Department of Conservation
Te Papa Atawhai

TONGARIRO FOREST KIWI SANCTUARY

ANNUAL REPORT

(July 2022– June 2023)

TONGARIRO DISTRICT OFFICE, CENTRAL NORTH ISLAND REGION

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December 2023

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Cover photo: Saros the kiwi, realising too late there was a camera!

This report and the previous ones are available from the departmental website in pdf form; **https://www.doc.govt.nz/nature/native-animals/birds/birds-a-z/kiwi/docs-work/reports-and-publications/**

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PARTNERSHIPS

Partnerships between the Department of Conservation (DOC) and Ngati Hikairo, The National Kiwi Hatchery Aotearoa (at Rainbow Springs), Sanctuary Mountain Maungatautari, Project Tongariro, Wairakei Golf + Sanctuary, and Save The Kiwi (formerly Kiwis for Kiwi) trust continue to be an essential part of the work in the Tongariro Forest Kiwi Sanctuary (TFKS).

THE NATIONAL KIWI HATCHERY AOTEAROA AT RAINBOW SPRINGS

The National Kiwi Hatchery Aotearoa plays a crucial role in the success of the TFKS, through the incubation and successful hatching of eggs lifted from nests via Operation Nest Egg™ (ONE).
Twenty-seven eggs were taken to Kiwi Encounter this season and 21 chicks hatched successfully which were released into Tongariro Forest for the last session of chick monitoring at TFKS.

NGATI HIKAIRO

Ngati Hikairo plays an important part in the TFKS and has a role and responsibility as kaitiaki for the enhancement of Western North Island brown kiwi within their rohe. Ngati Hikairo support recovery efforts by the Department of Conservation and are intent on kiwi conservation goals and objectives being met within the Tongariro Forest. The hapu's responsibility was greatly put at contribution during the numerous releases from Sanctuary Mountain Maungatautari this season (see next paragraph).

SANCTUARY MOUNTAIN MAUNGATAUTARI (SMM)

Maungatautari is a fenced mainland sanctuary (3,363 ha, surrounded by a 47 km predator "Xcluder" fence) situated in the Waikato. In 2006, the Department of Conservation and Ngati Hikairo made an agreement with Ngati Koroki-Kahukura to contribute 20 founders to the kiwi population at SMM. In return, 14 offspring of some of the original founders were released into TFKS between 2010 and 2013. Sanctuary Mountain Maungatautari re-strategised their kiwi programme in 2017, when a five-year widescale ONE programme was launched by the national charity trust "Save the Kiwi" (STK) in order to establish a permanent kiwi breeding population of around 500 individuals. This is part of a long-term national project focusing on growing source populations (kōhanga) of brown kiwi in fenced sanctuaries and offshore islands. The goal is to eventually translocate all surplus offspring into predator-controlled wild sites in the North Island. Maungatautari now acts as a kōhanga site for Western brown kiwi. The first set of planned releases occurred this season, with 61 kiwi being transferred from SMM back into TFKS.

PROJECT TONGARIRO

Project Tongariro are involved in ecological projects throughout Tongariro National Park and surrounding areas. The organisation has a pool of amazing volunteers who are very flexible and accommodating when regularly asked to assist the TFKS team with work such as transporting kiwi eggs and chicks to and from the National Kiwi Hatchery Aotearoa and carrying out other advocacy work.

NATIONAL KIWI CAPTIVE MANAGEMENT PROGRAMME

Since 2010, there has been a nationwide initiative to release all brown kiwi of the Western taxon from captive breeding institutions into multiple wild sites, following the completion of the western provenance DOC translocation plan. This approach is to enable captive institutes to have increased capacity to work with other (more endangered) taxa of kiwi. Fifteen kiwi have been released at TFKS since 2012, mainly from the Ōtorohanga Kiwi House. Two of these kiwi were translocated from Willowbank Wildlife Reserve at Christchurch. This season, no birds were released from captivity breeding institutions.

WAIRAKEI GOLF + SANCTUARY

Wairakei Golf + Sanctuary is a privately-owned golf course situated north of Taupo. A five kilometre "Xcluder" predator proof fence has been installed around the perimeter. This has created a predator free environment which can be used to benefit threatened plants and animals. The sanctuary is utilised as a kiwi crèche when undertaking ONE. This year, a late hatched chick of the 2021/22 cohort was still safely kept within the sanctuary until its release back into TFKS at safe weight in February 2023.

OWHANGO ALIVE

Owhango Alive is an association driven by the local community aiming at protecting the Ohinetonga Scenic Reserve near Owhango village, which is one of the two main gateways into the Tongariro Forest. The bridge over the Whakapapa River, linking the reserve to TFKS, is one of the main incursion routes for pests, in particular ferrets. The intensive trapping regime undertaken by the volunteers has thus become crucial in the battle against pests re-invading the Tongariro Forest. This 2022/23 season, six ferrets (69 since July 2018) were captured in Ohinetonga reserve and nearby farms, mainly in autumn and early winter. Forty-seven feral cats (207 since July 2018) were also captured this season.

NEW ZEALAND FOREST MANAGERS (NZFM)

Extensive plantation forests are situated south and east of TFKS and are managed by New Zealand Forest Managers Limited. Until last season, we were allowed to develop and sustain a crucial network of DOC250 traps on their managed forests bordering the TFKS and this reduced the risk of ferret invasion from the NZFM side (up to February 2023, 14 ferrets had been caught). This year though, for safety reasons, NZFM hasn't granted us access through their forest, which has had the consequence of proceeding to a different and more perennial (but more complicated) way to set up an east front trap network within the DOC boundary.

EXECUTIVE SUMMARY

Tongariro Forest Kiwi Sanctuary (TFKS, at 19,840 ha) was established in 2000 for the development and testing of landscape-scale (10,000 to 50,000 ha) kiwi protection techniques (ONE and aerial 1080 operations). Up until 2010, TFKS aimed to achieve and maintain a representative sample of 200+ pairs of Western North Island brown kiwi (*Apteryx mantelli*) by 2017, involve community, and enhance public awareness (Tongariro Forest Kiwi Sanctuary Operational Plan, 2009). However, ferret predation events within the Sanctuary between 2009 and 2018 made it clear that no target could be achieved unless ferrets were controlled effectively. A permanent ferret trapping regime was therefore added and implemented at the end of winter 2018. Since then, only two confirmed ferret depredations on kiwi have been recorded, both towards the end of winter, in August 2021 and 2022.

A key research focus of TFKS is to assess the effectiveness of cyclic landscape-scale aerial 1080 operations (broadcast at 1.5kg/ha) on kiwi chick survival and long-term population growth.
Since August 2011, the programme has shifted from a five-yearly 1080 cycle to a three-yearly cycle, aimed at achieving an annual growth rate of 4 % (TFKS annual report 2015/16), and accounting for the ferret predation events that initially only occurred after the third year following 1080 operations. However, since 2017, our observations have shown that ferret incursions can happen at any stage of a 1080 operation and that solely relying on three-yearly 1080 cycles is insufficient to prevent the TFKS kiwi population from becoming locally extinct. A combination of permanent ferret trapping and three-yearly 1080 operations became essential and this was implemented in the season 2018/19. This management regime would allow the kiwi population to increase by about 7 % annually (see 2020/21 TFKS Annual Report and Appendix 1). As the last 1080 operation was delayed by two years (performed on 27th May 2022), this last cycle was essentially a five-year one.

Twenty adult kiwi males were monitored in TFKS in 2022/23 (16 breeding males). There was a total of 27 eggs taken to Rainbow Springs, resulting in 21 successfully hatched chicks released back into the wild. This season marked the final session of chick monitoring at TFKS and a good chick survival rate of 49% was obtained.
Six adult females and five sub-adults were also monitored this year for recruitment into the tagged breeding population or as sentinel birds (which would provide an early warning for any ferret incursion if preyed upon). This monitoring also provides information about the distribution of kiwi within the Tongariro Forest and their survivorship. No females and sub-adults died this year.
On the other hand, two adult males died this season, and as of last year, one was confirmed to be preyed upon by a ferret along Top track. Additional DOC250 traps were therefore installed at the kill site and along ferret incursion pathways leading towards this area. No ferret was captured and no further ferret predations on monitored birds were reported. The number of ferrets that were caught in traps this season was comparable to last year, which is half of the number caught during the peak year of 2020/21.

One of the most significant milestones was reached this season, with the release of 61 birds from Sanctuary Mountain Maungatautari during April/May 2023. Future releases are also planned next season.

Small mammal indexing (SMI) continues to be measured using tracking tunnels in TFKS and the results showed a successful initial rat and stoat knock down (0 % tracking rate) four and a half weeks after the 27th of May 2022 1080 operation. As expected, rat re-colonisation occurred rapidly and returned to the usual 80% tracking rate mark about 15 months later. Mustelids were still tracking low towards the end of the season (7%)).
The much more sensitive trail cameras are also used at TFKS (deployed along tracking tunnel lines) and are part of a 5-year study ending in August 2023. Cameras detected Mustelids in 53% of the lines three weeks prior to the 1080 operation and did not detect any at all in all 15 lines four weeks after the 27th of May 2022. Mustelids began to reappear on camera within TFKS by September (with the return of weasels), three months after 1080. Stoat presence remains low 15 months after the operation as weasel numbers are making up for 70% of all mustelid camera detections in May 2023 (Appendix 2).

Ongoing kiwi call surveys are used to measure the extent of the impact of ferret predations on breeding birds by detecting the presence or absence of pairs in areas where no kiwi are monitored and by detecting any potential recruitment at historical listening sites. On average, 4.5 calls per hour were heard on the eastern side this season, which is up from the highest count ever recorded last season (4.3 calls/hour).

INTRODUCTION

Tongariro Forest Kiwi Sanctuary (Figure 1) was established for the protection and recovery of the Western North Island brown kiwi taxon (*Apteryx mantelli*) within the central North Island. It is one of five sanctuaries set up nationwide in 2000 to maintain significant populations of different kiwi taxa, and to develop and improve techniques in kiwi protection, specifically aiming to increase the survivorship of young kiwi as they are extremely vulnerable to stoat predation (Robertson 2004; Table 1). In addition, since ferrets have been identified as a major threat to adult kiwi, it has become essential to develop management prescriptions that effectively control ferrets.

This research has involved determining survival rates of kiwi chicks before and after aerial 1080 operations (Tables 1 & 2). TB Free NZ, in conjunction with the Department of Conservation carried out aerial 1080 operations as part of their regional TB-vector/possum control regime and for kiwi protection research in 2001, 2006, 2011 and 2014. This research was of national importance, indicating whether 1080 could be used as an effective tool for maintaining kiwi in large and/or relatively inaccessible areas throughout the country. Results showed that aerial 1080 operations benefited kiwi chick survival for two consecutive seasons in TFKS. Other forest birds also benefited from aerial 1080 operations with increased nest success for fantails for one or two consecutive seasons after 1080 operations, depending on the timing of rat re-colonisation (Robertson *et al*. 2019).

Our research objective between 2014 and 2019 was to measure the benefits of low sowing rates of aerial 1080 to kiwi chick survival (Scrimgeour *et al.* 2015). We moved from distributing 4kg/ha of toxin bait in 2006, to 2kg/ha in 2011 and down to 0.75kg/ha (with strip sowing) in 2014, whilst monitoring chick survival in response to these various regimes.
However, the focus for testing and pushing for low sowing rates was re-examined in 2016 and it was decided (based on the results from TFKS and from the national predator control programme called Tiakina Nga Manu (TNM)/"Battle For Our Birds") that the recommended sowing rate for future 1080 operation would be 1.5kg per ha with even broadcast sowing. This sowing rate has therefore been applied to the 2017 and 2022 1080 operations.

Another key objective is researching the need for effective ferret control, as it had become crucial to re-establish a high survival rate among the adult population (i.e. > 95 %) to prevent the TFKS population from becoming locally extinct. This has been a research-based approach for it to be applicable to other sites throughout the country (Tables 1 & 2).

Other work within the TFKS involves ongoing monitoring of adult kiwi for survival and breeding purposes, monitoring of sub-adult kiwi for breeding recruitment, and carrying out kiwi call surveys. Mustelid and rodent numbers are also monitored using the standard tracking tunnel methodology

(small mammal indexing) and trialling a 21-night mustelid survey using trail camera traps along the existing tracking tunnel transects (ended in August 2023).

This report presents results from these key areas of work for the 2022/23 financial year.

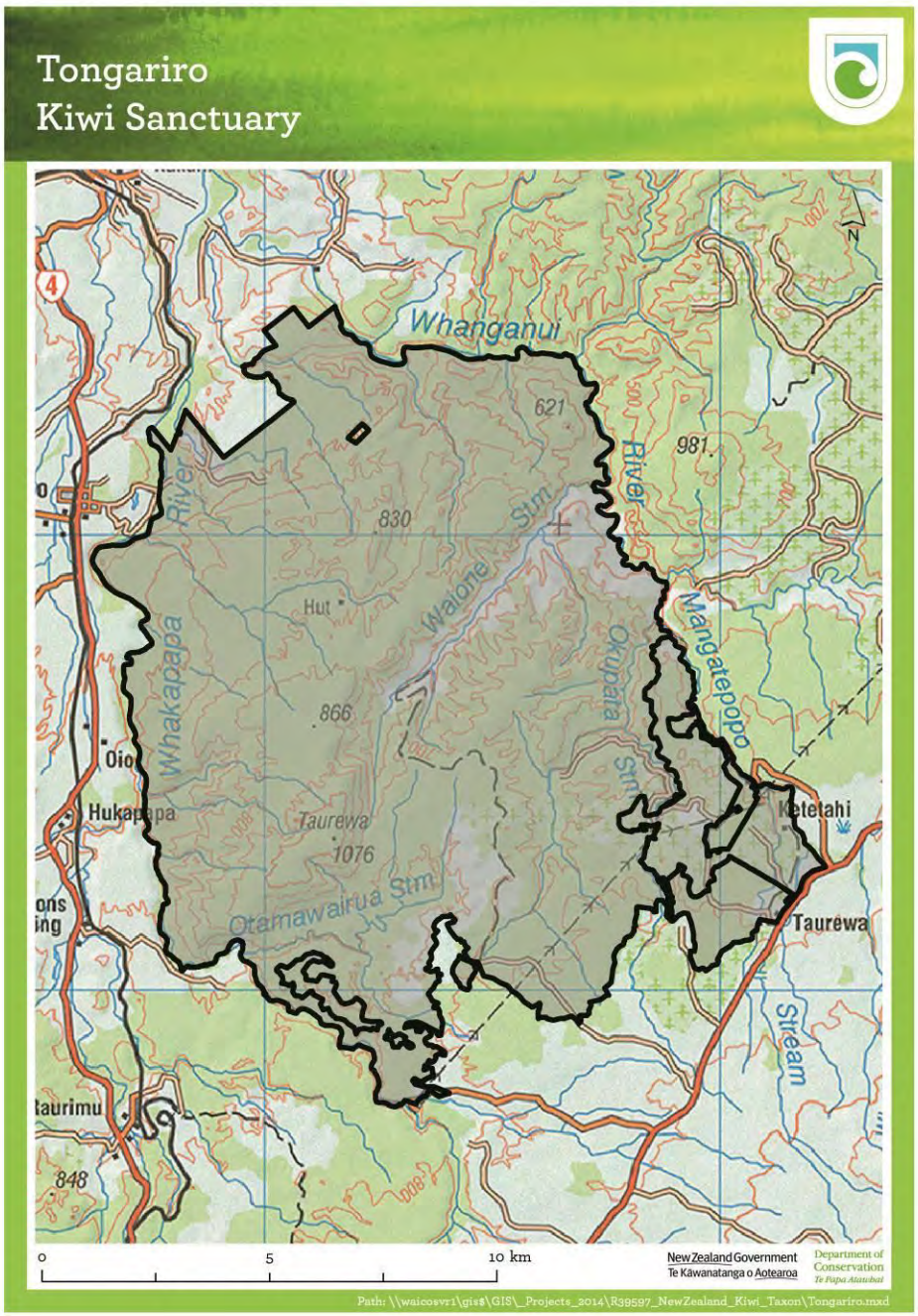

FIGURE 1: MAP OF THE TONGARIRO FOREST KIWI SANCTUARY, CENTRAL NORTH ISLAND

SANCTUARY OBJECTIVES AND ACTIONS

Five-year plan for Tongariro Forest Kiwi Sanctuary 2021-26, docCM-6415890

TABLE 1: TFKS VISION AND OBJECTIVES

Tongariro Forest is a whare wānanga – a place of learning – for conservation management	
Objectives	
We understand how to effectively protect kiwi	• The focus is to develop a transferable model of ferret control. • Developing result monitoring techniques to measure efficacy. Comparing camera traps with tracking tunnel results and kiwi chick survival. • Our understanding of the relationship between populations of rabbits and any future ferret incursions is improved to help predict and manage ferret risk. • The study is robust with adequate sample sizes and repetition to allow for clear conclusions.
What we learn teaches others to be successful	• This work informs national best practice for 1080, ferret control and outcome/result monitoring. • The method is tested in a way that can be transferred to other sites. • The team mentors/supports others with advice, leading transfer of knowledge.
We work successfully with our partners	• Tangata whenua feels a strong ownership of the sanctuary and the work that is done. • Community partnerships (e.g. private land owners allowing access, Owhango Alive catching ferrets) will be supported and sustained. • Sharing knowledge with stakeholders (e.g. Regional Councils, Manaaki Whenua) so that they can contribute to achieving the objectives of the plan.
If we are successful, kiwi will be protected, and the population will grow	

