Department of Conservation

2022-2023 Annual Outcome Monitoring and Predator Detection Report for the Aparima River Project, Southland

Prepared by:
Scott Melchert, River Ranger Aparima Project
Dr. Clement Lagrue, Science Advisor Ecosystems, Aparima Project Lead

Acknowledgements
I would like to thank Clement for his support throughout the project, and particularly his help in finding tern nests.

I would like to also extend a huge thanks to Penny Jacks for her help with the yearly bird survey, and her frequent and helpful advice.

Thanks to Grant McGregor and the Wreys Bush Concrete team for their support throughout the season. I would also like to thank everyone at the DOC Invercargill office for their help.

Summary of outcome monitoring (September 2022 – January 2023)

Outcome monitoring of the habitat restoration project completed its 7th season in 2022-2023. As in previous years, a seasonal DOC River Ranger was based on site for several month (September-January) to monitor river bird and introduced predators across an 8.8km long stretch of the Aparima river centred on the Wreys Bush SH96 bridge. The 4.4km stretch of river upstream of the bridge is defined as the treatment site, where habitat restoration is being implemented and tested through gravel extraction. The 4.4km of river immediately downstream of the bridge is used as a control to compare with the treatment site. No habitat restoration is conducted across the control site, and the river is left to its current state.

The DOC River Ranger, Scott Melchert for the 2022-2023 season, monitors river bird abundance and distribution, nesting success of 5 key river bird species (banded dotterel, black-fronted tern, black-billed gull, South Island pied oystercatcher and pied stilt), and predator diversity and abundance across both control and treatment sites. These are used as proxy for the success of habitat restoration trials and predation risks from introduced pests. Other data such as river flow/level and human disturbance are also recorded to account for their potential effects on bird nesting success. We are currently implementing short-term freshwater monitoring (invertebrates and fish) through two MSc projects led by students based at the University of Otago to document the effects of different gravel extraction approaches on freshwater values. Results will be presented in next year's report.

Data collected this season confirm trends documented by previous year's monitoring. Habitat restoration provides suitable nesting sites for river bird with all monitored species readily using restored areas. The number of birds and nests recorded across the restored site are both significantly and consistently higher than in the control site. We recorded a record number of banded dotterel and black fronted tern nests this season. Unfortunately, nesting success was variable and extremely low for terns. Flooding events, especially in late Spring/early Summer remain a constant threat to nests and chicks and future habitat restoration designs should provide areas of high gravel habitat as refuge for nesting birds. It is worth noting that river birds are adapted to flooding events and will rapidly renest after a flood. The main threats to nesting birds remain introduced predators. Mammalian pests are prevalent on the river with high diversity and densities of all pest species. The last 3 years have shown that Norway rats are becoming the main issue; this year alone, rats have been responsible for over 60 nest failures. Feral cats have also been an ongoing issue, predating both eggs and adult bird sitting on nests.

This season saw the implementation of a full trapping network on the river and the first 4 months of data presented here support and complement the 7 years of predator tracking in terms of diversity and density of predators. The potentially beneficial effects of this trapping network for bird nesting success will only become apparent over time and data collected in the next 3 years will be key to assess trapping efficiency for river bird protection. It seems clear that rats cannot be fully controlled by the trapping network and further reactive trapping will need to specifically target rodents. Next season, trapping will be complemented by light weight corflute tunnels fitted with rat traps and easily deployable directly onto nesting colonies of terns and gulls and/or nearby solitary nesting birds such as banded dotterel. Hopefully, the combination of a permanent trapping network targeting the whole range of pests and reactive, targeted trapping will allow higher nesting success for birds using restored river habitats.

Contents

General introduction

The Aparima River Restoration Project is a ten-year (2016-2026) river habitat enhancement project developing, trialling, and monitoring methods for restoring, improving and maintaining braided river habitats via commercial gravel extraction. Focus is on how native species, especially river nesting birds and more recently freshwater invertebrates and native fish, respond to habitat restoration. The study is centred around Wreys Bush, Southland. The study site is divided into a 4.4km stretch of river upstream of the SH96 bridge used as treatment (e.g., where gravel extraction and habitat restoration are conducted). The treatment area is matched by a control area of 4.4km long downstream of the bridge. The control site is not subjected to any gravel extraction or other enhancement work. Habitat restoration is achieved through a gravel extraction concession held by Grant McGregor, operator of Wreys Bush Concrete (WBC). Activity fees ($30K per year) are used to fund outcome monitoring (seasonal worker wages and operational expenses such as trail cameras, consumables, trap bait, etc.). In 2021, Environment Southland funded traps (DOC150 and DOC250 for a total of ~$27K) through an Environmental Enhancement Fund grant (special Thanks to Polly Bulling for her support on this) so that a trapping network could be implemented to protect nesting birds. This network was supplemented by 30 Tims traps and 30 SA2Traps funded through other DOC budgets.

Gravel extraction work under the current concession is designed to balance commercial aggregate harvesting with braided river conservation and restoration with the goal to both limit aggregate harvesting impacts on the ecosystem and provide habitat restoration benefits is degraded river bed areas, especially that overgrown by introduced vegetation and unsuitable to native bird nesting. Work started in August 2017 and details of the progress to date are available through yearly monitoring reports. Briefly, data gathered to date show that the novel gravel extraction approach trialled and monitored by this project not only limits the impacts of commercial gravel extraction on braided river ecosystems, both aquatic and terrestrial habitats, but also provides real opportunities for braided river restoration and habitat enhancement. Sediment and weed overburden are removed over large areas and clean gravel bars and islands are restored. Native birds, many of which are threatened, readily use restored areas for nesting while the control site have consistently seen very few nesting attempts over the last 7 years. Under the right context, such approach could provide a win-win situation for commercial operators and braided river conservation. We are working closely with Fish&Game, DOC Operations, Environment Southland, TAMI and commercial operators to apply this approach to other consents/concessions and rivers in the region.

In this report, we present the results of the seventh season of outcome monitoring (2022-2023) for braided river bird species and introduced predators. This season, four of the target bird species nested within the treatment area: black-fronted terns, banded dotterels, South Island pied oystercatchers and pied stilts. Black-billed gulls established a large colony just upstream of the treatment area and used the restored sites as feeding and roosting grounds. We also report data for yearly predator tracking and for the first four months of predator trapping. While trapping was successful at stopping most predators from impacting river nesting birds, Norway rats have become the main threats and seem to be very difficult to control. Alternative approaches will need to be developed to protect colony nesting birds such as terns and gulls.

River conditions/changes since project initiation

River flow data

The Aparima flow data presented is calculated using river gauge information provided by Environment Southland. As flow is not recorded at the Wreys Bush bridge, an average is taken from the two gauges closest to the study site. The Aparima River gauge at Dunrobin and the Hamilton Burn gauge at Waterloo Road are 34.3km and 47.6km upstream from the study site respectively. For this reason, the data presented in figures 1 and 2 are approximate daily maximum flows for the study sites at Wreys Bush only.

Over the seven field monitoring seasons since the initiation of the Aparima River habitat enhancement project in 2016, river flow conditions have varied greatly and with no consistent pattern (Fig.1). The 2016-17 season had one especially high flood event and a few smaller floods. The 2017-18 season had consistent low flows. The 2018-19 breeding season had several high flows and the 2019-20 season was characterised by consistently high flows accompanied by many major flood events that prevented all nesting attempts from monitored bird species. The 2020-21 season had predominantly low flows punctuated by flooding events in October and January which wiped out the only nesting colony of terns that year. 2021-22 had low flows with intermittent flood events with most target bird species managing to successfully nest.

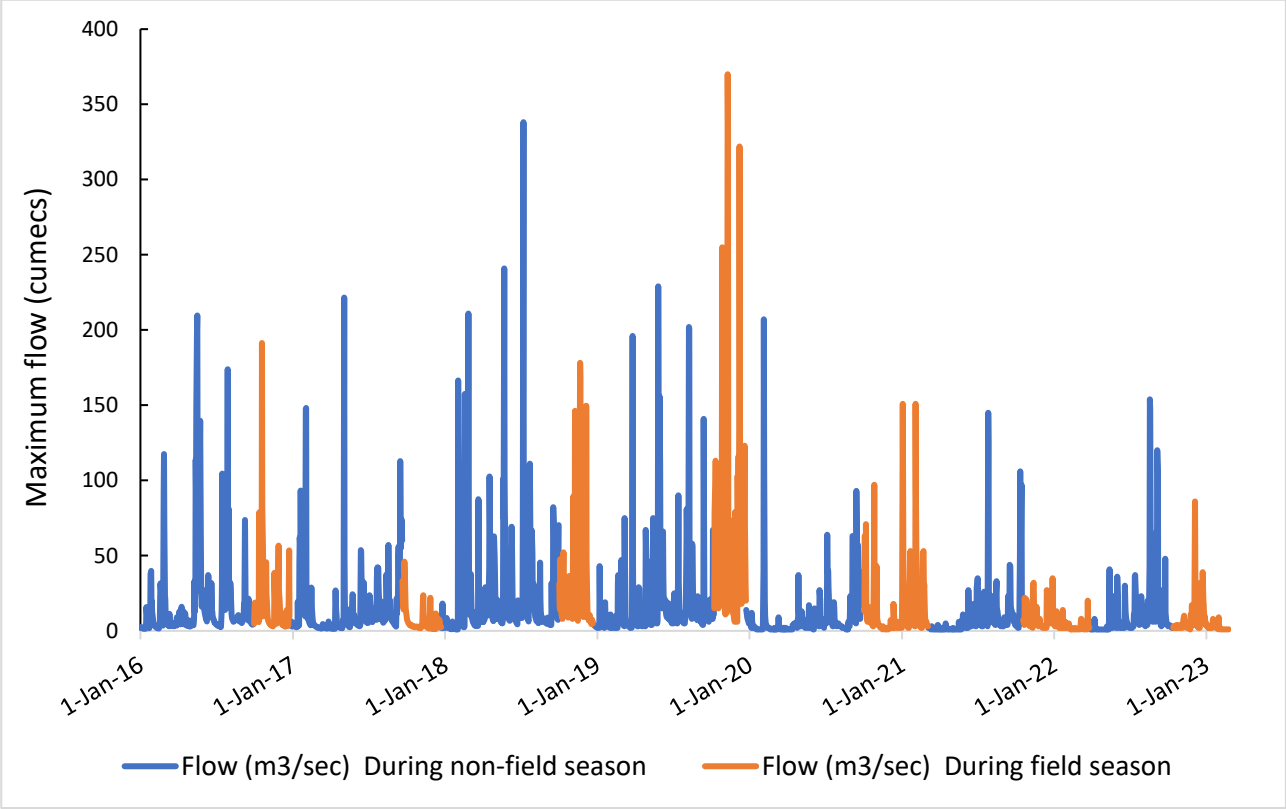

Figure 1. *Approximate daily maximum flow of the Aparima River at the field monitoring site at Wreys Bush gravel extraction for the duration of the project, Jan 2016 to January 2023. Data source: Environment Southland.*

This season again saw generally low flows punctuated by flood events throughout October and November (Fig.2). One particularly large flood event in November covered most gravel beds and islands, and washed

away tern, dotterel and SIPO nests, as well as flooding some access roads. December and January dry and hot weather translated into very low river flows which made islands easily accessible by Norway rats.

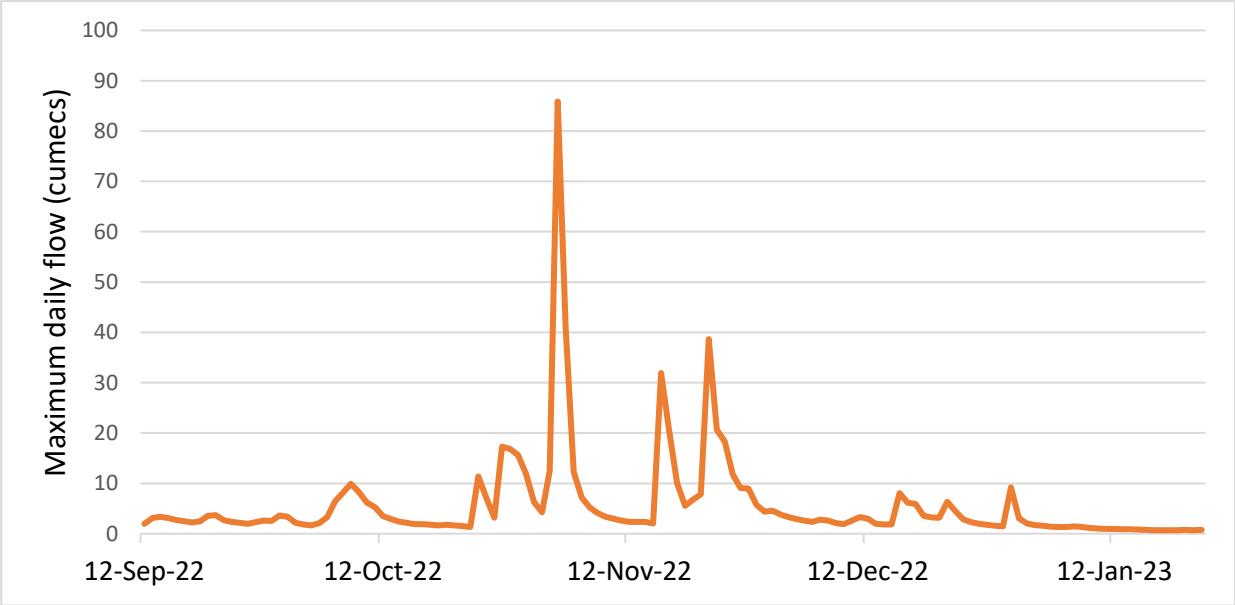

Figure 2. *Approximate daily maximum flow of the Aparima River at the field monitoring site at Wreys Bush gravel extraction for the sixth field season of the project, 12 September 2022 to 23 January 2023. Data source: Environment Southland.*

Gravel extraction

Aggregate harvesting and habitat restoration is taking place at several locations across the treatment site (Fig.3). In 2022-2023, two sites are active with ongoing overburden removal and gravel extraction. Gravel extraction and habitat restoration at the top of the treatment site (Top beach), down Transmission Line Road, was completed in 2020 and is now inactive. Initially diggers and dump trucks stripped the grass and sediment overburden off the riverbed and extract gravel. Overburden was carried outside of the riverbed and spread onto neighbouring farmlands. From 2017, a digger was used for extraction by stockpiling gravel and a loader was used to fill trucks which carted the gravel from site to the concrete plant. Overall, 11,000m^3 of aggregate were harvested from the "top beach" and extraction was completed in 2020. At that point over 4 hectares of braided river habitat with clean gravel islands and shallow side braids had been restored. Gravel extraction also widened the river channel, allowing a greater area for the river to move across during floods. As a result, this site has tended to aggrade in the last 3 years with more gravel depositing and the beach getting higher. Unfortunately, higher gravel bars tend to be colonized by weeds and after 5 years of providing great nesting habitats (black billed gulls started nesting while work was still ongoing in 2018) for monitored bird species, the top beach is now overgrown with weeds again (Fig.4). The start of the 2022/2023 nesting season saw several banded dotterel pairs nesting on the top beach, which was mostly bare gravel at the start of the season. However, by December, it had been almost completely overgrown with weeds (Fig.4). A new consent application is currently being processed that will allow Grant McGregor to maintain the beach free of weeds through root raking and superficial aggregate removal.

