3.2 Predator trapping

3.2.1 Kill trap results

Traplines were set up between July and November 2015, due to delays in ordering and arrival of traps the entire network was not established until November 2015. Hence trapping effort in the first year of the study is not as high as in other seasons.

An average of 223 predators were caught in kill traps each year during 134,495 trap nights at the three treatment sites. On average 154 hedgehogs, 81 stoats, 36 weasels, 26 ferrets, 12 rats, 10 cats, and 7 possums were caught (Figure 8, Table 1). Significantly more predators were caught at Swimming Hole, than Mitchell's Cutting or Bush Gully, probably because the area surrounding Swimming Hole is almost completely vegetated with broom providing cover for mammalian predators.

Hedgehog captures increased from 2016 when traps were modified to open the entrance to trap boxes; with no non-target species present in the Upper Waiau Toa mesh at entrance of trap boxes was removed to provide easy access for hedgehogs. Ship rats are usually absent in the Upper Waiau Toa, with significant numbers only caught in any numbers in 2019, with most captures at Swimming Hole. It is likely that mast seeding of tussock enabled rats to survive at this altitude.

Variability between trap nights and potentially trapping results will be influenced by the duration of trapping, trapping at each treatment site is turned off immediately post fledging or colony abandonment. For example, the high number of stoats caught in 2018 was due to high capture rat in January when trapping continued until the last week of January.

Analysis of the trapping data indicates that there is no clear trend in the location of predators caught in relation to the distance from the colony or river.

Figure 8. Stoat caught in a DOC150 trap, Mitchell's Cutting, Upper Waiau Toa August 2018.

Table 1. Total number of predators caught in kill traps at treatment colonies on the Upper Waiau Toa 2015 to 2019.

		2015	2016	2017	2018	2019	Average
Swimming Hole	Trap nights	34,640	50,215	48,734	44,707	45,862	44,832
	Cat	5	5	2	3	1	3
	Ferret	21	9	7	5	1	9
	Hedgehog	27	69	45	53	62	51
	Possum	0	0	5	1	5	2
	Ship Rat	0	0	0	0	20	4
	Stoat	18	34	17	44	22	27
	Weasel	11	7	17	6	19	12
Mitchell's Cutting	Trap nights	31,642	50,132	47,052	45,400	36,938	42,233
	Cat	5	6	3	2	1	3
	Ferret	7	8	6	1	1	5
	Hedgehog	13	49	34	29	12	27
	Possum	2	2	5	10	5	5
	Ship Rat	0	0	0	0	2	0
	Stoat	7	10	7	21	9	11
	Weasel	4	9	3	1	4	4
Bush Gully	Trap nights	34,374	49,152	49,634	46,158	36,309	43,125
	Cat	4	4	1	3	6	4
	Ferret	8	12	9	5	1	7
	Hedgehog	22	39	43	36	40	36
	Possum	1	0	4	1	0	1
	Ship Rat	0	1	0	0	1	0
	Stoat	8	13	3	4	4	6
	Weasel	1	4	11	4	2	4

3.2.2 Leg-hold trapping

Leghold trapping was carried out each season prior to breeding, but if the treatment colony was not being used for breeding the second session was not carried out.

On average 1,760 trap night were carried out each season, catching an average of 77 Australasian harriers, 71 Hedgehogs, 61 possums, 13 cats, and 6 ferrets, with the occasional stoat and weasel caught (Table 2).

Table 2. Total number of predators caught in kill traps at treatment colonies on the Upper Waiau Toa 2015 to 2019.