TABLE 2: TFKS ACTIONS

Protecting kiwi

#	Actions	Accountability	Priority	Progress
Predator Control and ONE				
1.1	Test the efficacy of protecting kiwi from ferrets by trapping dispersal pathways and hotspots.	TFKS	Essential	Ongoing
1.2	Record information on location of capture, gender, age and time of year of capture of ferrets and include in annual report. Collect tails for potential genetic analysis.	TFKS	High	Ongoing
1.3	Implement aerial 1080 every 3 years to supplement trapping.	Tiakina Nga Manu	Essential	Ongoing
1.4	Confirm with Tiakina Nga Manu certainty around aerial 1080 for the next two rounds.	TFKS	High	Achieved
1.5	Undertake ONE in non-treatment years only if capacity and resources allow.	TFKS	Low	Achieved
1.6	Work with DOC Compliance Officer and council if there are reports of wandering dogs, or if a kiwi is killed by a dog.	TFKS	High	Ongoing
1.7	Seek opportunities to improve signage highlighting rules about dogs in the sanctuary and provide aversion training opportunities.	TFKS	Low	Ongoing
Outcome and result monitoring				
1.8	Monitor a minimum of 30 adult and/or sub-adult kiwi annually to ensure a large enough sample to determine efficacy of management, with good geographic spread across the sanctuary.	TFKS	Essential	Ongoing
1.9	Support the camera trap trial as an index of mustelid abundance by maintaining the tracking tunnels and analysing camera footage until August 2023.	TFKS	High	Achieved *(data being analysed by Craig Gillies' team)*
1.10	Monitor chick survival in 2022/23 as a comparison against the camera index and to keep informing population models.	TFKS	High	Achieved this season
1.11	Undertake territory mapping/call counts as an additional outcome measure.	TFKS	Medium	Ongoing
1.12	Develop a rabbit monitoring study design with Horizons in 2021. Undertake annual rabbit surveys. to determine if there is a link between rabbit numbers, rabbit management and subsequent ferret incursions.	TFKS	High	Ongoing

Capacity and resourcing				
1.13	Use the wider Biodiversity and Recreation teams to support trapping and tracking tunnels.	TFKS	Essential	Ongoing
1.14	Work with the Save Our Iconic Kiwi (SOIK) programme about support available for ferret management prescriptions and seek other funding opportunities.	TFKS, KRG	High	Ongoing

Sharing knowledge

#	Actions	Accountability	Priority	Progress
2.1	Complete and publish the study on sub-adult survival, dispersal, territoriality and breeding age by 2025.	TFKS	High	Ongoing
2.2	Develop a ferret management resource that can be shared with kiwi practitioners (key lessons) – pro-active tips and tricks, as well as response plan.	TFKS	High	Ongoing
2.3	At least one presentation at the annual kiwi hui and western brown kiwi hui within the lifetime of this plan.	TFKS	High	Ongoing
2.4	Write an annual report and share with identified stakeholders by September each year (e.g. KRG, Manaaki Whenua, Regional Council, Conservation Board, Owhango Alive, landowners surrounding the sanctuary).	TFKS	Medium	Ongoing
2.5	Respond to re-active requests for advice depending on capacity at the time.	TFKS	Medium	Ongoing

SMALL MAMMAL INDEXING (SMI) USING TRACKING TUNNELS

Tracking tunnels for indexing rodent and mustelid (weasel, stoat and ferret) abundance are carried out during January, February, August and November every year to capture the peak in mustelid abundance. Methodology follows current DOC best practice (Gillies & Williams 2001). There are 15 tracking tunnel transects within TFKS; each line is 450 m long with ten tunnels, giving a total of 150 tunnels. This is the 23rd year (and is the last one under that form) of small mammal indexing data gathering, making it the longest tracking tunnel data set in the country. This supports and increases our knowledge and understanding of small mammal population dynamics in relation to aerial 1080 use.

TRACKING TUNNEL RESULTS, FIRST SEASON AFTER THE MAY 2022 AERIAL 1080 OPERATION USING 1.5 KG/ HECTARE OF PELLETS

After a delay of two seasons, making the previous 1080 cycle a five-year regime, the 1080 operation occurred late in the 2021/22 season, on the 27th of May. This makes the timing different to all the previous operations usually occurring towards the end of winter, immediately before kiwi chicks start hatching. It appears that this earlier timing has not significantly altered the beneficial impact that a 1080 operation usually has on the following breeding season as kiwi chicks survived well this season (see kiwi chick paragraph)

SMI operations/results:

Department of Conservation (through the TNM programme) carried out the aerial 1080 operation over TFKS and undertook a conventional even broadcast method using 0.15% 1080 pellets in a cereal bait at a sowing rate of 1.5kg per hectare (21,968 ha, excluding the 436 ha Owhango water catchment where baits were trickled only along the ridges away from the water courses).
The aimed result targets for immediately after an operation are:

- Less than 5 % rat tracking; and
- 0 % stoat tracking.

The two extra SMI operations performed approximately three weeks prior to, and four weeks after the 1080 operation, are showing that our targets have been exceeded in terms of rat and stoat suppression. Excluding three SMI lines located within the Owhango water catchment, rat tracking rates went from 48% in May to 0% one month after the 1080 drop and remain at 0% for more than three months after the operation (which is a first since SMI started in 2001). Mice tracking rates halved from 28% to about 14%. In comparison, within the water catchment, rat prints were found in all three lines after the operation and comprised a tracking rate of 23 %. This site provides one of the main sources of recolonisation of rats and stoats within TFKS. Similarly, mustelid tracking rates were

reduced from 1.43 % in May to 0 % one month later. The pest result targets were therefore met for this operation.

Initially, rats began to re-colonise slowly and yet, their numbers reached pre-1080 level by August 2023 (79.2%), about 15 months after the May 2022 operation (this is still within the usual 12 to 18 months re-invasion period). As it took longer than usual for the rats to re-appear, mouse numbers exploded this time and reached their peak by August 2022, which is more than twice as fast as the typical time it usually takes (6 to 10 months). Mouse tracking rate climbed to 42.2% and has since gradually decreased to remain above 20% a year later. The mustelid population has been slow to recover as tracking rates stayed at 0% during most SMI operations and merely reached 7% in May 2023, to drop again to 0% in August 2023 (Figure 4).

Tracking indices of rodents within the TFKS over the last two decades show the high relative abundance of rats (ca. 80 + %) typical of North Island indigenous forests in non-1080 treatment years. Interestingly, there was a decrease in rat tracking in 2020/21 prior to the May 2022 1080 operation. This decrease in rat numbers was reflected in local trap catch data, as well as for other sites within the North Island (e.g., northern Ruahine). This event could have been a result of the peak recorded in 2019/20, where rats tracked at a record high of 95 % in Tongariro Forest. Having depleted food resources, rat populations would have simply plummeted on their own accord. Mustelid tracking has incrementally decreased over each 1080-cycle period, with peaks recorded over summer during the dispersal phase of their offspring. At minimum, mustelids begin to recover three months after 1080 operations and take two to three years to reach pre-1080 levels (Figure 4 & Appendix 2).

Trail cameras:

The TFKS is the only research site in the North Island where cameras are trialled to monitor relative abundances of feral cats and mustelids (with kiwi chick survival and tracking tunnel data used as key comparisons against detection rates on the cameras). The cameras are left for 21 consecutive nights. Camera trap lines are set along the 15 tracking tunnel lines comprising four camera stations set at 200 metre spacings. Each camera is directed to a lure (fresh rabbit meat) pegged to the ground about 60 cm in front of the device.

This technique has shown a real difference in mustelid detection sensitivity and has allowed us to accurately identify stoats and weasels (Figure 2, Appendix 2). On the contrary, the use of the traditional three- night tracking ink cards detected either a few or no mustelid footprints (Table 3).

The camera traps also confirmed the decrease of rat detections observed during the tracking tunnel operations since August 2020 and the expected subsequent decline of stoat detections, which are the main predators of rats (Figure 2).

To date, no ferrets have been detected on the cameras.

The 2021/22 season was the first season to use trail cameras before and after a 1080 operation. No mustelids were detected on the more sensitive cameras immediately following the operation (Figure 2 & Table 3), which attests to the success of the operation. Stoats and weasels reappeared within the TFKS by September, three months after 1080 but were not detected again during the November 2022 session. One year later (May 2023), stoat numbers were still recovering to pre-1080 levels. In contrast, weasel numbers have peaked again at levels seen previously in 2019/20 (Figure 2 & Appendix 2). The number of stoat detections on cameras and mustelid tracking cards, averaged for each season (five seasons, from 2018/19 to 2022/23) were strongly positively correlated, meaning that there is a reasonable possibility of calibrating tracking data to the more sensitive camera detection data; an encouraging sign for future work. Data are currently being analysed by the DOC Hamilton Landscape Threats Science team (led by Craig Gillies).

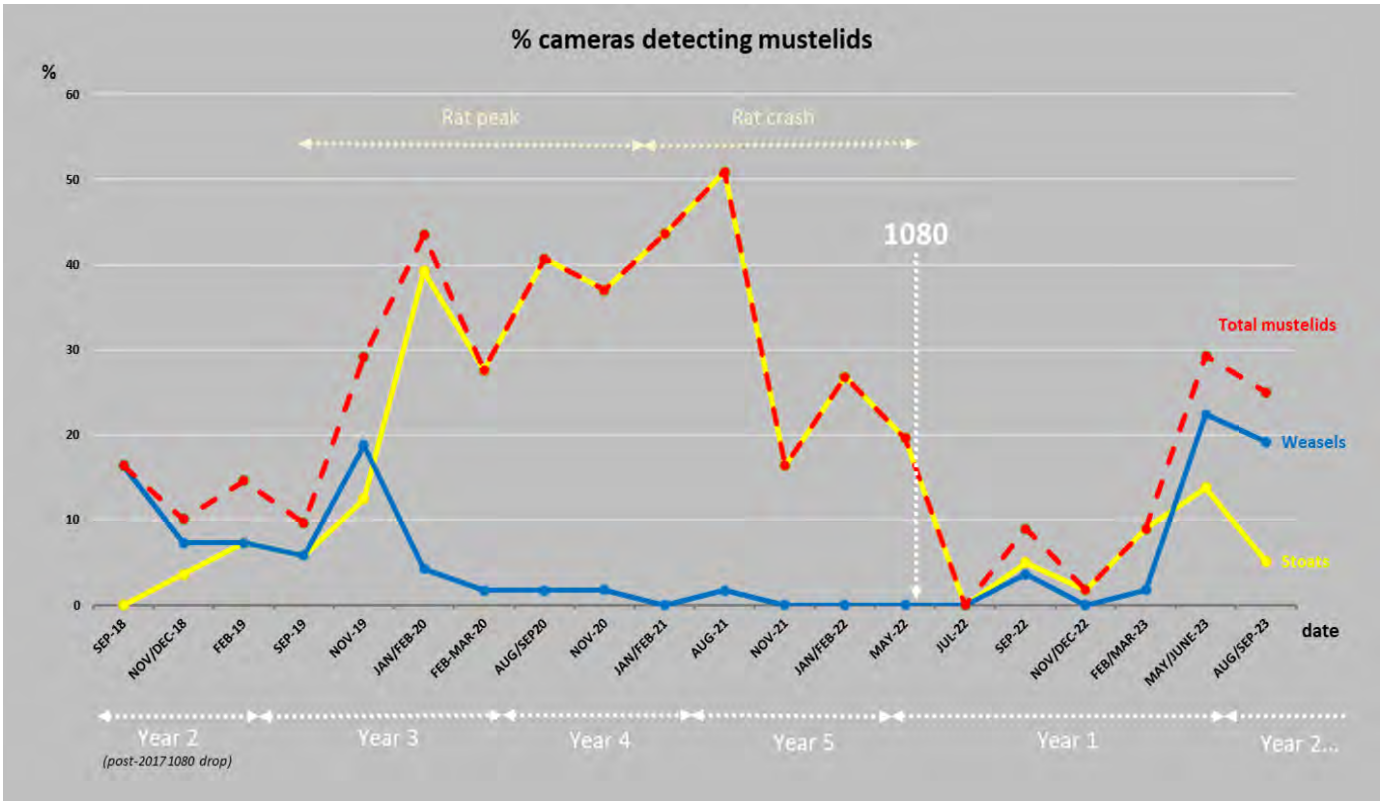

FIGURE 2: PERCENTAGE OF CAMERAS DETECTING MUSTELIDS

TABLE 3: MUSTELID COMPARISONS BETWEEN TRACKING CARDS AND CAMERA TRAPS

	3 nights (ink cards)		21 nights (cameras)	
	mean % tracking per line	% lines tracked	mean % tracking per line	% lines tracked
Sept-18	0	0	18.3*	46.7*
Nov-Dec-18	0	0	18.3*	46.7*
Jan-Feb-19	4	13.3	7.2*	26.7*
Sept-19	0	0	11.1	33.3
Nov-Dec-19	0	0	35.5	80
Jan-20	5	25	43.7	91.6
Feb-20	4	13.3	31.1	60
Aug-Sep-20	1.3	6.7	38.3	73.3
Nov-20	0	0	38.3	66.7
Jan-Feb 21	10.7	35.7	41.1	66.7
Aug-21	1.3	7	50.6	66.7
Nov-21	2.7	7	18.3	33.3
Jan-Feb-22	7.1	14	29.1	57.1
May-22	1.4	7.1	22.2	53.1
July-22	0	0	0	0
Sep-22	1.7	13.3	8.9	33.3
Nov-22	0	0	0	0
Feb-23	0	0	9.7	33.3
May-23	2.7	6.6	29.2	58.3
Aug-23	0	0	23.6	58.3

1080

10nights

Other detections:

Trail cameras are also a useful tool to detect cats and possums in the forest and before the last 1080 operation, it appears that their numbers started picking up from year four after the 2017 1080 drop, which would suggest that with a 3-year 1080 cycle, cats and possums would have a minimal impact on native fauna and flora (Figure 3). Until May 2022, the presence of cats was widespread as they had been observed in twelve out of the fifteen tracking tunnel/camera lines, predominantly on the western side of TFKS. They were often seen on the same cameras as monitored kiwi with some photos taken within hours of each other. This confirms and suggests that, within TFKS, adult kiwi and feral cats can cohabitate (no evidence of cat predation on kiwi have ever been recorded at TFKS).

Possums also had a widespread distribution as they were detected in 11 out of the 15 lines.

The latest 1080 operation reduced the number of detections to zero until one cat and one possum were detected respectively four and six months later (Figure 3). The detections, for both cats and possums, remained very low until August 2023, 15 months after the 1080 operation, when four cat and six possum detections were recorded, suggesting a faster recovery than what was anticipated (Figure 3).

