Seasonal Variation Of Introduced Mammalian Predator Activity In Native And Productive Forests Of The Central North Island

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Summary

Plantation forests can potentially serve as habitat for a range of forest dependent indigenous species. Introduced mammalian predators are a significant threat to forest birds and other indigenous fauna throughout New Zealand's indigenous and exotic forests. However, while there is a considerable body of work on mammalian predator activity in indigenous forests, introduced mammalian predator population dynamics in exotic plantation forests remains poorly understood. Here we attempted to refine methodology and understand the mammalian predator community and seasonal changes in abundance across three central North Island plantation forest sites (Matahina, Kaingaroa North and Kaingaroa South). Chew card, tracking tunnel and trail cameras were installed in five (native forest, clearfell, 4yr, 8yr, 16yr, and 20+ yr *Pinus radiata*) habitat types and monitored for one week in each of spring, summer, autumn and winter.

In total 180 chew cards and tracking tunnels were monitored quarterly, and 54 trail cameras positioned with three per habitat type per site. Camera data were collected over 1 512 trap nights with 54 613 images recorded, of which 41 287 were of target animals. Using a 30-minute time filter to ensure independent observations, total numbers of predators were: 8 mustelid, 25 cat, 205 hedgehog, 536 possum, and 1154 rodent. Rodents (rats and mice) were consistently higher in native forest remnants than any of the *P. radiata* habitat, irrespective of monitoring method. In *P. radiata* stands, rodents were more abundant in 20+ year old stands but there was no consistent trend with stand age. Chew cards and tracking tunnels gave an indication of site occupancy by rats and mice, however these two methods did not always correlate. Evidence suggests that high rat interaction with tracking tunnels reduces their attractiveness to mice, whereas this was not the case with chew cards. There were differences in the number of possums observed amongst different habitat types at all three sites, however these were not consistent between sites or seasons.

Rodents (rats and mice) are clearly the dominant predator in plantation forests, but their abundance is less than in native forests. Next steps:

- Understand the predator populations in a broader range of *P. radiata* forests with differing climatic conditions.
- Undertake longer periods of monitoring to understand seasonal processes.
- Shift to purely camera monitoring and ensure separation of rats and mice.

Introduction

New Zealand was predominantly forested prior to human colonisation (McGlone, 1989). Hence, much of the New Zealand biota is likely to be adapted to a forested environment. Since human colonisation the area of native forest has declined substantially with large-scale conversion of forests into a range of productive land use types, particularly pastoral agriculture and plantation forest (Ewers et al., 2006). Native forests still cover ~ 24 % of New Zealand (Ewers et al., 2006), with plantation forests contributing a further ~1.8 M ha of forest habitat (NZFOA & MPI, 2024). Plantation forests were established on land previously cleared for pastoral use and in some cases by the direct clearance of native forest, however the contribution of different afforestation pathways remains unclear. Current plantations are predominantly (>90%) *Pinus radiata* D.Don managed as even aged stands with clearfell harvesting.

For indigenous fauna and flora, plantation forests present potentially 'low contrast' highly suitable matrix habitat that has abiotic conditions more similar to a native forest than other productive land uses. Though differences in forest microclimate (e.g., temperature, wind) between plantation and native forests have not been explicitly studied in New Zealand, light transmission is known to decrease with stand age in plantations with no differences between plantation and native forests in stands 15 years and older (Forbes et al., 2019). This is suggestive that similar microclimatic conditions will occur in plantation stands older than 15 years and native forests as light penetration is a strong determinant of temperature in the understorey. This assumption is corroborated by the amelioration of climatic edge effects at native forest fragment boundaries when 20+ year old pine plantations are adjacent as opposed to open pastoral habitat ameliorate climatic edge effects.

Native species of plants (Allen et al., 1995; Brockerhoff et al., 2003; Ogden et al., 1997), birds (Seaton et al., 2010), mammals (bats) (Borkin & Parsons, 2011), and invertebrates (Pawson et al., 2009; Pawson et al., 2008) are known to occupy plantation stands. At the landscape scale plantations have been shown to mitigate some of the impacts of widespread deforestation on bird species richness (Ruffell et al., 2017). Recent research has shown that the abundance of insectivorous and frugivorous and nectivorous birds in Kaingaroa Forest had not changed between 1977/78 and 2023/24 (Grassick, 2024), suggesting no degradation in habitat suitability between rotations. Further research on inter-rotational changes in biodiversity of beetles is currently underway by Carl Wardhaugh (Scion). .

