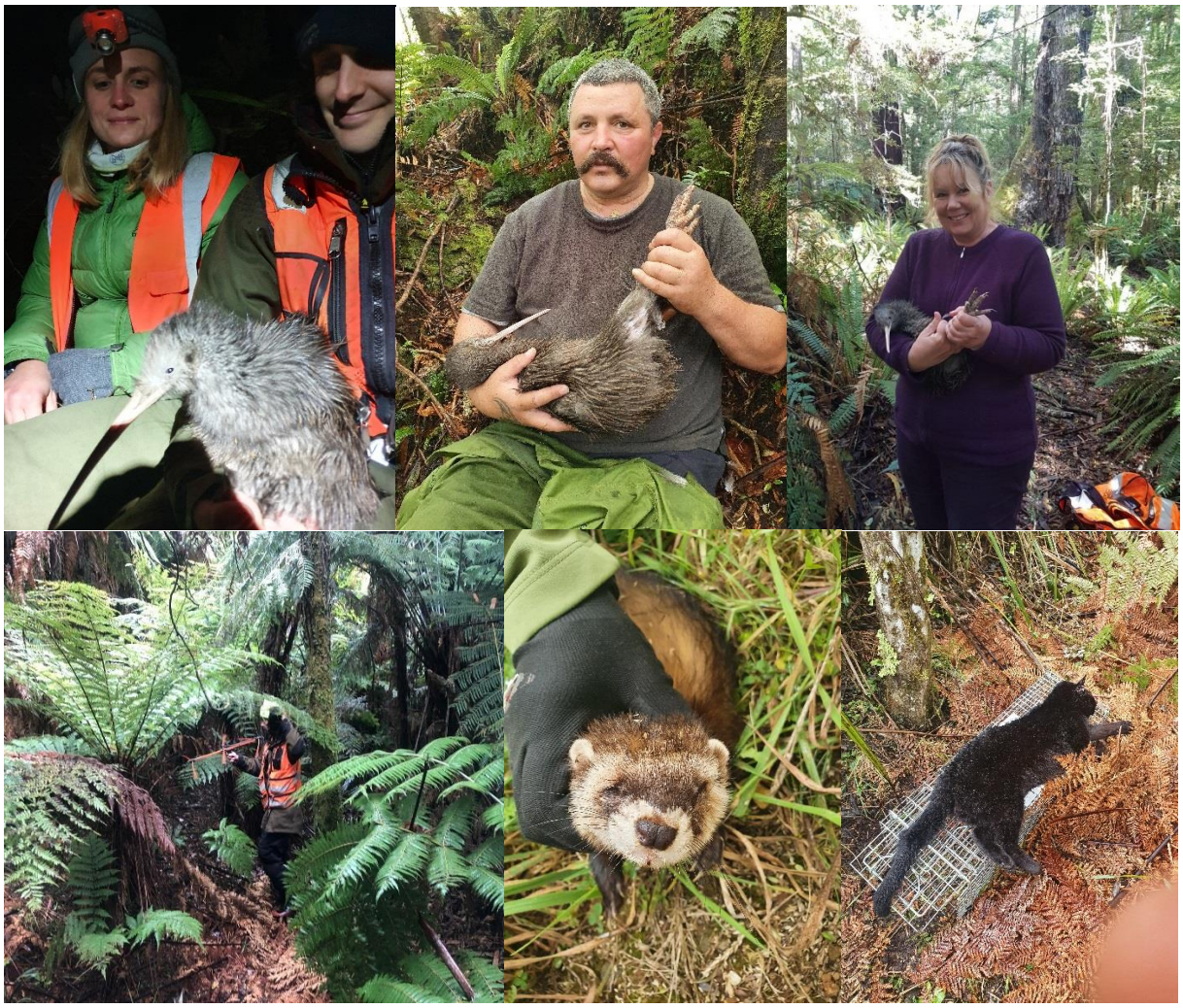
Department of Conservation
Te Papa Atawhai

TONGARIRO FOREST KIWI SANCTUARY ANNUAL REPORT

July 2020– June 2021

TONGARIRO DISTRICT OFFICE, CENTRAL NORTH ISLAND REGION



Ngati Hikairo ki Tongariro

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September 2021

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Cover photo: Clockwise from Top left: Recreation Ranger Katie Snowden and Kiwi Ranger Luke Easton holding a newly caught wild kiwi female at night, "Kasca" relaxing in the good hands of Whio Ranger Mathew Howell, Luke's mum volunteering for a day experiencing a magic moment with a wild kiwi, Kiwi ranger Jerome Guillotel in action trying to quietly pin point the location of a kiwi, a ferret freshly caught in one of the 490 DOC250 traps scattered around the Tongariro Forest, and one of the numerous cats roaming the forest caught in a live trap.

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/**

PARTNERSHIPS

Partnerships between the Department of Conservation and Ngati Hikairo, The National Kiwi Hatchery Aotearoa (at Rainbow Springs), Sanctuary Mountain Maungatautari, Project Tongariro, Wairakei Golf + Sanctuary, and 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). It was not planned to undergo ONE this season (2020/21), except for two eggs that were taken to Kiwi Encounter, which resulted in one chick hatching successfully. This chick was released later in the season at safe weight (1,200 g).

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.

PROJECT TONGARIRO

Project Tongariro are involved in ecological projects throughout Tongariro National Park and surrounding areas. Their volunteers assist the TFKS team regularly with work such as transporting kiwi eggs and chicks to and from the National Kiwi Hatchery Aotearoa and carrying out other advocacy work.

SANCTUARY MOUNTAIN MAUNGATAURI (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 (DOC) and Ngati Hikairo made an agreement with Ngati Koroki-Kahukura to contribute 20 founders to the kiwi population at SMM. This target was met last year with a total of 21 gifted kiwi. In return, since 2010 14 offspring of some of the original founders have been released into TFKS. Sanctuary Mountain Maungatautari re-strategized their kiwi programme in 2017, when a five-year widescale ONE programme was launched by the national charity trust “Kiwis for kiwi” (K4K) 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. To stock SMM with additional founders, which is a Kōhanga site for Western brown kiwi, the aim was to catch and put transmitters on at least 100 male kiwi in the Tongariro, Taranaki and Whanganui areas. However, after initially capturing 12 birds at Tongariro during the first two seasons of the K4K kōhanga programme, Ngati Hikairo indicated in 2019 that they would not support any further transfers of kiwi from TFKS to SMM over and above the original 20 founder agreement. No new birds were therefore caught during the last two seasons (2019/20 and 2020/21) at Tongariro. The programme nevertheless continued in other areas so that by June 2021, 239 chicks were released within SMM, bringing the total of known SMM founders to 328 individuals.

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. Thirteen kiwi, have been released at TFKS since 2012, mainly from the Otorohanga Kiwi House. Two of these kiwi were translocated from Willowbank Wildlife Reserve at Christchurch. This season, a pair from Otorohanga Kiwi House was released at the bottom of “Top Track” next to a monitored pair.

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 pest free environment which can be used to benefit threatened plants and animals. The sanctuary is utilized as a kiwi crèche when undertaking ONE. A sub-adult from last season was held within the safe enclosure until spring 2020 and a chick from this season grew to safe weight before being released back into Tongariro in autumn 2021.

OWHANGO ALIVE

Owhango Alive is an association driven by the local community aiming at protecting the Ohinetonga 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. Last season, 17 ferrets (55 since July 2018) were captured in Ohinetonga reserve and nearby farms, mainly in autumn and early winter. 60 feral cats were also captured.

NEW ZEALAND FOREST MANAGER (NZFM)

Extensive plantation forests are situated south and east of TFKS and are managed by New Zealand Forest Manager Limited. NZFM allowed us access to develop a crucial network of DOC250 traps on their managed forests bordering the TFKS and this reduces the risk of ferret invasion from the NZFM side.

EXECUTIVE SUMMARY

Tongariro Forest Kiwi Sanctuary (TFKS, at 19,840 ha) was established in 2000 for the development and testing of kiwi protection techniques, namely the use of Operation Nest Egg™ (ONE) and aerial 1080 operations. Up to 2010, TFKS aimed to achieve and maintain a representative sample of 200+ pairs of Western North Island brown kiwi by 2017, involve community, and enhance public awareness (Tongariro Forest Kiwi Sanctuary Operational Plan, 2009). However, between 2009 and 2017, multiple ferret predation events occurred within the Sanctuary and greatly compromised the integrity of the TFKS kiwi population. It became clear that no target could be achieved unless ferrets were controlled efficiently. A permanent ferret trapping regime was therefore implemented at the end of winter 2018. Since then, no ferret predations on kiwi have been recorded.

A key research focus of TFKS is to assess the effectiveness of cyclic landscape-scale aerial 1080 operations on kiwi chick survival and long-term population growth. Initial research results showed that in the presence of ferrets, a sole five-year cycle 1080 regime appeared to be insufficient to prevent the TFKS kiwi population from declining (see the Population Modelling section of this report). The programme thus shifted to a three-yearly 1080 cycle from August 2011, aimed at achieving an annual growth rate of 4 % (TFKS annual report 2015/16), taking in account the ferret predation events that appeared to occur in year three after 1080. However, after the August 2017 1080 operation, ferrets re-invaded the west side of the Tongariro Forest within seven months and killed 11 kiwi. This predation event showed that ferret incursions could 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 permanent ferret trapping network, in addition to 1080 operations, became essential and was implemented in the season 2018/19. This management regime would allow the kiwi population to increase by about 7 % annually (see the Population Modelling section of this report).