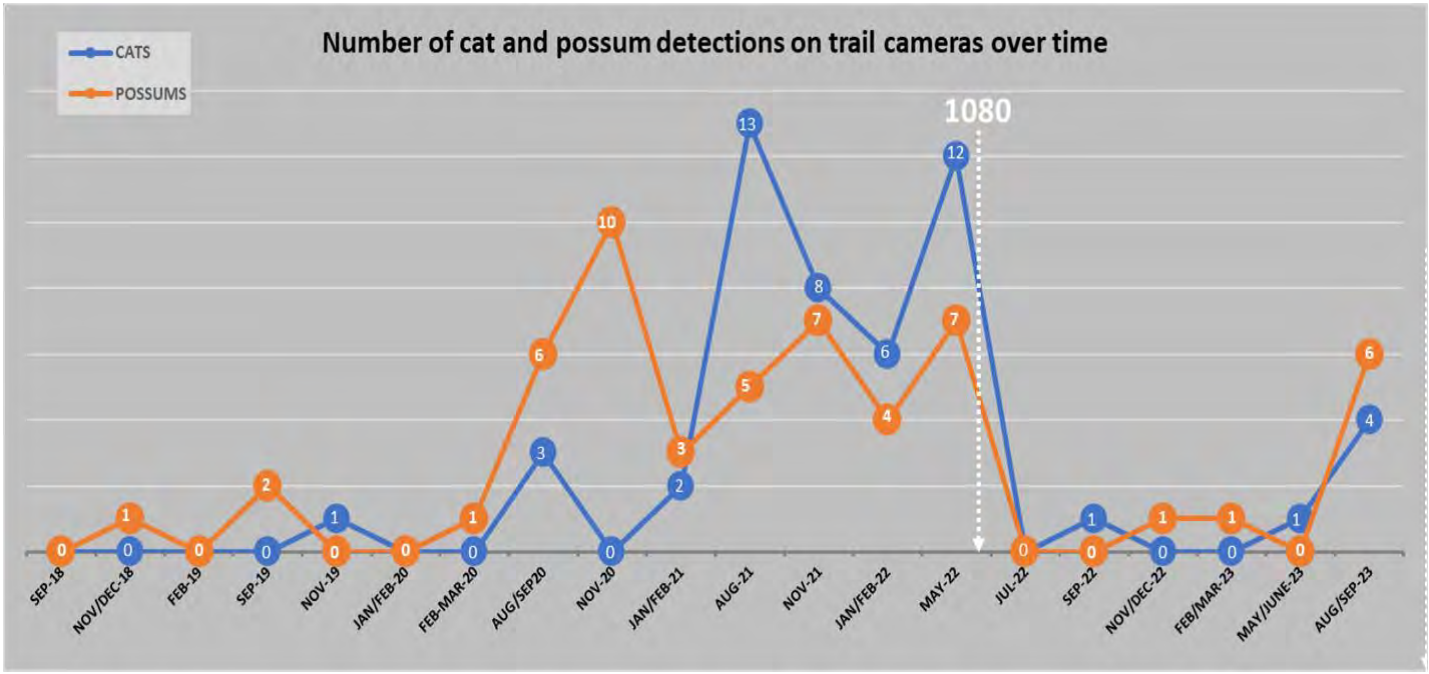

FIGURE 3: TREND OF CAT AND POSSUM DETECTIONS IN YEARS 2 TO 5 POST 2017 1080 OPERATION AND IN YEAR 1 AFTER THE 2022 1080 OPERATION

Kiwi have been regularly observed on eleven different lines and their detections have averaged at about seven per camera operation since September 2019. Numbers of detections have peaked in May 2022 and May 2023 with 15 and 14 pictures per operation, respectively. Late autumn is unsurprisingly the best time of the year to detect kiwi (as chicks from early clutches start dispersing and adults spend more time out and about foraging) and therefore holds potential to perform camera kiwi surveys.

Other bird detections worth mentioning are the Robin and Tomtit ones, which have been observed in good numbers throughout the 5-year camera trial. Detection rates per line fluctuated between 0 to 27% for Robins and 0 to 17% for Tomtits, before the May 2022 1080 drop (Table 4).

After the operation, Robin and Tomtit reached their highest mean detection rate respectively in February 2023 (53.3%) and May 2023 (22.8%) (Table 4).

Camera trap operations have shown real potential as an alternative/complementary survey tool for the above-mentioned bird species and also for most of the mammal species.

TABLE 4: ROBIN AND TOMTIT DETECTIONS ON CAMERAS

	Robins		Tomtits	
	mean % tracking per line	**% lines tracked**	**mean % tracking per line**	**% lines tracked**
Sept-18	8.3	41.7	9.4	41.7
Nov-Dec-18	10	26.7	1.7	6.7
Jan-Feb-19	**26.6**	**73.3**	3.3	13.3
Sept 19	9.6	33.3	1.9	6.7
Nov-Dec-19	8.3	26.7	0	0
Jan-20	6.5	13.3	0	0
Feb-Mar-20	**15.51**	**46.7**	1.7	6.7
Aug-Sep 20	5.1	13.3	1.7	6.7
Nov-20	0	0	0	0
Jan-21	**12.2**	**46.7**	9.4	26.7
Aug-21	7.2	26.7	5.5	20
Nov-21	12.8	33.3	3.3	13.3
Jan-Feb-22	**25.5**	**57.1**	8.3	28.6
May-22	22.7	73.3	**17.3**	**60**
July-22	6.25	25	4.9	16.7
Sept-22	4.2	16.7	13.2	50
Nov-22	22.2	50	2.1	8.3
Feb-23	**53.3**	**100**	12.5	33.3
May-23	30.5	75	**22.8**	**58.3**
Aug-23	18.7	50	2.1	8.3

1080

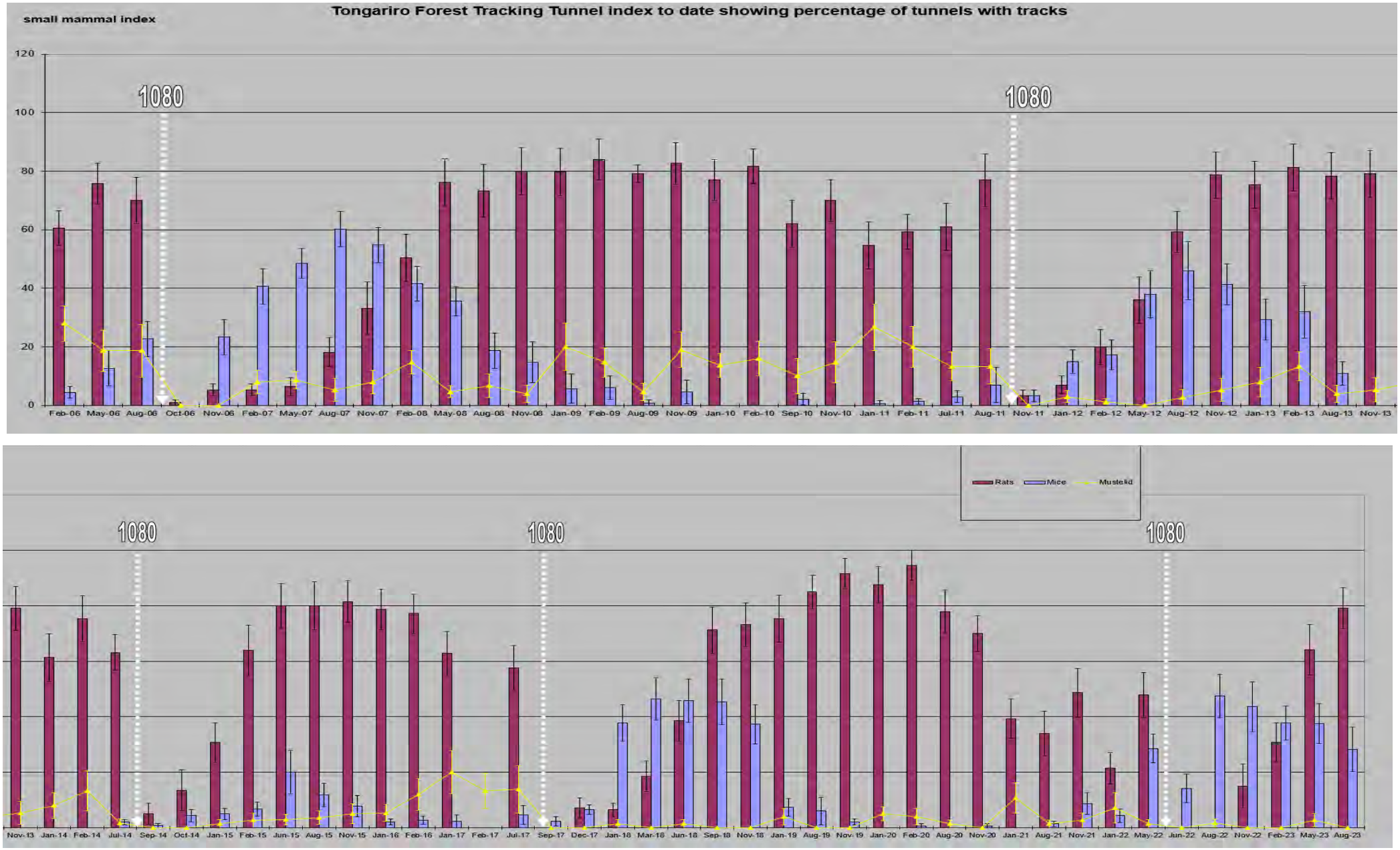

FIGURE 4: SMALL MAMMAL INDEXING RESULTS, TONGARIRO FOREST KIWI SANCTUARY, FEBRUARY 2006 – AUGUST 2023

ADULT/SUB-ADULT KIWI MONITORING AND NESTING

In this 2022/23 season, a total of 31 adult and sub-adult birds were tracked with radio transmitters, comprising 26 adults and five sub-adults. Of the 26 adults, 20 were male (Table 5). Twelve were known to nest this year, with 15 egg lifts undertaken. From the 27 eggs lifted, 21 chicks successfully hatched and were released into TFKS for the final chick monitoring study season (Table 6).

Two adult males died this season; Rocket was killed by a ferret in August 2022 (this is the second confirmed ferret predation since the permanent ferret regime was established in 2018) and Dani was found in the open in December 2022 but was too decomposed to determine cause of death. Dani was incubating his second clutch of eggs at the time of his death.

This season marked a significant milestone for the TFKS and the partnership among iwi with the release of 61 kiwi from Sanctuary Mountain Maungatautari (SMM). The first release occurred on 21/4/2023, with nine birds being gifted by Ngāti Koroki Kahukura back to Ngāti Hikairo ki Tongariro during a pōwhiri held at Otukou Marae, with both Minister Prime and the Deputy Director General in attendance. During 21/4/23–31/5/23, seven separate releases were performed on the east and west sides of the TFKS into areas away from or adjacent to known kiwi territories. On 25/5/23, two birds were deemed not fit for release (one had a weeping eye and the other an injured bill) and were transferred to Wildbase (Massey University, Palmerston North) for veterinary treatment. These were successfully rehabilitated and were released on 5/6/23. Of the 61 released, 46 were adults (22 females; 24 males), 11 were sub-adults (2 females; 7 males; 2 unknown), and four were juveniles (1 apparent female; 3 unknown).

Of these, three male and one female were fitted a transmitter for recruitment into the monitored population as two were caught as a pair (Poppy and Kath) and two others were male (Morty and Tangping) (Table 5). At this point, the pair has split apart as Kath has dispersed well away from her release site.

Further releases are planned for next season.

TABLE 5: MONITORED ADULTS AND SUB-ADULTS 2022/23

Adult males		Adult females	Sub-adults
Speedy	Harley	Pohonga	Dusty (Har7 ♂)
Dani†	Strike	Kasca (Co4)	Maya (Ku6 ♂)
Zazu	Jocko	Matata	Sunny (a.k.a. Yabba/Dn25♀)
Dino	Joe	Irirangi	Reverso (J2 ♀)
Pumpkin	Saros	Tapu	Kena (a.k.a. Chewbacca/Co7 ♀)
Rocket†	Rata	Kath*	
Koroki	Morty*		
Lego	Poppy*		
Thunderbird	Tangping*		
Kumara	Pumba (Zaz1)		

† *Died during the season*

**Translocated from SMM*

TABLE 6: NEST AND EGG OUTCOME SUMMARY

Male Kiwi (represents a breeding pair)	Confirmed nests	Total eggs lifted	chicks released to TFKS	Eggs not hatched/chick euthanised
Dani†	2	2	1	1
Dino	3	2	1	1
Harley	2	2	2	0
Jocko	3	6	4	2
Joe	2	2	4	0
Koroki	1	0	0	0
Kumara	2	2	2	0
Lego	0	0	0	0
Pumba	0	0	0	0
Pumpkin	1	1	1	0
Rata	unknown	0	0	0
Saros	2	1	1	1
Speedy	2	2	2	0
Strike	2	2	2	0
Thunderbird	2	3	3	0
Zazu	2	2	1	1
TOTAL	26	27	21	6

† Died during the season

KIWI CHICK MONITORING

This season marked the final time chick monitoring would be performed at TFKS as we gathered sufficient information on kiwi chick survivorship over the years. Chicks were monitored weekly (and monthly captured for health checks) from October 2022 onwards, within a year of the 27th of May 2022 aerial 1080 operation (2021/22 season). Twenty-one chicks were released at 16 to 29 days old (351–435 g). Of these, 11 were released on the western side and 10 were released on the eastern side. The first chick was released on 5/10/22 and the last chick was released on 15/3/23. Where possible, the birds were released back into their natal territories. In cases where this was not feasible, an appropriate release site was chosen randomly.

Kiwi chick outcomes and survival rates:

Of the 21 chicks being monitored this year, there have been a total of 10 recorded mortalities. The first chick being killed was on 11/11/22 and was one among the seven that were preyed upon by stoat during the summer period. Of the three others that died, two were a result of misadventure (one drowned and the other fell into a hole and could not escape) and one was from a confirmed dog attack on Christmas Day 2022. Of the remaining 11 chicks, two were lost due to failed transmitters and nine birds survived to six months of age (49 % survival, using the Kaplan-Meier survival model described in Robertson & Westbrooke 2005) (Figure 5). One juvenile from this chick monitoring season will be kept on transmitter to track its progress through the sub-adult stage. All other remaining surviving birds have had their transmitters removed.

Although we almost met the target for the May 2022 aerial 1080 operation, which was for kiwi chick survival to exceed 50 %, survival was still reasonably good compared with some previous years immediately following a 1080 operation. Ideally the 1080 operation would have been performed in August/September (just before chicks start hatching) as in previous operations, but the timing of the 2022 operation was determined by the District Health Board amidst a backlog of overdue 1080 operations scheduled for sites around the North Island. 1080 operations will return to a 3-yearly cycle (next one is therefore due in 2025). Whether this earlier timing significantly changed the beneficial impact that a 1080 operation usually has on the following breeding season is difficult to assess. However, given that the 2011/12 operation yielded similar results (Figure 5), the impact appears minimal.