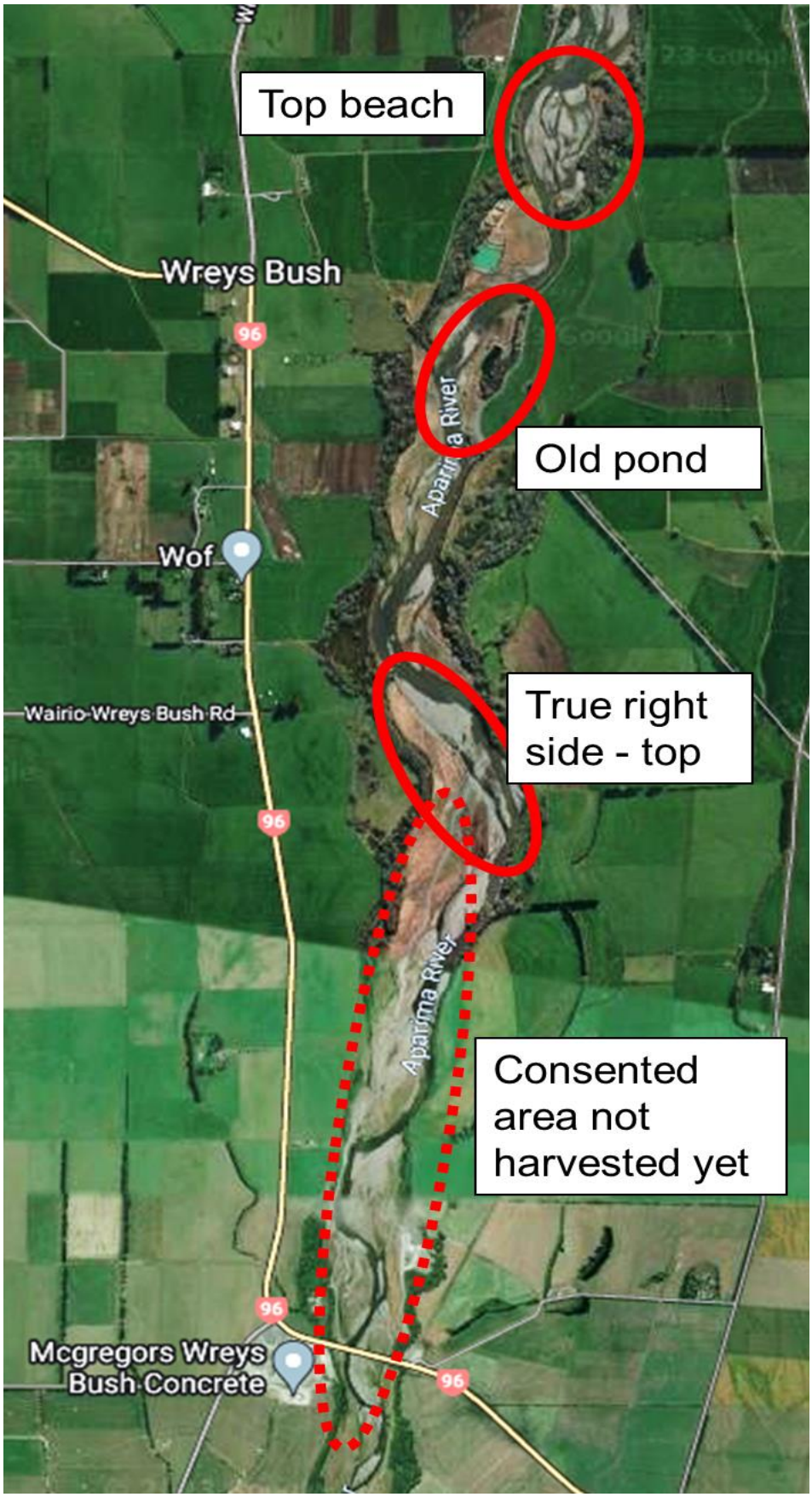

Figure 3. *Treatment site showing gravel extraction areas.*

Figure 4. *Top beach covered in weeds (January 2023). Photo by Scott Melchert.*

From 2020, active gravel extraction moved downstream in two different areas. A new access road approximately 2.5 km long was created along the true right side of the river, running from the Wreys Bush Bridge northwards. Concomitantly, work started around an old mining pond (Old pond site) to both harvest aggregate and restore braided river habitat by stripping weeds and overburden between the pond and river, and reconnecting the pond to the active river channel. The site is currently active.

In 2021, gravel extraction also began from the top end of the road created in 2020 (True right site). Between January 2021 and January 2023, a series of long and narrow shallow ponds 400 mm deep have been dug for aggregate harvesting (Fig.5).

Figure 5*. Active extraction pond isolated from the river looking upstream with reconnected pond, created island and river in the background. Photo by Grant McGregor.*

Once extraction is finished, each pond is reconnected to the river and a gravel bar left to create an island (Fig.6 and 7). Natural flooding events then naturally reshape these areas creating a mosaic of habitats with shallow braids as wadding/feeding areas, clean gravel bars and islands for bird roosting and feeding. Extraction moves downstream, creating series of ponds regularly turned into islands, gravel beaches and side braids.

Figure 6. *Reconnected pond looking downstream with active pond in the background. Photo by Grant McGregor.*

Figure 7. *Wider view of site across the whole bed. Photo by Grant McGregor.*

Outcome monitoring

Introduction

Five braided river bird species are monitored for the Aparima River Restoration Project: banded dotterel/pohowera (Nationally Vulnerable), South Island pied oystercatcher/tōrea (At Risk-Declining), black-fronted tern/tarapirohe (Nationally Endangered), black-billed gull/tarāpuka (At Risk-Declining), and pied stilt/poaka (Not Threatened) (Robertson et al. 2021).

Objective: To determine nesting, hatching and fledging success of the five monitored braided river bird species present on the Aparima River, and to track changes in the abundance and distribution of these key bird species over time and in relation to gravel extraction activities.

Methods and results for outcome monitoring are presented in two parts:

1. Nesting success, chick survival and recruitment of river birds

2. Distribution and abundance of river birds.

Methods

1. Breeding success, survival and recruitment of river birds

Nests of the five key species are systematically searched across treatment and control sites and located by observing adult bird behaviour, such as agitation to human presence, dive bombing, head bobbing and frequent calling. Flocking behaviours in colony nesting species (terns and gulls) are also good indicators. When nesting behaviours are detected, observers retreat at least 50m to determine the location of the nest bowl through following the adult with binoculars before approaching. These methods are described in more detail in the Tasman project protocols (Leseberg *et al.* 2005). Nests are then checked on a weekly basis when access allowed. When and where possible, nests are monitored via trail cameras.

For colony nesting birds, a subsample of nests within each colony are monitored via trail cameras; two cameras on nests at either end of the main nesting area and one camera on individual nests or small clusters of nests across the main nesting area. Black-fronted terns and black billed gulls are also monitored through 1) regular visits to the colony to observe with binoculars to limit disturbance to the birds; 2) a count of nests at the egg stage, and 3) walking through the colony once chicks were present to determine hatching success.

Nest failures are classified into the following seven categories: predation, failed unknown/predation, desertion (fertile eggs), flooding, died during incubation/infertile, damaged in nest, and failed/cause unknown. Predator species is specified when identification is possible from nest camera data. Egg loss is recorded, and eggs that fail to hatch are opened to determine whether they are infertile or have died during incubation. After eggs hatch, visual monitoring continues to determine survival and fledging success, but cameras are removed from the nest as chicks are highly mobile. Timing and causes of failure at the chick stage are difficult to determine because chicks

move off the nest, making it impossible to track using stationary cameras, but are recorded when and where possible.

The following nesting parameters are recorded:

a) Hatching success (probability of one or more eggs in a nest surviving until hatching date),
b) Egg success (probability of an egg hatching in a nest if it survives),
c) Fledging success (probability of a chick fledging once it hatches),
d) Breeding success (probability that an egg will successfully survive, hatch and fledge).

2. Distribution and abundance of river birds

Aparima River bird survey

A systematic survey of all river bird species and harrier/kāhu is carried out over one day in each season. Two observers walked downstream at a constant speed from the top of the treatment site (4.4 km above the bridge at Wreys bush) and continued to the bottom of the control site (4.4 km below the bridge). One observer typically follows the main channel, whilst the other follows smaller backwaters. Sections above and below the bridge are recorded separately as treatment and control.

Distribution surveys

During the 2022-23 season, four distribution surveys were carried out monthly on October 18th, November 23rd, December 13th, and January 18th focusing on the five key bird species (black-fronted tern, banded dotterel, pied stilt, SIPO and black-billed gull). GPS positions is recorded for each sighting and habitat type coded as: bare gravel, light vegetation, moderate vegetation, heavy vegetation, pool, riffle, run, backwater or flying. Observer's GPS location is recorded for flying birds, regardless of their position relative to the observer. Surveys are all performed by the same person for consistency.

Weekly abundance estimates

Weekly estimates of abundance of the five key river bird species are carried out, typically at the same time as other tasks on the river. These estimates were separate for the treatment and control sites.

Results and discussion

Breeding success, survival and recruitment of river birds

A total of 133 nests were found within the Aparima River study area and monitored in the 2022-23 season: 22 banded dotterel, 5 SIPO and 106 black-fronted tern nests.

Black-fronted terns

During this season, more tern nests were recorded than in any previous season, but no chick were recorded to successfully fledge with certainty (

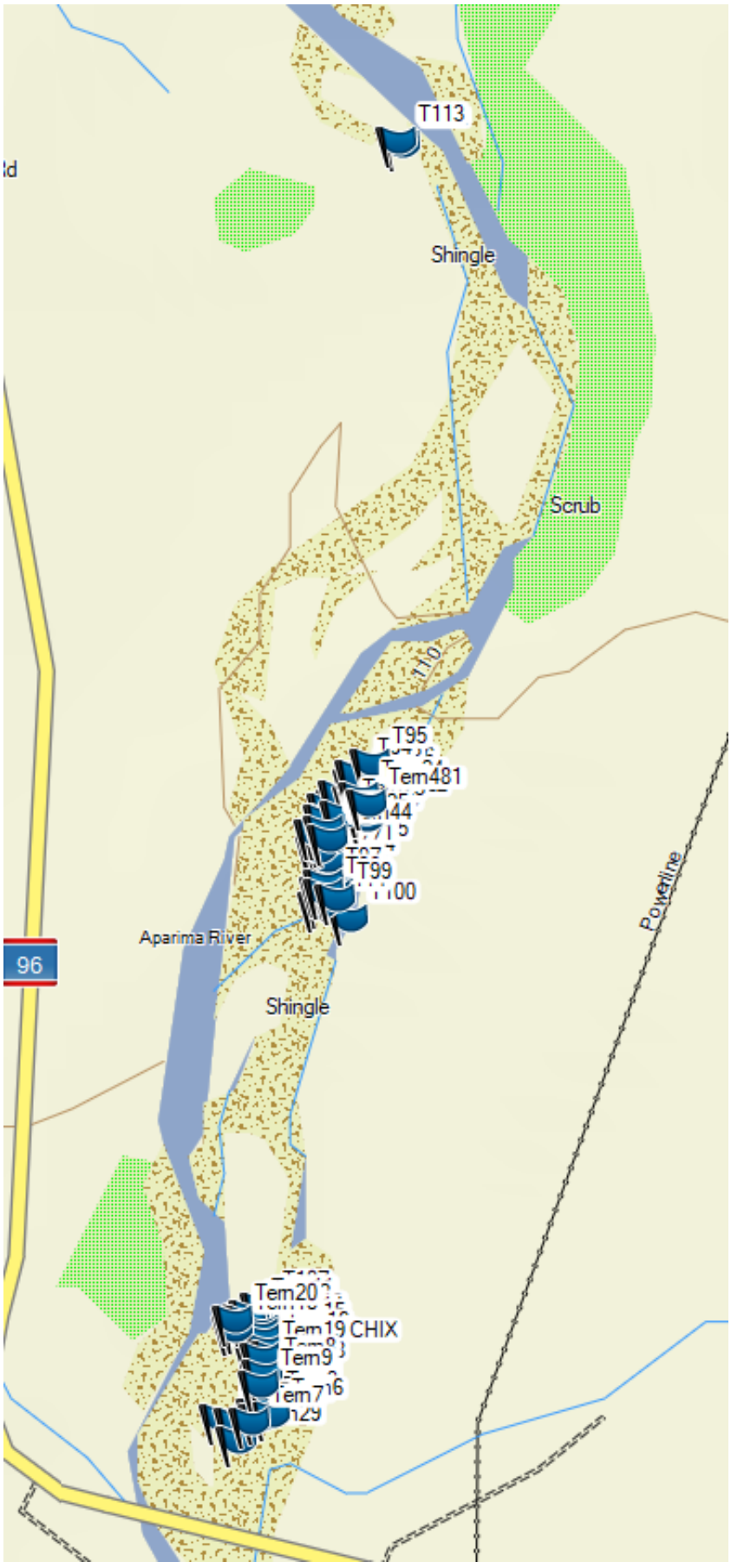

Figure ***8.*** *Tern nest locations on Aparima River.*

Table *1*). November floods washed out the first nesting colony while Norway drove all further attempt to failure via direct nest predation or abandonment. We even recorded a Norway rat killing an adult tern on the nest. Overall, all nesting attempts by black-fronted terns were located in the treatment site (Fig.8).