Twenty-two adult kiwi males were monitored in TFKS in 2020/21 (18 breeding males). Nests were not monitored this year, only live signals were obtained to measure survivorship and in preparation for next year's nesting season.

Eight sub-adults were also monitored this season for recruitment into the tagged breeding population. This monitoring also provides information about the distribution of kiwi within the Tongariro Forest and their survivorship. All monitored sub-adults survived the season.

Small mammal indexing (SMI) continues to be measured using tracking tunnels in TFKS. After the initial rat knock down (0 % tracking rate) following the 1080 operation in August 2017, rat tracking rate reached pre-1080 levels in September 2018 (70 %), 13 months after the operation.

This caused mice to decline dramatically from over 40 % tracking rate at its peak, to 7 % in January 2019 and 0 % since January 2020 when rat tracking reached its highest ever (95 %). Mustelid (weasel, stoat and ferret) footprints have been low since the 2017 1080 operation, with tracking only reaching 11 % in January 2021. On the contrary, the more sensitive trail camera traps deployed along the tracking tunnel lines since September 2018 have detected mustelids on many more lines than tracking tunnels (67 % of the lines compared to 36 % with tracking cards in January 2021). These results confirm that tracking tunnels have been inadequate for measuring mustelid indices during the last four post-1080 years.

Kiwi call surveys are also ongoing and 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 after the 2014 and 2017 1080 operations. On average, 3.6 calls per hour were heard on the eastern side, which is the highest count since the early 2000's.

INTRODUCTION

Tongariro Forest Kiwi Sanctuary (TFKS), which is approximately 20,000 ha (Figure 1), was established in 2000 for the protection and recovery of the Western brown kiwi taxon (*Apteryx mantelli*) within the central North Island. It is one of five sanctuaries set up nationwide 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 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, 2014 and August 2017. 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 "Battle For Our Birds" [BFOB]/Tiakina Nga Manu) that the recommended sowing rate for the 2017 1080 operation would be 1.5kg per ha with even broadcast sowing (Appendix 1). For the next 1080 operation, which has been postponed to September 2021, the sowing rate and method of application should remain the same.

Another key objective is 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 needs to be 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.

This report presents results from these key areas of work for the 2020/21 financial year.

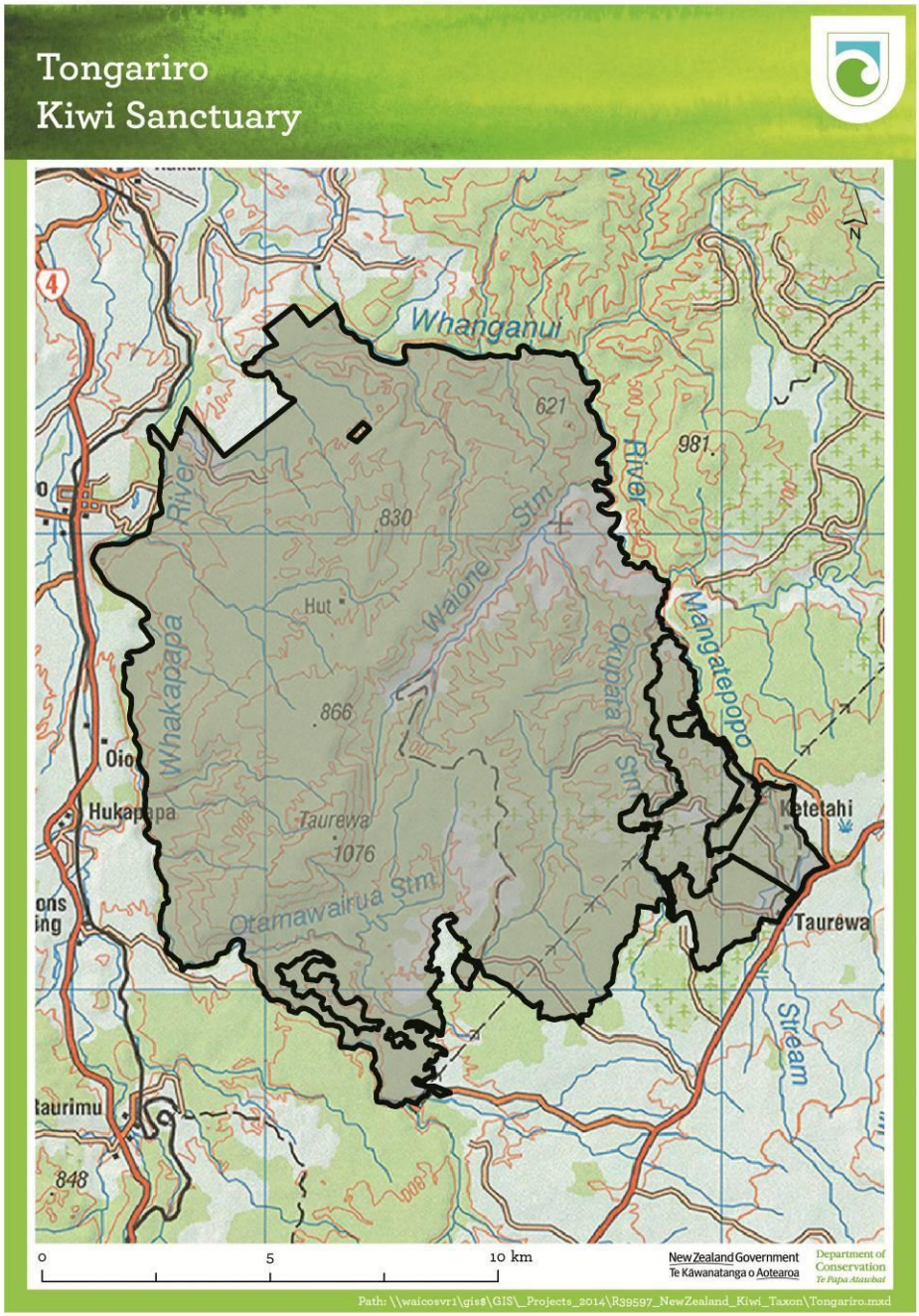

FIGURE 1: MAP OF THE TONGARIRO FOREST KIWI SANCTUARY, CENTRAL NORTH ISLAND

SANCTUARY OBJECTIVES AND ACTIONS

Five-year plan for Tongariro Forest Kiwi Sasnctuary 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 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
Predator Control and ONE			
1.1	Test the efficacy of protecting kiwi from ferrets by trapping dispersal pathways and hotspots	TFKS	Essential
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
1.3	Implement aerial 1080 every 3 years to supplement trapping.	Tiakina Nga Manu	Essential
1.4	Confirm with Tiakina Nga Manu certainty around aerial 1080 for the next two rounds	TFKS	High
1.5	Undertake ONE in non-treatment years only if capacity and resources allow	TFKS	Low
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
1.7	Seek opportunities to improve signage highlighting rules about dogs in the sanctuary, and provide aversion training opportunities	TFKS	Low
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
1.9	Support the camera trap trial as an index of mustelid abundance by maintaining the tracking tunnels and analysing camera footage until 2023	TFKS	High
1.10	Monitor chick survival in 2021/22 as a comparison against the camera index and to keep informing population models	TFKS	High
1.11	Undertake territory mapping/call counts as an additional outcome measure	TFKS	Medium
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
Capacity and resourcing			

1.13	Use the wider Biodiversity and Recreation teams to support trapping and tracking tunnels	TFKS	Essential
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

Sharing knowledge

#	Actions	Accountability	Priority
2.1	Complete and publish the study on sub-adult survival, dispersal, territoriality and breeding age by 2025.	TFKS	High
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
2.3	At least one presentation at the annual kiwi hui AND western brown kiwi hui within the lifetime of this plan	TFKS	High
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
2.5	Respond to re-active requests for advice depending on capacity at the time	TFKS	Medium

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. TFKS is entering its 21st year 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, FOURTH SEASON AFTER THE AUGUST 2017 AERIAL 1080 OPERATION USING 1.5 KG/ HECTARE OF PELLETS

The post-1080 season immediately after the August 2017 operation was a great success in terms of rat control as for the first time, rats were knocked down to a 0 % tracking rate. This allowed mice to increase rapidly with tracking rates well above 40 % until September 2018, when rats reached pre-1080 levels (about 13 months after the 1080 operation), which caused the mice population to decline. Since January 2020 mouse tracking has been extremely low and at times were undetected. Rat tracking rate reached its highest ever peak (95 %) last summer and then reduced to just under 40 % in January 2021; its lowest at this stage of a 1080 experiment since the commencement of the monitoring in 2001 (Figure 3).

Mustelids were also well suppressed immediately after the 1080 operation and their tracking rate has remained very low since. It has risen to a mere 5 % in February 2020 and to about 11 % in January 2021, well under the usual 13-20 % reached during the third and fourth post-1080 summer (Figure 3).