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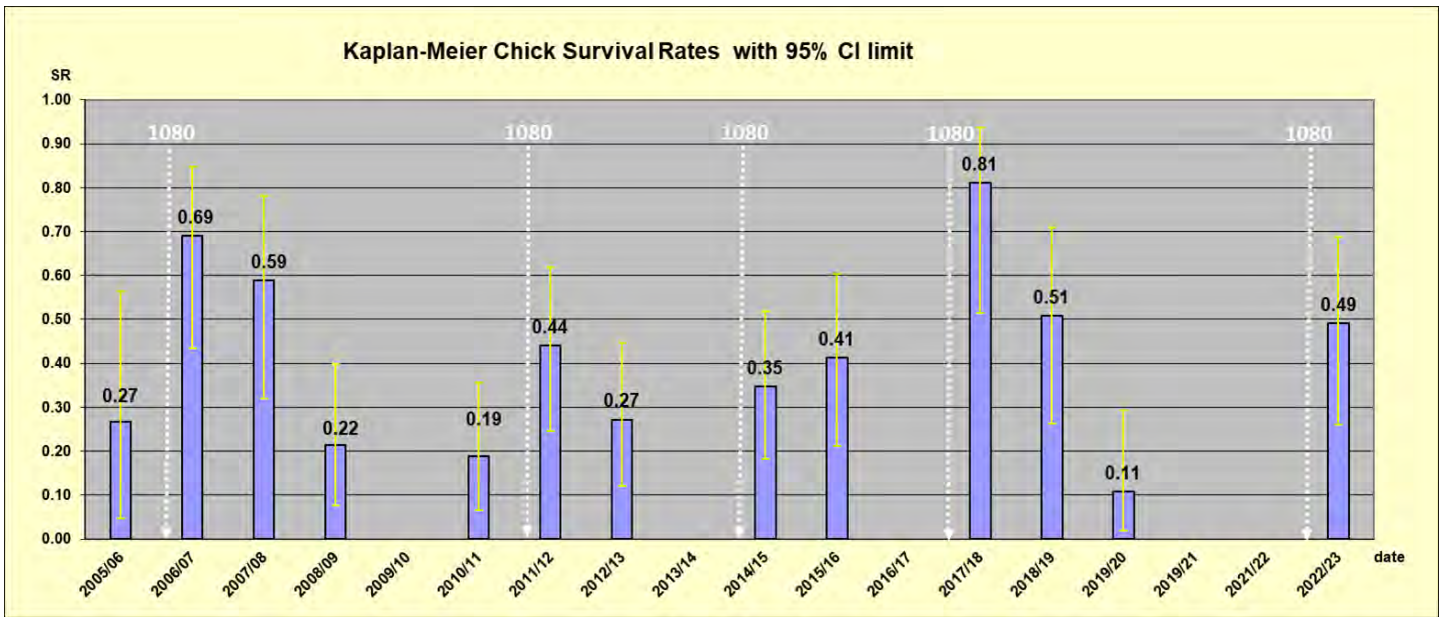

FIGURE 5: KAPLAN-MEIER KIWI CHICK SURVIVAL ESTIMATES FOR 13 BREEDING SEASONS, 2005-2023*

Over the years, there has been a marked difference between the eastern and western sides of Tongariro Forest, with the western side usually having a higher survival rate at the exception of two seasons directly following a 1080 drop. Western side chick survival rates have consistently reached at least 45% to 65% whereas the eastern side chick survival rates have fluctuated greatly between 0% and 100% (Figure 6). This could be due to the fact that kiwi habitat past Top Track on the western side are located deeper into the interior of the Tongariro Forest giving much more protection against mustelid re-invasion and colonisation as opposed to the eastern kiwi chick monitoring sites which are closer to farmland and more prone to mustelid re-establishment.

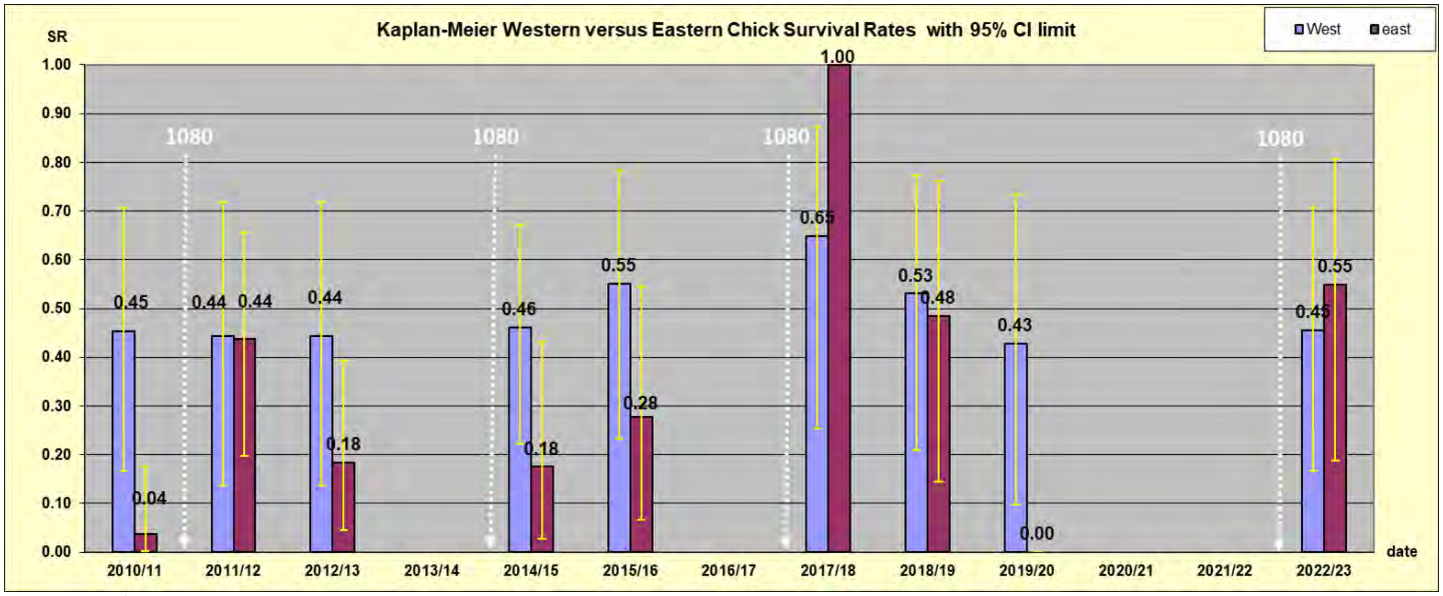

FIGURE 6: COMPARISON KAPLAN-MEIER KIWI CHICK SURVIVAL ESTIMATES BETWEEN EAST AND WEST OF TONGARIRO FOREST*

**Monitoring was not performed in 2009, 2013, 2016, 2020 and 2021. Error bars represent 95% confidence intervals.*

Some overall results:

Since 2005, kiwi chicks have been closely monitored during 13 breeding seasons and the cumulated data of mustelid predations (n=114) confirm that kiwi chicks are at their most vulnerable under 4 months of age (Figure 7), when less than 900g (Figure 8) and during December/January (Figure 9).

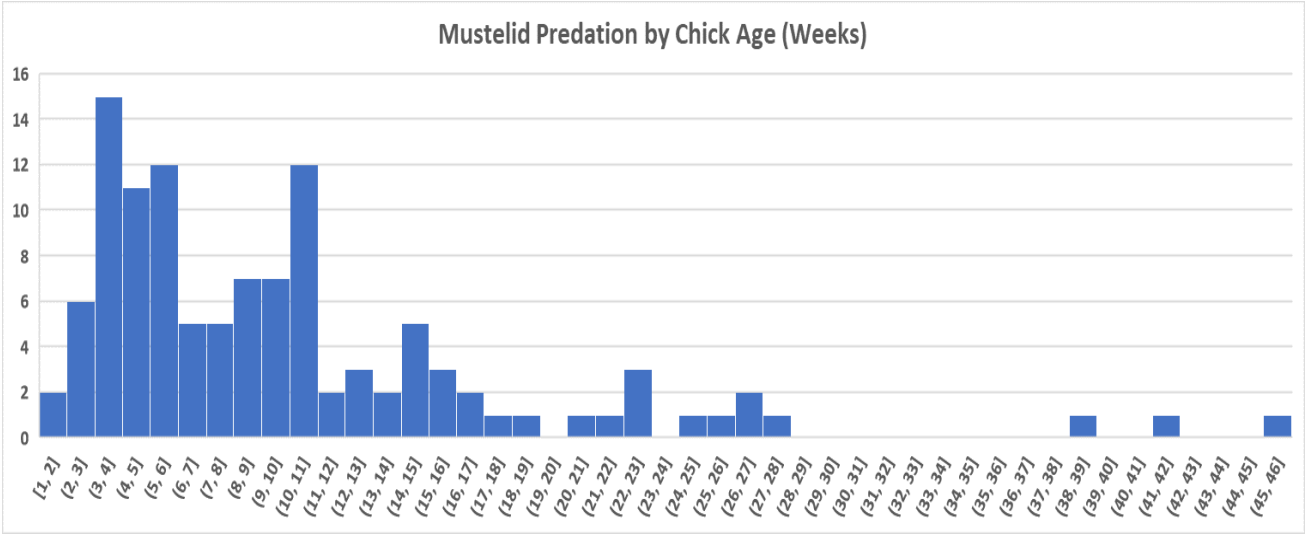

FIGURE 7: AGED CLASS OF CHICKS PREYED UPON BY MUSTELIDS FROM 2005 TO DATE

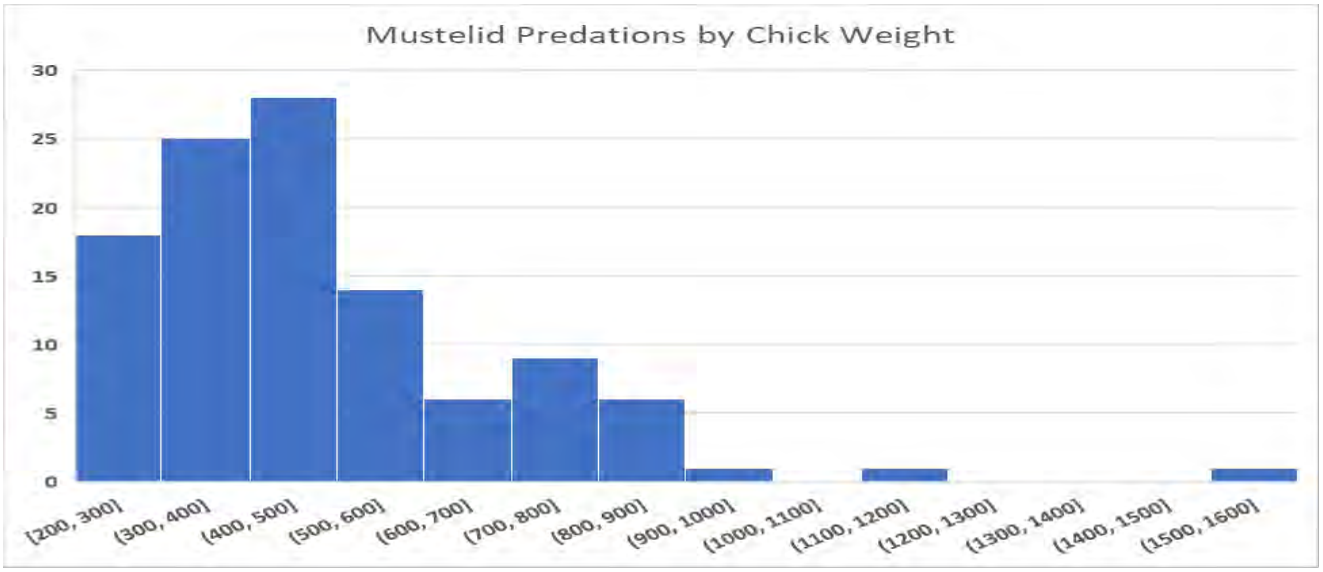

FIGURE 8: CHICK WEIGHT IN RELATION TO SUSCEPTIBILTY TO MUSTELID PREDATION

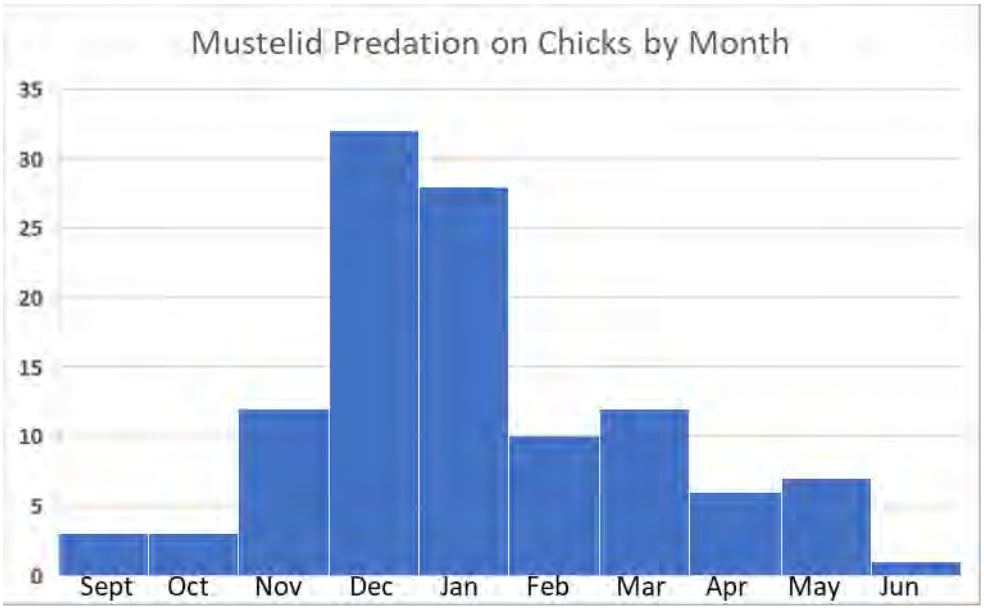

FIGURE 9: TIMING OF MUSTELID PREDATION

FERRET TRAPPING

The TFKS suffered significant losses of kiwi due to ferret incursions occurring in seven seasons out of eleven between 2008 and 2018. In total, at least 54 transmitted kiwi (of all ages and including both members of a single pair in the same burrow) were killed by ferrets over the last 15 years (Table 7). Due to the extremely high abundance of rabbits within private farmland surrounding the TFKS, there is constant pressure for ferrets to disperse and expand their range throughout the Forest (map in Appendix 3). Ferret predation on kiwi is thus intrinsically linked to their relative abundance, with peak periods of ferrets during the dispersal phase of young ferrets over autumn and the breeding season in spring (Figures 10 and 11).

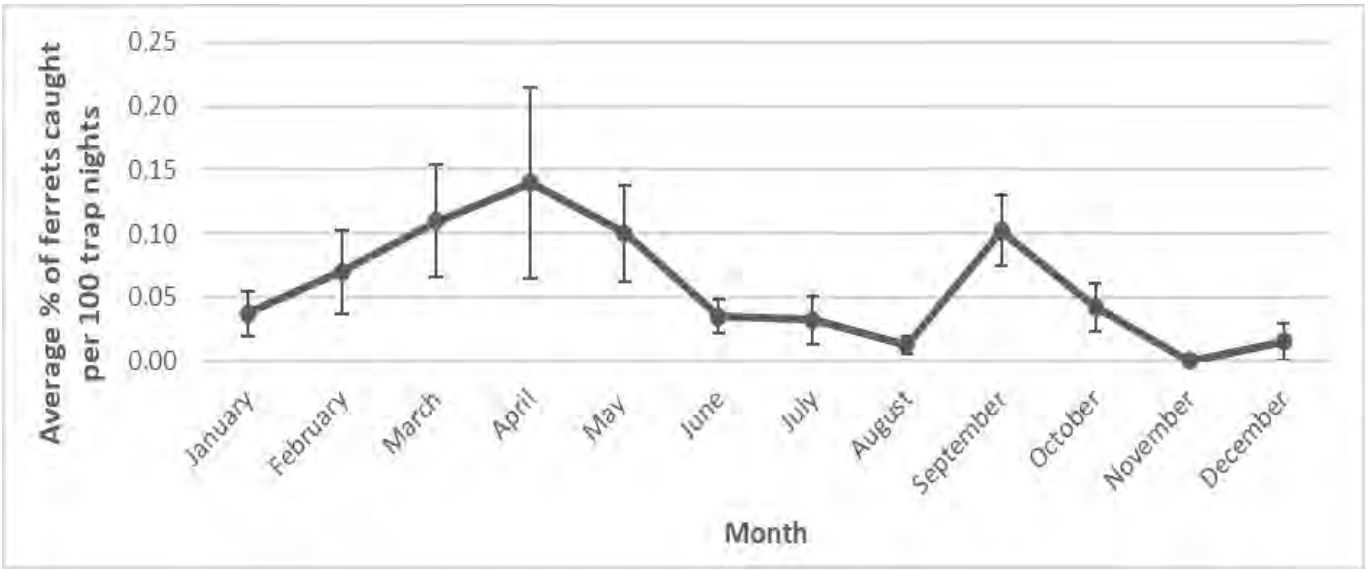

FIGURE 10: FERRET TRAP CAPTURE RATES (2018-2023, DOC 250 TRAP CAPTURE DATA ONLY)