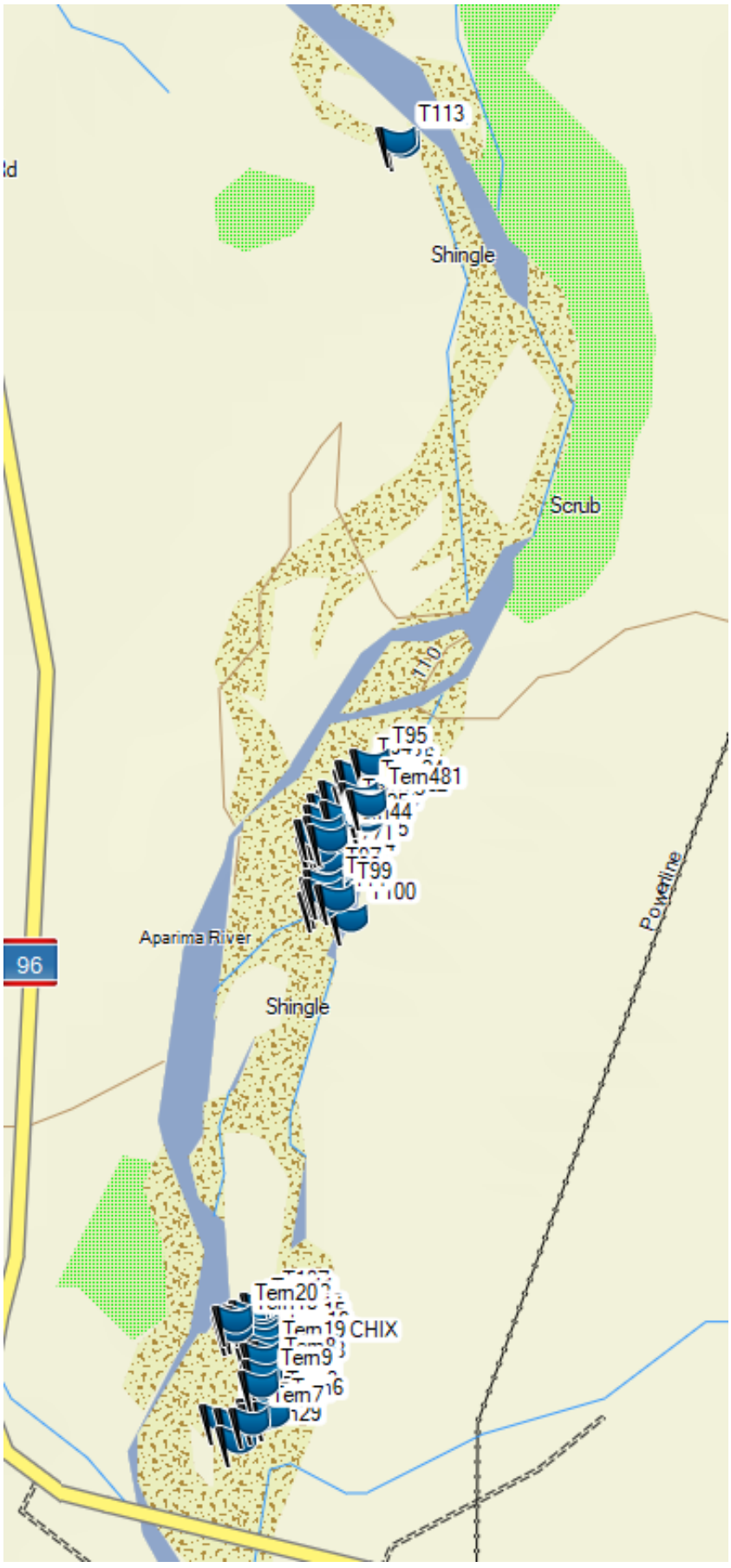

Figure 8. *Tern nest locations on Aparima River.*

Table 1. Summary of nesting, hatching and egg success rates for black-fronted terns.

Black-fronted tern	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	Total since 2016-17
Total no. of nests	27	74	0	18	28	39	106	292
No. of nests with known outcome (A)	27	74	-	18	28	16	92	255
No. of nests (A) that hatched ≥ 1 egg (B)	10	35	-	0	0	12	10	67
No. of nests that failed	17	39	-	18	28	4	82	198
Total no. of eggs laid	52	138	-	36	48	59	186	519
Of the nests in (A):								
No. of eggs laid where fate known (C)	52	138	-	36	48	28	6	308
No. of eggs laid where fate unknown	0	0	-	0	0	31	4	35
Of the eggs in (C):								
No. of eggs – infertile or died during incubation (D)	0	15	-	0	0	6	0	21
No. of eggs that failed – other causes	33	61	-	36	48	4	6	
Total no. of eggs that hatched (E)	19	62	-	0	0	18	6	
***Hatching success* (F) = B/A**	0.37	0.47	-	0	0	0.75	0.11	
***Egg success* (G) = (C-D)/C**	1	0.89	-	0	0	0.79	1	

The initial tern colony of 29 nests that established just upstream of the bridge late October, in a similar location to previous years (NZTME E1221952 N4890804), was wiped out by the large flood event in early November. This colony was on an island in the middle of the river as well as an adjacent shoreline on the true right bank. Chicks had begun to hatch in this colony at the time of the flood (Fig.9). A second tern colony of at least 4 nests further north (around NZTME E1222023 N4891816) was lost around the same time as all nests were predated by rats.

Figure 9. *Tern with newly hatched chicks in rising floodwaters shortly before being washed away.*

In December, a new colony settled down in the same area as the second colony, on a large island near the true right side access road. Early monitoring of this colony recorded 51 nests with more birds establishing nest bowls. Unfortunately, the island was raided by Norway rats again around late December - early January (Fig. 10) and was abandoned. Nests were either predated or abandoned (Table 2). Four nests survived in a satellite colony and two of these hatched chicks.

Figure 10. *Rat eating a tern egg.*

Four more nests were found on another island on 11th January (around NZTME E1222009 N4892870). Two nests contained only eggshell with signs of predation, and the remaining two were eaten by rats in the 2 following nights. A few tern pairs made a last nesting attempt on the island by the bridge where the first colony established in October. Eleven nests were found in this location. On the last day of fieldwork (23rd January), three nests were found to have 1 chick in each.

An additional tern colony was observed just upstream of the treatment site where they shared a large gravel island with nesting black-billed gulls. There were at least 15 nests in this area. This colony was also raided by rats and a trail camera recorded a fatal attack on an adult tern by a Norway rat (Fig.11). Despite this, the terns in this area appeared to have some success, as fledged and close-to-fledging chicks were later observed on the top beach at the upstream end of the treatment site on 21st January 2023.

Figure 11. *Rat attacking and killing an adult tern on the nest.*

Table 2. Causes of (a) nest failures and (b) egg loss (b) for black-fronted terns.

(a) **Nest failure**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of nests that failed	17	39	-	18	28	4*	92	106
Nest failure because of:								
Predation	16	14	-	0	19	0	43	89
Failed unknown/ predation	0	5	-	2	0	1	0	8
Desertion (fertile eggs)	1	6	-	0	0	0	0	9
Abandoned and scavenged	-	9	-	0	4	0	20	33
Flooding	0	0	-	16	5	0	29	50
Died during incubation/infertile	0	5	-	0	0	1	0	6
Damaged in nest	0	0	-	0	0	0	0	0
Heat stress	0	0	-	0	0	2	0	2
Failed, cause unknown	0	0	-	0	0	0	0	0
(b) **Egg loss**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**		**Total since 2016-17**
Total no. of eggs that failed	33	76	-	36	48	10*	166	358
Egg failure because of:								
Predation	31	24	-	0	31	1?	92	178
Failed unknown/predation	0	10	-	4	0	0	0	14
Desertion (fertile eggs)	2	10	-	0	0	0	3	15
Abandoned and scavenged	-	16	-	0	7	0	32	55
Flooding	0	0	-	32	10	0	37	79
Died during incubation/infertile	0	15	-	0	0	6	4	19
Damaged in nest	0	0	-	0	0	0	0	0
Heat stress	0	0	-	0	0	3	0	0
Failed, cause unknown	0	1	-	0	0	0	0	1

**with known outcome*

Overall breeding success was very low for black fronted tern this season (Table 3). Data clearly shows that rats and unseasonably high flash floods are the greatest threats to tern nesting success. The large areas of exposed gravel riverbeds in the treatment site clearly provide good nesting habitat for terns, as shown by the repeated nesting attempts and large number of nests. However, low gravel areas are vulnerable to flooding and sufficiently high, clean gravel bars and/or islands must be provided as refuges against floods. Despite some of these nests being close to areas frequented by members of the public, terns seemed largely undisturbed by their presence and no people or dogs were observed near their nests by trail cameras this year. Targeted trapping of rats will be key to protecting tern colonies and increasing nesting success in the future.

Table 3. Fledging and breeding success of black-fronted terns.

Black-fronted tern	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of ♀'s that attempted to breed* (H)	27	74	0	18	28	16	92	255
No. of nests - hatched ≥ 1 egg	10	35	-	0	0	12	10	67
No. of nests - fledged ≥ 1 chick	0	6	-	0	0	12	0	18
No. of nests - lost all chicks	10	29	-	18	28	0	6	91
No. of nests - unknown fledging outcome	0	0	-	0	0	0	13	13
No. of chicks fledged as min–max (I)	0	6-12	-	0	0	0-2	0-20	6-32
Fledging success as min-max (J) =I/E	0	0.1-0.19	-	0	0	0-0.11	0-3.33	
Breeding success as min-max (F x G x J)	0	0.04-0.08	-	0	0	0-0.07	0-3.44	
Hatching success per female (E/H)	0.70	0.84	-	0	0	1.13	0.06	
Fledging success per female as min-max (I/H)	0	0.08-0.16	-	0	0	0-0.125	0-0.22	

* excludes females that attempted to breed, but where outcome was unknown

Black-billed gulls

For a fifth year in a row, black-billed gull did not establish breeding colonies within our study site in the 2022-23 season (Table 4). Adult birds were regularly sighted in large groups (up to 96 individuals) throughout late October and early November near the island that black-fronted terns initially nested but the nesting colony established just upstream of the treatment site, outside of the monitoring area and numbers were not included in the dataset. Approximately 890 nests were counted on 15th November. These nests had 2-3 eggs each (more commonly 2) and were monitored with trail cameras at the north and south ends of the colony (NZTME E1222347 N4895294 and E1222385 N4895231). No predator incursions were observed, despite nearby tern nests being attacked by Norway rats during this time. When the cameras were removed on 10th January the majority of nests had hatched and were empty, with large groups of chicks observed in the colony ranging in age from freshly hatched to fledged (Fig.12). No exact count of chick numbers was undertaken. Observations indicate that black-billed gul are less vulnerable to rat predation than terns, potentially because of their larger size or a more aggressive behaviour despite adjacent tern nests being predated. Overall, gulls seem to be more selective for nesting locations but less vulnerable once established.

Table 4. Number of nests and chicks fledged from black-billed gull colonies.

Black-billed gulls	2016-17	2017-18	2018-19	2019-20	2020-21	2021- 22	2022-23	Total since 2016-17
Approx. colony size	0	450	1100	0	0	0	0	1550
Approx. no. nests (A)	0	211*	450	0	0	0	0	661
Approx. no. chicks fledged (B)	0	120	170	0	0	0	0	290
Fledging success per nest (B/A)	0	0.57	0.38	0	0	0	0	

*number of nests counted 18 October 2017, more were added after this time but it is unknown how many

Figure 12. *Black billed gull nesting colony, with a downy chick on the left and a fledgling on the right still sitting on its nest bowl. Photograph taken by trail camera.*

South Island Pied Oystercatcher (SIPO)

This season, 5 SIPO nests were located within the study area (Table 4, Fig.14). Four were in the treatment section, and one in the control. One nest in the treatment area was lost during a flood event on 3rd November (along with the trail camera; Table 5). Another nest was presumed lost in the same flood, but survived with the parent keeping the floating eggs in place (Fig.13). These eggs later hatched. Most SIPO chicks leave the nest area after hatching and are very difficult to monitor until fledging; only one chick was confirmed to fledge while the others moved away with the adults before being fully fledged and their fate is technically unknown (Table 6).