The trail camera trial has nonetheless shown that the mustelid abundance within TFKS was very high (Figure 2, Table 3), which was verified by the 2019-20 kiwi chick monitoring. The reason why tracking tunnels appear to not detect any increase of mustelid presence during this 1080 cycle as per past 1080 operations is unknown. High interference from the high number of rats could have been the explanation last year but this is no longer valid for this season.

Camera trap lines:

The TFKS is the only site in the North Island where camera traps are trialled to monitor relative abundances of feral cats and mustelids (with 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 consisting of 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 (the latter seemed to be more abundant in the winter/spring period at first but now appears to have almost disappeared following the increase in stoat numbers) (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).

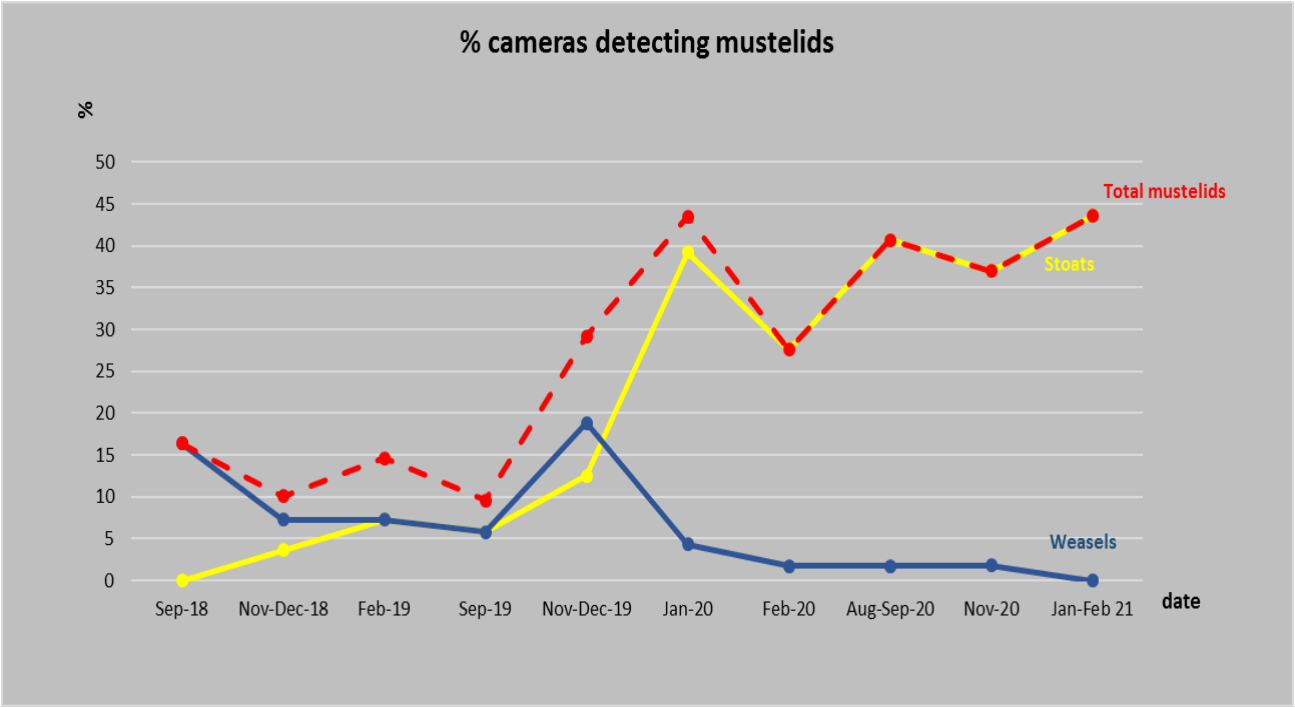

FIGURE 2: PERCENTAGE OF CAMERAS DETECTING MUSTELIDS

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

**10 nights*

If cameras are left for more than 21 nights (usually left between four to eight weeks), they may be a useful supplementary tool to detect the presence of kiwi, which have been observed in eight out of ten camera trials performed so far. When cameras were run between January and March 2021, kiwi were detected on nine different cameras across six separate tracking tunnel lines. Other animals such as: rats, cats, dogs, red deer, goats, pigs, possums, rabbits, tomtits, robins, fernbirds, moreporks, riflemen, silvereyes and introduced birds were also detected. The number of robin and tomtit detections have increased again this year, being detected in 46.7 % and 26.7 %, of the lines in January 2021 respectively, probably benefiting from the rat tracking rates plummeting to 39.3 % this summer from its highest peak of 95 % in January 2020 (Figure 3, Table 4).

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

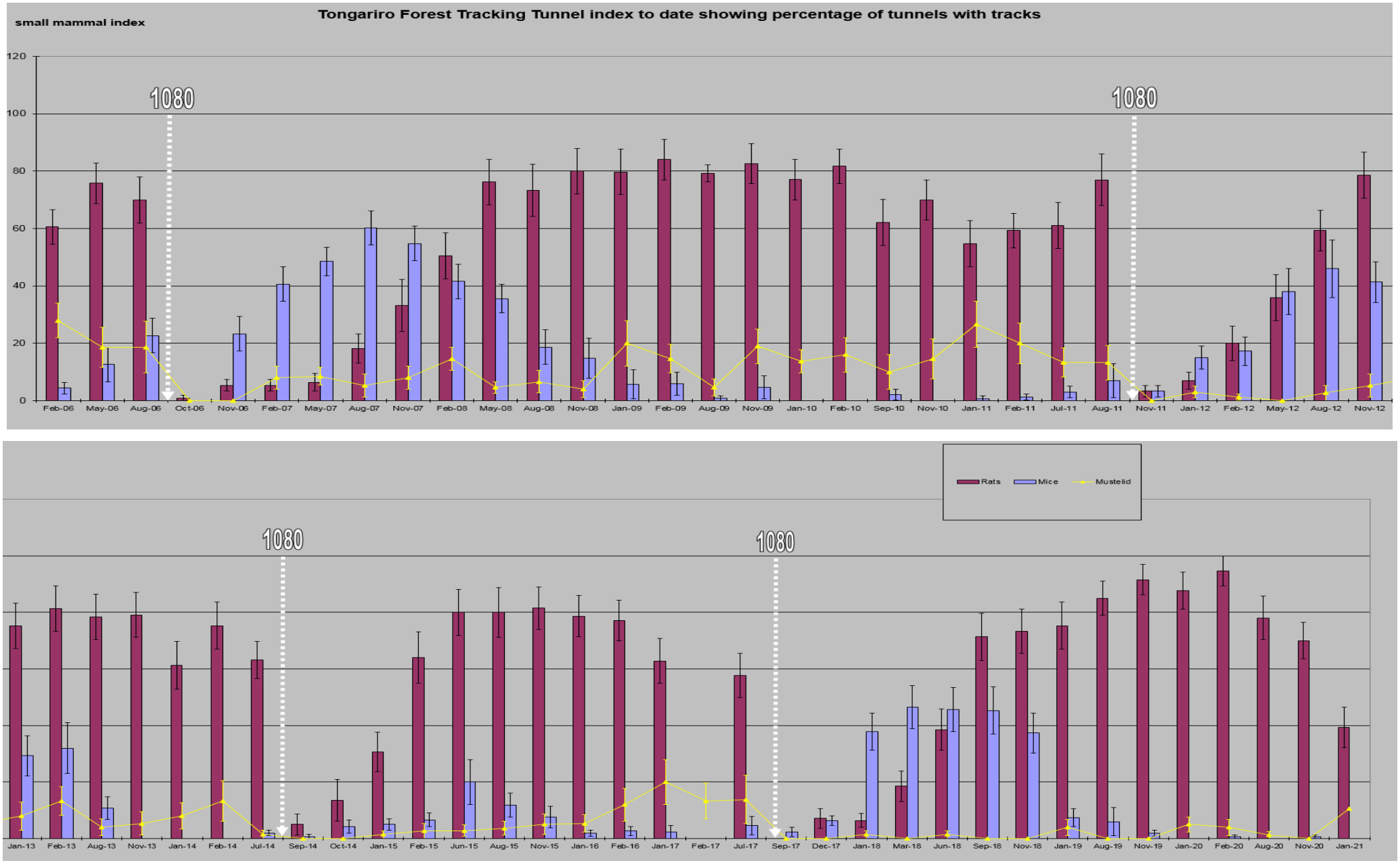

FIGURE 3: SMALL MAMMAL INDEXING RESULTS, TONGARIRO FOREST KIWI SANCTUARY, FEBRUARY 2006 – JANUARY 2021

ADULT/SUB-ADULT KIWI MONITORING AND NESTING

In this 2020/21 season a total of 38 adult and sub-adult birds were tracked with radio transmitters, comprising of 30 adults and 8 sub-adults.

Of the 30 adults, 22 were male (Table 5). Eighteen males nested this year, but it was decided not to monitor nests and lift eggs due to reduction of funding and the departure of an experienced staff member (the position was filled later in the season).

