Five-year report: Lower Waitaki River island enhancement project for black-fronted tern 2015-2020

Prepared by the Department of Conservation for Environment Canterbury.

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Cover: Two Freshly Hatched Black-fronted Tern/Tarapirohe Chicks in Nest. *Photo: Jemma Welch*

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Contents

1 Introduction

1.1 Context

The Lower Waitaki habitat restoration project was initiated in 2016, and was initially setup as part of a doctoral dissertation by Ann Schlesselmann (Schlesselmann, 2018). The purpose of the study and subsequent work was to assess the effectiveness of using cleared braided river islands as a management technique for improving black-fronted tern (*Childonias albostriatus*; nationally endangered) nesting success. This is done by clearing all exotic vegetation and creating refugia for the tern from introduced mammalian predators. Since 2017 the project continues to be jointly funded by the Department of Conservation (DOC) and Environment Canterbury (ECan), with island maintenance and outcome monitoring being organised and undertaken by DOC staff.

The purpose of this document is to provide an overview of the habitat enhancement work that has been carried out since 2016, and to describe the outcomes this work has had for black-fronted tern breeding success. Information for this for this document was summarised and collated from Ann Schlesselmann's PhD dissertation and from Department of Conservation annual project reports (Schlesselmann 2018, Edwards and Buchholz 2018, Welch *et al* 2019, Kimber 2020).

1.2 Background

The black-fronted tern/Tarapirohe is a small, nationally endangered tern species endemic to New Zealand (Robertson et al., 2016). A braided river specialist, black-fronted terns are highly adapted to nesting on clear shingle areas of the braided rivers in the eastern and southern South Island. Predation of adults, eggs and chicks by introduced mammals, and breeding habitat degradation/loss are believed to be the primary threats to black-fronted terns (Keedwell, 2005). Attempts at improving black-fronted tern nesting success have primarily involved using localised or landscape-scale predator-trapping regimes and have been trialled with some success (Welch et al., 2018). Black-fronted terns have also been shown to respond to vegetation clearance by using the resulting bare gravel for roosting and nesting (Maloney et al., 1999).

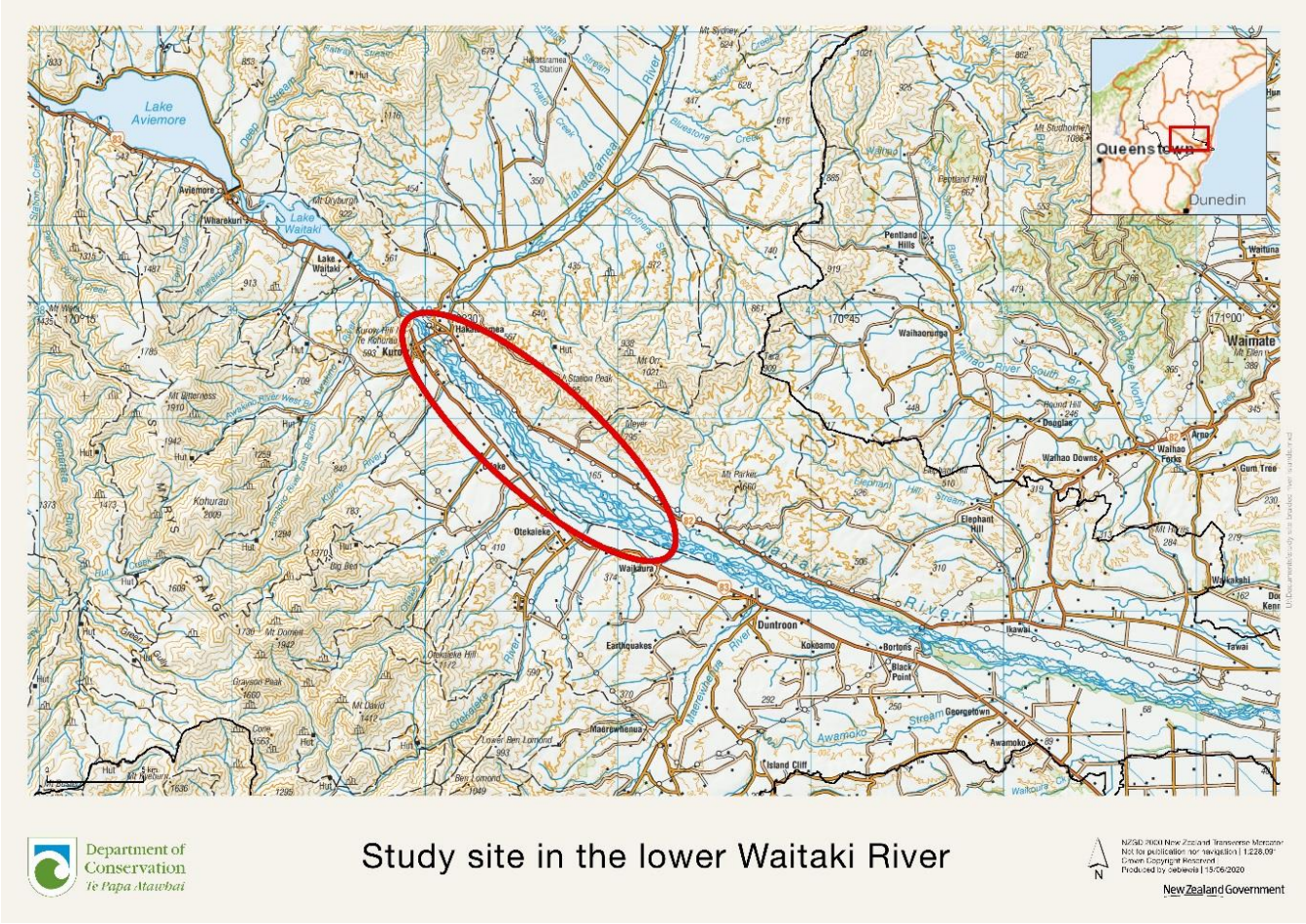
Braided river islands smaller than 3.5ha, clear of exotic vegetation, over 20m from their adjacent vegetated islands/riverbanks and separated by a channel with a flow higher than $6m^3$/sec, were shown by Pickerell (2015) to have fewer mammalian predators than their adjacent vegetated islands or riverbanks. The purpose of this project is to investigate whether clearing braided river islands in the Waitaki River of exotic vegetation reduces pressure from mammalian predators, thus improving the nesting success of black-fronted terns.