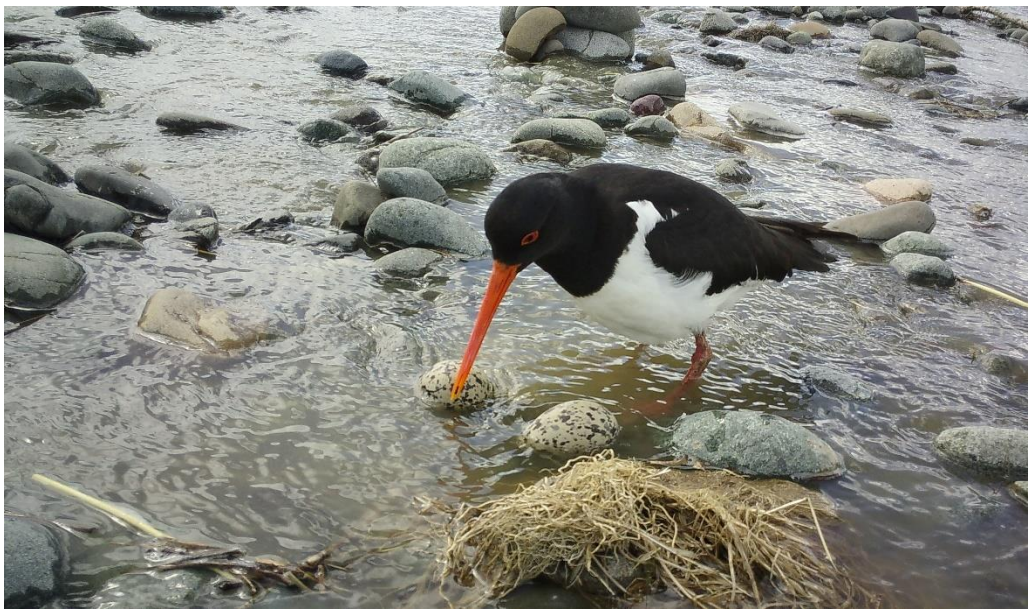

Figure 13. *SIPO maintaining its eggs in the nest bowl during a flood event. Image taken by trail camera*.

There were a further two SIPO pairs seen in the treatment area with one chick each, but their nest location was not found or recorded. It is possible they nested on nearby farmland, or that their nests were simply not found before hatching – in one case, SIPO parents were observed acting territorial on the gravel area around NZTME E1221847 N4890857(calling loudly, broken wing displays), but a nest could not be located. Both chicks stayed in the same area until fledging and it is likely that the nest was local but without certainty.

Additionally, there was one pair in the control area that was displaying nesting behaviour (flying around observer, calling) but the nest could not be located. Two chicks were seen at the site on 13th October, after about four weeks of this behaviour. They did not remain in the area until fledging. There were also incidental sightings of several nearly fledged or fledgling SIPO chicks throughout the control site during October and November. It is impossible to say if these were birds that had nested on the nearby farmland and moved to the river to feed, or if they had moved from elsewhere within or outside the study area.

Table 5. Summary of nesting, hatching and egg success rates for SIPO.

SIPO	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	Total since 2016-17
Total no. of nests	4	5	1	-	-	4	5	19
No. of nests with known outcome (A)	4	3	1	-	-	1	5	11
No. of nests that hatched ≥ 1 egg (B)	3	2	1	-	-	1	4	11
No. of nests that failed	1	1	0	-	-	?	1	3
Total no. of eggs laid	8	6	2	-	-	8	7	31
Of the nests in (A):								
No. of eggs laid where fate known (C)	8	6	2	-	-	2	2	20
No. of eggs laid where fate unknown	0	0	0	-	-	6	5	11
Of the eggs in (C):								
No. of eggs – infertile or died during incubation (D)	0	0	0	-	-	0	1	1
No. of eggs that failed – other causes	3	2	0	-	-	0	0	5
Total no. of eggs that hatched (E)	5	4	2	-	-	2	1	14
Hatching success **(F) = B/A**	0.75	0.67	1	-	-	1	0.8	
Egg success **(G) = (C-D)/C**	1	1	1	-	-	1	0.5	

Table 6. Causes of nest failures of SIPO (a) and causes of SIPO egg loss (b).

(a) **SIPO**	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	Total since 2016-17
Total no. of nests that failed	1	1	0	-	-	0	1	3
Nest failure because of:								
Predation	0	1	0	-	-	0	0	1
Failed unknown/ predation	0	0	0	-	-	0	0	0
Desertion (fertile eggs)	0	0	0	-	-	0	0	0
Flooding	1	0	0	-	-	0	1	2
Died during incubation/infertile	0	0	0	-	-	0	0	0
Damaged in nest	0	0	0	-	-	0	0	0
Failed, cause unknown	0	0	0	-	-	0	0	0
(b) **SIPO**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of eggs that failed	3	2	0	-	-	0	1	6
Egg failure because of:								
Predation	1	2	0	-	-	0	0	3
Failed unknown/predation	0	0	0	-	-	0	0	0
Desertion (fertile eggs)	0	0	0	-	-	0	0	0
Flooding	2	0	0	-	-	0	1	3
Died during incubation/infertile	0	0	0	-	-	0	0	0
Damaged in nest	0	0	0	-	-	0	0	0
Failed, unknown cause	0	0	0	-	-	0	0	0

Table 7. Fledging and breeding success rates of SIPO.

SIPO	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	Total since 2016-17
Total no. of ♀'s that attempted to breed* (H)	4	3	1	-	-	1	2	9
No. of nests - hatched ≥ 1 egg	3	2	1	-	-	1	1	7
No. of nests - fledged ≥ 1 chick	0	1	1	-	-	1	1	3
No. of nests - lost all chicks	1	1	0	-	-	0	0	2
No. of nests - unknown fledging outcome	2	0	0	-	-	0	3	5
No. of chicks fledged as min–max (I)	0 - 2	0 – 1	1	-	-	2	1-	0 - 2
Fledging success as min-max (J) =I/E	0 – 0.4	0 – 0.25	0.5	-	-	1		
Breeding success as min-max (F x G x J)	0 – 0.3	0 – 0.17	0.5	-	-	1		
Hatching success per female (E/H)	1.25	1.34	2	-	-	2		
Fledging success per female as min-max (I/H)	0 – 0.5	0 – 0.33	1	-	-	2		

* excludes females that attempted to breed, where outcome or number of eggs laid was unknown

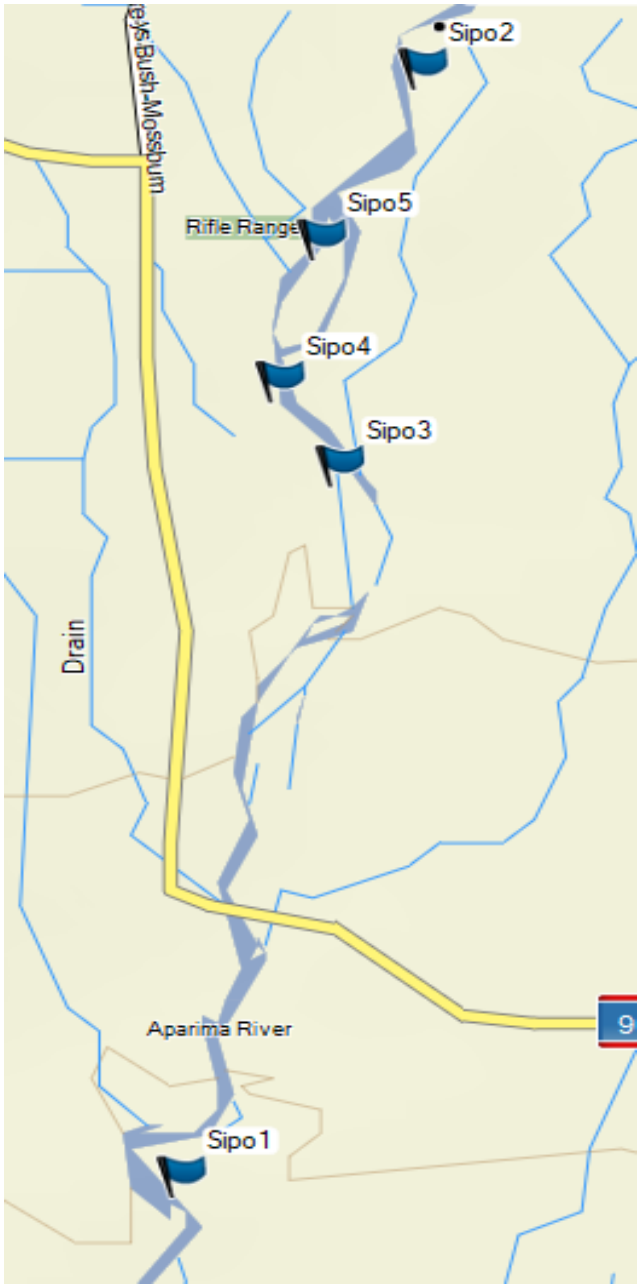

Figure 14. *SIPO nest locations across the study site.*

Banded dotterel

22 banded dotterel nests were found this year, most of them in the treatment area (Fig.15). While this was a record high number of nests, it is likely that nests discovered later in the season were birds renesting after failed attempts (Table 7). Several late nests were found close to earlier failed nests. Failures were mainly due to the large November flood and from predation by cats (Table 8), especially early in the season, when prey were likely scarce.

Table 8. Summary of nesting, hatching and egg success rates for banded dotterels.

Banded dotterel	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of nests	4	8	10	-	-	14	22	58
No. of nests with known outcome (A)	3	7	7	-	-	7	15	43
No. of nests that hatched ≥ 1 egg (B)	2	5	3	-	-	5	14	33
No. of nests that failed	1	2	4	-	-	2	8	17
Total no. of eggs laid	12	15	20	-	-	29	65	145
Of the nests in (A):								
No. of eggs laid where fate known (C)	9	14	20	-	-	28	45	120
No. of eggs laid where fate unknown	3	1	0	-	-	1	20	25
Of the eggs in (C):								
No. of eggs – infertile or died during incubation (D)	3	3	1	-	-	3	5	15
No. of eggs that failed – other causes	0	3	13	-	-	2	10	29
Total no. of eggs that hatched (E)	6	9	6	-	-	23	30	77
***Hatching success* (F) = B/A**	0.67	0.71	0.43	-	-	0.82	0.933	
***Egg success* (G) = (C-D)/C**	0.67	0.8	0.95	-	-	0.90	0.89	

Three nests were situated in gravel areas that members of the public use as carparks. One nest was flooded in November but the other two survived to hatching. Due to their location and the risk of theft, these nests were not fitted with a trail camera. Quantify the exact levels of disturbance from people, cars and dogs was thus impossible. One nest in the control area was particularly exposed, with vehicles, dogs and groups of people regularly observed very close by. It seems that dotterels can tolerate a certain level of this disturbance and are able to remain unnoticed to untrained eyes. For example, a 4WD vehicle was observed in January metres from a recently hatched nest (NZTME E1221817, N4893160) and one camera in the control area (NZTME E1221959 N 4890242) was shot on 19th December while the adult was incubating. Fortunately, nest and birds were not harmed, and the nest still hatched.

Chicks are difficult to locate after hatching due to their small stature and cryptic colouring, and when sitting still among rocks they are almost indistinguishable. Pairs with chicks were spotted several times walking along Grant's access road in the treatment area on the true right and would run from a slow moving car but appeared indifferent to a stationary one. Chicks would usually move to a body of water (like the river's edge or a transient pool) nearby their original nest site and could reliably be found around that area until fledging. Nest for which chicks could be reliably monitored to fledging, success was relatively high this season, likely due to favorable weather conditions later in the season (Table 9).

Table 9. Causes of nest failures of banded dotterels (a) and causes of banded dotterel egg loss (b).

(a) **Banded dotterel**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of nests that failed	1	2	4	-	-	2	8	15
Nest failure because of:								
Predation	0	1	2	-	-	1	3	6
Failed, unknown predation	0	0	0	-	-	0	1	0
Desertion (fertile eggs)	0	0	0	-	-	0	0	0
Flooding	0	0	2	-	-	0	2	4
Died during incubation/infertile	1	1	0	-	-	1	0	2
Damaged in nest	0	0	0	-	-	0	1	1
Failed, cause unknown	0	0	0	-	-	0	1	1
(b) **Banded dotterel**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of eggs that failed	3	6	14	-	-	6	32	61
Egg failure because of:								
Predation	0	1	6	-	-	3	8	18
Failed, unknown predation	0	0	0	-	-	0	3	3
Desertion (fertile eggs)	0	0	0	-	-	0	0	0
Flooding	0	0	6	-	-	0	6	12
Died during incubation/infertile	3	3	1	-	-	3	11	21
Damaged in nest	0	1	0	-	-	0	2	5
Failed, unknown cause	0	1	1	-	-	0	2	2

Table 10. Number of chicks fledged and fledging and breeding success rates of banded dotterels**.**

Banded dotterel	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**Total since 2016-17**
Total no. of ♀'s that attempted to breed (H)	5*	7	7	-	-	7	15	41
No. of nests - hatched ≥ 1 egg	3**	5	3	-	-	5	14	30
No. of nests - fledged ≥ 1 chick	2	3	1	-	-	5	8	19
No. of nests - lost all chicks	1	2	2	-	-	0	0	5
No. of nests - unknown fledging outcome	0	0	0	-	-	0	6	6
No. of chicks fledged as min-max (I)	2	0-2	0-2	-	-	0-2	8-23	10-31
Fledging success as min-max (J) =I/E	0.29***	0-0.22	0-0.33	-	-	0-0.08	0.27-0.77	
Breeding success as min-max (F x G x J)	0.13	0-0.13	0-0.14	-	-	0-0.06	0.22-0.64	
Hatching success per female (E/H)	1.2	1.29	0.86	-	-	3.29	2	
Fledging success per female as min-max (I/H)	0.4	0-0.29	0-0.29	-	-	0-0.29	0.53-1.53	

* excludes females that attempted to breed, where outcome was unknown. Includes a female from a nest that was not found, but the two chicks were found soon after hatching, one of which survived.