This season, one breeding male was found dead in a deep, inaccessible hole under a podocarp tree. The cause of death could thus not be confirmed so this mortality was recorded as a "misadventure". Two other breeding males dropped their transmitters (Table 5).
In an attempt to offset the loss of those three breeding males, kiwi night captures were undertaken in May 2021. Despite our efforts and determination, this resulted in the capture of no males but two females. One of the females was identified as Spike, who is paired with Zazu. We nearly captured a male that was with Spike that night, thus we assumed this to be Zazu. It was then that we realised that the size of kiwi pair territories is potentially larger than previously thought (80 ha compared to 40 ha). Either that or this pair had been pushed out by another pair from their original territory in the adjacent area.

During the last three seasons, there has been no confirmed predation from ferrets which corresponds with the start of the implementation of the permanent ferret trapping regime towards the end of the winter 2018 (Tongariro Forest Long-term Ferret Trapping Plan, Beath 2018).

TABLE 5: MONITORED ADULTS AND SUB-ADULTS 2020/21

Adult males		Adult females	Sub-adults
Speedy	Thunderbird	Pohonga	Elara ♀
Hiver	Marohirohi**	Oligo	Emmet (Har2 ♂)
Zazu	Kumara	Georgie	Pumba (Zaz1 ♂)
Dino	Harley	Irirangi	Lima (Ltm10 ♂)
Dani	Strike	Tapu	Kasca (Co4 ♀)
Rocket	Jocko	Eclipse	Dusty (Har7)
Comet	Joe	Spike	Jk04
Pumpkin		Matata	Yabba (Dn25)
Little Moa**	Ruwhenua		
Koroki	Ipo		
Matariki*	Saros		
Lego			

**Died during the season*

*** Dropped transmitter, failed transmitter or transmitter removed*

SUB-ADULT DISPERSAL AND SETTLEMENT (USING AN INDIVIDUAL-BASED BEHAVIOURAL SHIFT MODEL)

We assessed all sub-adult location data in order to compare dispersal and settling patterns between females and males, and between ONE and wild-hatched birds. As previously reported (see, for example, the 2008/09 Annual Report), female kiwi disperse further than males, with monitored females travelling (based on straight line distances) an average of *ca.* 18 km (irrespective of origin), compared to *ca.* 15 km and 11 km for males (ONE and wild, respectively), by the time they reach 3.5 years of age (Figure 4). Females and males begin dispersing at a similar age at around 1 year old, although 75 % of wild males (n = 19) dispersed before 1 year of age compared to 50 % for wild females (n = 16) (Figure 5). In the 2008/09 Annual Report, about 65 % of birds were recorded to begin dispersing between 4–8 months of age. Wild sub-adults tend to disperse by the following breeding season as their parents become aggressive and drive them out of their natal territory. Sub-adults derived from ONE undergo dispersal slightly later (at around 1.3 years old) than wild sub-adults as they are released when they are older at safe weight (Figure 4, Table 6).

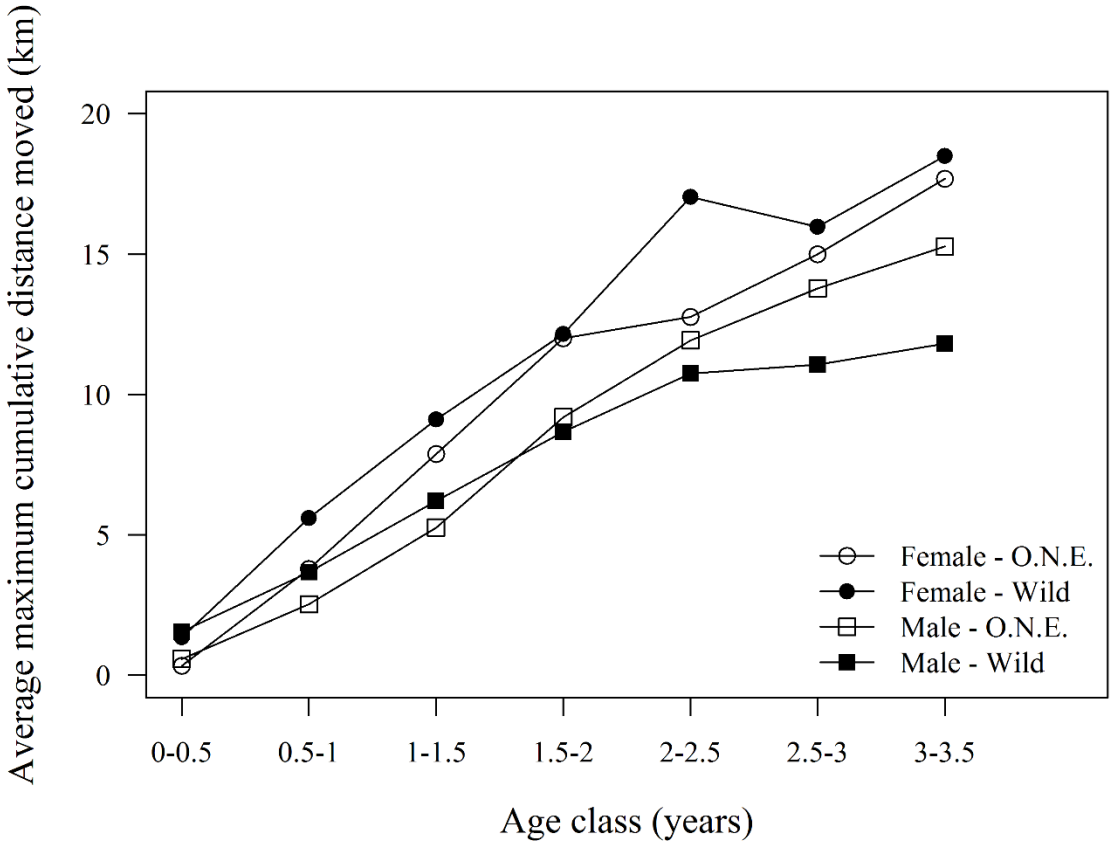

FIGURE 4: AVERAGE MAXIMUM DISTANCE MOVED OVER TIME FOR SUB-ADULTS (N = 111)

There were no major differences in the settling age for birds – individuals generally settled by around 2 years old. Approximately 80 % of wild females (n = 5) and males (n = 17) settled by the

time they were 2 years old. Again, ONE birds were slightly older when settled than wild-caught birds because of the timing of their releases (Table 6).

TABLE 6: AGE AT DISPERSAL AND SETTLEMENT

Group	Age at dispersal (years)	Age at settlement (years)
Female – O.N.E.	*N* = **21**	*N* = **14**
	Average (95% CI) = **1.4 (1.1–1.7)**	Average (95% CI) = **2 (1.6–2.4)**
	Range = **0.8–2.7**	Range = **1–3.2**
Female – Wild	*N* = **16**	*N* = **5**
	Average (95% CI) = **1.2 (0.8–1.6)**	Average (95% CI) = **1.6 (1–2.2)**
	Range = **0.3–2.3**	Range = **0.9–2.1**
Male – O.N.E.	*N* = **24**	*N* = **16**
	Average (95% CI) = **1.3 (1–1.6)**	Average (95% CI) = **1.9 (1.5–2.3)**
	Range = **0.7–3.5**	Range = **0.9–3.5**
Male – Wild	*N* = **19**	*N* = **17**
	Average (95% CI) = **0.9 (0.6–1.2)**	Average (95% CI) = **1.6 (1.2–2)**
	Range = **0.3–1.9**	Range = **0.8–3.5**

OUTCOME OF THE IMPLEMENTATION OF A LONG-TERM FERRET TRAPPING REGIME

During 2016-17 season, an unprecedented build up in the ferret population on surrounding farmland caused an increasing number of ferrets to disperse and expand their range further and further into TFKS. The invasion of ferrets inside TFKS resulted in 23 radio-tagged kiwi (17 adults) being preyed upon during that time. Therefore, the combination of a 3-yearly 1080 cycle and a reactive trapping approach in response to these predation events was ineffective to prevent ferret expansion within the TFKS. It appeared that a permanent trapping network was more adequate to protect adult kiwi on a large scale, which is achievable within Tongariro Forest as the area is bordered by major rivers that act as natural barriers to ferrets (ferrets don't like swimming). To achieve this ground-breaking, landscape-scale ferret trapping operation with limited resources, trap locations needed to be strategically selected to target preferred ferret habitat such as open landscapes on surrounding farmland and boundaries of TFKS. Ferret dispersal pathways (directly linking the surrounding farms to the forest) and "hotspots" within TFKS were also identified as a priority to trap. The main objective is to reduce the density of ferrets on bordering farmlands so that vacant territories outside the forest would be available again for young ferrets in search of new territories to fill. This approach would considerably decrease pressure on the TFKS boundaries and should reduce, in the medium-term, ferret dispersal into the forest. The other important objective is to target ferrets that are already present within the forest by reinforcing the number of traps in known ferret "hotspots" (the locations being determined based on previous kiwi kills, ferret sightings and ferrets captures). The camera traps (trail cams) that have been used on existing

tracking tunnel lines since August 2018, could be a useful additional tool for detecting ferrets (although none were detected so far).