Bird richness and abundance in New Zealand has declined significantly with historical forest loss a significant contributing factor (Innes et al., 2010), particularly in areas where little (less than 5 to 10%) forest remains (Ruffell & R.K., 2017). In a review of experimental and circumstantial evidence Innes et al. (2010) conclude that introduced mammalian predation is the primary constraint on bird populations in large areas of native forest. Removing this pressure (i.e., pest control) shifts the limitation to habitat area, food supply, disease, and avian predators (e.g., NZ harrier hawk). Although exotic plantation forests have been suggested as 'high-quality matrix habitat', e.g., Ruffell et al. (2017), there is little empirical evidence quantifying the abiotic or biotic attributes of exotic *P. radiata* plantations to support this conclusion. This assertion is largely based on indirect evidence, that is the diversity and/or abundance of various groups of native species, e.g., plants, birds, bats, invertebrates, that are present in plantation stands or the ability of species to use plantations as habitat corridors where natural forests are fragmented. Fundamental studies that quantify the potential abiotic or biotic constraints on habitat quality, e.g., microclimate, predation pressure, food supply, or inter and intraspecies competition remain limited. However, as yet, no systematic study has been conducted of introduced mammalian predator abundance in a range of different aged *P.*

radiata plantations in New Zealand. We are aware of at least three studies that have quantified predator abundance in exotic plantation forests, but in each case the scope of monitoring is limited:

- Whilst studying possums in a 15 year old *P. radiata* stand east of Tokoroa Clout (1980) noted a sharp increase in apple baits missing from cage traps in March 1974. Rodent snap-traps caught a density of 11.5 ship rats per 100 trap-nights, which is considered high compared to other forests. Clout notes that capture rate is a function of both density and trapability and that strong conclusions on ship rat density in plantations could not be drawn other than they may at sometimes be abundant. Interestingly, dissections showed that rats were predominantly eating invertebrates and fungi with no fruit or seeds featuring, which are a common winter dietary component in native forests.
- King et al. (1996) is the most substantial study that documented 5 years or quarterly kill trap data where they compared catch rates in logged and unlogged native podocarp forests and young and old exotic plantations between 1982 and 1987. However, the young exotic forest was 4-year-old *P. radiata* at the time sampling was initiated in 1982 and the 'old' exotic forest was a mix of *Eucalyptus delegatensis* and *Pseudotsuga menziesii* stands. Mice were found to be most common in the young *P. radiata* stand with rats (ship and Norway) and stoats largely absent whereas ship rats and stoats were common in the older exotic forest. Presence of ship rats was correlated with trapping sites near fruiting understorey trees. Thirty of the 57 stoats caught during the study were in the old exotic forest with 13 of those caught in the first 2 sampling events. One stoat was caught in the young *P. radiata* block in the first sampling and no stoats were caught subsequently, despite abundant mice in some subsequent sampling years. Whilst the study was temporally comprehensive it unfortunately confounded different aged exotic forest with tree species composition, i.e., did not compare young and old *P. radiata* stands, which limits its inference of what is happening in current *P. radiata* dominated landscapes like the Kaingaroa plateau. It did show that young *P. radiata* had low rat activity and that in older exotic forest rats were present (but at a lower abundance than native forests) and linked with the understorey vegetation. Innes et al. (2001) reported in more detail on the rats caught in this study and concluded that exotic forest was poor habitat for ship rats, particularly younger plantations with open canopies and that rats caught were smaller and lighter in the older exotic forests.
- McArthur et al. (2019) studied NI Robin survival and reproduction in 24 unmanaged native forest fragments over 12 years and compared this with 3 years of sampling from 3 sites in a 1200ha *P. radiata* forest at Pureora that was planted between 1973 and 1984. This plantation was close to the site used by King et al. (1996) . Whilst the focus of the study was NI Robin ecology they also quantified rat abundance using 16 peanut butter-baited tracking tunnels per *P. radiata* site. They found that mean rat tracking numbers were low (0.11) in the plantation sites, which was consistent with grazed native forest fragments (0.14). Fenced native fragments had mean rat tracking of 0.66. The lower density of rats in pine plantations compared to native was consistent with King et al. (1996), but did not result in better nest survival or reproductive success. McArthur et al. (2019) attribute the higher female robin survival but lower reproduction rates in mature *P. radiata* to the presence of stoats that are attuned to nestling activity. They cite King et al 1996 as evidence that stoats were more abundance in mature exotic plantations, however it remains unknown whether stoat abundance differs between the mature *P. radiata* sampled by McArthur et al. (2019) and the *E . delegatensis* and *P. menziesii* sampled by King et al. 1996.