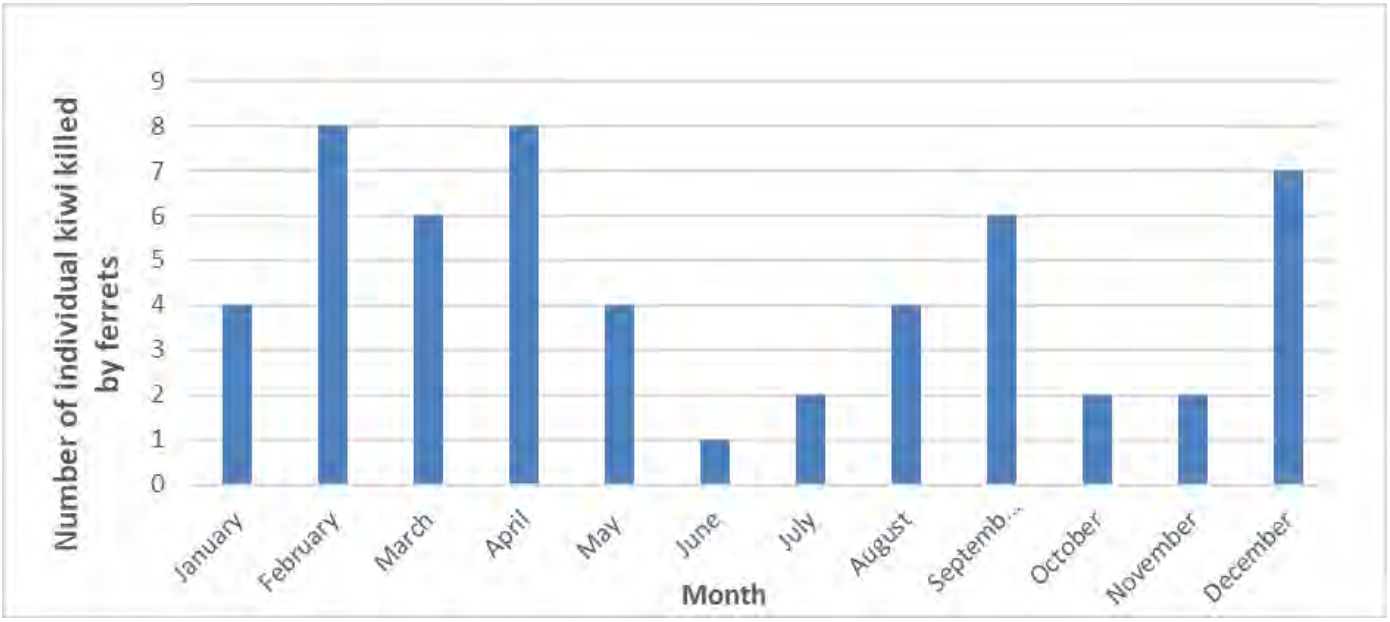

FIGURE 11: KIWI PREDATED BY MONTH OVER ENTIRE PROJECT

A combination of 3-yearly 1080 cycles and reactive trapping at ferret predation sites (using both kill and live cage traps) was ineffective in preventing further ferret incursions within the TFKS. A permanent trapping network comprising *ca.* 391 DOC 250 traps (map in Appendix 3) was therefore established in August 2018 by placing traps at preferred ferret habitats such as open landscapes on the surrounding farmland and boundaries of TFKS. Ferret dispersal pathways (directly linking the surrounding farms and exotic plantations to inside TFKS) and "hotspots" (the locations being determined based on previous kiwi kills, ferret sightings and ferrets captures) within TFKS were also necessary to trap. The main objective for trapping is to reduce the density of ferrets on bordering farmlands so that vacant territories outside the forest would remain available for young ferrets in search of new territories to fill, thus decreasing the likelihood of ferrets dispersing into the TFKS. Another important objective is to target ferrets that are already present within the forest by reinforcing the number of traps in known ferret "hotspots" and dispersal paths. The trap network is bordered by three major waterways (the Whakapapa and Whanganui Rivers, and the Mangatepopo Stream) which act as natural barriers to ferrets (they don't like swimming, unlike stoats) (map in Appendix 3). Traps are added and moved as needed (e.g. if a ferret was caught at a site, more traps would be shifted into that area if not enough traps were present) and are checked/rebaited at least monthly.

Outcome:

Twenty-one ferrets were caught this season (including four juveniles trapped in DOC200s as part of the whio protection project), which is essentially the same number caught last season (22 ferrets in 2021/22) (Figure 12, map in appendix 4). Two adult ferrets were caught in the Frost Flat on the eastern side of the TFKS in July 2022, both in the same trap (18 days apart between checks) (map in Appendix 4). This season's result brings the total number of ferrets caught to date (in both DOC200 and DOC250 traps) to 217 individuals since December 2016 (inside TFKS n=32, outside TFKS n=185) (map in Appendix 4)

Some ferret traps within Rotoaira and Taurewa forestry blocks (East border of TFKS) could not be checked since Cyclone Gabrielle hit in February. Rotoaira forestry traps regularly catch ferrets, but cyclone damage prevented us from accessing these areas. We are therefore unsure what state these traps are in.

As for last year, almost 50 % fewer ferrets were caught this season compared to the peak year 2020/21 (Figure 12)

In addition, 70 cats were caught in DOC250s this season, mainly on the farms north of TFKS.

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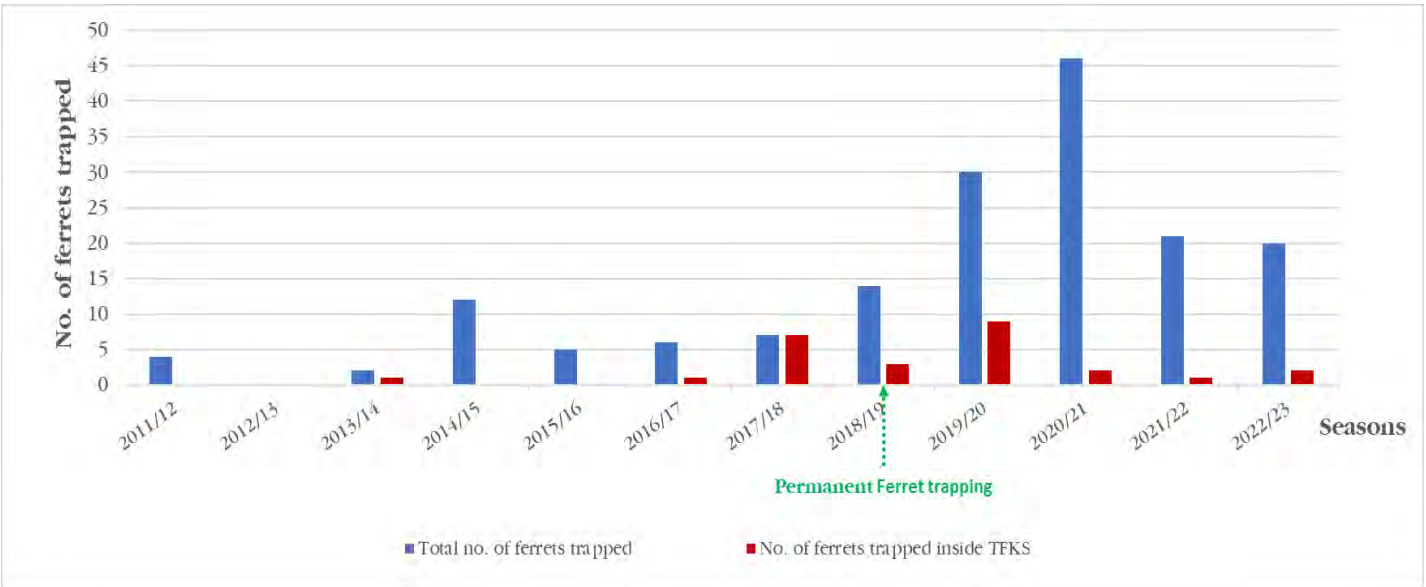


FIGURE 12: NUMBER OF FERRETS CAUGHT EACH SEASON IN DOC200 AND DOC250 TRAPS, INCLUDING THOSE INSIDE TFKS (EXCLUDING OWHANGO ALIVE CAPTURES)

Key findings:

Prior to 2017, ferret incursions have been episodic within the east Tongariro Forest (Taurewa ridge being the dividing line). Ferret-related mortality was virtuality zero during the first two years following a 1080 operation before predations commenced once again (Table 7). The eastern side has experienced five seasons of ferret incursions, with one or two ferrets each year responsible for at least 31 kiwi deaths over nearly a decade (Table 7 & map in appendix 5). In comparison, predations in the western side began during the 2016/17 season and continued again only seven months after the 2017 1080 operation. In the 2022/23 season, the single ferret predation occurred only three months after the 1080 operation (Table 7 & map in Appendix 5). This demonstrates that ferret incursions can occur at any stage of a 1080 operation. At least 21 ferret predations occurred on the western side over a three-year period, the peak of which occurred in 2017/18 (Table 7 & map in Appendix 5), when three or more ferrets were simultaneously roaming through the TFKS. Permanent trapping has had an immediate positive impact at reducing the number of roving ferrets within the sanctuary, preventing any further serial kiwi deaths to date (Table 7). Since September 2018, only two kiwi have been proven to be killed by ferrets, each at the end of winter (2021 and 2022) and in the same western side area of the of TFKS (Top Track).

At this time of the year, roaming ferret males are likely to enter the Sanctuary in search of females and Top Track, along with the Mako valley, seems to be an important ferret pathway. It has become clear that more trapping efforts should be concentrated in this area. Therefore, a dozen more DOC 250 traps were added and positioned in strategic places before and past the two kiwi death locations along Top Track. About ten other traps were added quite far down the start of Mariners track, linking the Northen farm to TFKS and ingressing thru to the Mako valley (map in Appendix 3).

At the time of writing, December 2023, three more ferrets were caught along the Mako valley and Top Track in October 2023, suggesting that ferrets have perhaps wintered in the sheltered and sunny Mako valley before dispersing during early spring. The trapping network has been proven to be efficient though as no kiwi were killed this time (bearing in mind though that ferret dispersions at this time of the year don't seem to initiate any mass killing events).

The population size of kiwi within the TFKS is estimated to be at least 230 birds in 2023 (not taking into account the releases from SMM that occurred this year as this hasn't been considered yet into the population modelling exercise), this is expected to double in less than a decade provided permanent trapping and 3-yearly 1080 operations are consistent (Appendix 1 - Table A1 & Figure A1).

Table 7: KIWI KILLED BY FERRETS THROUGH FIVE 1080 CYCLES WITHIN THE TFKS

		Kiwi killed by ferrets (n=54)	
1080 cycle	**Year in cycle**	**EAST**	**WEST**
2006	Year1	0	0
	Year2	1**	0
	Year3*	5	0
	Year4*	12	0
	Year5*	6**	0
2011	Year1	0	0
	Year2	0	0
	Year3*	3	0
2014	Year1	0	0
	Year2	0	0
	Year3*	4	6
2017	Year1*	0	11**
Aug 2018	Year2*	0	4
	Year3	0	0
	Year4	0	0
	Year5	0	1
2022	Year1	0	1

Start of permanent trapping network

**Years of ferret mass predation*

*** Numbers have changed slightly from previous reports following a review of ferret predations*

Key learnings so far:

- Increasing the size of the entrance hole in the DOC250 trap boxes (95 x 95mm) has been a key learning; ferrets are much more likely to go into a trap where they don't have to squeeze into the box (cats also). This is a deviation from best practice (80 x 80mm entrance size), and we accepted the increased risk of non-target catches as a result. However, after five years of trapping within the Sanctuary, no kiwi were accidentally caught in the traps, which demonstrates that the risk of kiwi by-catches is low at Tongariro and probably at any landscape-scale controlled areas.

- The traps must be well placed; our best catching traps have been placed on either side of bridges (which forces the ferret to travel through that spot), along water courses, on sections of forest tracks linking farms and TFKS, at fence line intersections situated at the bottom or top of a hill, along bluff edges, on tracks that funnel through steep edges, near hay barns and more generally, on farmland with high rabbit populations.

- The Owhango community, through "Owhango Alive", have been key in the fight against ferrets; the town borders one of the main entrances into Tongariro Forest. Their work and the intensive trapping on the surrounding farmlands have been key in stopping ferrets before they get into the forest.

- We use large pieces of fresh rabbit as bait, and the traps are checked and rebaited at least monthly, but generally more often as traps are cleared if we see something in them when we are travelling past. Fresh stoats (and rats to a lesser degree) have also proved to be extremely good bait for ferrets- we have had good success leaving freshly caught stoats in the traps (especially for trapping female ferrets). We also used fresh horse meat in the past and its good catching results seems to indicate that it could be beneficial to alternate the type of bait from time to time.

- Trap maintenance is important- keep the traps well maintained and cleaned (and ideally use stainless steel mesh)

- Moving traps in clusters to hot spots where ferrets were caught in the past is crucial as ferrets tend to follow paths used by conspecifics and as they can travel in family groups this would increase the chance of multiple simultaneous captures.

- Increase trap visits to clear hedgehogs out of the traps during the critical peak periods for ferrets (spring and autumn).

MINI CALL SURVEY USING CALL RECORDERS

For this season's four-day kiwi call survey (using the two hours recorded just after dark), data were used from the period between the 22dn and 26th of May 2023 (the first four fine nights). At the traditional sites used since the early 1990s ("Carcass Hill", "Douglas Fir", "Slip Way", and "Ponds"), the recorder at "Ponds" failed, despite working during a test run beforehand. The remaining three detected on average 4.5 calls per hour which confirms the steady increase in call rates since 2015, when the call rate was at its lowest (1 call per hour) (Table 8).

TABLE 8: COMPARISON BETWEEN CALL RECORDERS RESULTS AT THE 4 TRADITIONAL SITES

	2011	**2013**	**2014***	**2015**	**2017**	**2020****	**2021**	**2022**	**2023****
2h/night, 4 nights	1.15	1.27	1.92	1.03	2.31	2.5	3.63	4.28	**4.5**

**3 nights **3 sites*

Another four recorders were placed at sites used since 2013 (Table 9) and experienced as well one recording failure at the "Waione" site (it had too many internal interferences and data could not be used). The overall results from the eight eastern sites have also shown a steady increase in call rate since 2013, having reached a high of 4.7 calls per hour last season and a 4.5 calls per hour this season (Table 9).

TABLE 9: COMPARAISON BETWEEN CALL RECORDERS RESULTS AT EIGHT SITES USED SINCE 2013 (2H/NIGHT, 4 FINE NIGHTS*) ** except in 2014 when only 3 nights were used*

	2013 (48h listened)	**2014* (48h listened)**	**2015 (64h listened)**	**2021 (64h listened)**	**2022 (64h listened)**	**2023 (48h listened)**
Carcass hill*	15	14	14	34	45	51
Douglas fir*	7	12	4	18	12	31
Ponds*	7	19	8	6	32	*Didn't record*
Slip Way*	11	1	7	58	48	26
Opposite Canyon	2	0	14	38	49	45
Graffiti Bank	*Not surveyed*	19	27	47	48	33
Mamaku lookout	10	17	33	49	50	31
Waione	*Not surveyed*	7	9	21	16	*Didn't record*
TOTAL CALLS	**52**	**89**	**116**	**271**	**300**	**217**
CALLS/HOUR	**1.08**	**1.85**	**1.81**	**4.23**	**4.69**	**4.52**

Three other recorders were also placed at locations with historical data, though these sites were not part of repeated surveys ("Pukehinau", "Top of Andy's Track", "Frost Flats"). In addition, five recorders were placed out west in locations to be used for future surveys; these too did not form part of this season's survey but instead act as reference data for future surveys planned for the majority of the TFKS (approximately 31 sites; map in Appendix 6).