Based on this, the proposed permanent ferret management regime was decided during winter 2018 and about 280 DOC 250s were deployed by October 2018. Traps have been added and moved as needed (i.e. if a ferret was caught at a site, more traps would be shifted into that area if not enough traps were present) and more traps have been set up on surrounding farmlands, particularly those adjacent to the northern margin of the forest. The trapping on farmland directly south of the forest has also been increased considerably as it provides an ideal ferret dispersal route that funnels into TFKS without encountering any major natural obstacles. DOC250s were also set up on the Hillary Outdoor Pursuit Centre side of the forest (east of the Mangatepopo river) as it was identified as another possible source from which ferrets can disperse (over the last 10 years, around twenty ferrets have been caught in DOC200 traps used in that area for whio protection) through river fords and the main SH47. To date, around 490 DOC 250s have been set up and are checked at least once a month.

Outcome:

After four 1080 cycles during which ferret predation events occurred, a difference appeared in the frequency and extent of ferret incursions between the western and the eastern side of the forest (Taurewa ridge being the dividing line). Ferret incursions seem to be episodic in the east whereas predations in the west occurred severely for the first time during the 2016/17 season and again during the following season, seven months after the last 2017 1080 operation. Ferret predations showed no sign of decline until a permanent trapping network was implemented in 2018. Rapidly, the traps had a positive impact and reduced the number of roving ferrets within the sanctuary, preventing any further kiwi deaths since October 2018 (and for the first time any deaths from ferrets in year three and four after a 1080 operation) (Table 7). No ferrets were captured in the known hotspots this season, suggesting that it might be the first season with no presence of resident ferrets within the TFKS since the predations began in 2016.

Eastern side:

On this side, adult kiwi mortality from ferrets has always been suppressed during the first two years of a 1080 operation and predations would start from year three after each experiment. Since ferret predation was first noticed in the season 2008/09, the eastern side has experienced five seasons with high kiwi mortality caused by one or two individual ferrets each year, resulting in 31 kiwi known deaths (including 25 adults) over a period of nine years (Table 7).

This pattern seems to be confirmed by this current 1080 cycle where no birds died in the first two years and no ferrets were caught in the newly set up permanent trapping network until the third season after 1080, when a ferret was trapped in the middle of the “Frost Flats” (from where every

incursion event began in the past) in January 2020. This year, no other ferrets were caught within that side of the TFKS except on surrounding landcorp farms and forestry blocks (n= 17).

Western side:

Ferret predation started for the first time during the third year of the 2014 1080 cycle and despite the effectiveness of 1080 the following season, ferrets had re-colonised TFKS from the western side for the first time in year one of a 1080 cycle and showed that the forest can be re-invaded by ferrets at any stage of a 1080 operation. It became urgent to undertake further ferret control to prevent the population from becoming locally extinct. In three consecutive seasons, 19 monitored kiwi deaths (including 14 adults) have been attributed to ferret predation and, during the 2018/19 season, at least three ferrets were dispersing simultaneously through TFKS. During the 2019/20 and 2020/21 seasons, no kiwi were proven killed by ferrets, suggesting that the trapping regime put in place on the nearby farms and sanctuary has been effective in suppressing ferrets.

Last season, one ferret was caught in February 2020 in the middle of "Mako Track" where previous ferret predation episodes occurred in the past thus this capture, along with seven others that were caught along the start of the 42 Traverse, likely contributed to no kiwi adult deaths last year. This season only two ferrets were trapped within the boundary of the Sanctuary at the start of the 42 Traverse and on the outskirts of the forest (Appendix 4). All other captures occurred on the surrounding farms and the adjacent Ohinetonga reserve (n= 44).

Overall:

Since the beginning of the season, two ferrets were caught within the boundary of the Sanctuary (on the margin), 27 were caught on the surrounding farms and pine forests, whilst 17 were caught by Owhango Alive members within Ohinetonga reserve and adjacent farms. In total, 61 ferrets were caught this year, making a total of 156 ferrets caught since December 2016 (inside TFKS n=27, outside TFKS n=87).

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

		Kiwi killed by ferrets (n=50)	
1080 cycle	**Year in cycle**	**EAST**	**WEST**
2006	Year1	0	0
	Year2	0	0
	Year3	5	0
	Year4	12	0
	Year5	7	0
2011	Year1	0	0
	Year2	0	0
	Year3	3	0
2014	Year1	0	0
	Year2	0	0
	Year3	4	6
2017 Aug 2018	Year1	0	9
	Year2	0	4
	Year3	0	0
	Year4	0	0

Start of permanent trapping network

Key learnings so far:

- Increasing the size of the entrance hole in the DOC250 trap boxes 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, and we accept the increased risk of non-target catches as a result.
- 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 haybarns 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 fresh rabbit meat as bait (big pieces), 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).
- Trap maintenance is important- keep the traps well maintained and cleaned
- 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.

MINI CALL SURVEY USING CALL RECORDERS

A total of eight automatic call recorders were placed on the eastern side of the forest. Four were placed at the same traditional locations used since the early 1990s and four were situated further within the sanctuary and along the 42 Traverse at sites that were used in 2013, 2014 and 2015.

For the traditional four-day kiwi call survey using the two hours listened just after dark, data were used from the period between the 2nd to 5thth of June 2021. The acoustic recorders (n=4) detected on average 3.6 calls per hour which is a considerable increase from last season's count and particularly since 2015, when 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**
2h/night, 4 nights	1.15	1.27	1.92	1.03	2.31	2.5	**3.63**

**3 nights **3 sites*

The four other recorders placed further along the 42 Traverse were left in the forest between the 7th and the 30th of June and set to record from 1800 to 1200 each evening. The four first fine nights (the 9th, 12th, 17th and 18th of June) and the two hours listened after dark were used to compare call rates between years. These results have also shown a large increase since they were first listened to in 2013 and have reached a high of 4.4 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)**
Carcass hill*	15	14	14	44
Douglas fir*	7	12	4	18
Ponds*	7	19	8	6
Slip Way*	11	1	7	58
Opposite Canyon	2	0	14	38
Graffiti Bank	*Not surveyed*	19	27	47
Mamaku lookout	10	17	33	49
Waione	*Not surveyed*	7	9	21
TOTAL CALLS	**52**	**89**	**116**	**281**
CALLS/HOUR	**1.08**	**1.85**	**1.81**	**4.39**

The analysis of the overall data since 1993 confirm the population growth noted last year within the core area of the Sanctuary and it appears that the number of kiwi calls detected have bounced back to numbers heard in the late 1990s when kiwi call rates were at their peak (Figure 5). The main difference though is that overall, kiwi territory has shrunken dramatically since the 1990s and in particularly since the first ferret incursion occurred in 2009. The number of kiwi within the core area should continue to increase though as the trapping regime put in place in 2018 (in combination with a 3 year 1080 cycle) supresses any further incursions from ferrets into TFKS and kiwi should recolonise lost territories from ferret predation.

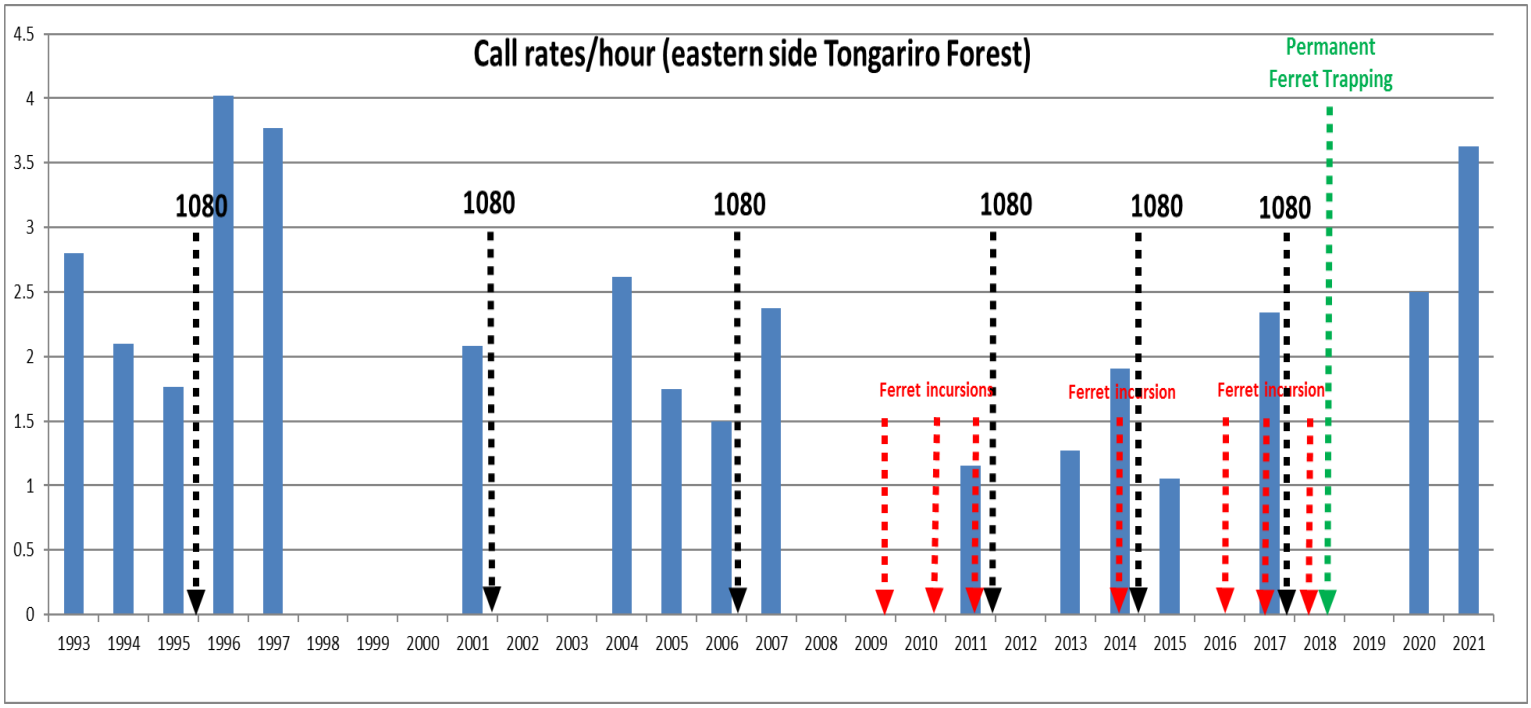

FIGURE 5: CALL RATES AND FERRET INCURSIONS SINCE 1993

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 10).