Plantation forests represent ~20% of New Zealand's forest habitat and disproportionately more in some lowland areas, hence it is potentially suitable habitat for forest adapted species and could provide connectivity with remaining natural forest fragments. Thus, it is important to understand the potential constraints that may prevent native species from utilising this habitat. Mammalian predators are recognised as the predominant threat to native birds when habitat is not limiting (Innes et al., 2010), yet predator diversity and population dynamics in *P. radiata* plantations remains poorly understood. This study is a pilot to refine methods and start to quantify the abundance of a range of mammalian predators across a range of different aged plantation stands in different seasons. We compare plantation stands with native forest remnants to understand points of difference and identify similarities between these habitats.

Methods and Analysis

Activity of introduced mammalian predators was compared between natural forests and five different age classes (0, i.e., recent clear fell, 4, 8, 16, and 20+ years old) of *Pinus radiata* in three (Matahina, Kaingaroa North, and Kaingaroa South) sites in the central North Island. The three sites represent a north/south gradient of increasing elevation and decreasing annual average temperature (Figure 1). All sites chosen had not structured predator control, e.g., aerial 1080, applied for at least 3 years.

A single line of 10 monitoring stations was established in each habitat for each site. Sampling consisted of a chew card and tracking tunnel at each of the 10 stations placed 50 m apart with the first station at least 50 m from the road edge. Three cameras were placed on each transect at the 3rd, 6th, and 9th station, respectively. If a camera location coincided with visibility of plantation stand road, then it was moved to the nearest station further away from the road to minimise camera theft.

Chew cards (Connovation, Auckland, New Zealand) and tracking tunnels (Black Trakka, Connovation, Auckland, New Zealand) were baited using peanut butter. Cameras (Browning. model BTC-6DCLN, Birmingham, United States) were set ~0.5m above the ground and approximately 1.5 m from an Erayz rabbit bait and the peanut butter chew cards that were within the image frame. Camera settings were; mode: trail, capture delay: 1 second, picture size: 8MP, multishot: RPF-3Shot, motion detect: long, smart IR: on, and night exposure: fast motion. Erayz baits were placed in white plastic pottles perforated with multiple holes and secured with a large U-shaped peg contained a block of Erayz dried rabbit jerky (Connovation, Auckland, New Zealand). Samples were taken quarterly (Table 1) with chew cards, tracking tunnels, and cameras established on day 1, tracking tunnel cards removed on day 2, and chews and camera removed after 7 days. All tracking tunnel cards and chews were analysed by Charles Te Kowhai and recorded as present/absent for individual species. Images were screened using Ecoassist to exclude all images with no animals of interest present, e.g., photos of people or wind movement of foliage. All images with animals were manually checked using the Ecoassist software interface and assigned to animal classes rodents (included rats and mice), possums, hedgehogs, mustelids, and cats. Because of the variability in distance between the camera and the attractant baits it was not possible to accurately determine the ratio of rats to mice in the camera images. This ratio can be assessed from the chew and tunnel data.

Table 1: Day of sample initiation during four seasons at three sites in the central North Island.

Region	Winter	Spring	Summer	Autumn
Matahina	4/6/2024	3/9/2024	2/12/2024	10/3/2025
Kaingaroa North	4/6/2024	2/9/2024	2/12/2024	10/3/2025
Kaingaroa South	4/6/2024	2/9/2024	2/12/2024	10/3/2025