** this is different from (B) as it includes the nest that was not found, where the chicks were found soon after hatching

*** E includes one extra egg to account for the chick from the nest which was not found.

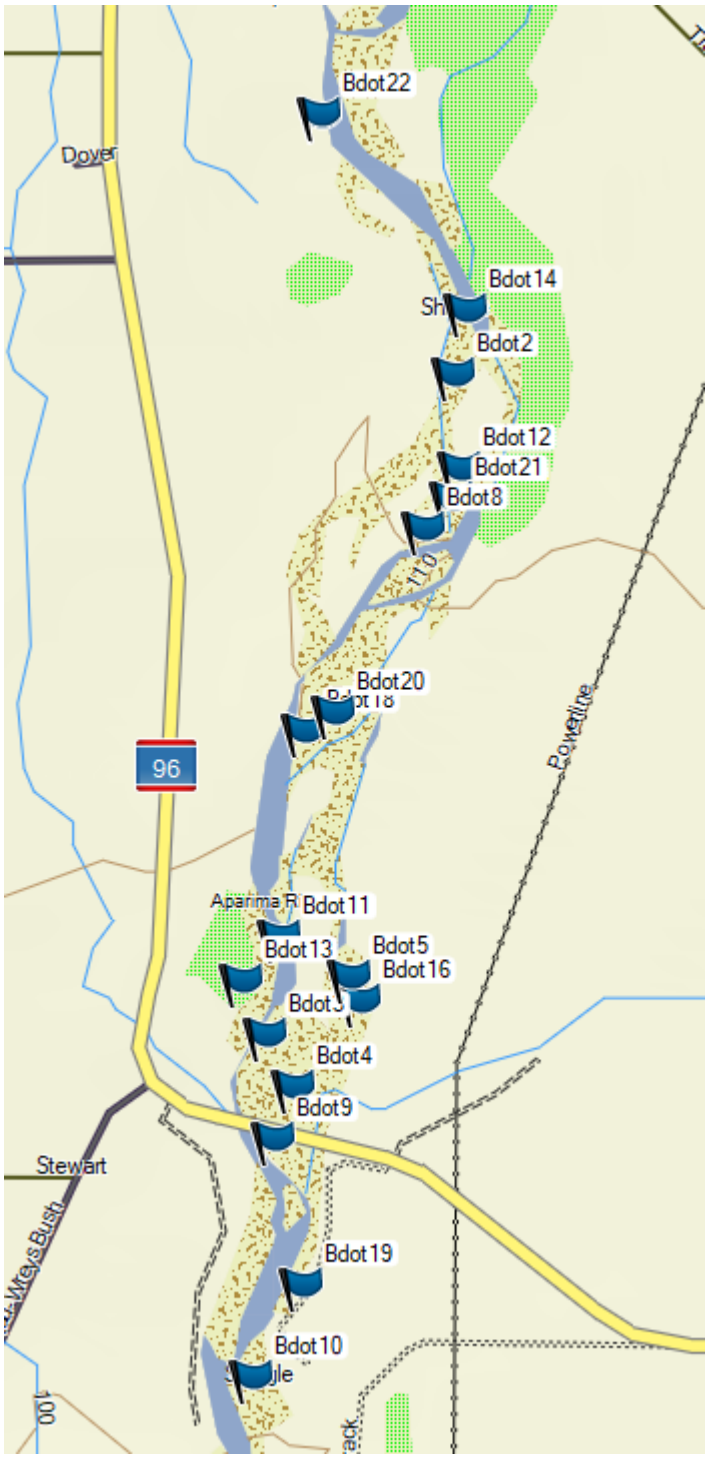

Figure 15. *Banded dotterel nest locations across the study site.*

Pied stilts

In the 2022-23 breeding season, no pied stilts nests were found across the study site (Table 10). In January, large groups of 10-20 individuals were seen throughout the study area, often with fledged chicks, in post-breeding groups actively feeding or roosting on the river. One young fluffy chick was spotted with parents in the control area, and it is likely this was from a pair nesting on nearby farmland that migrated to the river after the chick hatched to feed.

There was one stilt pair that was fiercely territorial of a particular patch of gravel in the treatment area and would fly around calling until observers left the area. Hiding in the bushes to observe, there was no sign of the birds sitting on a nest or tending to chicks. This behaviour continued from late December through to the end of the field observations, and it is likely that this pair had a nest somewhere in the area.

Table 11. Summary of nesting, hatching and egg success rates for pied stilts.

Pied stilt	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021- 22**	**2022-23**	**Total since 2016-17**
Total no. of nests	2	17	-	-	-	-	-	18
No. of nests with known outcome (A)	1	9	-	-	-	-	-	10
No. of nests that hatched ≥ 1 egg (B)	1	2*	-	-	-	-	-	3
No. of nests that failed	0	7	-	-	-	-	-	7
Total no. of eggs laid	8	54	-	-	-	-	-	62
Of the nests in (A):								
No. of eggs laid where fate known (C)	4	35	-	-	-	-	-	39
No. of eggs laid where fate unknown	4	0	-	-	-	-	-	4
Of the eggs in (C):								
No. of eggs – infertile or died during incubation (D)	2	0	-	-	-	-	-	2
No. of eggs that failed – other causes	0	27	-	-	-	-	-	27
Total no. of eggs that hatched (E)	2	8	-	-	-	-	-	10
***Hatching success* (F) = B/A**	1	0.22	-	-	-	-	-	
***Egg success* (G) = (C-D)/C**	0.5	1	-	-	-	-	-	

*this number does not include the 2 nests that were not found, each having 3 chicks found shortly after hatching

Distribution and abundance of river birds

3. Distribution and abundance surveys

In the 2022-23 season, the total bird counts were higher in the treatment area (n = 538) than the treatment area (n=347). Noticeably, total counts of the five key species were 440 and 32 for treatment and control areas respectively (Table 1). The treatment area had large flocks of black-fronted terns nesting and gathering on gravel beds along the main river channel (n=351), while the control area had large flocks (n=307) of grey/mallard ducks on the main river and backwaters. 4 fledged terns chicks were seen during the survey, which likely came from the tern colony established to the north just outside the edge of the treatment area. As with the 2022 survey, no SIPOs were observed. In previous years this survey has been carried out in October, when SIPOs tend to be more common on the river; whereas in 2022 it was carried out in February, and in January in 2023. SIPO numbers tend to be higher in late Spring-early Summer.

Table 121. *Number of river birds counted on the Aparima River treatment (a) and control (b) sites.*

(a) Species	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**
Banded dotterel	2	12	12	-	-	22	9
Pied stilt	3	24	8	-	-	5	36
Black-fronted tern	6	105	12	-	-	11	351
SIPO	11	11	1	-	-	0	0
Black-billed gull	4	501	1582	-	-	0	44
Black-fronted dotterel	0	3	2	-	-	0	1
Spur-winged plover	1	4	31	-	-	42	0
Southern black-backed gull	4	0	5	-	-	5	4
Swamp harrier	2	6	6	-	-	4	2
Grey/Mallard duck	7	23	19	-	-	161	75
Paradise shelduck	1	4	2	-	-	0	0
Caspian tern	0	0	0	-	-	1	0
White-faced heron	1	6	1	-	-	3	7
Little shag	0	0	0	-	-	2	0
Black shag	5	6	4	-	-	0	2
Australasian shoveler	1	1	0	-	-	0	0
TOTAL	48	710	1685	-	-	181	538
(b) Species	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**
Banded dotterel	0	1	4	-	-	1	2
Pied stilt	0	10	0	-	-	15	14
Black-fronted tern	1	20	3	-	-	5	16
SIPO	6	5	5	-	-	0	0
Black-billed gull	1	0	11	-	-	80	0
Black-fronted dotterel	0	0	0	-	-	2	1
Spur-winged plover	0	0	5	-	-	37	0
Southern black-backed gull	0	2	1	-	-	0	2
Caspian tern	0	0	0	-	-	1	0
Swamp harrier	1	4	7	-	-	1	3
Grey/Mallard duck	2	36	32	-	-	461	307
Paradise shelduck	0	0	2	-	-	1	0
White-faced heron	0	1	3	-	-	1	1
Black shag	2	2	1	-	-	1	1
Australasian shoveler	0	0	0	-	-	0	0
TOTAL	13	81	74	-	-	606	347

Distribution surveys

Sightings of the five species of interest were more frequent in the treatment area than in the control (12). This is almost certainly due to the far greater availability of gravel beaches and calm braids of the river created by gravel extraction in the treatment area, which likely provide better resting, nesting, and feeding habitat.

Table 12. Number of river birds recorded during a survey of the Aparima River treatment (a) and control (b) sites on October 18th, 2023; data from previous years are provided for comparison.

(a) Treatment	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**
Banded dotterel	11	12	12	8	6	19	16
Pied stilt	13	103	14	52	27	10	15
Black-fronted tern	15	27	8	2	78	20	92
SIPO	4	14	1	12	53	14	9
Black-billed gull	0	501	1582	0	8	0	54
TOTAL	43	657	1617	74	172	63	186
(b) Control	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**
Banded dotterel	1	1	4	2	4	0	3
Pied stilt	3	21	3	5	4	0	10
Black-fronted tern	2	10	0	0	9	4	14
SIPO	5	5	5	2	4	6	5
Black-billed gull	0	0	11	0	2	0	2
TOTAL	11	37	23	9	23	10	34

The season's data in *Table 12* has been taken from the October round of monthly distribution surveys in 2016-17, 2017-18, 2018-19, 2021-22 and 2022-23 seasons and an annual survey in 2019-20 and 2020-21 seasons as the survey methods were the same.

Weekly abundance estimates

Variable numbers of the five key river bird species were observed in the treatment and control areas from September to January (Table). In all weeks surveyed there were higher numbers of the five key species in the treatment area than the control area (Fig. 16 & 17). Frequent high flows throughout the 2022-23 season resulted in partial area surveyed due to access issues around the river.

Table 13. Weekly abundance estimates for the five key bird species in treatment (a) and control (b) areas.

(a) Week	**38**	**39**	**40***	**41***	**42**	**43**	**44**	**45***	**46**	**47***	**48**	**49**	**50**	**51***	**2***	**3**
SIPO	11	11		4	9	7	9		6	6	6	11	9	3	12	0
Banded dotterel	28	24		16	16	17	19		10	6	13	13	7	8	27	24
Black-fronted tern	34	54		61	92	59	68		10	4	10	17	50	170	40	134
Black-billed gull	2	9		4	54	45	96		6	0	9	19	12	7	150	51
Pied Stilt	0	15		4	15	7	20		8	0	11	25	9	25	84	80
(b) Week	**38**	**39**	**40***	**41***	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**2**	**3**
SIPO	4	7		2	5	6	6		2	8	3	4	3	0	0	0
Banded dotterel	3	4		5	3	1	1		3	1	1	3	10	4	2	5
Black-fronted tern	4	6		9	14	1	4		0	0	1	1	0	0	0	10
Black-billed gull	0	0		0	2	0	0		0	0	0	0	0	0	0	0
Pied Stilt	0	2		0	10	2	22		2	0	2	1	0	0	0	22

*partial survey or not completed at all

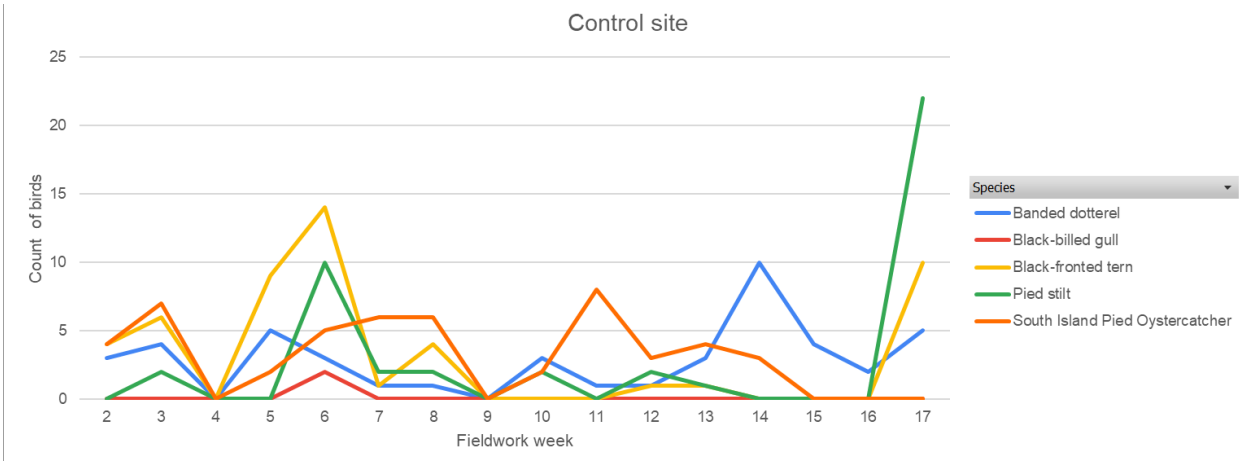

Figure 16. *Weekly abundance estimates of the five key bird species in the Aparima River control area.*

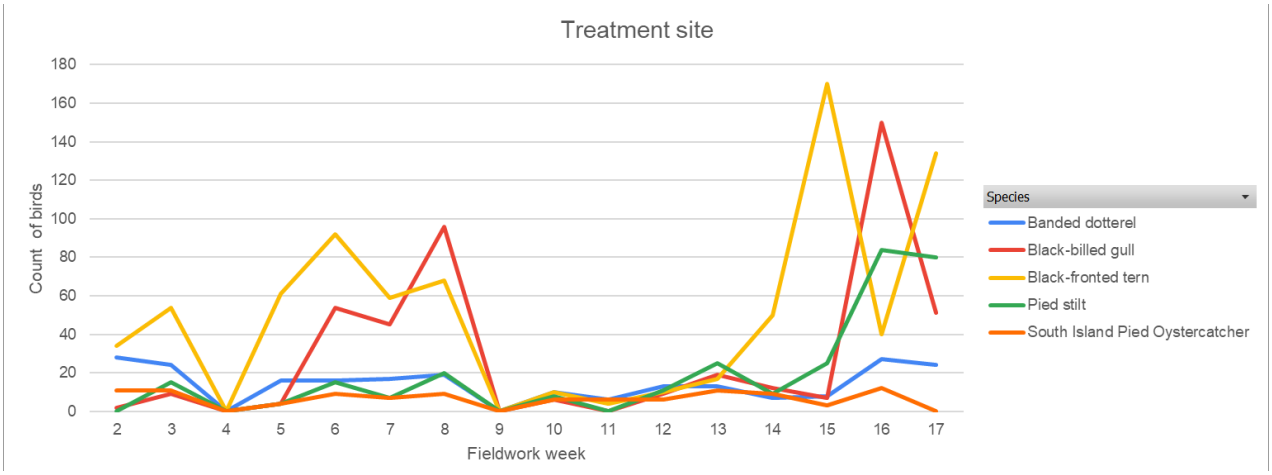

Figure 17. *Weekly abundance estimates of the five key bird species in the Aparima River treatment area. Note that Y-axis scales are different between control and treatment graphs.*

Predator monitoring

Tracking tunnels

Six tracking tunnel lines were set up across the study area following the centre of the riverbed, the true left and true right riparian margins, in both treatment (lines 1-3) and control (lines 4-6) areas (Fig.18). Tracking tunnel lines are usually run for a 9-night period each month from October to January, when river levels allow. Bait used for the tunnels is peanut butter for one night, followed by four nights with beef mince and a re-bait of beef mince for another four nights.