Following a season of baseline monitoring of black-fronted tern breeding attempts and mammalian predator presence on vegetated islands and gravel patches in the Lower Waitaki River in the 2015-16 breeding season, seven islands were cleared then of exotic vegetation and built up to approximately 0.5m above the mean watermark using a bulldozer (Image 1). During the 2016-17 breeding season, monitoring of predators and black-fronted tern nesting was carried out on and on both cleared and vegetated islands (Schlesselmann et al., 2018). Follow-up weed control and island maintenance was arranged by DOC at the start of each breeding season from 2017 – 2019.

2 Methodology

2.1 Study site

The selected study site is in the upper reaches of the Lower Waitaki River on a 15 km stretch of river from 1 km upstream of the SH 83 Kurow Bridge, to the confluence of the Penticotico Stream on the true left of the Waitaki River (Map 1). This section of river was selected as it was observed to have high density of black-fronted tern in the previous year (Schlesselmann 2017).



Map 1 Location of study site in the lower Waitaki River

2.2 Habitat Enhancement

2.2.1 Island selection

Seven braided river islands, approximately 1km apart, were selected in the mid Waitaki River between Otiake Stream and Kurow township. Island selection was based on the following criteria: 1) size of the pre-existing islands, 2) accessibility for the bulldozer, 3) height above average flow (i.e. available gravel materials and protection against flooding) and 4) channels with a minimum width of 14m from adjacent riverbanks or other vegetated islands. Note that there are physically eight islands, however for black fronted-tern nesting colonies islands 7a and 7b are functionally one and referred to in this document together as ‘island 7’.

2.2.2 Island clearing and raising

Each of the seven selected islands were cleared of all vegetation (between 0.4 – 2 ha, average 0.94 ha) during April and May 2016 using a 2006 Komatsu D65 px bulldozer with a 4m wide blade (Schlesselmann, 2018; Image 1). The islands were modified to be approx. 1ha in size and built-up to approximately 0.5m above the mean watermark to protect from flooding. The total cost of the initial enhancement work was $50,000.

Image 1 Cretion of first two islands using a digger, showing raised level and cleared gravels

2.2.3 Island maintenance

The aim of the vegetation control was to prevent vegetation growth and maintain a clean cobble appearance on the islands, thereby creating a desirable breeding habitat for black-fronted terns and other river birds, while theoretically discouraging mammalian predators. The primary vegetation types targeted during maintenance include gorse, broom, willow, blackberry, exotic grasses, Californian poppy and Lucerne. The seven cleared islands were heli-sprayed by Heliventures NZ Ltd with 5L/ha Grazon^{TM}, 7L/ha Glyphosate Green and 2L/h Spray Gold Ultra (as per the ECan consent) at the beginning of each breeding season between 2017 and 2020. The total area sprayed each season was approximately 8.3 ha. The annual cost of spraying ranged from $6846 to $9083 (Table 1).

Additional follow up work to sculpt islands and further isolate them from berms was carried out in September 2017 for $9000 (Edwards and Buchholz, 2018). No additional island maintenance was deemed necessary in the 2018-19 and 2019-20 breeding seasons.

Table 1 Annual aerial spraying cost for maintance of the seven cleared islands.

Breeding season	Approximate cost
2017/18	$7,000
2018/19	$6,846
2019/20	$9,083

2.3 Predator monitoring

This section details the methodology used for mammalian predator monitoring within the study area. This section is presented two sub-sections: 1) baseline and year-one monitoring and 2) year-two onwards. This is because the initial monitoring was done as part of a PhD project (Schlesselmann, 2018), and included monitoring on vegetated islands and riverbanks, whereas follow-up years was on the seven cleared islands only.

2.3.1 Predator monitoring – Baseline and year one (2015/16 and 2016/17)

Information for this section is summarised from Schlesselmann (2018), see this source for full methodology and statistical tools used.

The presence of mammalian predators on riverbanks was surveyed at two sites, one on the southern and one on the northern bank of the Waitaki River study site. At each site, five large tracking tunnels were placed at 200m intervals along a 0.8km transect running parallel to the river. Transects were placed in vegetation to maximise the chance of predator detection. Each tunnel was checked and re-baited with fresh rabbit (*Oryctolagus cuniculus*) meat every 10-days for a total of 70 days per black-fronted tern breeding season.

Mammalian predators were also monitored on 13 vegetated braided river islands during each of the two breeding seasons, and the seven cleared islands after the vegetation was removed prior to the 2016/17 breeding season. Depending on the water flow, the selected vegetated islands may have been connected to other vegetated islands on the river, but never to the banks of the river. One tracking tunnel was placed on each island. Tunnels were checked and re-baited every 12–15 days on vegetated islands in the 2015/16 season, and every 5–10 days for vegetated and cleared islands in the 2016/17 season.

Footprints on tracking cards were identified to species level where possible with the exception of mustelids. Ferret, *(Mustela furo)*, stoat (*M. erminea*) and weasel (*M. nivalis*) were all classified as ‘mustelids’ because their footprints overlap in size depending on sex and age of animals. Mean tracking rates over the entire period that the tracking tunnels were used, and the minimum and maximum tracking rates of each interval between checks of tracking tunnels were calculated.