Population modelling shows that the current three-year 1080 cycle management combined with an efficient ferret trapping regime has allowed the TFKS kiwi population to grow at about 7 % per year since 2019. 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 models 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 (Figure 6).

TABLE 10: 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.*

Three ferret incursions from year three after the 2006, 2011 and 2014 1080 operations on the eastern side and the various incursions on the western side since 2016 have had a serious impact on the adult kiwi of which survival is a crucial determinant factor for the population to be sustainable. With no management, the population would decline at a rate of 22 % per year and would become locally extinct within the next 15 to 20 years. It shows the importance to remove ferrets from the environment and the projection for the three-year 1080 cycle experiment

combined with strategic ferret trapping shows that there is real potential for the population to grow remarkably (Figure 7). The population size of kiwi within the TFKS is currently estimated to be 201 birds (70 pairs, plus 61 single sub-adults and juveniles) (Figures 6 & 7; see Table 12 in Appendix 3 for details on how this estimate was calculated).

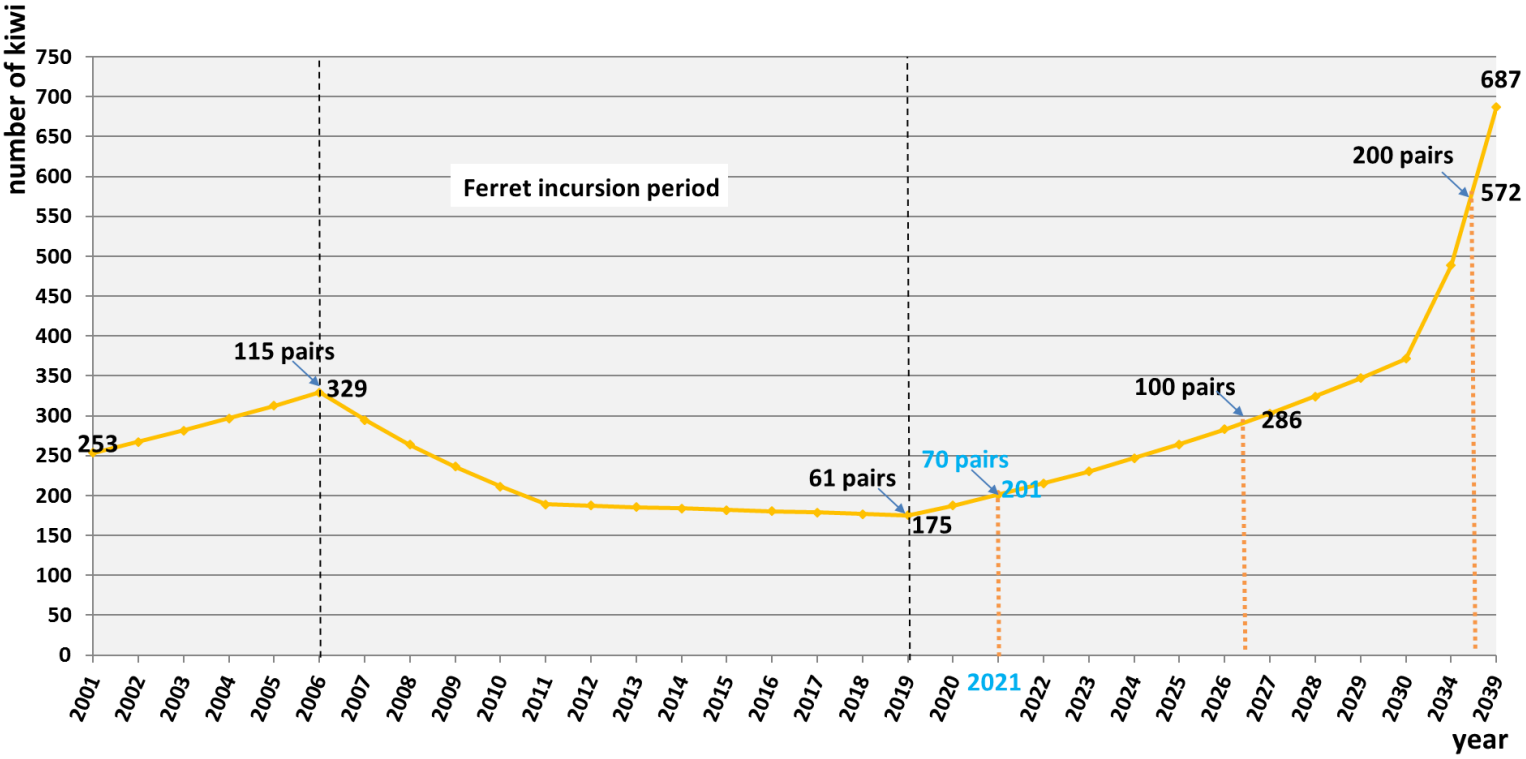

FIGURE 6: OBSERVED AND FORECASTED POPULATION VARIATION SINCE 2001

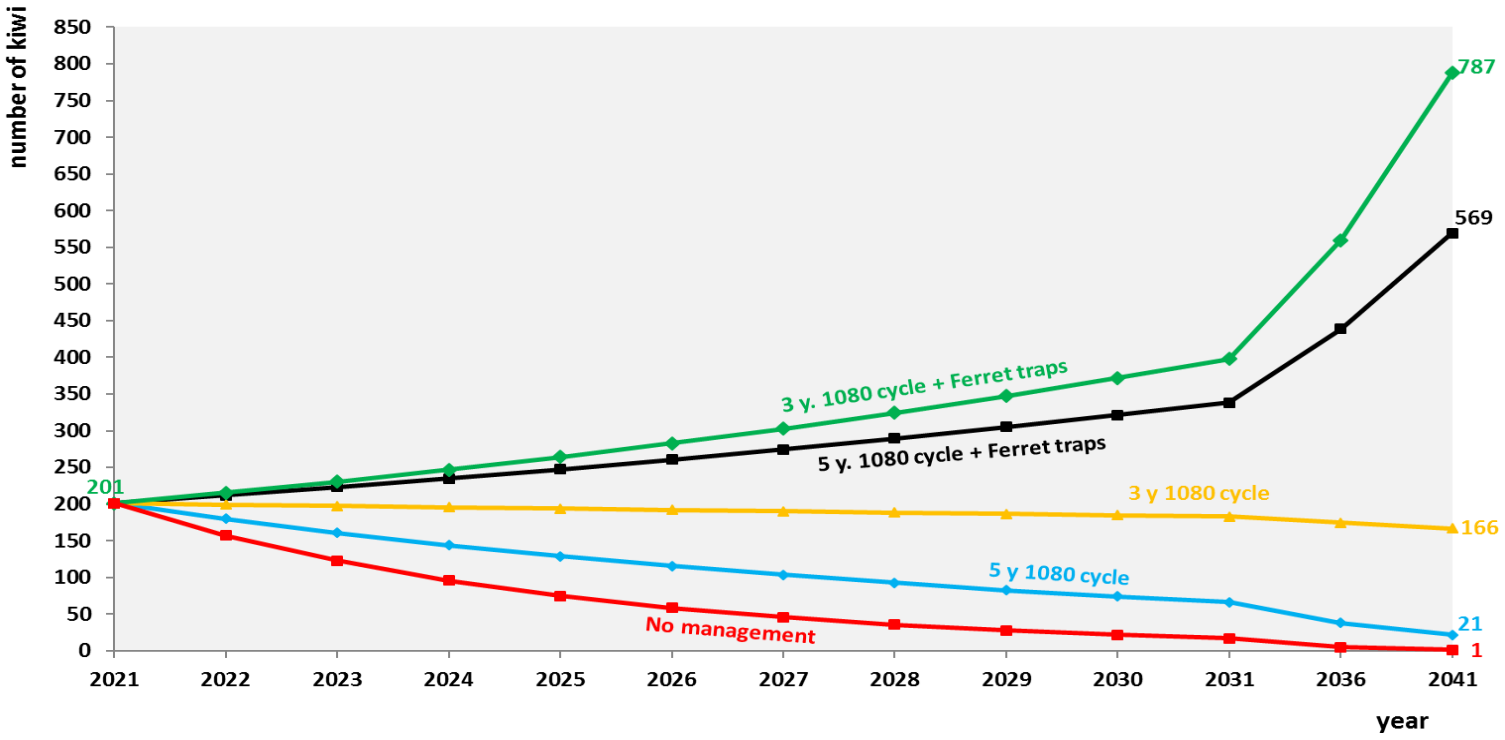

FIGURE 7: POPULATION MODELLING PROJECTED SCENARIOs UNDER DIFFERENT REGIMES

FUTURE DIRECTIONS

The Kiwi Recovery Group and the DOC National Threats Advice team continue to explore funding and priorities in terms of ferret research nationally (understanding ferret movements, rabbit-ferret relationships, etc.) to fill the gaps around ferret knowledge, especially on a landscape scale (10,000-50,000 ha). Tongariro Forest is therefore an ideal place for this to happen. The focus around ferret trapping and monitoring sentinel birds has become vitally important and remains the priority in order to test whether ferret control can be achieved on a landscape scale using a strategic approach to protect kiwi.