The analysis of the overall data since 1993 shows the number of kiwi calls detected have reached a historical record this season and have bounced back, since the season 2021/22, to numbers heard in the late 1990s when kiwi call rates were at their peak (Figure 13). The main difference though is that overall, kiwi range has shrunken dramatically in TFKS since the 1990s, particularly since the first ferret incursion occurred in 2009. Nonetheless, Given the release of 61 new birds this year and further planned supplementary releases from SMM in the future, along with the return to a 3-yearly 1080/permanent trapping regime, the number of kiwi within the core area should continue to increase and expand to vacated territories.

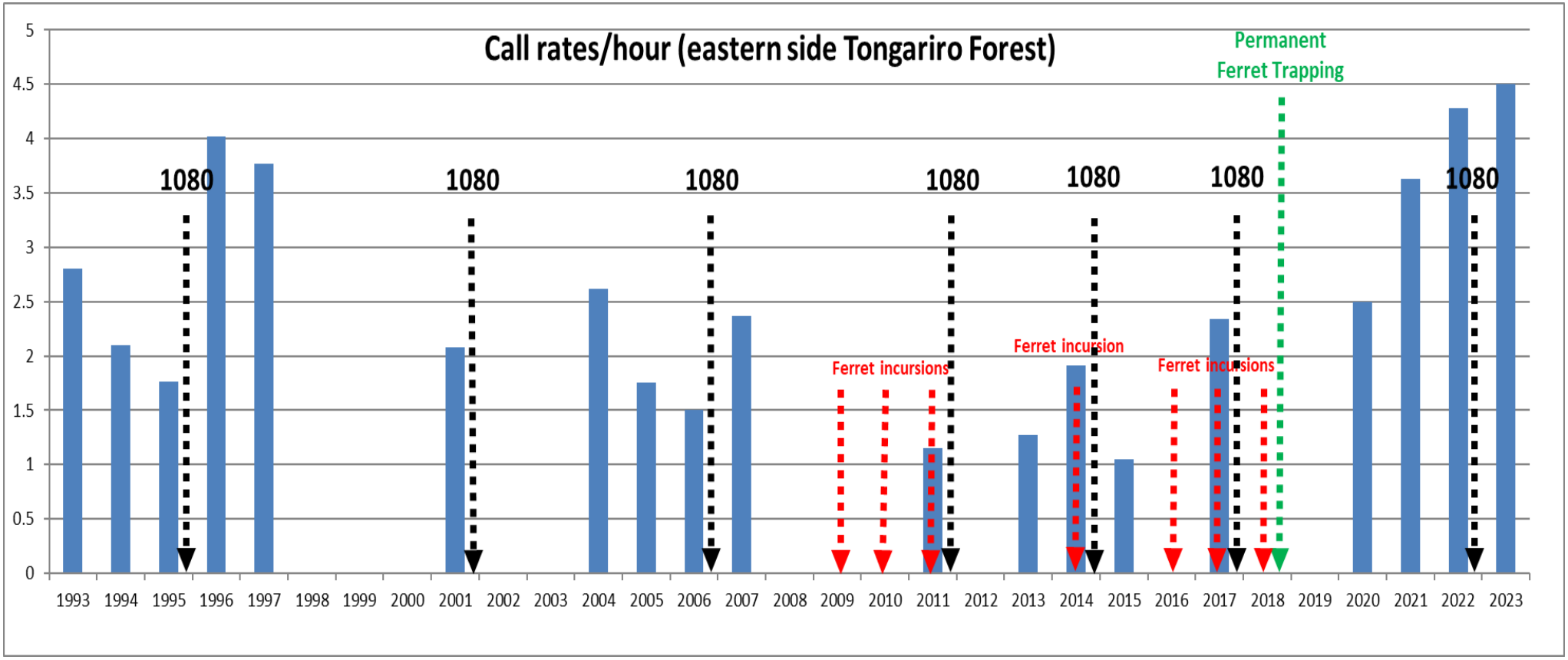


FIGURE 13: CALL RATES AND FERRET INCURSIONS SINCE 1993

FUTURE DIRECTIONS

The focus around ferret trapping and monitoring sentinel birds remains the priority. The current pest-control regime of 3-yearly 1080 and permanent ferret trapping will therefore continue in order to meet the target of the Kiwi Recovery Plan (Germano *et al.* 2018) of growing and maintaining kiwi populations by at least 2 % annually at a landscape level. Under the current regime, we expect population growth to exceed this goal by increasing 7 % annually within the TFKS (Appendix 1). This figure will likely be bolstered by the additional planned releases from SMM.

Over the next three years, however, the TFKS is entering its wind-down phase of intensive survival monitoring. Transmitters will be removed from most of the birds by 2026. Outcome monitoring will thereby transition to acoustic call surveys. These surveys are of course not as sensitive in detecting ferret incursions compared with radio-tracking birds, thus the next several years will focus on calibrating survival with call rates from these wider surveys. Rat and mustelid outcome monitoring will also continue, but with some adjustments under the protocol of the National Predator Control Program. SMI operations will be performed twice a year for rats and once a year for stoats (21 nights in February). The location of three of the tracking tunnel lines have been shifted outside the TFKS boundaries to match better the area covered by the future 1080 operations. Trail camera study performed by Craig Gillies ended in August 2023 and a new protocol will be implemented using one camera per line along nine out of the 12 remaining lines within TFKS.

It is also planned to perform camera runs along potential ferret dispersal corridors to assess whether we can correlate these detection indices with adult survival in the meantime and call rates for the long-term. Perhaps the most exciting next step however is our trial using electronic live-capture traps in ferret “hot spots”, which we intend to begin in the 2023/24 season – yet another tool to help the recovery of this significant kiwi population.

REFERENCES

Beath, A.M. 2018. Tongariro Forest longterm ferret trapping plan. DOCCM-5510459

Five-year plan for Tongariro Forest Kiwi Sanctuary 2021-2026. Unpublished report. Department of Conservation, Whakapapa kiwi team and Kiwi recovery group, DOCCM-6415890

Germano J, Barlow S, Castro I, Colbourne R, Cox M, Gillies C, Hackwell K, Harawira J, Impey M, Reuben A, Robertson H, Scrimgeour J, Sporle W, Yong S 2018. Kiwi recovery plan 2018–2028. Threatened species recovery plan 64. Wellington, Department of Conservation.

Gillies, C.; Williams, D. 2001. Using tracking tunnels to monitor rodents and other small mammals. Department of Conservation. Unpublished best practice protocol.

Gillies, C. 2018. Interim DOC trail camera guide v1.0.1: Using camera traps to monitor feral cats and mustelids. DOCCM- 5489451

Haigh, A.; Poutu N.; Sutton N. 2014. Rat, Possum and Stoat control in Tongariro Forest Kiwi Sanctuary 2014. Unpublished operational plan. Department of Conservation, Whakapapa. DOCDM-1334298

Kiwis for kiwi investment strategy. Target: 2%, Working with New Zealanders to Grow Kiwi Populations, 2017

Kiwi Sanctuaries Management Plan, 2015-2020. Unpublished report. Kiwi Recovery Group. DOCDM-1570100

McLennan, J. 2006. Western North Island brown kiwi (*Apteryx mantelli*): pathways to conservation and recovery. A technical report prepared for the Wanganui, Tongariro/Taupo and Waikato Conservancies of the Department of Conservation.

McLennan, J.A.; Potter, M.A; Robertson, H.A.; Wake, G.C.; Colbourne, R.; Dew, L.; Joyce, L.; Mccann, A.J.; Miles, J.; Miller, P.J.; Reid, J. 1996. Role of predation in the decline of kiwi, apteryx spp., in New Zealand. New Zealand Journal of Ecology 20 (1): 27-35

Robertson, H.A.; Guillotel, J. ; Lawson, T. ; Sutton, N. 2019. Landscape-scale applications of 1080 pesticide benefit North Island brown kiwi (*Apteryx mantelli*) and New Zealand fantail (*Rhipidura fuliginosa*) in Tongariro Forest, New Zealand. *Notornis 66* : 1-15.

Robertson, H.A. ; Colbourne, R.; McLennan, J. 2003. Kiwi Best Practice Manual.

Robertson, H.A.; Westbrooke, I.M. 2005: A practical guide to the management and analysis of survivorship data from radio-tracking studies. Department of Conservation Technical Series 31. Department of Conservation, Wellington. 47p.

Robertson, H. 2004. Research and monitoring plan for the kiwi sanctuaries. Science for Conservation 241. 24p.

Robertson, H.A.; Demonchy, P.J. 2012: Varied success from the landscape-scale management of kiwi *Apteryx* spp. in five sanctuaries in New Zealand.

Scrimgeour, J.; Germano, J.; Robertson, H.; Colbourne, R.; Sporle, W.; Beath, A.; Booth, A.; Livingstone, J.; Tawa, D.; Whitwell, L. National Kiwi Sanctuaries Management Plan 2015-2018. Unpublished report. Department of Conservation, Taupo. DOCDM-1570100.

Tongariro Forest Kiwi Sanctuary Operational Plan. July 2009-June 2014. Unpublished report. Department of Conservation, Whakapapa. DOCDM-207772

Tongariro Forest Kiwi Sanctuary Annual Reports 2015/16 and 2020/21.
Unpublished reports. Department of Conservation, Whakapapa. DOCDM-1472890,
DOCCM -2569795 and DOCCM–2824987.

APPENDICES

Appendix 1: POPULATION MODELLING

LESLIE MATRICES:

We used a population matrix model using data from different scenarios which were analysed in life tables (Leslie matrices) in PopTools (Microsoft Excel add-in) and translated into a population growth rate (Table A1).

Population modelling shows that the five-year 1080 cycle management (as this last run has essentially been a 5-year cycle) combined with an efficient ferret trapping regime has allowed the TFKS kiwi population to grow at about 5.3 % per year since 2019 (from now on though, under a 3-year regime, annual growth should be over 7%). It also shows that before 2006, when ferrets were absent and under five-year 1080 cycles, the population grew rapidly at about 5 % per year. On the contrary, during the period with multiple ferret incursions (2006-2019) the model confirms that the population declined dramatically under the five-year 1080 cycle at a rate of 10.5 % per annum (2006-2011) and continued to decrease, although at a much slower pace (- 0.94 % per year) after the switch to a three-yearly 1080 regime in 2011.

TABLE A1: LIFE HISTORY PARAMETERS AND POPULATION GROWTH RATES

scenarios	3 y. 1080 cycle with no ferret	3 y. 1080 cycle with ferret	5 y. 1080 cycle with no ferret	5 y. 1080 cycle with ferret	No management
Chick survival (0-1y. old)	0.316	0.297	0.236	0.222	0.109
Sub-adult survival (1-2y)	0.842	0.831	0.842	0.831	0.831
Sub-adult survival (2-3y)	0.909	0.917	0.909	0.917	0.917
Sub-adult survival (3-4y)	0.968	0.919	0.968	0.919	0.919
Annual adult survival	0.982	0.878	0.982	0.777	0.708
Life expectancy (years) (*based on adult survival only*)	**54.3**	**8.2**	**54.3**	**4.5**	**3.5**
Leslie Matrix, λ	1.071	0.991	1.053	0.895	0.781
Annual population growth	**7.1%**	**-0.94%**	**5.35%**	**-10.5%**	**-21.89%**

**Productivity of 0.52 chick per adult per year was also used in the matrices.*

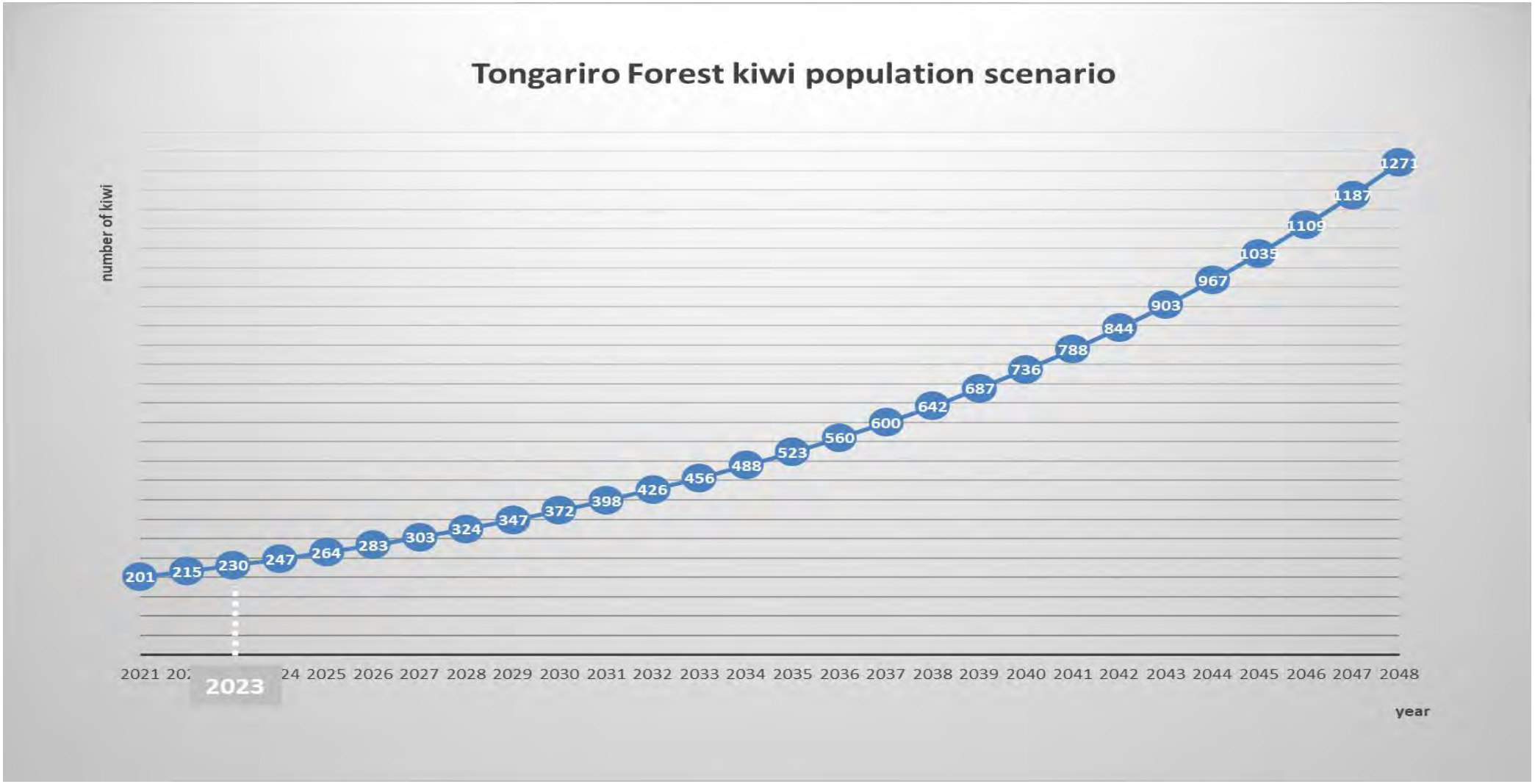
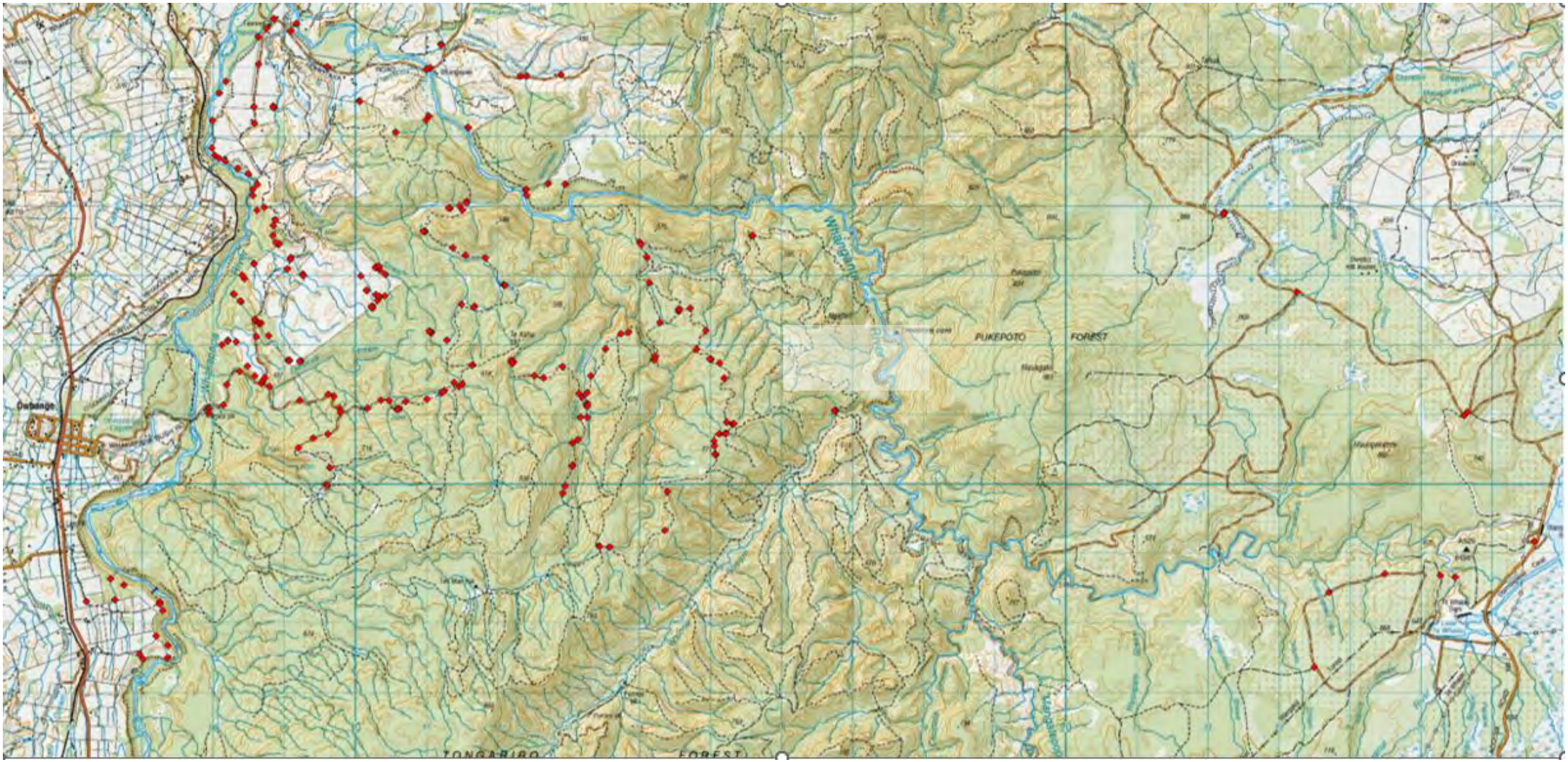