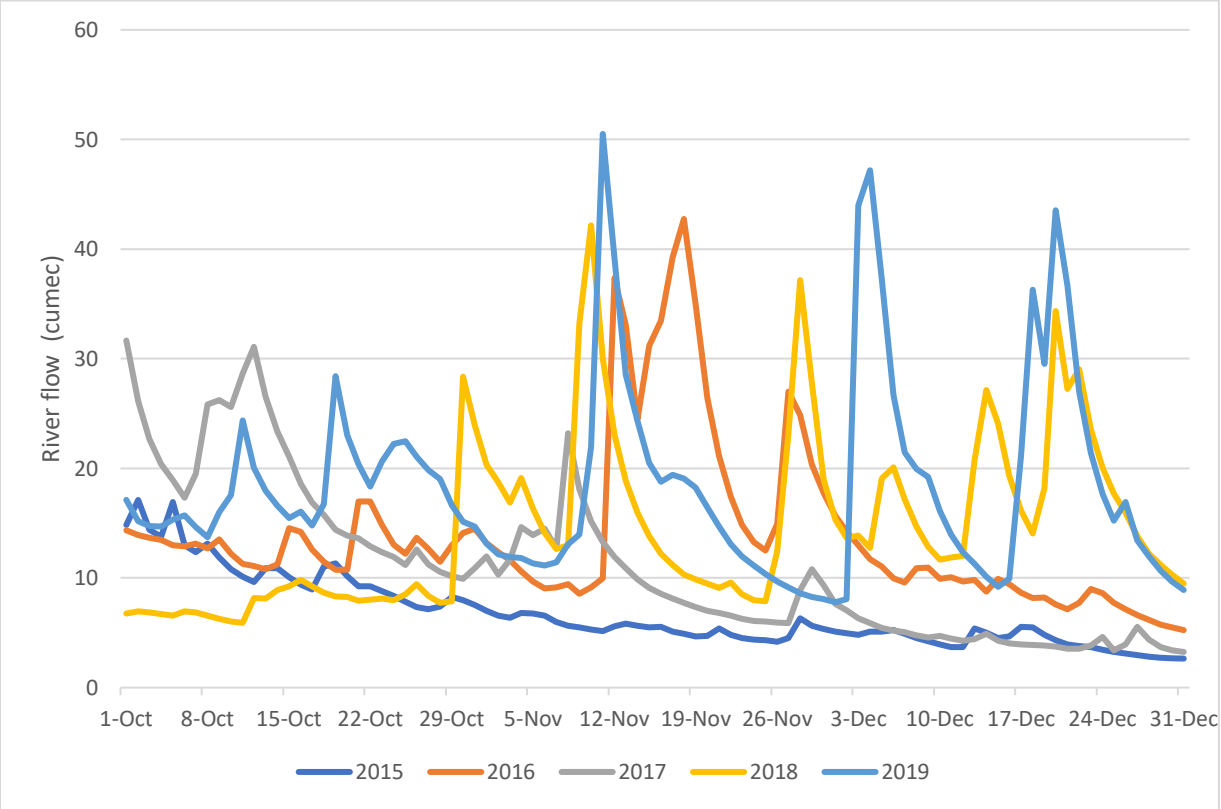
		2015	2016	2017	2018	2019	Average
Swimming Hole	No. Trap nights	578	570	540	600	645	587
	Sessions	2	2	2	2	2	2
	Australasian harrier	17	26	27	38	21	26
	Cat	5	4	5	3	5	4
	Ferret	2	1	3	4	0	2
	Hedgehog	15	18	43	28	14	24
	Possum	4	14	20	32	32	20
	Stoat	0	0	0	0	0	0
	Weasel	0	0	0	0	0	0
Mitchell's Cutting	No. Trap nights	613	540	523	320	300	459
	Sessions	2	2	2	1	1	2
	Australasian harrier	18	23	30	17	12	20
	Cat	2	5	3	2	3	3
	Ferret	0	1	3	0	0	1
	Hedgehog	11	25	26	4	4	14
	Possum	7	19	19	14	9	14
	Stoat	1	0	0	0	0	0
	Weasel	0	0	2	1	1	1
Bush Gully	No. Trap nights	563	525	460	640	302	498
	Sessions	2	2	2	2	1	2
	Australasian harrier	23	33	26	27	34	29
	Cat	5	5	3	6	1	4
	Ferret	3	2	2	7	1	3
	Hedgehog	14	21	42	20	5	20
	Possum	5	1	16	11	4	7
	Stoat	0	0	0	1	0	0
	Weasel	0	0	0	0	0	0

3.3 Natural events

3.3.1 Flooding

Flooding is a significant risk to braided river shorebirds, and conservation management projects. In the Upper Waiau Toa flood events >30 cumecs causes widespread loss of black-fronted tern nests. Throughout the project only two seasons have been unaffected by such events, 2015 and 2017 (although in 2017 a 31 cumec flood at the very start of the season did have minor disruption). There were two >30 cumec floods in 2016, and three in the 2018 and 2019 breeding seasons (Figure 9).

Figure 9. Upper Waiau Toa mean daily river flow (cumec) recorded at Jollies Pass.



Just prior to the start of the 2017 breeding season, two significant flood events in September washed out the bridge at the Acheron bridge on the Upper Waiau Toa (Figure 10). These same flood events also limited access across the river, reducing access for both kill trapping and leghold trapping.

Figure 10. Wash out at the Acheron Bridge on the Upper Waiau Toa, September 2017.

3.3.2 Snow Fall

Significant snowfall events in 2017 effected trap check frequency. Following the initially setting of traps on July 5 2017, snow prevent checks of traps on the true right (and Bush Gully true left) until August 4, and on the true left of Swimming Hole and Mitchell's until August28 (due to high river flows prevent river crossings).

In both 2018 and 2019 snowfall events during spring (October and November) created cooler temperatures throughout the early stages of the breeding season and appeared to cause black-fronted terns to delay (Figure 11).

Figure 11. Black-fronted tern incubating in snow after a late snow fall event, 1 November 2018, Upper Waiau Toa.

4 Black-fronted tern breeding

4.1 Local population size and distribution of breeding colonies

The black-fronted tern population in the Upper Waiau Toa/ Clarence River catchment has declined since research began in 2012 (Figure 13a, Table 3). This has largely been driven by a significant decline in the Acheron River population, whereas the Upper Waiau Toa population has slightly increased during this period (Figure 13b, Table 3). The number of colonies in the Upper Waiau Toa each season has been relatively stable (mean 12; range 9 – 14), whereas the number of colonies on the Acheron River has declined since 2015 (Table 3).