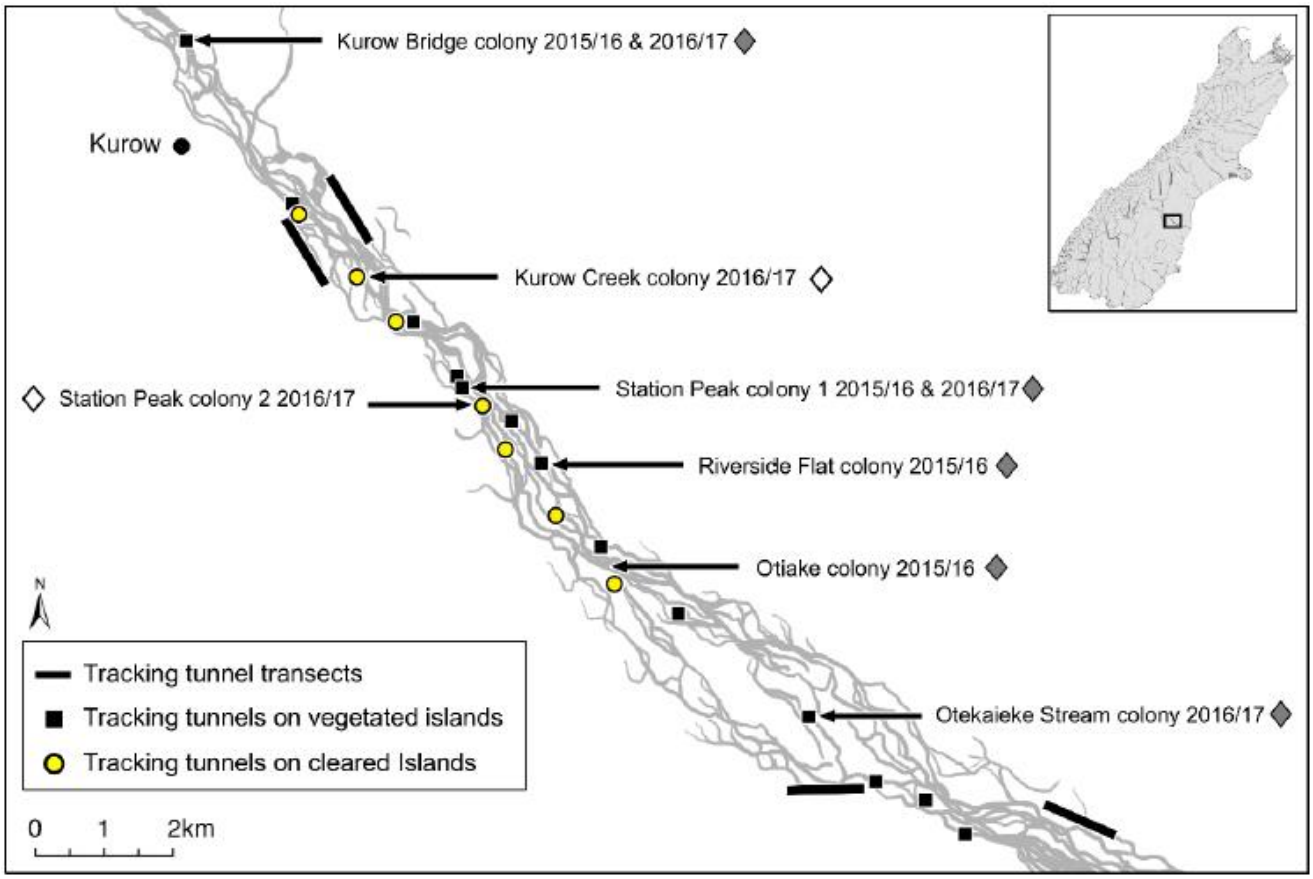


Figure 1 Map of study site in the Waitaki River showing the locations of monitored islands and tracking tunnel transects for the 2015/16 and 2016/17 breeding seasons. Diamond symbols after the location name and breeding season indicate whether it was on a cleared (white) or vegetated (grey) island. Figure taken from Schlesselmann (2018).

2.3.2 Predator monitoring follow-up years (2017/18 to 2019/20).

During the 2017/18 – 2019/20 breeding seasons only cleared islands were monitored for mammalian predators. The monitoring methodology varied from year to year, so each season is detailed separately. All comparisons of mammalian predator occurrences on riverbanks and vegetated islands are with the baseline data collected in 2015/16 and 2016/17

2017/18 breeding season (Edwards and Buchholz 2018)

One cat size tracking tunnel was established on each of the islands on 3rd Nov 2017, and maintained with fresh papers, ink and rabbit bait on 9th and 22nd November and 1st, 13th and 19th December during the 2017/18 breeding season (Edwards and Buchholz 2018).

2018/19 breeding season (Welch *et al.* 2019)

During the 2018/19 breeding season, three to five small tracking tunnels were placed down the length of each of the seven cleared islands at approximately 50m intervals on the 30th of October 2018. Tracking cards were baited with peanut butter and were checked, and either replaced or rebaited every 7 days. Tracking tunnels were removed on the 11th of December after black-fronted terns appeared to have ceased nesting. No camera monitoring was carried out this season.

2019/20 breeding season (Kimber 2020)

No tracking tunnels were used for monitoring during the 2019/2 breeding season. Trail cameras were used at nest sites on island 1 and island 4. Details for the timing of camera placement are not available.

2.4 Black-fronted tern breeding success monitoring

Monitoring of black-fronted tern breeding success was carried-out each breeding season (Oct- Jan) from 2015/16 – 2019/20. The use of islands by other river bird species was also recorded most seasons, with any obvious breeding behaviour noted and their nests opportunistically monitored if found.

2.4.1 2015/16 and 2016/17 breeding seasons

The initial two seasons were part of the PhD research in two phases: 1) A pilot study before vegetation clearance in 2015/16 and 2) an extensive study post-vegetation clearance 2016/17.

In both seasons, systematic searches for black-fronted tern colonies were carried out by observing birds either from the riverbanks, or from a jetboat on the river. Once a colony was located, systematic searches for nests were carried out. All nests were marked with a small rock cairn (10–15 cm tall) approximately 1m upstream of the nest. Additional nests were searched for from the second visit onwards. Only 30 nests per colony were monitored at a time to minimise disturbance and stress to breeding birds. The status of the nests was assessed by regular walk-through checks on islands at the same intervals as tracking tunnel checks, every 12–15 days in the 2015/16 season, and every 5–10 days in the 2016/17 season.