Kiwi chick survival research will occur next season 2021/22 following the 1080 operation scheduled in August/September 2021.

Tracking tunnel monitoring will continue in the lead-up to the next scheduled Tongariro Forest aerial 1080 operation in spring 2021. The camera trap trial will also be continuing to keep refining this new method of monitoring mustelid abundance.

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APPENDICES

Appendix 1: AERIAL 1080 OPERATION AUGUST 2017 (OPERATIONAL DETAILS)

Department of Conservation and TB Free NZ carried out a jointly funded aerial 1080 operation over TFKS in August 2017. This operation used 0.15% 1080 pellets in a cereal bait at a sowing rate of 1.5kg per hectare. Based on TFKS and "Battle For The Birds" programme research, the sowing rate was lifted from 0.75kg/ha to 1.5kg/ha and reverted from a strip sowing method (2014/15 TFKS Annual Report) to a more conventional even broadcast method (i.e. aiming for even coverage of baits throughout the forest with no gaps in bait coverage).

The result targets for this operation were:

- Less than 5 % rat tracking September/October 2017; and
- 0 % stoat tracking September/October 2017.

The outcome target was for kiwi chick survival to exceed 50 % the season immediately after the operation.

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**

Appendix 3: TERRITORY SIZE AND NUMBER CRITERIA/ASSUMPTIONS:

1. Assume each pair's territory size is that of Zazu's territory (at about 80 ha).
2. Based on the land area of where the density of kiwi is the highest within the Tongariro Forest, assuming a homogenous distribution of territories, determine the potential capacity of territories within the area.
3. Using data from acoustic surveys and monitored birds, it was assumed there to be 50 % occupancy of potential territories.
4. Exclude areas where there are no data at all to ascertain the possible presence of a pair.
5. Assume that for any pest control regime, population growth rate is homogenous throughout the different age classes (necessary to estimate number of pairs at start of each season).

This approach gives a figure of at least 70 pairs (**140 adults**) within Tongariro Forest in **2021**.

Determining how many juveniles and subadults there are is necessary to obtain a population estimate for kiwi in Tongariro Forest in 2021. To do so, population growth rates (based on estimated survival rates [SR]) were calculated for each year from 2017 to 2020 (which encompasses the length of time it takes for a chick to reach the adult stage, i.e. 4 years). Pest control regimes varied over the years therefore corresponding survival rates were used for each year. The pest control regime for the 2020/21 season was assumed to be equivalent to a 5-yearly 1080 cycle (with trapping) given the 1080 operation was delayed. Productivity per adult individual is 0.52 chicks per year.

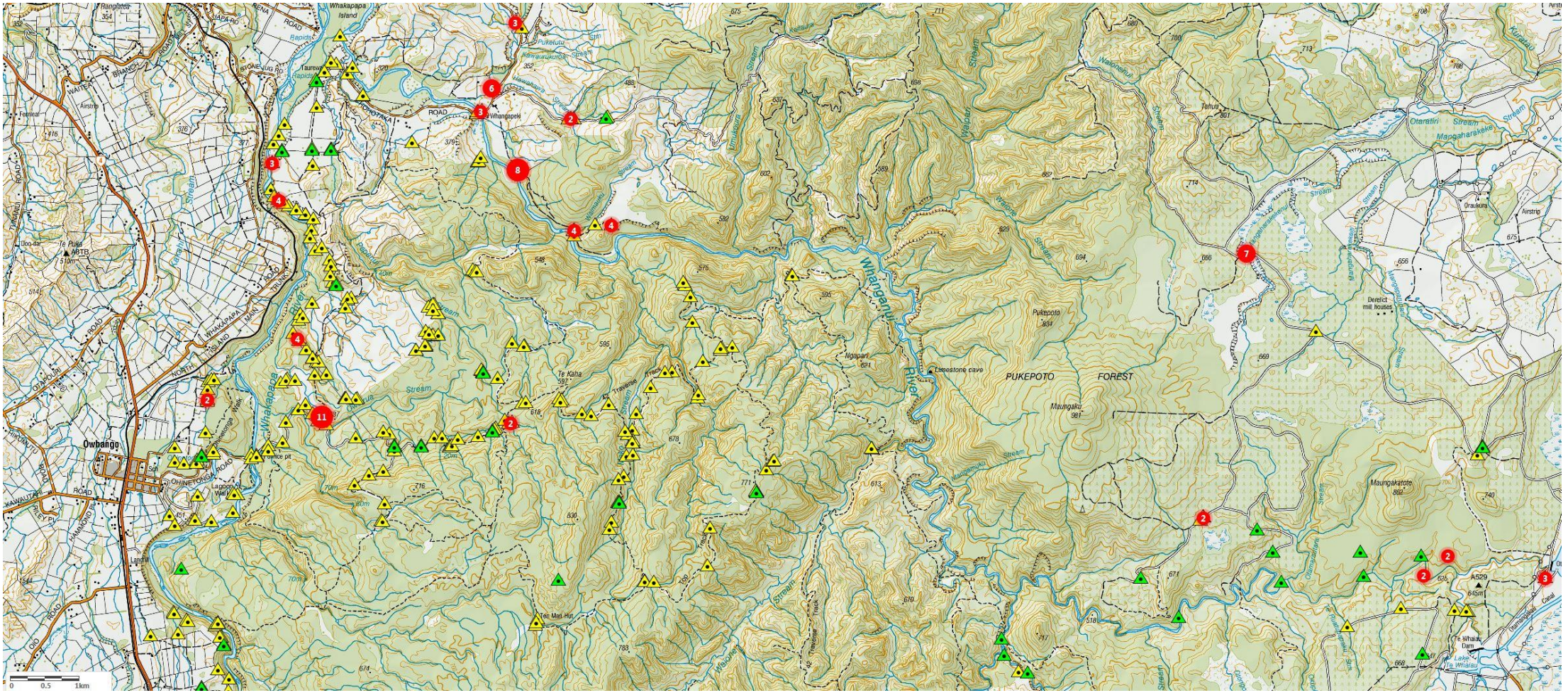
This give us an estimated kiwi population of **201 birds** within TFKS in **2021** (Table 12)