Between 2012 and 2019 a total of 91 colonies were monitored in the Upper Waiau Toa/ Clarence River catchment; mean colony size was 24 nests (range 1-105 nests). Colony locations were similar in each season, with terns often nesting on the same islands within the river, or in similar stretches of the river (Figure 14)

Figure 12. Colour banded black-fronted tern, Upper Waiau Toa November 2017.

Figure 13a. Maximum number of nests recorded in the Upper Waiau Toa/Clarence River catchment 2012-2019.

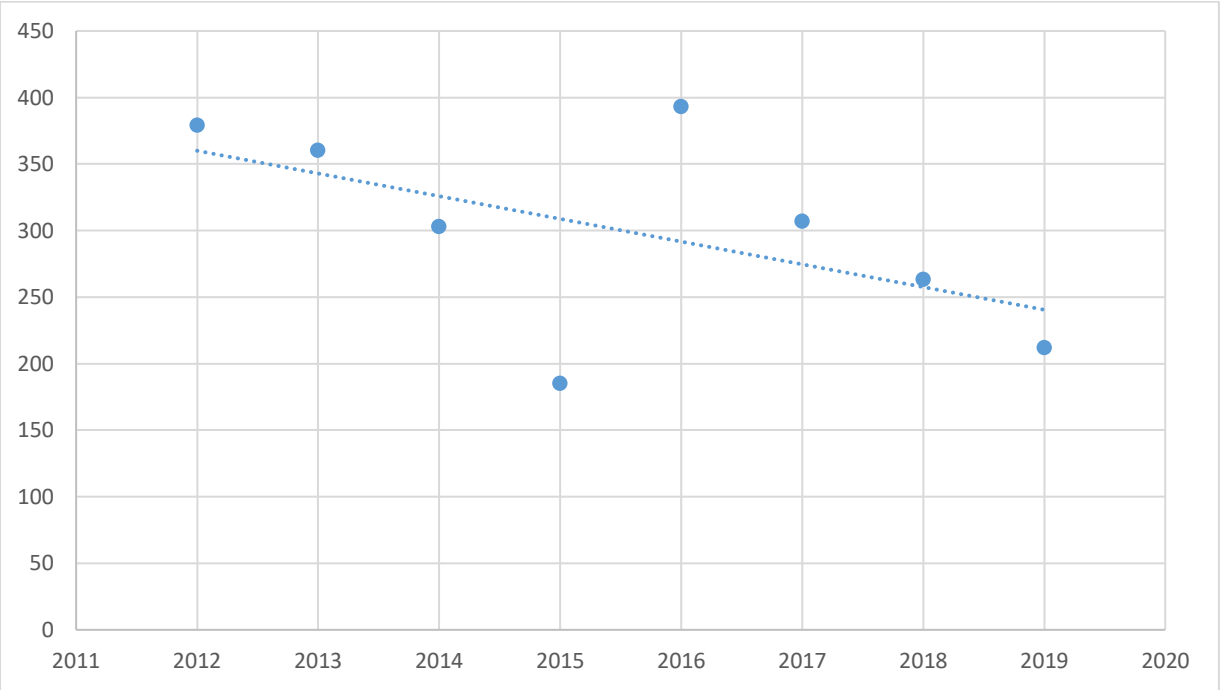


Figure 13b. Maximum number of nests recorded in the Upper Waiau Toa (grey dots and dashed trend line) and the Acheron River (blue dots and dashed trend line) 2012-2019.