Remote cameras were used in the 2016/17 breeding season to determine the identity of any predators in the case of nest failure caused by predation. Between two and seven motion-detector cameras were set-up in colonies (colony-size dependent), with the aim of at least 20% of the walk-through monitored nests being additionally monitored with a camera. Camera footage showed that incubating adults returned to the nest within 5 min of researchers leaving the colony.

Nest outcomes were classified into the following categories:

1) Successful: if one or more eggs hatched and at least one chick was observed in or close to the nest bowl (black-fronted tern chicks are precocial and leave their nest, which is why fledging success is difficult to measure accurately).
2) Failed due to predation: no adults were present as the nest was approached, the nest bowl was either empty or contained damaged eggs, and no sign of chicks was observed.
3) Failed due to flooding: high watermark, flattened vegetation or didymo (*Didymosphenia geminata*) fragments around the nests and/or discoloured eggs.
4) Failed due to desertion: nest was un-attended and eggs were cold
5) Unknown: nest outcome was unclear.

2.4.2 2017/18 breeding season

Six of the seven islands were serviced by foot by wading river channels to reach them. Island 2 below Kurow Creek -Waitaki River confluence was not visited because the channel between Island 2 and the berm was significant and prevented crossing on food. Observations from the berm were used for this island. To gain foot access, trips had to be coincided with relatively low flow events using Meridian Energy's dam control flow estimates. A high variation in flow rates was experienced during the season with rates from 100-550cumecs within a 24-hour period.

Four colonies were established and monitored on the six islands that could be reached. For 'island 2' Observations were carried out from bermside using binoculars and spotting scope.

The first monitoring visit occurred 27th October, by the 19th December no bird activity was occurring.

2.4.3 2018/2019 breeding season

Breeding attempts were monitored on all seven islands throughout the 2018/19 breeding season. Between the 8th of October 2018 and the 14th of January 2019, islands were visited every 7-10 days except for two visits where 15 days passed since their previous visits (one in late-October and one after New Year's). Islands were monitored throughout the season by one consistent observer with occasional volunteers. Islands were accessed by jetboat courtesy of Braided River Jetboating.

On approaching islands, birds observed flying above the island, or using adjacent channels, were recorded and tallied. The islands were then slowly walked around, with additional birds recorded and tallied. For larger black-fronted tern colonies where it can be difficult for one person to count birds during walk-throughs, assistance from people on the riverbanks was provided by counting birds from a distance. Bird's behaviours were noted, and for any displaying nest or chick behaviour, their nests or chicks were searched for more thoroughly.

All nests found were GPSed and marked as described in section 2.4.1. Nests that lost eggs between visits were checked for signs of hatching (parents with chick behaviour, faeces in and around nest for black-fronted terns) or failure (abandoned eggs, broken eggs or eggshell, yolk or albumen). Failed nests were classified as preyed upon, preyed upon then deserted, deserted, flooded, damaged in nest, died during incubation/infertile and unknown cause. Any hatched chicks not seen during subsequent visits were assumed alive if an adult pair in the vicinity was observed with chick behaviour. Fledging was confirmed were possible when chicks near to fledging or fledglings were observed.

2.4.4 2019/2020 breeding season

Nesting monitoring in the 2019/20 was carried out by staff from the Raukapuka/Geraldine office. There was an initial visit to the site on the 29th of September 2019. After the second visit on the 23rd October 2019 all seven islands were checked every 7 -10 days, with the exception of December, when high water levels caused a month between one of the checks. Islands were accessed by jetboat courtesy of Braided River Jetboating.

On approaching islands, birds observed flying above the island, or using adjacent channels, were recorded and tallied. The islands were then checked on foot, with additional birds recorded and tallied. For larger black-fronted tern colonies, estimates were aided by counting birds from the banks. Bird's behaviours were noted, and for any displaying nest or chick behaviour, their nests or chicks were searched for more thoroughly. All nests found were GPSed and marked as per section 2.4.1. Nests were then monitored through to failing or hatching as per section 2.4.3.

3 Results

3.1 Habitat Enhancement

Overall, the island enhancement work and follow-up maintenance were generally successful in maintaining a clean, cobble appearance, clear from any significant weed growth on the cleared islands throughout the breeding seasons (Edwards and Buchholz 2018, Welch et al 2019, Kimber 2020). The island edges had more exotic vegetation cover than the island centres, which had, at most, a few isolated plants. However, when compared to the nearby vegetated islands this weed cover was negligible (Welch et al 2019).

Image 2 Pictures of Islands Three (top) and Four (bottom) showing the extent of weed cover in the 2018/19 season. Photos: Jemma Welch

3.1.1 2020 Flood Event

In December 2019 there was a large release of water down the Waitaki River from the hydro-electric dam following heavy rainfall. This release increased river flow by 300 – 500 cumecs, reaching to up to 1125 cumecs for several days. These high flows caused considerable damage to six of the seven cleared islands (Fraser 2020). The damage recorded includes reduced channel size and depth, enabling mammalian predators to access islands (islands 1 and 3), damage reducing the size of the island and requiring extensive maintenance work to islands 3 (0.2ha), 4 (now 0.3ha), 5 (now 1.4ha), 6 (now 1.2 ha), and 7b (0.1ha), and completely destroyed Island 7. Only Island 2 (now 2.2ha) remained largely undamaged from the flood events (Fraser 2020). Images 3-10 from Fraser (2020).

Image 3: Reduced depth in Southern channel of Island 1.

Image 4: Island 2 with no significant changes.

Image 5: Island 3 with very low flow separating the island and adjacent land. Reduced significantly in size.

Image 6: Island 4 significantly reduced in size.

Image 7: Island 5 requires maintenance work to restore size of island and downstream channel.

Image 8: Island 6 channel is narrow and less than 0.5m in places.

Image 9: Island 7a has been destroyed.

Image 10: Island 7b reduced size and susceptible to flooding.