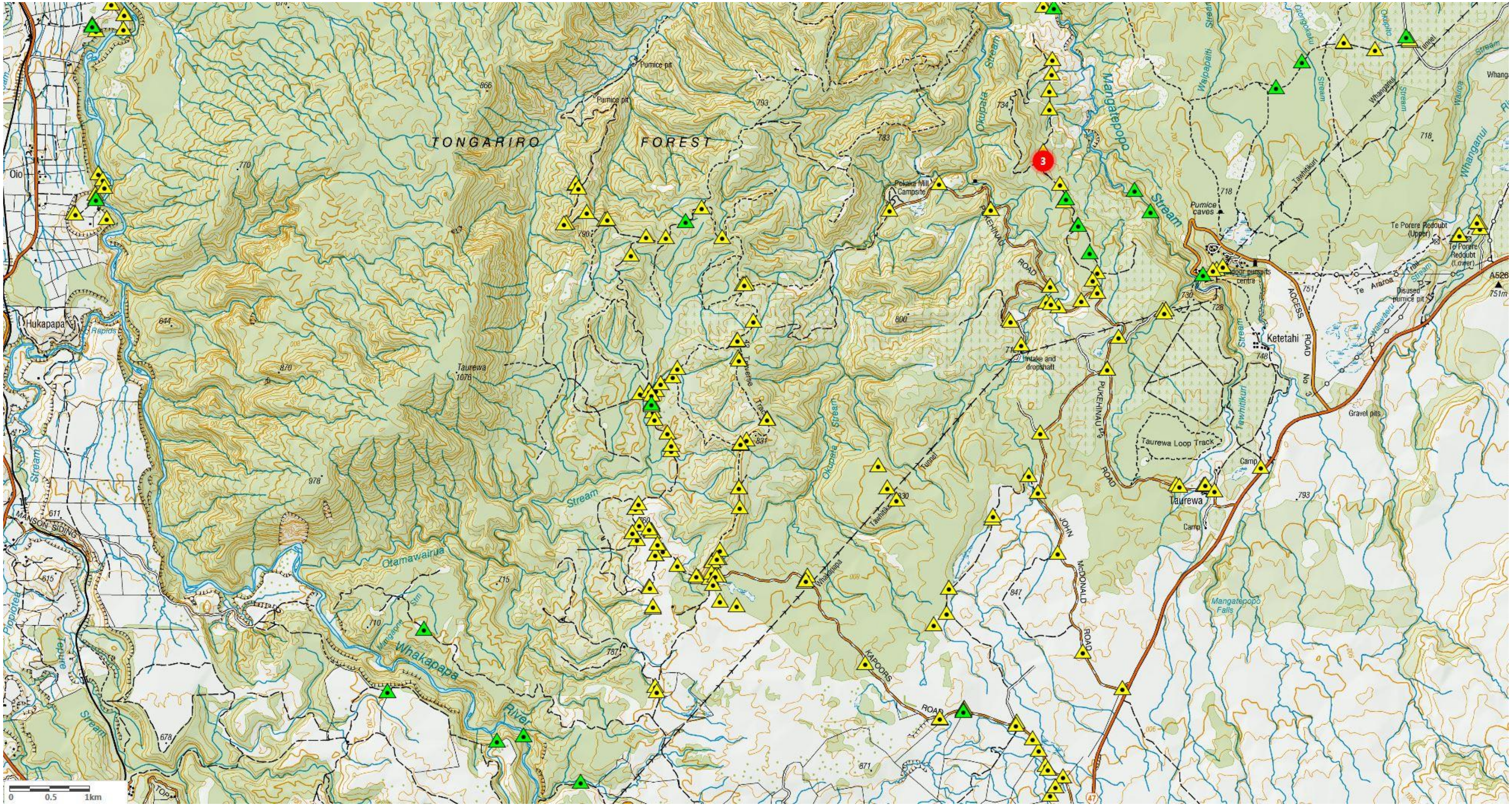
TABLE 12: POPULATION MODELLING PARAMATERS USED TO ESTIMATE POPULATION SIZE

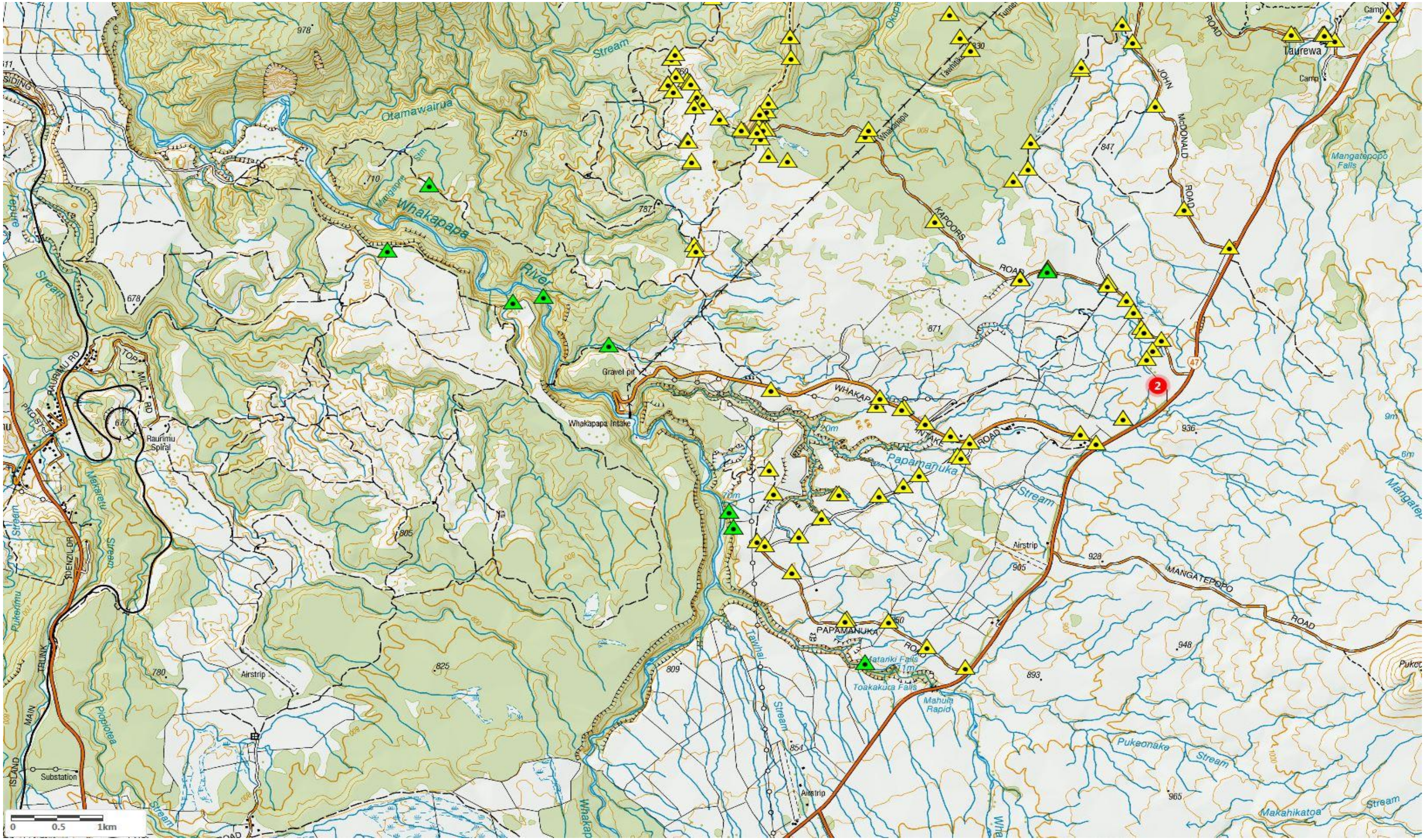
Estimated no. of individuals in each age class (years)							
Season	**Regime**	Chick (0-1)	Juvenile (1-2)	Sub-adult (2-3)	Sub-adult (3-4)	**Population growth**	
2017/18	3 yr cycle (Yr 1 post-1080)	126 adults x 0.52 x SR_{0-1} (0.2969) = **19.45**	N/A	N/A	N/A	- 0.94 %	
2018/19	3 yr cycle (Yr 2 post-1080)	125 adults x 0.52 x SR_{0-1} (0.2969) = **19.29**	19.45 x SR_{1-2} (0.8313) = **16.17**	N/A	N/A	- 0.94 %	
2019/20	3yr cycle (Yr 3 post-1080) + ferret trapping	124 adults x 0.52 x SR_{0-1} (0.3157) = **20.36**	19.29 x SR_{1-2} (0.8419) = **16.25**	16.17 x SR_{2-3} (0.9093) = **14.70**	N/A	+ 7.07 %	
2020/21	5 yr cycle (Yr 4 post-1080) + ferret trapping	132* adults x 0.52 x SR_{0-1} (0.2357) = **16.18**	20.36 x SR_{1-2} (0.8419) = **17.14**	16.25 x SR_{2-3} (0.9093) = **14.77**	14.70 x SR_{3-4} (0.9677) = **14.22**	+ 5.35 %	**TOTAL in June 2021** 16 + 17 + 14 + 14 + 140 adults = **201 birds**

To calculate the number of adults (X) at the start of season 2020/21 (growth rate = 5.35 %) is as follows: X+5.35/100(X)=201=> X(1+5.35/100)=201 => 1.0535X=201 => X=201/1.0535=132**. The same applies to estimate the number of adults at the start of each year using the corresponding population growth rate.*

Appendix 4: FERRET DOC 250S TRAPPING NETWORK WITH CAPTURED FERRETS SINCE 2016 (SINGLE CAPTURE IN GREEN TRIANGLE, MULTIPLE CAPTURES IN RED CIRCLE).




TONGARIRO
FOREST
Pumice pit
Pumice pit
Pokaka Mill Campsite
Oio
Hukapapa
Taurewa 1076
Otamawairua
Whakapapa
River
Mangatepopo
Stream
Pumice caves
Ketetahi
Taurewa Loop Track
Taurewa
Camp
Intake and dropshaft
PUKEHINAU
ROAD
JOHN McDONALD ROAD
KAPOORS ROAD
ACCESS ROAD No 3
Te Porere Redoubt (Upper)
Te Porere Redoubt (Lower)
Disused pumice pit
Gravel pits
Mangatepopo Falls
MANSON SIDING
0 0.5 1km


Whakapapa
River
Otamawairua
Stream
Gravel pit
Whakapapa Intake
Raurimu Spiral
WHAKAPAPA INTAKE ROAD
Papamanuka
Stream
KAPOORS ROAD
JOHN McDONALD ROAD
Taurewa
Camp
Mangatepopo Falls
MANGATEPOPO ROAD
PAPAMANUKA ROAD
Airstrip
Substation
Tawhai Stream
Pukeonake Stream
Makahikatoa Stream
Mahuia Rapid
Toakakuka Falls
MAIN TRUNK
RAURIMU RD
DENZIL DR
Piopiotea
0 0.5 1km