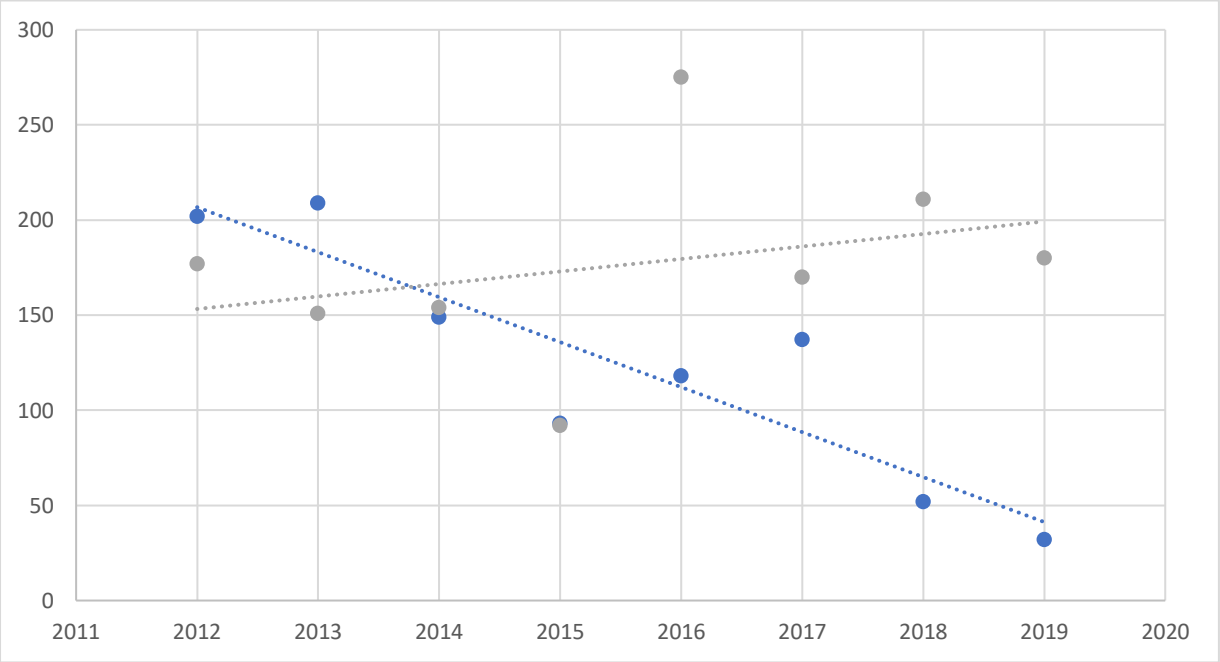


Table 3. Number of nests and adult birds present on the Upper Waiau Toa and Acheron Rivers at the peak breeding, 2012-2019 breeding seasons.

		2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Acheron	Max active nests	202	209	149	93	118	137	52	32
	Number of colonies	9	10	7	9	6	8	3	1
Waiau Toa	Max active nests	177	151	154	92	275	170	211	180
	Number of colonies	9	10	14	14	13	13	13	11
Total	Max active nests	379	360	303	185	393	307	263	212
	Number of colonies	18	20	21	23	19	21	16	12
	Max breeding birds	758	720	606	370	786	614	526	424

Figure 14. Locations and relative size of black-fronted tern colonies monitored on the Upper Waiau Toa and Acheron Rivers 2015-2019 breeding seasons.

Insert map – sorry I have not been able to get this map completed in time. But it basically shows that the terns return to the same stretches of river year after year!

4.2 Black-fronted tern breeding success

4.2.1 Black-fronted tern nest monitoring

Throughout the five-year study a total of 1,880 nests were monitored in 91 colonies in the Upper Waiau Toa/ Clarence River Catchment. Each year the three treatment sites were monitored, although black-fronted tern did not breed on them in all years. At these treatment sites terns nested both on the enhanced island, and at times on the mainland immediately adjacent to these islands (Table 4).

In further analysis of the results in this report, "treatment" colony results only include nests on enhanced islands at these treatment sites. As this study was to determine if enhanced islands with mammalian predator control improved black-fronted tern breeding success, it is only these nests which are considered under treatment.

Table 4. Number of monitoring nests and colonies each season in the Upper Waiau Toa/ Clarence River Catchment. (Note: 2016 season data includes only Upper Waiau Toa nests due to the Kaikoura earthquake prevent access to the Acheron River for most of the season).

		2015	2016	2017	2018	2019
Treatment (Enhanced Island)	Number of nests	45	139	82	42	18
	Number of colonies	3	3	3	3	1
Treatment (Mainland)	Number of nests	34	9	3	13	1
	Number of colonies	3	1	1	3	1
Non-treatment	Number of nests	401	353	441	501	249
	Number of colonies	20	16	18	14	10

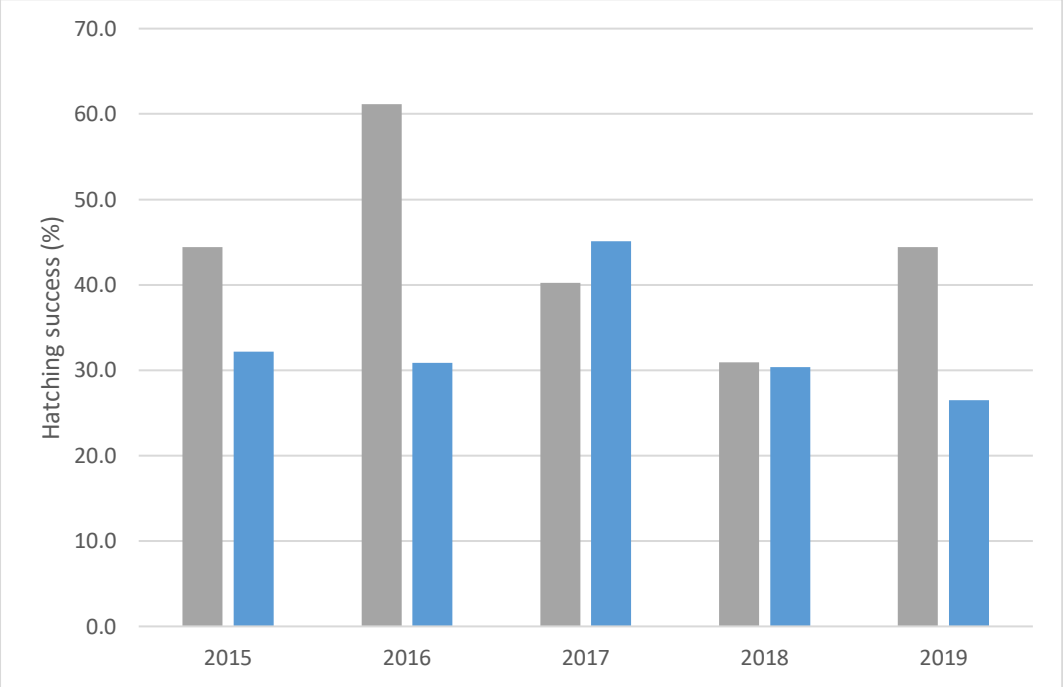
4.2.2 Black-fronted tern hatching success

Throughout the five-year study black-fronted tern mean hatching success each season in treatment colonies (enhanced islands) was significantly higher (Ttest p = 0.045, mean = 44.2%, range 31.4 – 61.2%) per season, than at non-treatment colonies (mean = 33.0%, range 26.5 - 45.1%) (Table 5, Figure 15).