3.2 Island use by braided river birds

Prior to clearing, black-fronted terns were not observed on any of the seven islands (Schlesselmann, 2018). However, black-fronted terns were observed using five the islands immediately after they were cleared, and established colonies on two of the islands in the first breeding season following vegetation removal (Table 2). Terns continued to use at least five of the seven cleared islands in subsequent breeding seasons. In the 2017/18 breeding season five islands had colonies and in the 2018/19 season they were present and nesting on all of the seven cleared islands. In the 2019/20 season black-fronted terns nested on five of the islands and were observed during the season on, or in, channels adjacent to all islands. All of the islands were used by tern during at least two of the four monitored breeding seasons following island clearing. Island three was the only island not used for nesting, but was used for feeding and roosting. Island 4 was used for nesting during all 4 breeding seasons, and islands 1, 2 and 7 were each used in all four seasons for roosting/feeding, and three seasons for breeding.

Table 2 Cleared island use by black-fronted tern by year and individual island.

Year	Islands used by black-fronted tern						
	1	2	3	4	5	6	7
Pre-clearing 2015/16	-	-	-	-	-	-	-
2016/17	Present	Nested	Present	Nested	-	-	Present
2017/18	Nested	Present	-	Nested	Nested	-	Nested
2018/19	Nested	Nested	Present	Nested	Present	Nested	Nested
2019/20	Nested	Nested	-	Nested	Nested	Present	Nested

The cleared islands were also found to be attractive habitat for other braided river species, with the critically endangered black-billed gull (*Larus bulleri*) being recorded nesting during two of the breeding seasons (Table 3). Banded dotterel *Charadrius bicinctus*, vulnerable), South Island pied oystercatchers (*Haematopus finschi*, (declining), wrybill (*Anarhynchus frontalis* vulnerable) and pied stilts (*Himantopus himantopus*) were all recorded nesting on the cleared islands during the study period.

In the 2016/17 breeding season black-billed gulls established a large colony on island 6 consisting of approx. 730 birds on nests and 394 other birds (Schlesselmann 2018), and they were recorded present on three islands and nesting on one on the 2018/19 season. There are no data on their island use in the 2017/18 breeding season and no nests were located in the 2019/20 season, but a small number of birds were seen near some of the islands during this breeding season.

Wrybills were observed nesting on five of the islands in the 2016/17 breeding season, and on two of the islands in each of the 2018/19 and 2019/20 breeding seasons. Banded dotterels were observed on 6-7 of the islands, and nesting on 5-6 of the cleared islands for each season that data were recorded. South Island pied oystercatchers were observed on three islands, but there was no recorded breeding activity. Pied stilts were present on 5-6 of the islands and recorded nesting on 2-3 islands each season that data were recorded.

Southern black-backed gulls (*Larus dominicanus*) and Australasian harriers (*Circus approximans*) , known predators to other avian species, were also recorded at the cleared islands. Southern black-backed gulls were observed on all islands and recorded as nesting on island seven in the 2018/19 and 2019/20 seasons. Australasian harriers were recorded as present in the 2018/19 breeding season.

Table 3 Total number of islands on which braided river bird species were observed as 'present' or 'nesting' during each breeding season.

Species	Season							
	2016/17		2017/18		2018/19		2019/20	
	Present	Nesting	Present	Nesting	Present	Nesting	Present	Nesting
Black-fronted tern	5	2	?	5	7	7	7	5
Black-billed gull	2	1	N/A	N/A	3	1	-	-
Wrybill	6	5	N/A	N/A	4	2	3	2
Banded dotterel	7	6	N/A	N/A	6	6	6	5
SIPO	3	-	N/A	N/A	5	2	4	1
Pied stilt	5	3	N/A	N/A	6	4	5	2

3.3 Predator monitoring

Comparison of mammalian predators detected on vegetated banks, vegetated islands and cleared islands showed that the cleared islands had fewer mammalian predator types, and fewer mammalian predator occurrences, than either the riverbanks or vegetated islands.

Monitoring results from the 2015/16 and 2016/17 tern breeding seasons showed that four of the five mammalian predator groups of interest during this project were present on riverbanks (Table 4) (Schlesselmann, 2018). Cats (*Felis catus*), possums (*Trichosurus vulpecula*), hedgehogs (*Erinaceus europaeus occidentalis*), mustelids, and mice (but not rats) were detected on riverbanks during both breeding seasons. Vegetated islands also had possums, mustelids and mice detected on them, but no cats or hedgehogs. In both years, mustelids were detected on approximately half of the vegetated islands (2015/16: 53.8%; 2016/17: 46.2%). The cleared islands were monitored during the 2016/17 season (after they were cleared) and were found to be almost entirely free from mammalian predators. Mice were the only mammalian predator species detected, and on only one of the seven cleared islands. No rats were detected in any of the monitored habitat types during the 2015-2017 study period.

Table 4 Mammalian predators identified on cleared islands for the 2015/16 and 2016/2017 breeding season.

Habitat type	Cats	Mustelids	Mice	Hedgehogs	Possums	Rats
Riverbank	√	√	√	√	√	-
Vegetated islands	-	√	√	-	√	-
Cleared islands	-	-	√	-	-	-

Mustelids were detected on four of the cleared islands in the 2017/18 season, all of which contained black-fronted tern colonies. On two of the islands, single events of mustelid presence were detected with tracking tunnels. On the other two islands, mustelid presence was detected with cameras and/or tern carcases showing characteristic skull damage from mustelids. Mustelids and mice were again detected in the 2018/19 season, each was detected on only one island between the 13th -21st November. During the 2018/19 breeding season tracking cards were either blown or pulled out of tracking tunnels on five islands and showed indistinct prints, suspected to be avian. One rat was detected by camera on one of the cleared islands during the 2019/20 season. The rat was recorded on Island 1 eating an egg from a nest. This is the only rat occurrence detected on any of the cleared islands.

Although mammalian predator presence on the cleared islands was low, presence of avian predators (specifically southern black-backed gulls) was confirmed at the islands during each

of the monitored tern breeding seasons. In the 2016/17 season southern black-backed gulls were confirmed at 21 black-fronted tern nests and suspected to have been responsible for predation at a further 10 depredated nest sites. During the 2017/18 breeding season black-backed gulls were confirmed via camera at three of the cleared islands with black-fronted tern colonies.