Difficult field conditions and high river levels have caused the success of these methods to vary across seasons, with deployment times ranging from 5-12 nights in the past and tunnels being inundated in high flows. This season, tunnels were set for 9 nights in October and November, 6 nights in December, and 7 nights in January. An unseasonal snowstorm during the October survey seemed to cause lower animal activity. A total of 60 tunnels were set and baited as per the planned methods with both peanut butter and beef mince. An additional line of 7 cameras was set for 9 nights in October in the restored site at the northernmost end of the treatment area, in response to high predation of nests as well as cats and stoats being observed on nest cameras in this area (Fig.19). This line was only set in October as there were no birds nesting in the area by the time of the next survey. Only 59 tunnels were set in January, as the location for one tunnel was inaccessible due to stock placement. Tunnels were removed and redeployed between the October, November and December surveys. Tunnels in the treatment area as well as those in the control area not accessible by livestock or the public were left in place over the Christmas period to reduce deployment times in the January survey.

In the 2022-23 season, mice were the most common species detected in both treatment and control sites (Table 14). This trend has been consistent throughout the course of the project, though appears most pronounced this season. Hedgehog numbers appear to be trending downwards, with no detections in the control site. Cats were only detected at the control site this season after having not been detected in 2021-22. Mustelids were more common at the treatment site than in previous years, being detected in every survey. Possum detections were more common in both sites as well. Rat numbers were lower at the treatment site in previous years, and similar in the control site. A lizard was again detected at the treatment site.

Table 14. Monthly percentage tracking by species in the (a) treatment and (b) control areas.

	2016-17				2017-18			2018-19[+]			2020-21			2021-22		
(a) Treatment	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Oct**	**Nov***	**Dec**	**Oct**	**Nov**	**Dec**	**Dec**	**Jan**	**Feb**
Mouse	6.7	30.0	30.0	76.7	53.3	60.0	73.3	0.0	4.4	0.0	-	13.0	-	50.0	43.3	60.0
Rat	3.3	0.0	6.7	0.0	6.7	13.3	10.0	3.3	4.4	6.7	-	0.0	-	13.3	30.0	6.7
Hedgehog	10.0	6.7	3.3	0.0	13.3	3.3	16.7	13.3	13.0	6.7	-	0.0	-	6.7	23.3	13.3
Mustelid	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	-	4.0	-	0.0	0.0	13.3
Cat/ferret	0.0	0.0	3.3	0.0	6.7	3.3	0.0	0.0	0.0	0.0	-	4.0	-	0.0	0.0	0.0
Cat	0.0	0.0	3.3	0.0	0.0	3.3	0.0	23.3	17.4	6.7	-	26.1	-	0.0	0.0	0.0
Possum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	4.0	-	0.0	3.3	3.3
Lizard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	-	0.0	0.0	3.3
Unknown	6.7	3.3	10.0	0.0	13.3	16.7	26.7	6.7	0.0	6.7	-	0.0	-	0.0	0.0	0.0
(b) Control	**Oct**	**Nov**	**Dec**	**Sep**	**Oct**	**Nov**	**Dec**	**Oct**	**Nov***	**Dec**	**Oct**	**Nov**	**Dec**	**Dec**	**Jan**	**Feb**
Mouse	13.3	16.7	33.3	43.3	26.7	40.0	26.7	0.0	7.7	3.3	-	20.0	-	30.0	43.3	69.0
Rat	0.0	0.0	0.0	6.7	3.3	3.3	0.0	0.0	0.0	0.0	-	0.0	-	6.7	6.7	0.0
Hedgehog	10.0	10.0	10.0	13.3	13.3	43.3	30.0	6.9	15.4	6.7	-	0.0	-	0.0	0.0	0.0
Mustelid	0.0	3.3	0.0	0.0	0.0	10.0	3.3	0.0	0.0	0.0	-	3.3	-	0.0	0.0	3.4
Cat/ferret	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	3.3	-	0.0	0.0	0.0
Cat	0.0	3.3	3.3	0.0	0.0	0.0	6.7	13.8	7.7	20.0	-	10.0	-	0.0	0.0	0.0
Possum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	3.3	-	20.0	10.0	0.0
Cow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	-	3.3	0.0	0.0
Unknown	3.3	13.3	16.7	3.3	0.0	3.3	3.3	10.3	0.0	10.0	-	3.3	-	0.0	0.0	0.0

	2022-23			
(a) Treatment	**Oct**	**Nov**	**Dec**	**Jan**
Mouse	39.1	60.4	73.8	66.7
Rat	6.5	2.1	0.0	0.0
Hedgehog	0.0	8.3	0.0	2.6
Mustelid	6.5	4.2	4.8	5.1
Cat/ferret	0.0	0.0	0.0	0.0
Cat	0.0	0.0	0.0	0.0
Possum	0.0	12.5	4.8	2.6
Lizard	0.0	0.0	0.0	2.6
Insect	8.7	2.1	4.8	5.1
Unknown	0.0	0.0	0.0	0.0
(b) Control	**Oct**	**Nov**	**Dec**	**Sep**
Mouse	20.6	43.5	34.4	31.3
Rat	2.9	0.0	12.5	3.1
Hedgehog	0.0	0.0	0.0	0.0
Mustelid	2.9	0.0	3.1	3.1
Cat/ferret	0.0	0.0	0.0	0.0
Cat	0.0	6.5	15.6	3.1
Possum	0.0	0.0	3.1	9.4
Cow	2.9	4.3	0.0	0.0
Insect	17.6	15.2	6.3	34.4
Unknown	0	0	0	0

[+]In the 2018-19 season beef mince was the only lure applied (in past seasons peanut butter was also used).

*The November 2018 round of tracking tunnels was heavily affected by flooding of the river and my not be representative.

Note: no data was collected in 2019-20.

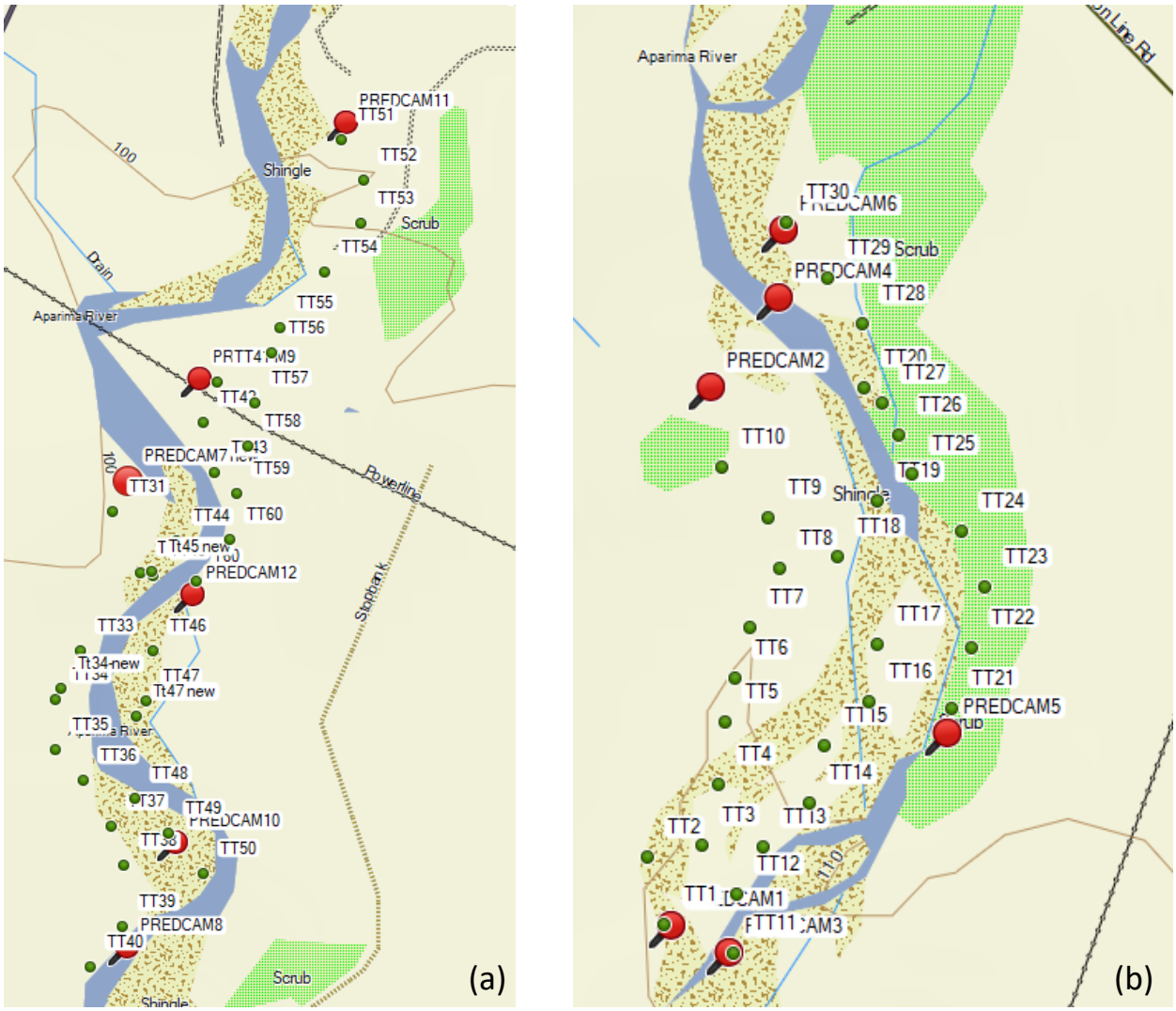

Figure 18. *Tracking tunnel (green dots) and camera (red pins) locations across the control (a) and treatment (b) sites.*

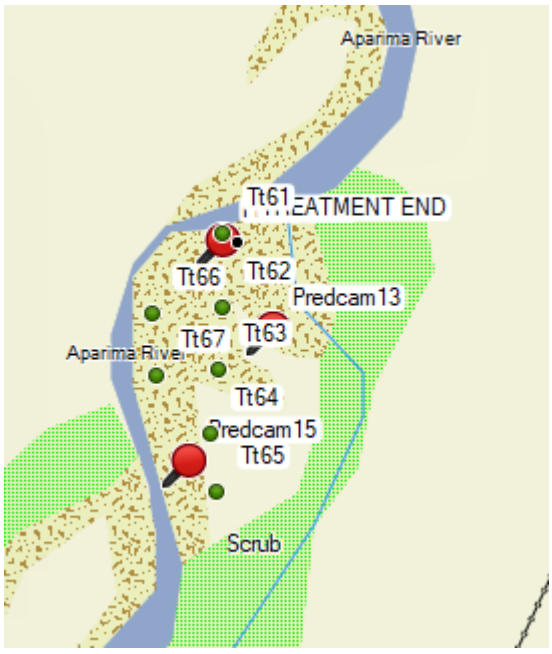

Figure 19. *Tracking tunnel (green dots) and camera (red pins) locations at the restored site (Top beach).*

Predator cameras

At either end of each tracking tunnel line, a trail camera (Acorn Ltl-5310 or Browning Dark Ops Pro XD) was set up on the first day tracking tunnels were deployed (Fig.18 & 19). Each of the twelve cameras was baited with fresh mince and run for the same nine nights as the tracking tunnels, being rebaited with fresh mince after one night. In previous seasons this has occurred monthly from October to January with variations depending on other tasks, weather conditions and river levels. In 2022-23, these surveys were run monthly from October to January. The relative abundance of each predator species was assessed separately for the treatment and control areas through calculating detections per 100 camera trap nights. One detection was defined as an animal that was caught on camera and any subsequent triggers within a 30-minute window. If the animal triggers the camera again after 30 minutes, a second detection was counted. Vegetation directly in front of the camera was trimmed using snips or pulled by hand to reduce false triggers.

During the first survey during October, two cameras were stolen from the control site. After this care was taken to ensure the cameras were placed in areas that were not easily accessible or visible to member of the public.

A wide range of predators was recorded at the treatment site, including cats, hedgehogs, possums, mice and ferrets (Table 15). Lagomorphs were also commonly seen. Cats were very common in the October survey (n=22.2) but were not detected on camera after this. Rats were only detected in the treatment area during the December survey (n=2.8). These two species were responsible for all direct nest predation events observed this season, and it seems that their presence is still a significant threat to nesting birds even at low numbers.

Lagomorphs continued to be the most commonly detected species at the control site, with rats and cats also recorded (Table 15). Mice were also common, which is consistent with their high tracking rate in the tracking tunnel surveys. No harriers were seen in either site this season. Not included in the table but seen often were sheep and common passerines such as song thrushes and blackbirds.

Table 15. Predator detection rates per 100 camera trap nights in (a) treatment and (b) control areas.