Table 5. Hatching success recorded in at treatment and non-treatment colonies in Upper Waiau Toa/ Clarence River Catchment, 2015 - 2019. (Note: 2016 season data includes only Upper Waiau Toa nests due to the Kaikoura earthquake prevent access to the Acheron for most of the season).

		2015	2016	2017	2018	2019
Treatment (Enhanced Island)	Number of nests	45	139	82	42	18
	Hatched nests	20	85	33	13	8
	Hatching success	44.4%	61.2%	40.2%	31.4%	44.4%
Non-treatment	Number of nests	401	353	441	501	249
	Hatched nests	129	109	199	152	66
	Hatching success	32.2%	30.9%	45.1%	30.3%	26.5%

Figure 15. Hatching success recorded in at treatment and non-treatment colonies in Upper Waiau Toa/ Clarence River Catchment, 2015 - 2019. (Note: 2016 season data includes only Upper Waiau Toa nests due to the Kaikoura earthquake prevent access to the Acheron for most of the season).



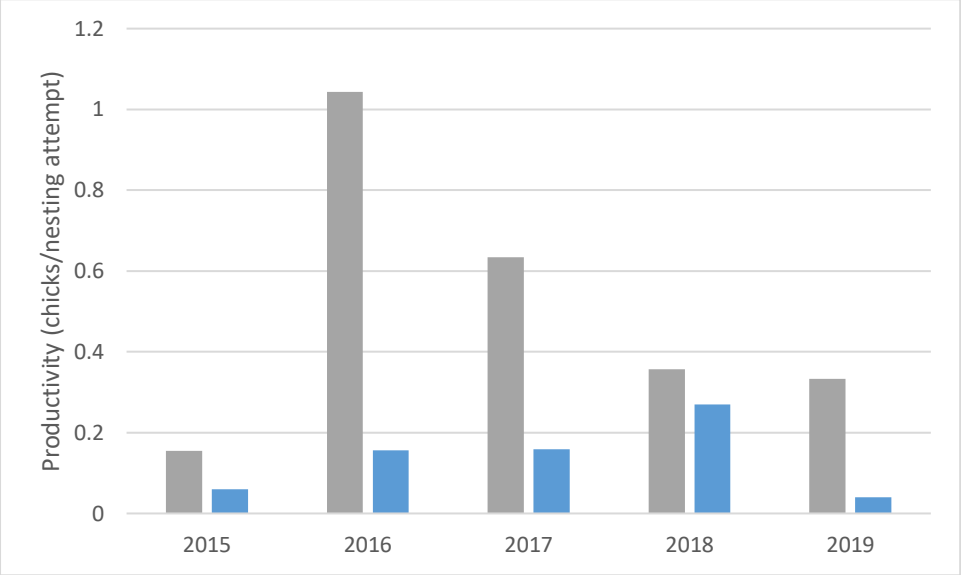
4.2.3 Black-fronted tern fledging success

Throughout the five-year study black-fronted tern mean annual productivity at treatment colonies (enhanced islands) was significantly higher (TTest P = 0.025, mean = 0.5 chicks/ nesting attempt, range 0.16 – 1.04 chicks/ nesting attempt) than non-treatment colonies (mean = 0.14 chicks/ nesting attempt, range 0.06 – 0.27 chicks/ nesting attempt) (Table 6 and Figure 16).

Table 5. Black-fronted tern productivity (chicks/ nesting attempt) each season in the Upper Waiau Toa/ Clarence River Catchment. (Note: 2016 season data includes only Upper Waiau Toa nests due to the Kaikoura earthquake prevent access to the Acheron for most of the season).

		2015	2016	2017	2018	2019
Treatment (Enhanced Island)	Number of nests	45	139	82	42	18
	Fledglings	7	145	52	15	6
	Productivity	0.16	1.04	0.63	0.36	0.33
Non-treatment	Number of nests	401	353	441	501	249
	Fledglings	24	55	70	135	10
	Productivity	0.06	0.16	0.16	0.27	0.04

Figure 16. Black-fronted tern productivity (chicks/ nesting attempt) each season in the Upper Waiau Toa/ Clarence River Catchment. (Note: 2016 season data includes only Upper Waiau Toa nests due to the Kaikoura earthquake prevent access to the Acheron for most of the season).



4.3 Video monitoring to determine causes of nest failure

Throughout the five-year project the cause of nest failure at 50 nests within treatment colonies (enhanced islands) and 319 non-treatment nests were determined using video monitoring (Table 7 and 8, Figure 17 and 18).