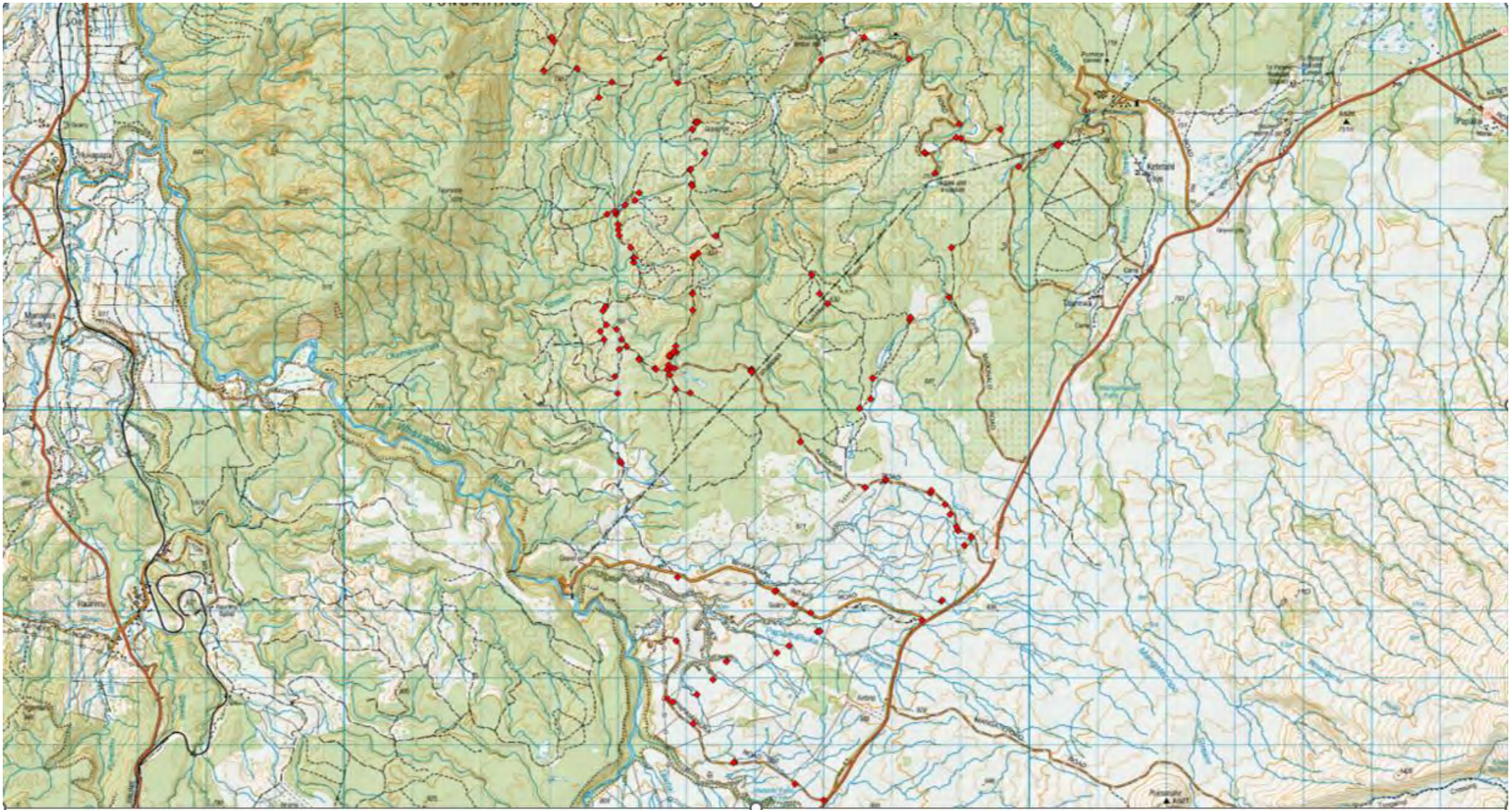
FIGURE A1: ESTIMATED KIWI POPULATION GROWTH AND COUNTS FOR THE NEXT 25 YEARS (*not taking into account regular releases from SMM*)

Appendix 2: DETECTED MUSTELIDS ON TRAIL CAMERAS SINCE THE START OF TRIAL

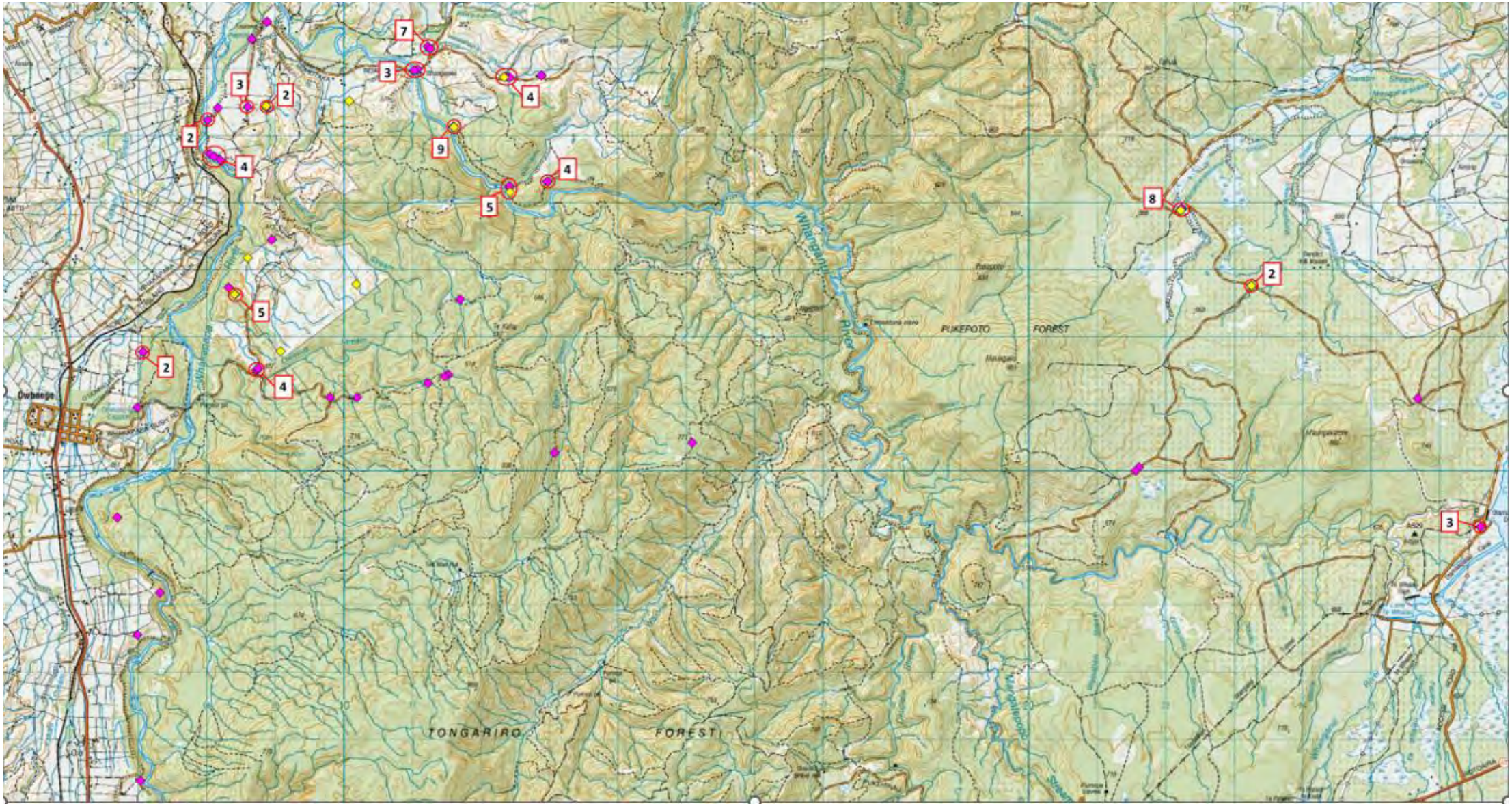
	Stoats		Weasels		Total mustelids	
	Number of detections	% cameras detecting Stoats	Number of detections	% cameras detecting Weasels	Number of detections	% cameras detecting mustelids
Sept-18	0	**0**	31	**16.4**	31	**16.4**
Nov-Dec-18	6	**3.6**	15	**7.3**	21	**10.1**
Feb 19	9	**7.3**	7	**7.3**	16	**14.6**
Sept-19	6	**5.8**	63	**5.8**	69	**9.6**
Nov-Dec-19	8	**12.5**	26	**18.8**	34	**29.2**
Jan-20	60	**39.2**	2	**4.3**	62	**43.5**
Feb-20	28	**27.6**	1	**1.7**	29	**27.6**
Aug-Sep-20	64	**40.7**	1	**1.7**	65	**40.7**
Nov-20	77	**37**	1	**1.8**	78	**37**
Jan-Feb 21	131	**43.6**	0	**0**	131	**43.6**
Aug-21	105	**50.9**	1	**1.7**	106	**50.9**
Nov-21	12	**16.4**	0	**0**	12	**16.4**
Jan-Feb-22	45	**26.8**	0	**0**	45	**26.8**
May-22	72	**19.6**	0	**0**	72	**19.6**
July-22	0	**0**	0	**0**	0	**0**
Sept-22	5	**5**	3	**3.6**	8	**9**
Nov-22	1	**1.8**	0	**0**	1	**1.8**
Feb-23	5	**9**	1	**1.8**	6	**9**
May-23	10	**13.8**	21	**22.4**	31	**29.3**

Appendix 3: DOC 250 FERRET TRAPS WITHIN TFKS AND THE SURROUNDING FARMS (*Owhango Alive traps not included*) ***WEST SIDE***