(a) Treatment			2016-17			2017-18			2018-19			2020-21			2021-22			2022-23		
Per 100 nights	Oct	Nov	Dec	Sep	Oct	Dec	Jan	Feb	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec	Jan
Cat	23.6	10.9	24.1	3.7	1.9	0	0	0	9.3	9.3	20.0	3.6	20.0	-	3.7	-	22.2	0	0	0
Hedgehog	3.6	0	0	3.7	3.7	0	8.7	0	7.4	0	3.3	0	6.7	-	0	-	0	16.7	0	0
Harrier	16.4	9.1	5.6	5.6	0	0	2.2	10.4	0	0	0	3.6	0	-	0	-	0	0	0	0
Deer	3.6	3.6	3.7	0	0	0	0	0	0	1.9	0	0	0	-	0	-	0	0	0	0
Dog	0	0	0	0	1.9	0	0	0	0	0	0	0	0	-	0	-	0	0	0	0
Human	0	0	0	0	3.7	0	2.2	0	0	0	0	0	0	-	0	-	1.85	0	0	0
Possum	10.9	0	0	5.6	1.9	13.5	10.9	12.5	1.9	0	3.3	0	3.3	-	3.7	-	7.4	5.6	16.7	11.9
Lagomorph	29.1	63.6	9.3	11.1	11.1	13.5	4.3	4.2	31.5	14.8	36.6	7.1	6.7	-	3.7	-	13	3.7	2.8	0
Rat	-	-	-	0	0	16.2	0.0	2.1	7.4	5.6	0	0	3.3	-	0	-	0	0.0	2.8	0
Mouse	-	-	-	1.9	0	0.0	0.0	0.0	0	0	0	0	0	-	35.2	-	13	0.0	0.0	9.5
Ferret	0	0	0	0	0	0.0	0.0	0.0	0	0	0	0	3.3	-	1.9	-	1.85	0.0	0.0	0
Stoat	0	0	0	0	0	2.7	4.3	0.0	0	0	0	0	0	-	0	-	0	0	0.0	0
Unknown	10.9	5.5	0	0	0	8.1	0.0	2.1	1.9	0	0	3.6	0	-	1.9	-	9.3	1.9	0	0

(b) Control			2016-17			2017-18			2018-19			2019-20			2021-22			2022-23		
Per 100 nights	Oct	Nov	Dec	Sep	Oct	Dec	Jan	Feb	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec	Jan
Cat	18.3	1.9	5.6	9.3	3.7	0.0	0.0	2.5	0	0	0	7.7	20.0	-	1.9	-	1.9	1.9	0	2.4
Hedgehog	1.7	0	0	0	9.3	0.0	0.0	0.0	12.2	0	6.7	0	10.0	-	0	-	0.0	0.0	0.0	0
Harrier	6.7	0	7.4	0	0	0.0	2.8	0.0	0	1.9	0	0	3.3	-	1.9	-	0.0	0	0.0	0
Deer	0	0	1.9	0	1.9	0.0	0.0	0.0	0	0	0	0	0	-	0	-	0.0	0.0	0.0	0
Dog	5.0	0	3.7	3.7	1.9	0.0	2.8	5.0	0	3.7	6.7	0	0	-	0	-	0.0	0	0	0
Human	0	1.9	0	0	0	0.0	0.0	0.0	0	7.4	3.3	0	3.3	-	0	-	1.9	1.9	0.0	0
Possum	3.3	0	0	1.9	3.7	2.2	11.1	2.5	2.0	0	0	0	0	-	0	-	0	0	0	0
Lagomorph	33.3	31.5	0	57.4	16.7	11.1	25.0	35.0	6.1	16.7	33.3	0	0	-	27.8	-	3.7	35.2	5.6	4.8
Rat	-	-	-	1.9	0	17.8	0.0	0.0	0	0	0	0	0	-	0	-	1.86	0.0	2.8	0
Mouse	-	-	-	9.3	0	2.2	0.0	0.0	0	0	0	0	0	-	0	-	9.3	0	5.6	23.8
Ferret	0	0	0	0	0	2.2	0.0	2.5	0	0	0	0	0	-	0	-	0	0.0	0	0
Unknown	6.7	5.6	0	0	1.9	0.0	0.0	2.5	10.2	0	0	0	0	-	0	-	1.9	0.0	0	0

Nest cameras

This season, we collected a total of 414 camera nights at SIPO, banded dotterel and black-fronted tern nests (Table 16). Lagomorphs were again the most common species detected, with mice detected for the first time. Lethal predation events from both cats and rats were observed this season, on dotterel and tern nests respectively (Fig.20). One of the terns was observed sitting on the nest for a day after the eggs had been eaten by a rat. One dog was observed sniffing a dotterel nest but did no harm to it.

Table 16. Lethal and non-lethal detections of predators at monitored nests per 100 camera nights.

Year	2016-17	2017-18	2018-19	2020-21	2021-22	2022-23
Total camera nights	233	325	60	10	188	414
Lethal						
Cat	0	1.85	3.33	0	0	0.24
Harrier	0	0.62	0	0	0	0
Other bird*	0	0.31	0	0	0	0
Dog	0	0	0	0	0.53	0
Rat	0	0	0	30.0	0.53	1.93
Non-lethal						
Cat	3.4	0.31	1.67	0	0	0.24
Rat	0	0	0	0	0	0.72
Harrier	0.4	0.62	0	0	0	0
Human+	1.7	0.31	1.67	0	9.57	0.48
Hedgehog	0	0.31	0	0	0	0
Other bird*	6.4	19.69	0	0	7.45	3.62
Lagomorph	43.8	22.77	21.67	0	8.51	4.59
Dog	0	0	0	0	2.66	0.24
Deer	2.6	0.62	0	0	0	0
Unknown	3.0	0	0	10.0	0.53	0.24
Mouse	0	0	0	0	0	0.48

+ A pair or group of humans was counted as one detection event, rather than each individual.
* Another species of bird, different from the nesting species, which has approached within 2m of the nest or is visibly aggravating the nesting adult.
Note: only data from active nests (while eggs/chicks were still in the nest, and not abandoned) is included. This means data beyond a predation event is not included as the nest is no longer active. No data was collected in the 2019-2020 season.

At least three cameras were placed in each tern colony (where camera numbers allowed). These were spaced throughout the colony to cover as many angles as possible, both on the outskirts and in the centre. This was helpful for capturing breeding outcomes as well as predator incursions. Several of these cameras were submerged during a flood, but luckily did not travel too far from their original placement so they were found, and the data was recovered from SD cards.

Initially cameras were placed in backwaters near where dotterel chicks had hatched to aid in keeping track of them, however these cameras had low detection rates and as the season progressed, this was discontinued as there were insufficient cameras to use. Not included in the table is one stoat that was seen roaming the beach at the restored site on one of these cameras.

Figure 20. *Cat detected by a dotterel nest; the incubating adult escaped but the eggs were predated.*

Trapping

Leghold and cage trapping: As part of a feral cat tracking project started in 2020, 629 trap nights have been invested across the study sites (573 leghold and 56 cage trap nights). These were targeting feral cats using meat and fish bait but yielded significant by-catches of possum and ferrets with a few other species accidentally caught (Table 17).

Table 17. Catch record for leghold and cage trapping for the 2020-2022 period.

		Catch (# animals)				
Date	# Trap nights	Feral cat	Possum	Ferret	Hedgehog	Rat (N)
Nov-20	74	12	9	4	1	1
Apr-21	112	9	8	4	-	-
Jun-21	98	7	7	2	1	-
Aug-21	69	4	8	1	-	-
Sep-21	45	3	2	1	-	-
Oct-21	36	2	5	3	1	-
Jan-22	107	1	8	3	2	-
Jul-22	28	2	1	2	1	-
Sep-22	36	2	4	1	1	-
Oct-22	24	1	3	0	-	-
TOTAL	**629**	**43***	**55**	**21**	**7**	**1**

* Of the 43 feral cats trapped, 5 were recaptured collared individuals first captured in Nov-20: 38 individual feral cats were captured in total.

Catch rates of feral cats seem to have decreased overtime, likely indicating a reduction in the number of resident individuals and thus a likely decreased risk of predation for river birds, at least locally. However, this year's predator tracking indicates that transient individuals or new colonisers will constantly be immigrating into the area and trapping will need to be ongoing to maintain gains. We are aiming to have two flushes of leghold trapping targeting feral cats in Winter (July-August) when food is scarce, and adults are mobile and hungry, and late Spring

(October-November) when young individuals disperse to maintain feral cats at low densities around the study site.

Trapping network: A grant from Environment Southland Environmental Enhancement Fund obtained in 2021 and further funding from DOC allowed us to implement a full trapping network across the study. Trapping started in September 2022 and traps are checked, reset and rebaited monthly. The trapping network (see Appendix I for details and trap locations) consists of 200 trap boxes (150 DOC150 double set and 50 DOC250 single set), 30 Tim traps (flipping Timmy model) and 30 SA2 Traps. Trap boxes are secured to a waratah to avoid disturbance by stock and member of the public, and displacement by floods (Fig.21). Both Tim and SA2 traps are raised on ramps or trees to protect dogs and stock. We are using a combination of grain and meat based dry baits, and long life clay based lures as the hot Spring and Summer weather is not suitable for fresh bait. We will alternate with eggs and fresh meat/fish bait in the Winter.

Figure 21. *Flipping Timmy trap raised on a willow tree (left), trapped possum provides scale for height above ground. SA2 trap raised on a ramp (middle). DOC150 double-set (long and narrow box) and DOC250 single-set (wide and short box) bolted to waratahs on the Aparima riverbank. These boxes are likely to be flooded but will not be swept away as they are securely anchored. Pink markers are added for ease of location among the high and dense Spring/Summer vegetation. All traps are identified by an individual alphanumeric aluminium tags for catch data recording.*

From the first four months of trapping, catch data and trapper observations show that mouse densities were extremely high across the study site. Even though DOC150 are not design or set for mice, we still recorded high capture rates and all traps showed signed of mouse occupancy (droppings and bite marks on bait, Fig.22). Mouse density was so high that we had to use inedible clay-based lures to avoid baits being eaten too quickly in traps. The mild Winter and warm and wet Spring might have driven mouse numbers higher than usual but that will only be confirmed with ongoing monitoring and trapping. At this stage, we are not planning on trapping mice as they are not directly impacting river birds. The use of poison is not currently considered due to public push back and risks to stock and dogs.

Figure 22. *Trap box showing signs of mouse occupancy with droppings and eaten bait. Mice are usually too light to trigger the DOC 150 traps, let alone the DOC250.*

A wide diversity of mammal pests was captured in traps (Table 18). Total catch rate has remained stable over the first 4 months of trapping, but specific trends are apparent. Hedgehogs are the most common catch, especially on farmlands immediately adjacent to the river. Catch numbers are stable and it is likely that we are only harvesting hedgehogs, the goal being to stop nearby individuals from venturing onto the riverbed. Rodents are also numerous. Ship rat numbers have been stable, but Norway rats numbers seem to have increased in Summer, which is a worrying trend given that they are the main nest predators on the river. Ferrets were caught in the first 2 months with no capture since. Whether it is a seasonal trend or local numbers have already been lowered by trapping is unclear and will take time to confirm. Contrastingly, stoat numbers are generally low but increased in January, likely as a result of young individuals dispersing from female territories. The high number of weasels captured has been somewhat of a surprise since weasels have been barely detected in previous years of predator tracking. Whether we can lower the density of mustelids over time and how rodent numbers will be affected by both trapping and predator reduction will only be clear with more data being collected. Possum numbers have been consistently high on the river has indicated by catch rates from leghold trapping and kill trapping. Again, whether we can reliably lower local densities to protect river nesting birds remains to be shown by longer term data collection.

Table 18. Catch records for the trapping network between October 2022 and January 2023 period. Rats are identified as Ship (S) or Norway (N).

	Catch (# animals)										
Date	Cat	Ferret	H/Hog	Mouse	Possum	Rabbit	Rat (N)	Rat (S)	Stoat	Weasel	**Total**
Oct-22	-	7	13	9	-	2	-	7	-	12	**50**
Nov-22	-	1	18	9	7	1	-	11	1	3	**51**
Dec-22	1	-	14	18	11	-	6	8	1	8	**67**
Jan-23	1	-	12	4	11	1	3	10	5	4	**51**
Total	**2**	**8**	**57**	**40**	**29**	**4**	**9**	**36**	**7**	**27**	**219**

Conclusions and future tasks

This season saw the highest number of banded dotterel and black-fronted tern nests on the river since the project began. In addition to these nests, large flocks of birds of all target species were observed in the treatment site as the weather got warmer. Habitat restoration through gravel extraction in the treatment site seems to be successful in creating habitat that is attractive to river bird species for feeding, roosting, and nesting. Gravel extraction may prove to be a highly effective tool for future management of braided river ecosystems if design carefully and applied appropriately.

Weed (re)invasion remains a constant problem. Throughout the season, herbaceous weeds and introduced grass rapidly colonised bare gravel beds and bird numbers in these areas dropped significantly as weed cover increased. The restored site (top beach) was the most dramatic example of this. In October, it was a very popular site for nesting birds, especially banded dotterel, but by the end of the season it was rare to see any birds in this area.

The main threat to the successful nesting of threatened birds on the Aparima continues to be predation by introduced mammals. It is important that trapping continues, as rats in particular pose a constant threat to tern colonies on the river. Unfortunately, it is not a numbers game as monitoring indicates that a single individual of Norway rat is responsible for the failure of a 60+ nest tern colony. We need to stop all predators from reaching nesting colonies. Since the trapping network was only implemented in September, only time will tell whether predator density decrease, and trapping efforts, are sufficient to reduce predation rates on nesting birds. Dotterels seem to be most in danger from cats. Flushes of leghold trapping in Winter, when food is scarce, should help keep cat numbers at low level around the study site. Next season, light weight, quickly deployable trapping tunnels fitted with Victor rat traps will be deployed on bird nesting colony to try and protect nests from rats.

Flood events were the other main cause of nest loss this year. Floods are an ever-present, and mainly natural risk that cannot be controlled so it is important that other risks are managed to mitigate their impact on nesting bird populations. Higher gravel bars and island should also be provided through gravel extraction to provide shelter to nesting birds during small fresh and medium intensity floods. Unfortunately, high gravel bars and islands are also less likely to be maintained weed free by floods and will need to be mechanically cleared on a regular basis to remain suitable for bird nesting. A new consent is being processed to allow Grant McGregor to maintain restored areas free of weeds and increase ecological values.