3.4 Nesting success of black-fronted terns

This section presents the results of nest monitoring over the five breeding seasons between 2015 and 2020. The two breeding seasons between 2015 – 2017 are detailed separately from the subsequent seasons because nest on vegetated islands were only included for the first two years of this project. All other breeding seasons and the overall nesting success are included in section 3.4.2. Information for section 3.4.1 is from Schlesselmann (2018). Details for section 3.4.2 are from Schlesselmann (2018), Edwards and Buchholz (2018), Welch et al (2019) and Kimber (2020).

3.4.1 Black-fronted tern nesting success in the 2015/16 and 2016/17 breeding seasons

In the breeding season immediately following island clearing, black-fronted tern established three colonies on two of the cleared islands. They also used the other islands for roosting and feeding. None of these islands were used by black-fronted tern in the 2015-16 season while they were vegetated.

In the 2015/16 breeding season 78 nests were monitored in four colonies each on a different vegetated braided river island (Schlesselmann, 2018). During the 2016/17 breeding season 108 nests were monitored in three colonies on three vegetated islands, and 77 nests monitored in three colonies on three cleared islands (**Error! Reference source not found.**). In both years, approximately half of the nests hatched at least one chick. There was no overall difference in nesting success of colonies between cleared and vegetated islands. In 2016/17, most nest successes occurred in October and November, while later in the breeding season (December) almost all nests failed primarily because of predation. The primary cause of nesting failure in both seasons was predation (21.8% and 31.6%) followed by flooding (15.4% and 2.1%) and desertion (2.6% and 6.4%). The primary predator was southern black-backed gulls, responsible for 62.5% of predation events. It is likely that the lack of difference in nesting success between cleared and vegetated islands is because black-backed gulls depredate tern eggs irrespective of vegetation cover around nests (Schlesselmann, 2018).

In addition to the walk-through nest checks, 56 nests were monitored with remote cameras in 2016/17 (24 nests on cleared islands and 32 on vegetated islands). Eighteen of these nests were successful and 32 nests were depredated, primarily by the southern black-backed gull (62.5% of preyed upon nests). The study does not identify which islands (cleared or vegetated) the predation occurred on. It is suspected that the ten nests for which the predator identity could not be confirmed were likely also preyed upon by southern black-backed gulls. This is because all failures resulting from predation occurred in December in colonies where all other nests failed due to southern black-backed gull predation.

3.4.1 Black-fronted tern nest success in all breeding seasons

Throughout the five-year duration of the study 630 black-fronted tern nests were monitored on the seven cleared islands and an additional three vegetated islands (the latter were only monitored for the 2015/16 and 2016/17 seasons). During the five-year study period nest success (hatching ≥1 egg) varied between seasons with a range of 0.8% (one nest) and 51.5%

(44 nests), with an overall nest success rate of 32.9% of nests with known outcomes. Predation was the most common cause of nest failure in each of the five monitored breeding seasons (23-87%) (Fig. 2). This was the only cause of nest failure that was consistently high every breeding season, and accounted for 75% of the total nest failures throughout the five-year monitoring period. Flooding accounted for 14.5% of losses and desertion accounted for 10.1%. Desertion following predation accounted for 1.9% percent of failed nests. In 2019 there was no predation recorded on Island 4, which recorded a 76.8% nest success rate for that breeding season with all known losses being attributed to flooding. Predation was the most common cause of nest failure in followed by

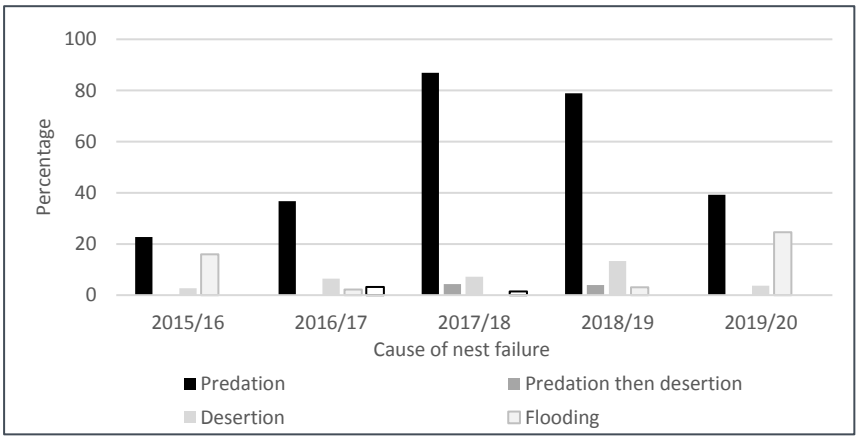


Figure 2 Percentage of monitored nests lost to predation, predation then desertion, desertion, flooding or infertility during each year of the four years of nest monitoring

3.4.2 Black-fronted tern egg hatching success: 2017/18 and 2018/19 breeding seasons.

Of 1135 monitored eggs laid during the five-year study, 39.8% have a recorded outcome. These are all from the 2017/18 and 2018/19 breeding seasons. During these two seasons 496 eggs were monitored. Of these eggs, the outcome is known for 452, or 91.1% of the eggs, 97.3% of which failed to hatch. Predation accounted for the majority of losses (64.8%) followed by flooding (23.5%), desertion (9.1%) and infertility/failure to hatch at 1.3% of known losses. This is largely due to the flooding in December 2019 during which 40 nests and 99 eggs were lost to a flooding events, 48 of the eggs lost to flooding were on a single island (Island 4). In the 2019/20 year two chicks were recorded to reach fledgling age on Island 4, no records of other islands is provided for that year. No monitored nests were recorded to have chicks reach fledgling age in any other year.

Table 5 Annual nesting details for monitored nests on all islands. For the 2019/20 season,island 4 is excluded from the total and placed seperatly next to the data for the other six islands. This is for consistency with annual reports and to highlight the nesting success of Island 4 prior to the December flood event.