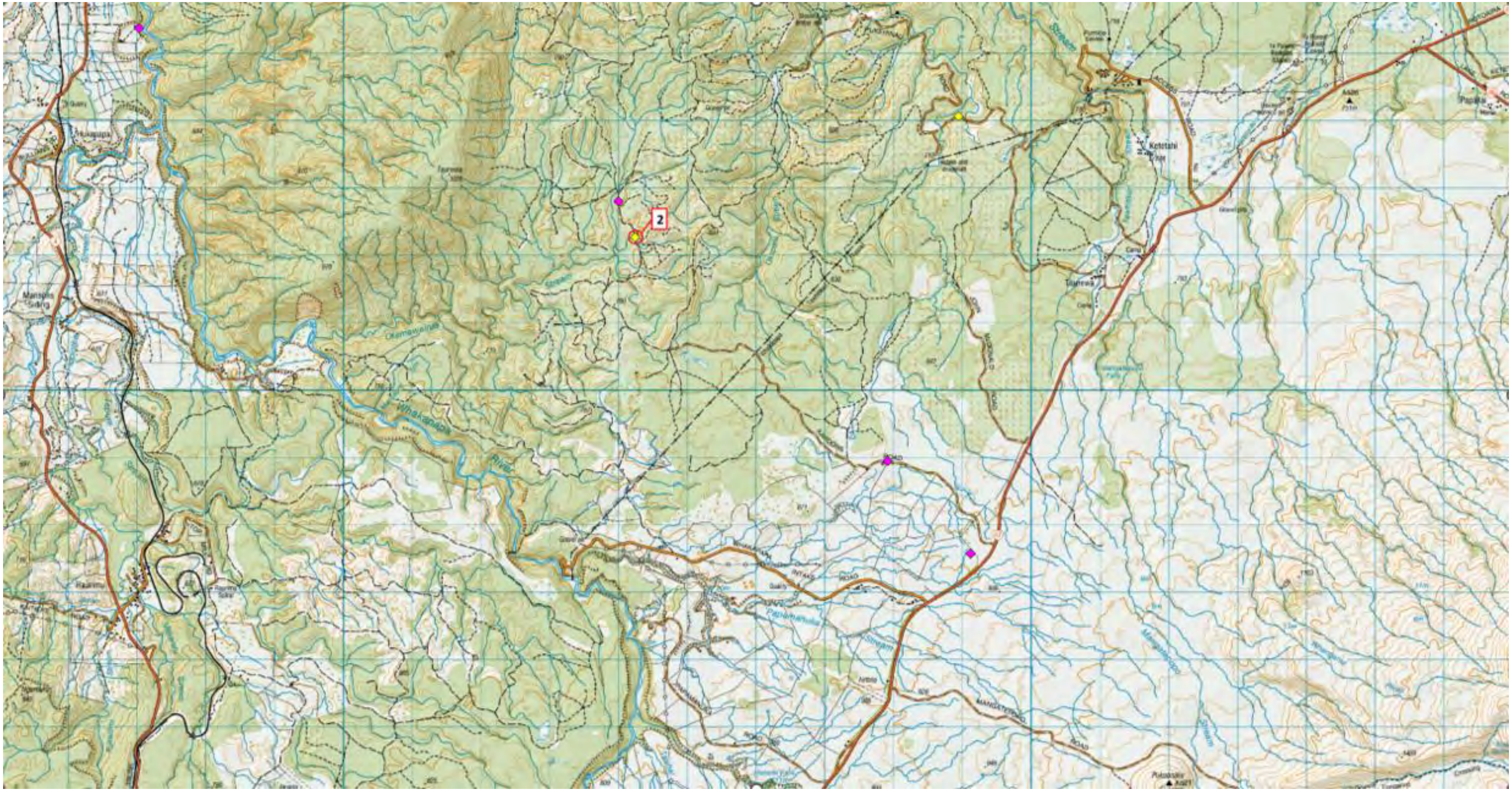




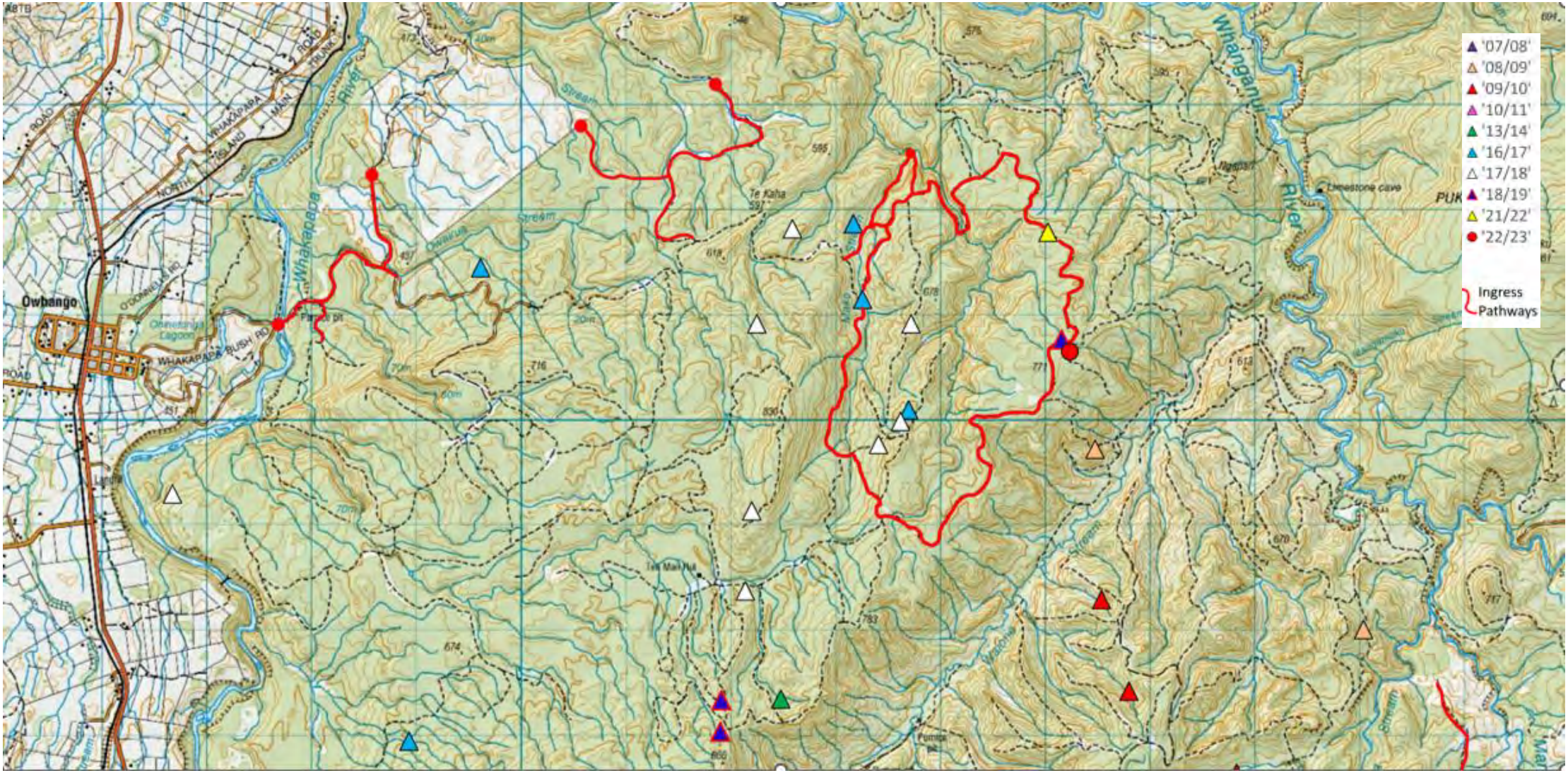
Appendix 4: FERRET CAPTURES IN DOC250 TRAPS AS OF JULY 2023, TFKS (*yellow dots represent captured ferrets during this 2022/23 season*) *WEST SIDE*



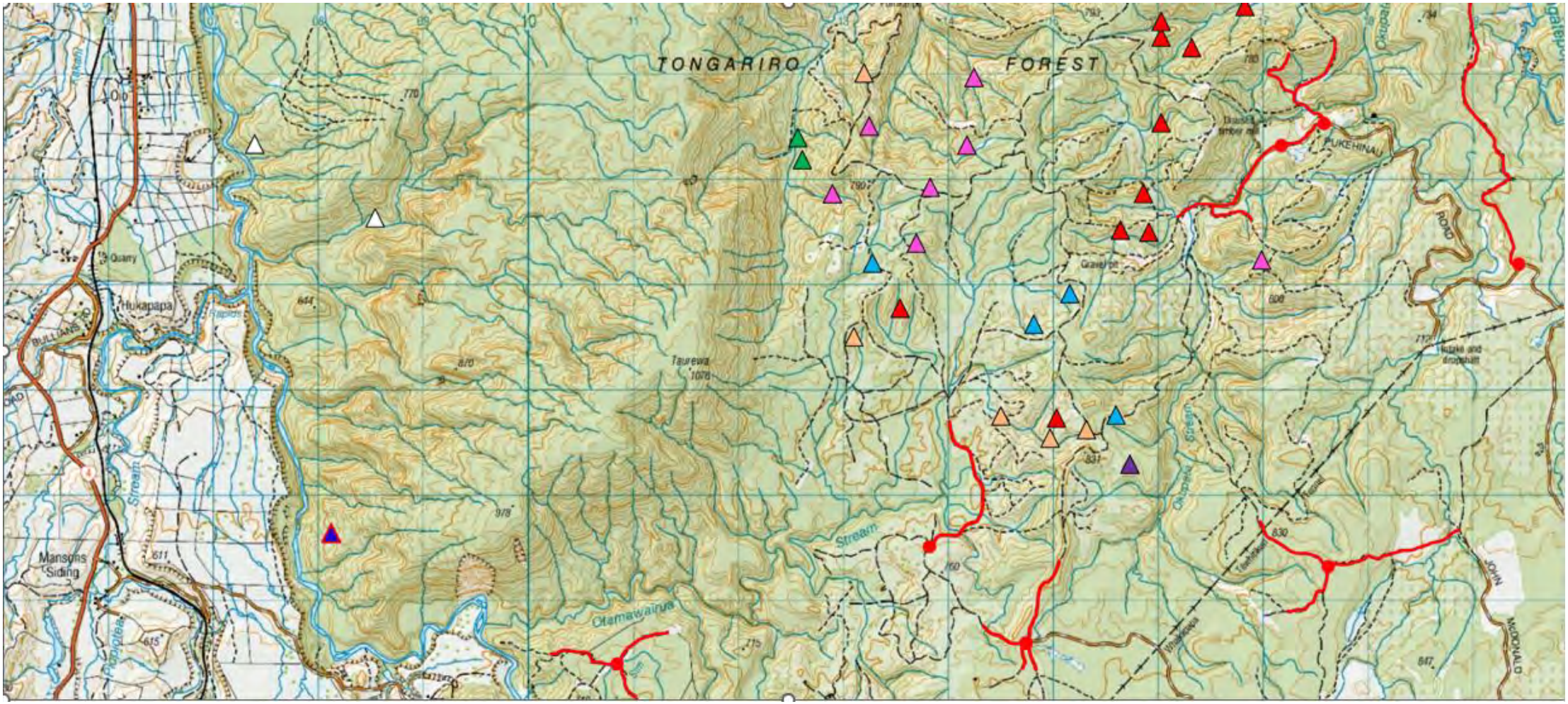
EAST SIDE



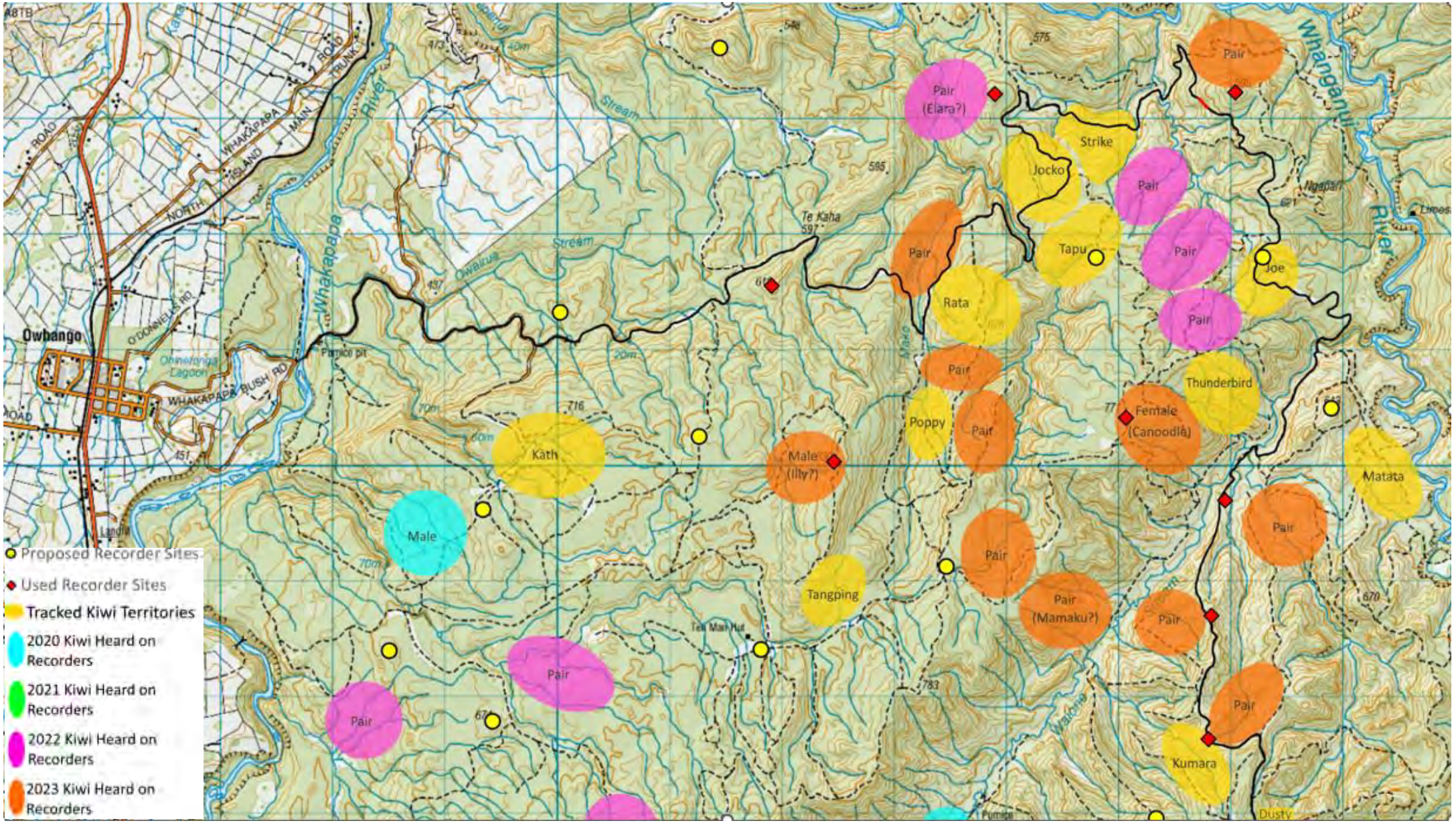
Appendix 5: LOCATIONS OF KIWI KILLED BY FERRETS OVER TIME, SEPARATED BY SEASON *WEST SIDE*



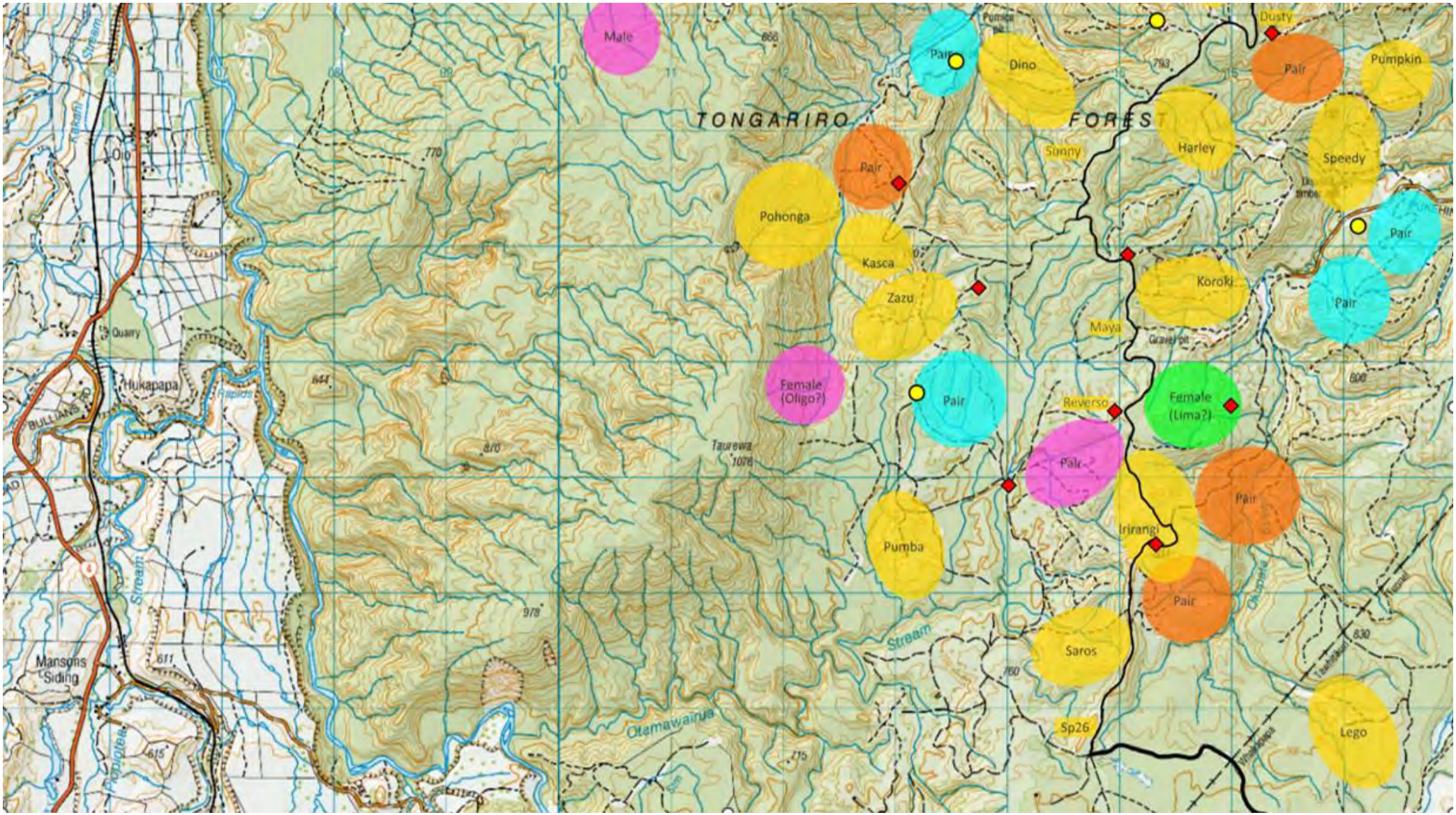
EAST SIDE


TONGARIRO
FOREST
PUKEHIKUA
ROAD
Quarry
Hukapapa
BULLIANS ROAD
Taurewa
1078
Stream
Mansons
Siding
Otamawairua
Stream
JOHN
McDONALD

Appendix 6: PROPOSED AND USED CALL RECORDER LOCATIONS WITHIN TFKS FOR THE KIWI CALL SURVEY *WEST SIDE*



EAST SIDE


Male
Pair
Dino
Dusty
Pair
Pumpkin
TONGARIRO
FOREST
Harley
Sonny
Speedy
Pair
Pohonga
Kasca
Zazu
Koroki
Pair
Maya
Female (Oligo?)
Pair
Reverso
Female (Lima?)
Pair
Pair
Irirangi
Pair
Pumba
Pair
Saros
Sp26
Lego
Quarry
Hukapapa
Mansons Siding
Taurewa
Otamawairua
Stream