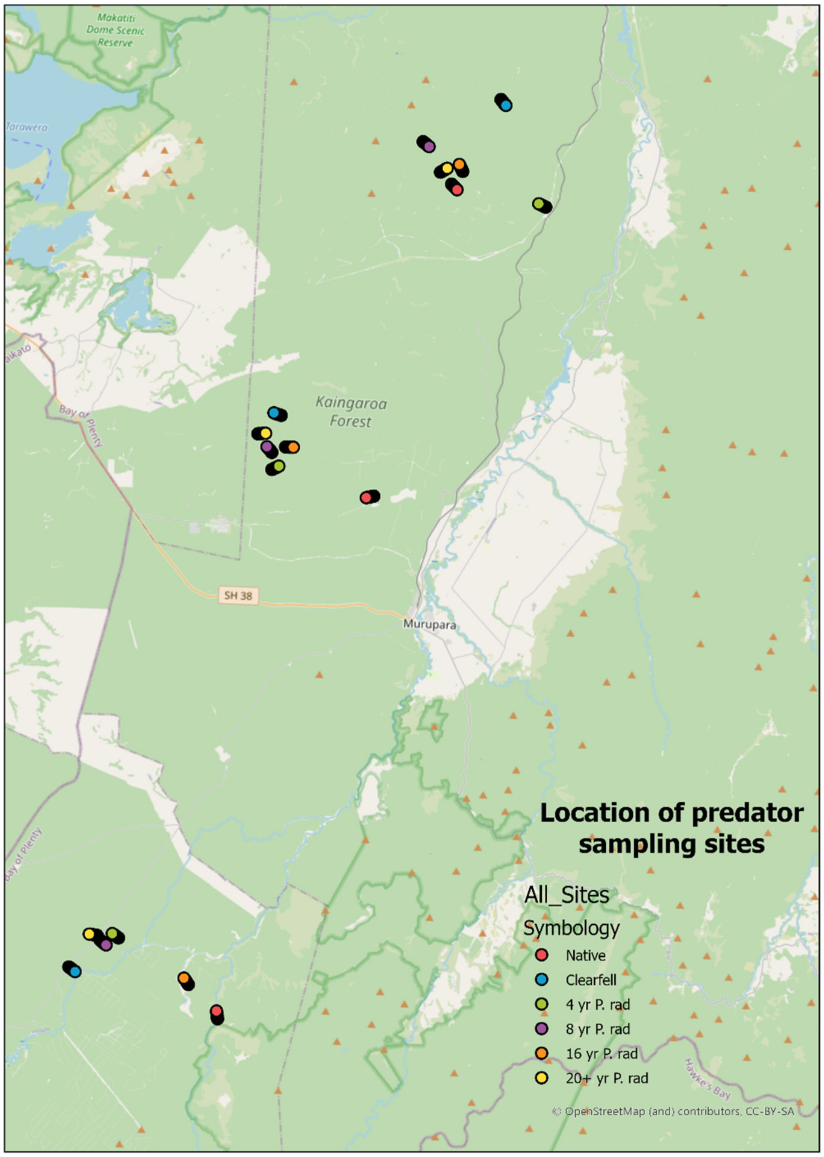

Fig. 1: Location, habitat and age of sampled stands in the central North Island.

Fig. 2: Exemplar camera trap photo showing position of chew, Erayz bait pottle. In this case the tracking tunnel is visible, but that was not consistently applied to each location.

Statistical analyses

For the chew cards and tracking tunnels, we calculated an interaction index per transect and sampling period as the proportion of cards or chews interacted with by each of possums, mice, and rats. For possums we only calculated chew card indices, while mice and rats both had chew card and tracking tunnel indices. For the rodents, we compared their interactions with both types of device using Spearman's rank correlation tests, to determine whether both device types were being interacted with similarly at a given location. For each of the tracking tunnel and chew card indices, we then performed Spearman's rank correlation tests to compare the results for the device type between mice and rats, to determine if there were any correlations between the two groups of rodents interacting with a particular device type across the locations. Finally, to examine the effects of sampling period, forest site, and habitat type on the chew card and tracking tunnels, we used generalised linear models (GLM) with a binomial error structure, to examine the effects of these three predictor variables on the tracking tunnel or chew card indices for a given species. We included an interaction term between habitat type and forest site in these models. For these GLMs, we assessed the significance of fixed effects using Type III Wald chi-square tests (Anova function in the *car* package (Fox & Weisberg, 2019)). Post-hoc pairwise comparisons among factor levels were conducted using estimated marginal means with Tukey adjustment for multiple comparisons (emmeans function in the *emmeans* (Lenth, 2025) package).