	2015/16	2016/17	2017/18	2018/19	2019/20	Total
Nests Monitored	78	188	69	132	107 + 56	**630**
Number of nests with known outcome (A)	75	185	69	128	107 + 56	**620**
Of nests in (A):						
Number of nests hatching ≥1 egg (B)	44	95	13	1	8 + 43	**204**
Nests failed (total)	31	90	56	127	99 + 11	**414**
Eggs laid	148	353	138	220	185 + 91	**1135**
No. eggs laid with fate known (C)	-	-	-	219	185 + 2	**452**
Off eggs in (C):						
No. eggs infertile of died in incubation (D)	-	-	-	0	6 + 0	**6**
No. eggs failed other causes	-	-	-	217	176 + 89	**482**
No. chicks hatched	-	-	-	2	10 + 43	**55**
Hatching success (B/A)	-	0.5	-	0.008	0.07 / .77	**0.3**
Egg success (G) = (C-D)/C	-	-	-	1	1 / 1	**0.99**
Cause of nest failures:						
No. nests predation	17	68	60	101	64 + 0	**290**
Predation then desertion	0	0	3	5	0	**8**
Desertion	2	12	5	17	6 + 0	**40**
Flooding	12	4	0	4	29 + 11	**60**
Died during incubation/infertile	0	6	1	0	0	**7**
Damaged in nest	0	0	0	0	0	**0**
Cause of egg loss:						
No. eggs failed	-	-	-	217	175 + 48	**440**
No. eggs predation	-	-	-	175	118 + 0	**293**
No. eggs flooding	-	-	-	7	51 + 48	**106**
No. eggs desertion	-	-	-	35	6 + 0	**41**
No. eggs failed hatch or infertile	-	-	-	0	6 + 0	**6**
Unknown outcome	-	-	-	1	4 + 0	**1**

4 Discussion

Clearing braided river islands appears to be an effective way to create attractive nesting habitat for braided river birds. Cleared islands have mammalian predator numbers that are heavily reduced (mustelids and mice), or eliminated (cats, hedgehogs and possums). Prior to being cleared, the seven islands in this project were not used by black-fronted terns. Once cleared they were used all four breeding seasons immediately following clearing (2016/17 – 2019/20) by black-fronted tern and other braided river bird species. Black-fronted tern nested on the cleared islands every year of this project, nesting on two in the 2017/17 season and five in each of the 2018/19 and 2019/20 seasons. Island 3 was the only island not selected by black-fronted tern for nesting, but it was still used for roosting and feeding. Most of the islands have been used by the terns and other bird species for feeding and roosting, and all but one of the islands have been used by black-fronted tern for nesting.

Comparison of mammalian predators detected on vegetated banks, vegetated islands and cleared islands in the first two years of this project showed that the cleared islands had less mammalian predator types, and less occurrences of mammalian predators, than were detected at the riverbank or vegetated island sites (see section 2.3.1). Although the monitoring results from the 2016/17 tern breeding season, during the comparison of vegetated vs. cleared islands, did have the lowest detection of mammalian predators on the cleared islands during the four-years of monitoring, even in the subsequent years the detection levels of the predators were very low compared to the baseline data for vegetated islands and riverbeds. There were also less mammalian predator types identified on the cleared islands during the entire monitoring period than the two years of baseline data collection for vegetated islands. There were no possums detected on cleared islands, despite being present on vegetated islands and the cleared islands being closer to the riverbanks than the vegetated islands. Additionally, there were no cats or hedgehogs detected on any of the island types, although they were present on adjacent riverbanks.

Despite the cleared islands having very few mammalian predators detected, there was no increased nesting success for tern on the cleared islands compared with the vegetated ones in the 2016/17 comparison, with both having approximately 50% hatching success (Schlesselmann, 2018). Throughout the entire 5-year monitoring period 32.9% of the monitored nests hatched one or more chicks. The failures were primarily because of egg predation from southern black-backed gulls. Gull predation was detected in almost half of the nests and was responsible for 65% of the losses of monitored eggs. In the absence of mammalian predators, southern black-backed gulls were confirmed to be the primary predator of black-fronted tern nests in each of the monitored breeding seasons. This is likely to be a combination of three things: (1) a super-abundant population of black backed gulls in the area; (2) the ability of gulls to access all islands, and (3) possibly because southern black-backed gulls are not dependent on vegetation for cover, thus vegetation clearance (bare ground) was not a deterrent for them. In upland rivers with lower gull numbers, mammals have been found to be the primary predators of black-fronted tern nests (e.g., the Upper Clarence River, the Tasman River). It is very likely that overall predation rates would be significantly lower, and thus nesting success higher, if gulls were also removed from the vicinity of the cleared islands.

In summary, to ensure a safe nesting habitat, and therefore increased nesting success for black-fronted tern, islands need to be cleared of exotic vegetation to create habitat relatively free of mammalian predators, and have concurrent control of southern black-backed gulls to

remove avian predation pressure. Alternatively, future island clearing could be done in areas with naturally low, or ideally no, southern black-backed gulls.

Removing or reducing southern black-backed gulls on the lower Waitaki River, or trailing island clearing in areas with naturally less gulls, will also better allow for the accurate assessment of the impact of mammalian predators on cleared islands. Cleared islands appear to have less predation pressures from introduced mammalian predators than vegetated islands. However, further study would be beneficial to properly determine this. Currently, any attempts to assess the actual predation pressure by mammals is likely to be confounded by the significant predation pressure by southern black-backed gulls early in incubation. To assess the actual impact of mammalian predators, southern black-backed gull predation pressure needs to be lessened or removed. What is clear, is that these islands gain significant advantage as safe sites from mammalian predators without the need for ongoing trapping and control programmes targeting mammals, and this is a large annual cost saving. A proven control programme around these islands in other rivers cost in the order of $5,000 - 10,000 per island per annum, so the "pay-back" period for initial island clearance over trapping is only 1-2 years, and is even shorter if the initial trap purchase and set-out cost are included.