Flooding was the leading cause of nest failure at both treatment (40% of nests) and non-treatment nests (51%).

Predation by harriers was responsible for 10.7% of nest failure in non-treatment colonies, but for only 2% of treatment colony nests. Feral cats were responsible for 14% of predation events on treatment colonies, with predation only occurring in two seasons. The first in 2015 prior to island enhancement and deployment of the full trapping gird, and the second in 2017 when a cat accessed Mitchell's cutting island and depredated nests (predation caused by a single predator gaining access to the island).

AT non treatment sites, mammalian predators accounted for 21.7% of nests, at treatment sites for 2016 mammalian predators were responsible for 18% of predation events, however 6 of 9 of these events occurred in 2015 prior to island enhancement and full predator control.

Table 7. Causes of observed black-fronted tern nest failure at non-treatment colonies in the Upper Waiau Toa/ Clarence River Catchment 2015-2019.

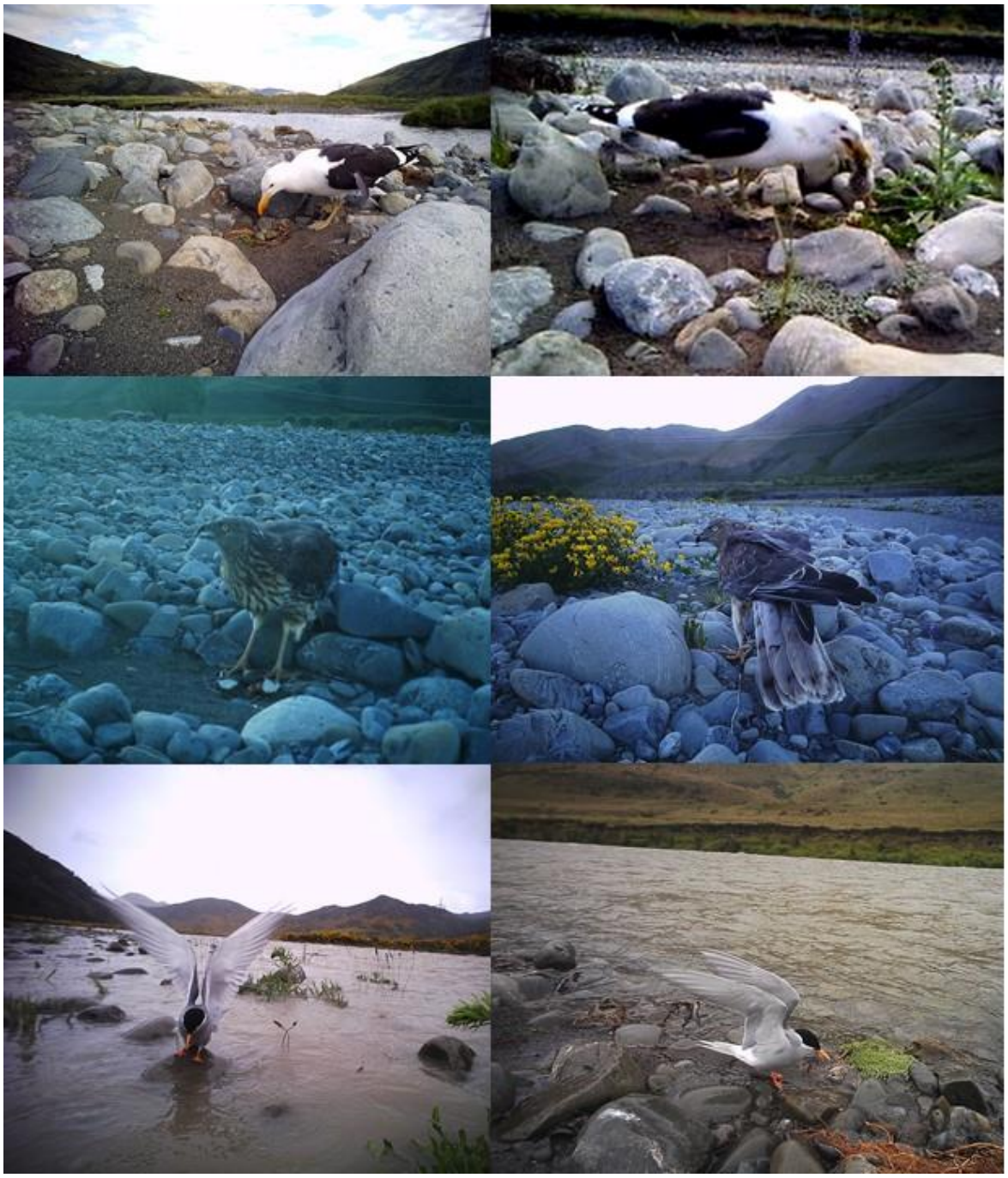
Cause of nest failure	2015	2016	2017	2018	2019	Total
Flooding	9	13	32	35	74	163 (51.1%)
Australasian harrier	9	0	8	16	1	34 (10.7%)
Feral cat	11	14	3	0	0	28 (8.8%)
Ferret	7	8	1	1	0	17 (5.3%)
SBBG	0	0	9	1	6	16 (5%)
Hedgehog	1	7	2	0	2	12 (3.8%)
Cow	0	0	2	5	4	11 (3.4%)
Stoat	5	1	1	0	0	7 (2.2%)
Rabbit	1	1	1	0	2	5 (1.6%)
Possum	0	4	0	0	0	4 (1.3%)
SIPO	2	1	0	0	0	3 (0.9%)
Ship rat	0	0	0	0	3	3 (0.9%)
Hare	1	0	1	0	0	2 (0.6%)
Pig	0	0	1	0	0	1 (0.3%)
Magpie	0	0	0	1	0	1 (0.3%)
Total	46	55	64	62	92	319