Contrastingly to the last 2 years, this nesting season saw limited direct impacts from vehicles, people, and dogs on the birds. However, the theft of two cameras and intentional destruction of a third was disruptive to the project and a stern reminder that not all members of the public are supportive of the project. Regular posts on local social media have increased local awareness and gathered mainly positive feedback and support for the project, but not exclusively. There is still some underlying defiance towards DOC and conservation efforts on the river, especially around predator control. There is an engrained feeling in a small part of the local community that DOC “is taking the river” and looking at preventing access for recreational use. The sign near the tern colony by the bridge warning public of bird nests nearby has also been vandalised in the past and a proportion of people chose to ignore advice provided. Fewer people were seen at the north end of

the treatment site, where the other sign is located. Communication with the public is vital for the smooth running of the project, the protection of the birds, and long-term benefits of the work. We are thus putting significant efforts in regular, positive communication through local community group social media.

The previous year identified heat stress as a potential stressor for nesting birds and young chicks, and that continued this year. Birds were frequently seen panting or sheltering in pools on hot days. Climate change and weather events like this year's La Nina mean that this will be a continuing threat for braided river species. Temporary shelters for nesting birds, and particularly chicks, have been tested in Canterbury and may need to be deployed on the Aparima River if hot and dry Summers keep repeating.

Overall, we are still learning and adjusting our approaches to bird protection from the data gathered through this project, but it is becoming clear that successful habitat restoration can be achieved via carefully designed gravel extraction. However, providing habitat for river birds is not enough without predator control and long-term maintenance of weed free gravel bars and islands. Questions around the benefits of this approach for freshwater habitats and species remain outstanding but we currently have two MSc students looking at freshwater invertebrates and native fish; results should be available next season. The project has also been attracting attention from different stakeholders and we will thrive to keep engaging and providing advice and information to inform better approach to gravel extraction on braided rivers.

References

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Leseberg, A., Maloney, R.F. and Wahlberg, E.J. 2005. Kaki Recovery Programme, protocols for Tasman Valley Predator Control Project. Department of Conservation, Twizel. Internal Report Number 05/07. DOCDM-43801.

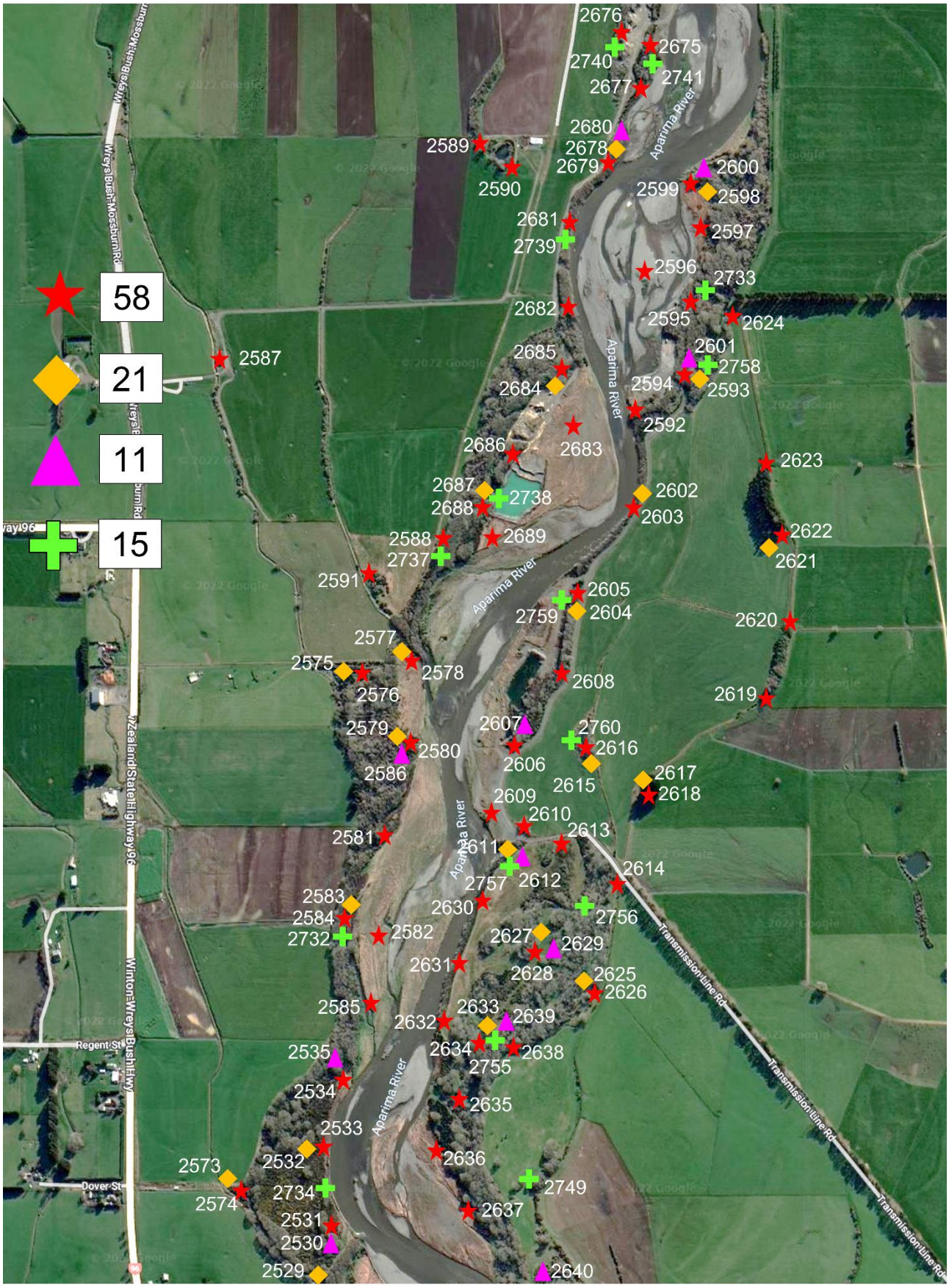
Appendix I. Trapping network implemented in September 2022 across the study site. Traps were installed over 3 months (July-September) during 3 weekly trips. The network will be tweaked over time as catch rates are recorded and we learn more about river movements and predator occupancy. Traps are checked, cleaned and reset if required, and rebaited monthly.

DOC150: 150

DOC250: 50

Flipping Timmy: 29 (1 vandalized in November)

SA Kat Trap: 30


58
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Aparima River
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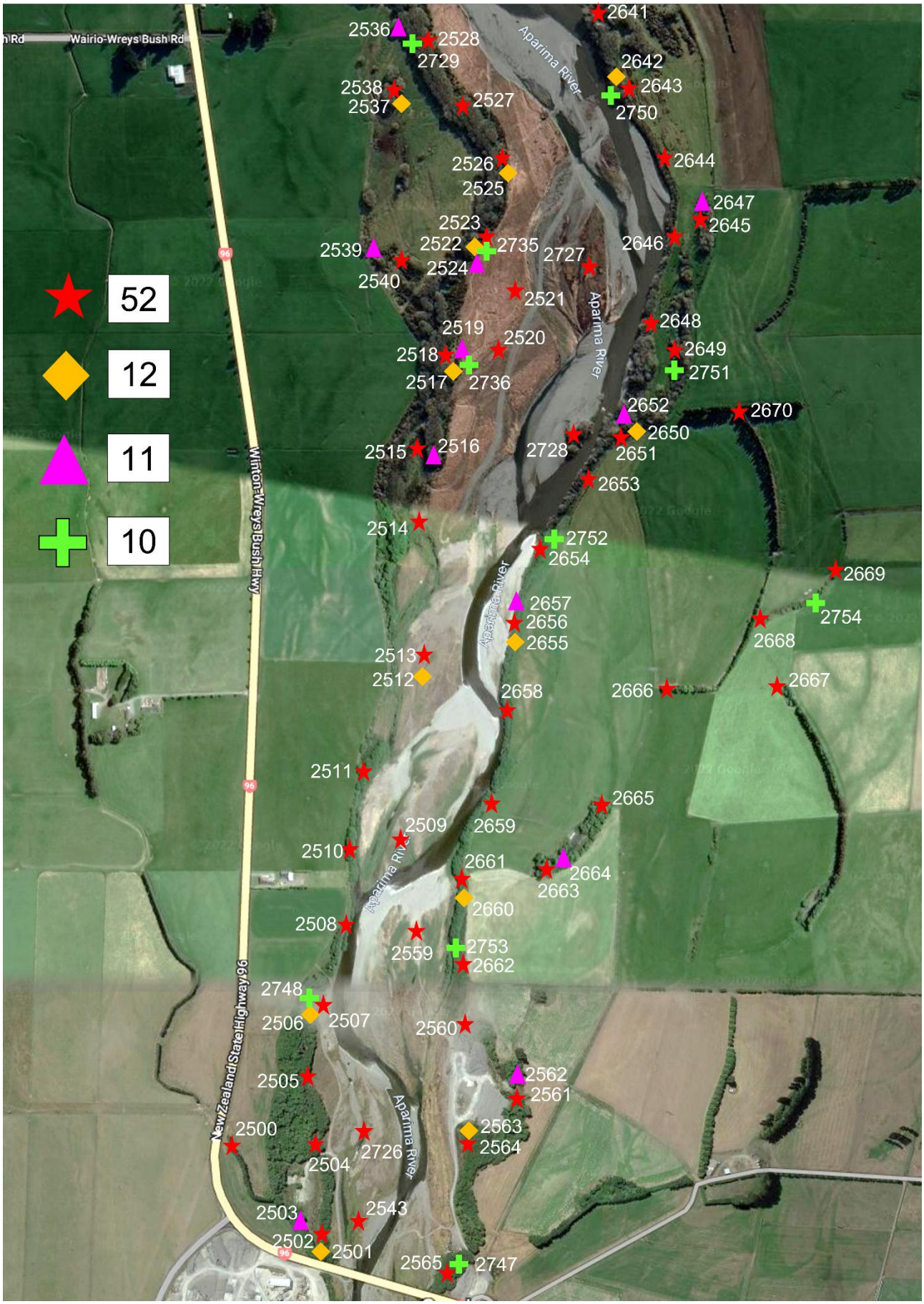
New Zealand State Highway 96
Winton-Wrey's Bush Hwy
Regent St
Dover St
Transmission Line Rd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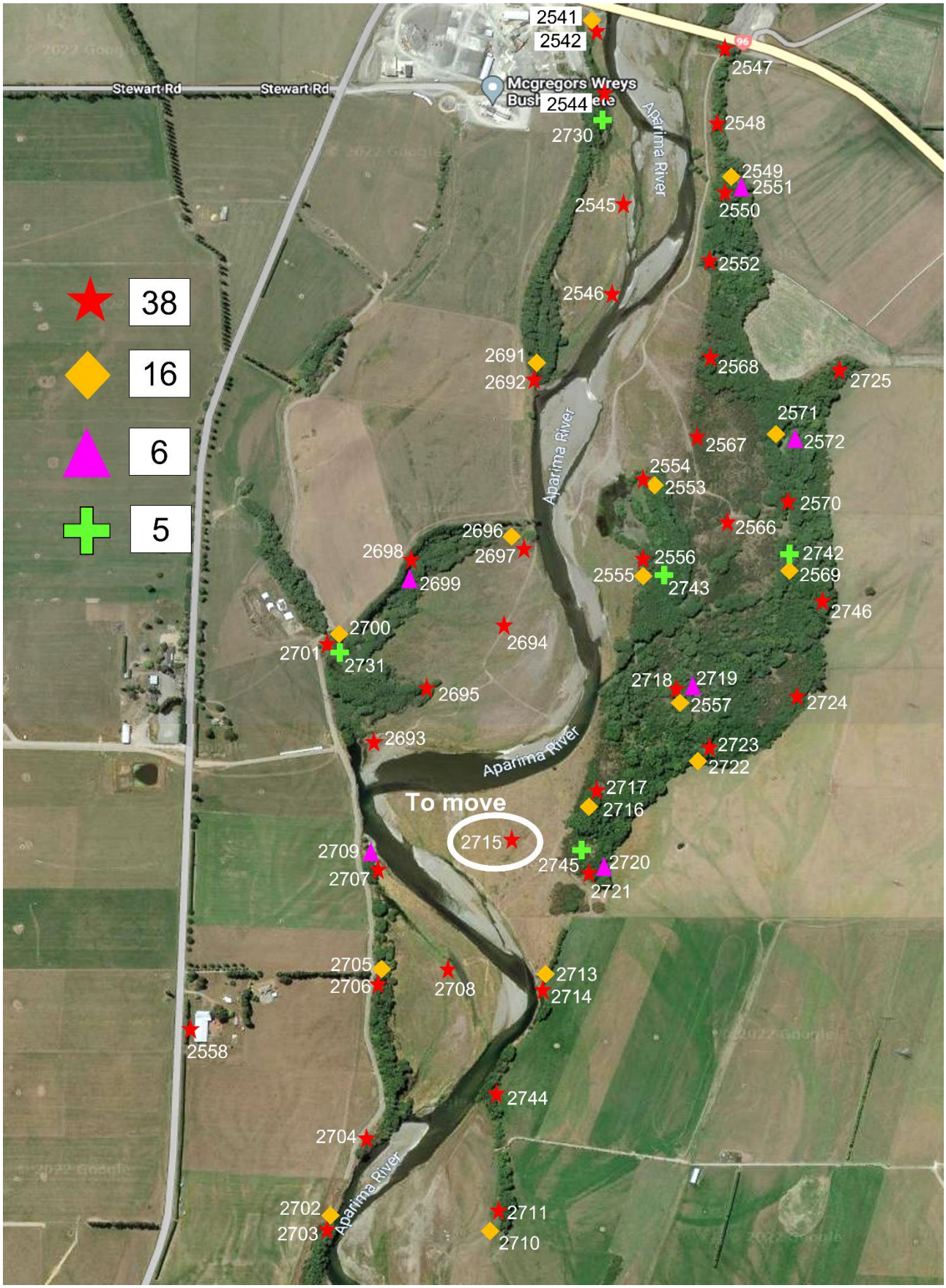
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