Flooding was the second largest cause of nest failure, with 10% of nests being lost to flooding, over half of those being in the December 2019 flood. Therefore, it is important to ensure islands are built up to 0.5m above the mean water mark, and that there is ongoing maintenance of cleared islands to ensure they maintain this height, or to ensure that fledging success rates in most years is high, to offset flooding losses following occasional very large flooding events.

Annual maintenance also needs to include clearing of any emergent exotic vegetation. Throughout the study the seven cleared islands remained relatively clear of weeds between breeding seasons, with the exception of the island edges. The centres of the islands had occasional, sparse weed growth, but exotic vegetation around the edges of islands was denser. Dense edge vegetation can limit access of braided river birds to water margins, and increase hiding places and food resources for ground predators.

The increased exotic vegetation around island edges is most likely a limitation of the aerial helicopter spraying. While helicopter spraying is effective and efficient for covering the large areas in the centre of the islands, the edges cannot be precisely sprayed from a helicopter without risking introducing the sprays to the water. It is recommended that for maintenance of the islands, and for any future islands, knapsack spraying is used in conjunction with helicopter aerial spraying to control any vegetation around the edges. In some years, if there is minimal weed regrowth, it may be an option to eliminate the helicopter spraying and use the knapsacks only. Establishing a standardised method of assessing both island height and exotic vegetation extent on islands (i.e. set photo points from which photos can be compared pre- and post-control) may be of use to aid decision making on the need to add to the islands height, helicopter use and to better determine the efficacy of the different maintenance techniques.

Edwards and Buchholz (2018) noted that during the 2017/18 breeding season black-fronted tern formed the largest colony on the largest island, which was also the most isolated. This was recorded for the 2016/17 breeding season. This colony also appeared to be the most resilient to predator impacts by remaining active longer than any other. They concluded that this supported building larger, more isolated islands. The relationship between colony size and success with island size and isolation should be further explored.

The flood event in December 2019 caused to damage to most of the cleared islands, including reduced channel size and depth enabling mammalian predators to access to two islands, reducing the size of four islands and completely destroying one island. Only one of the islands remains intact as built. In some instances, the flood also provided new habitats of cleared gravels. The islands need to be repaired or rebuilt for future breeding seasons. Fraser (2020) provides an assessment of the islands following the floods and makes the following recommendations:

- Island 1: No significant damage to island, however channel south of island needs clearing.
- Island 2: No significant damage. No work required.
- Islands 3 and 4: Do not restore, create a new island on a newly exposed patch of gravel downstream from island 4.
- Island 5: This island did not flood at 1200 cumecs, but the eastern/downstream section and southern channels require maintenance to restore to an adequate size.
- Island 6: requires work on the western/upstream and southern channels to restore to an adequate size. These channels were found to be less than 0.5m deep in places and a hare was observed crossing the upstream channel.
- Island 7 (this is specific to 7b, 7a was destroyed): Build height back up.

5 Recommendations

Based on the monitoring results of this project over the past 5-years, the following recommendations are made to increase black-fronted tern nesting success by enhancing black-fronted nesting habitat to create refugia from predators:

- Five of the seven islands cleared for this project were damaged in the December 2019 flooding. The cleared islands have been shown to drastically reduce mammalian predators at nest site. Therefore, restoring the lower Waitaki River islands, or clearing and building up new islands is highly recommended.
- Despite the lack of mammalian predators, black-fronted tern nests suffered heavy losses to predation from black-backed gulls. Ensuring control of gull numbers is an essential next step in braided river island enhancement for black-fronted tern. This may be achieved by controlling gull numbers in areas with gull presence, or by clearing and building up islands in areas with naturally low gull numbers.
- Flooding was the second most common cause of nest failure after predation. To help protect nest from flood events, cleared islands should be built-up to and maintained at a minimum of 0.5m above the mean water mark, at least in a proportion of the island at the downstream end.
- Although the islands are kept relatively free from weeds with aerial spraying, the outer areas that can't be sprayed with helicopter are subject to weed infestation each year. Adding knapsack spraying to the island maintenance plan will allow for full coverage of the island and reduce exotic vegetation cover in the following year.
- To better inform future restoration work, it would be beneficial to establish a consistent monitoring programme of the height of islands in various flows, and of the exotic vegetation cover before and following treatment.

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7 Literature cited

Edwards, B. and Buchholz, L. (2018). Project report 2017-18 breeding season: Waitaki habitat restoration for black-fronted terns. Department of Conservation Internal Report. Department of Conservation, Geraldine/Raukapuka Office. 4p.

Fraser, I.D.L. (2020). Lower Waitaki Tern Islands Post-Flood Assessment. Department of Conservation Internal Report. Department of Conservation, Geraldine/Raukapuka Office. 21p.

Keedwell RJ 2005. Breeding biology of black-fronted terns (*Sterna albostriata*) and the effects of predation. Emu 10: 39-47.

Kimber, M. 2020. Lower Waitaki habitat restoration for black-fronted terns 2019-20 breeding season. Project River Recovery Internal Report. Department of Conservation. 9p.

Maloney RF, Keedwell RJ, Wells NJ, Rebergen AL, Nilsson RJ 1999. Effect of willow removal on habitat use by five birds of braided rivers, Mackenzie Basin, New Zealand. New Zealand Journal of Ecology 23: 53-60.

Pickerell, G.A. (2015). Braided-river islands as refuges from introduced mammalian predators: characteristics influencing predator presence, and consequences of reduced Flow. Unpublished PhD thesis. University of Otago, Dunedin. 271p.

Schlesselmann, A-K.V. (2018). Linking science and management for effective long-term conservation: A case study of black-fronted terns/tarapirohe (*Childonias albostriatus*). Unpublished PhD thesis. University of Otago, Dunedin. 168p.

Welch, J., Nelson, D., Edwards, B. and Maloney, R. 2019. Lower Waitaki habitat restoration for black-fronted terns 2018-19 breeding season. Project River Recovery Internal Report. Department of Conservation. 10p.