Table 8. Causes of observed nest failure events at treatment colonies (enhanced islands) on the Upper Waiau Toa; 2015 to 2019.

	2015	2016	2017	2018	2019	Total
Flooding			3	17		20 (40%)
BFT		4	8	1		13 (26%)
Feral cat	4		3			7 (14%)
SBBG			3	1	2	6 (12%)
Possum	2					2 (4%)
Harrier		1				1 (2%)
Cow				1		1 (2%)
Total	6	5	17	20	2	50

Figure 17. Images from video monitoring of black-fronted tern nests in the Upper Waiau Toa/ Clarence River catchment showing mammalian predation. A) Feral cat depredating eggs B) Hedgehog depredating eggs C) Stoat killing an adult black-fronted tern on its nest D) Possum depredating eggs E) Ferret depredating eggs F) Cow trampling eggs in nest

Figure 18. Images from video monitoring of black-fronted tern nests in the Upper Waiau Toa/ Clarence River catchment showing avian predation and flooding. A) Southern black-backed gull depredating eggs B) SBBG eating young chick C) Harrier depredating eggs D) Harrier depredating eggs E) Black-fronted tern at nest site during flood after eggs washed away F) Black-fronted tern at nest site with sggs floating in nest.



Loss of nests by flooding has been the leading cause of nest failure throughout the study. As previously stated, flood events >30 cumecs have widespread impacts on black-fronted tern breeding. Annual fluctuations in river flow have impacts on the number of nests flooded each season, but also on the proportion of nests depredated by cats and mustelids.

In seasons with high mean flows more nest are lost to flooding (Figure 19), although fewer nests are predated by feral cats and mustelids (Figure 20).

Figure 19. The relationship between average flow of the Upper Waiau Toa (15 October – 31 December, recorded at Jollies Pass) and the percentage of nests that were flooded each season (P<0.001).

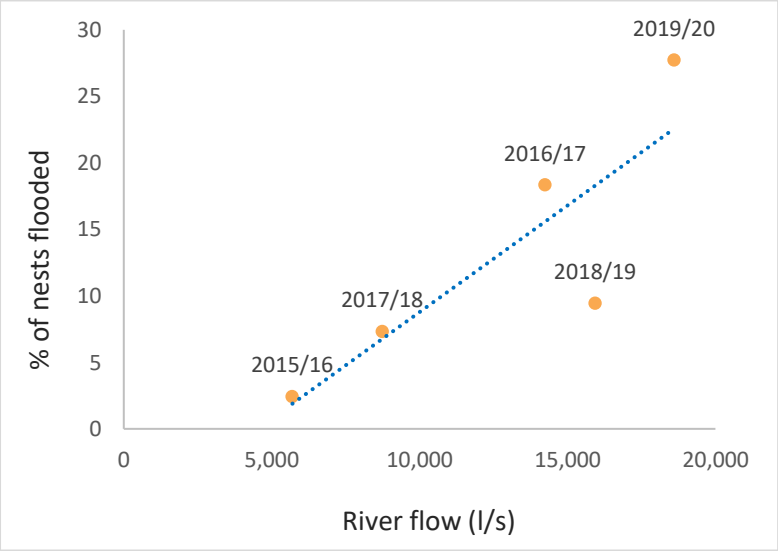
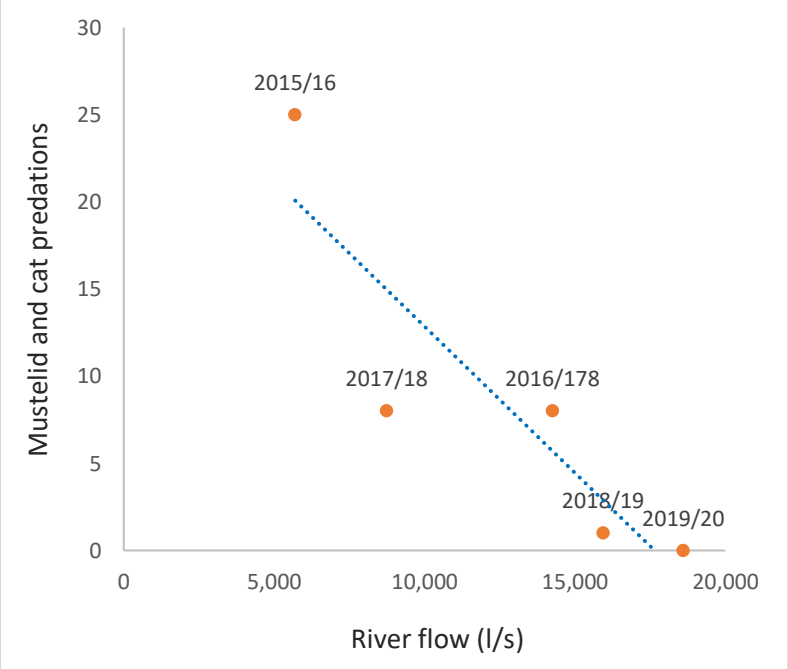


Figure 20. The relationship between average flow rate (October 15th-December 31st) throughout 2015-2019 along the upper Clarence river and the percentage of nests that were depredated on by mustelids and cats throughout each monitored season (P<.001).



4. DISCUSSION

Management at three sites on the Upper Waiau Toa have seen an improvement in black-fronted tern breeding success compared to unmanaged sites. Both hatching success and productivity were significantly higher on enhanced islands than at colonies with no management. Across the five years, mean hatching success at enhanced islands was 44.2% compared to 33.0% without management. Mean productivity on enhanced islands was 0.5 chicks/ breeding attempt, whereas at non-managed colonies was only 0.13 chicks/ breeding attempt.

Within the Upper Waiau Toa, bulldozer work to enhance islands appears to have had several benefits. The bulldozer work cleared woody vegetation providing clear gravels for tern breeding, and improved flows around islands (along with predator control) appears to have reduced mammalian predation.

The Upper Waiau Toa is a medium flow river, and the bulldozer work to deepen and widen channels survived for several seasons before remedial work was required, highlighting that such mechanical island enhancement in medium flow rivers is a cost-effective way to create improved breeding habitat for black-fronted terns.

Following island enhancement and completion of the entire trapping grid (2016-2019), only one mammalian predator has made it onto an enhanced island and predated nests. In 2017 a feral cat gain access to Mitchell's Cutting during a period of sustained low flows (<10 cumecs) and depredated several nests. Throughout the study, at non-treatment colonies mammalian predators accounted for 22% of nest losses. This highlights that the combination of island enhancement and predator control has largely prevent mammalian predation on enhanced islands.

Furthermore, leghold trapping captures a significant number of harriers each season, and this appears to have reduced harrier predation at treatment colonies. Australasian harrier has been recorded predating only a single nest at enhanced islands (2% of filmed nests), but are responsible for 10.7% of nest failures at unmanaged sites – the highest proportion of nests taken by any predator (including mammalian predators).

On non-treatment colonies, there has been a decline in mammalian predation rates in the last 2-3 seasons. This corresponds to increased river flows over theses seasons, and there is a strong correlation between higher flows and lower feral cat and mustelid predation. High river flows ensure islands have better channels which makes islands less accessible to mammalian predators.

Southern black-backed gull has become an issue over the last three seasons. No SBBG breed on the Upper Waiau Toa, and a small colony occurs in the Acheron. SBBG predation has only been recorded late in the breeding season (late December and January) and possibly coincides with the end of the SBBG breeding season when birds are dispersing from their breeding colonies.

5. RECOMMENDATIONS

Based on the results from this five-year project the following recommendations are made:

- Further enhanced islands should be created within the Upper Waiau Toa between Bush Gully and Swimming Hole to provide more choice of enhanced nesting habitat. These sites should be created within a changed trapping network as discussed below.
- Islands selected for enhancement should be either of sufficient height or be able to be raised to sufficient height to withstand a 40 cumec flood.
- Consideration should be given to using social attraction techniques to encourage black-fronted tern to breed on enhanced islands. Hamblin (2017) found that black-fronted tern responded to decoys and audio playback during early stages of colony formation, although often did not remain to breed. Potentially social attraction could be used to encourage terns to breed on enhanced islands and could trigger earlier breeding which may minimise predation from Southern black-backed gulls (most SBBG predation is recorded in January).
- Small shelters made as naturally as possible could be added to islands as a location for chicks to hide during aerial predator attacks, or to shelter from extreme weather conditions (both snow and heat). A study in Tokyo, Japan, found that the fledgling rates in a little tern (*Sterna albifrons*) colony was more successful following the establishment of chick shelters (Hayashi *et al.* 2002).
- That the trapping regime should be changed to spread traps out across the river, rather than using a grid system. For the same number of traps (i.e. the same effort) a double line of traps on each side of the river would protect 7.2km) and a single line of traps 14.4km. Feral cat, ferret and stoat have large home ranges, and extending the trap spatial coverage, is likely going to reduce predator abundance over a wider area. Combining this with enhancing more islands is likely to provide much greater benefits to black-fronted tern.
- Australasian harrier should be targeted during using funnel cage traps to further reduce the impacts of harriers on black-fronted tern breeding.
- The Southern black-backed gull colony in the Acheron river should be controlled, and no gulls should be allowed to establish a breeding colony in the Upper Waiau Toa. The aim should be to remove SBBG as a breeding species from the Upper Waiau Toa/ Clarence River catchment.

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