For the camera trap images, we first applied a 30-minute time-based filter to ensure independent observations, whereby images of the same species on taken by the same camera less than 30 minutes apart were assumed to represent a single encounter (Garvey et al., 2022; Nottingham et al., 2021). We then modelled the number of independent observations of both rodents and possums using generalised linear mixed-effects models (GLMM) with a Poisson error distribution and log link function, using the glmer function in the *lme4* (Bates et al., 2015) package. Habitat type and sampling period were included as fixed effects, and camera station (replicate) was included as a random intercept. We assessed the significance of fixed effects using Type III Wald chi-square tests, with pairwise comparisons made using estimated marginal means. All analyses were undertaken in R v. 4.5.0 (R Development Core Team, 2019).

Results

Chew card and tracking tunnels

There was considerable variation in both the chew card and tracking tunnel indices: among habitats at a site, among sites, and among sampling periods within a site and habitat (Table 2). The highest indices for rats were in all native habitats, and the Kaingaroa North 20-year-old plantation (Table 2), with rats interacting with 100% of the chew cards and 85% of the tracking tunnels at the Kaingaroa North native habitat. Conversely, the highest indices for possums were in plantation sites at Matahina (16-year-old), Kaingaroa North (four-year-old), and Kaingaroa South (eight-year-old). The indices were lower for mice than rats, with the highest indices being 54% of chew cards interacted with at the Matahina 20-year-old plantation habitat, and 50% of tracking tunnels at Kaingaroa eight-year-old habitat (Table 2).

Generalised linear models examining the effects of habitat type, forest site, and sampling period on possum, rat, and mouse chew card and tracking tunnel indices found significant effects of these variables. For mice, there was no effect of forest site on either chew card or tracking tunnel indices ($P > 0.05$), but significant effects of sampling period and habitat type ($P < 0.01$). For both possums and rats, habitat type, forest site, and sampling period all significantly related to the chew card (possums and rats) and tracking tunnel (rats) indices ($P < 0.05$), with a significant interaction between forest site and habitat type. At Matahina, rat chew card and tracking tunnel indices were highest in the native forest habitat, although this was only significant for the tracking tunnels. At Kaingaroa north site, rat numbers were highest in native and 20-year-old plantation, significantly so for both chew cards and tracking tunnels, and at Kaingaroa South numbers were significantly lower in the plantation stands than the native habitat (Table 2). When looking at the tracking tunnels, patterns for mice were similar to rats, however sites and habitats with relatively high indices for the chew cards, such as the three native habitats often had low mice indices for the tracking tunnels (Table 2).

While chew cards and tracking tunnels give an indication of site occupancy by the different target species, these two methods did not always correlate as observed with the GLM results (Table 2). For mice, the rank correlation indicated no relationship between the chew card and tracking tunnel indices ($P = 0.862$, Spearman's $\rho = -0.209$; Fig. 3a). Conversely, for rats there was a significant correlation between the chew card and tracking tunnel indices ($P < 0.001$, Spearman's $\rho = 0.723$; Fig. 3b). When comparing the indices between both groups of rodents, the results differed for the tracking tunnels and chew cards: there was a significant negative correlation between mouse and rat tracking tunnel indices ($P = 0.011$, Spearman's $\rho = -0.299$; Fig. 3c), while a significant positive correlation for the chew card indices ($P < 0.001$, Spearman's $\rho = 0.388$; Fig. 3d). Crucially, the comparison of the tracking tunnel indices suggested that where rat interactions with tracking tunnels are high, mouse interactions are low (Fig. 3c), yet the chew card results indicate that mice may still be occupying these sites and are undetected by the tunnels.

Table 2: Relative differences among habitats and forest sites of chew card and tracking tunnel indices for rat (*Rattus* spp.), mouse (*Mus musculus*), and possum (*Trichosurus vulpecula*) interactions with the device during the sampling periods. These are the model-adjusted means (± standard error), which take into account the other variable in the model (sampling period) and represent the expected value of the response variable for each habitat and forest, averaged over the other factors in the model. Models are generalised linear models with a binomial error distribution. Different letters signify significant differences between forests and habitat types per device and species (i.e. within a column; $P < 0.05$). Indices represent the proportion of cards chewed or tunnels visited by each species at each site during the sampling period.

Site	Habitat	Chew card index			Tunnel index	
		Rat	Possum	Mouse	Rat	Mouse
Matahina	Native	0.779 (0.07) FGH	0.205 (0.06) ABCD	0.397 (0.08) BC	0.759 (0.07) DE	0.022 (0.02) A
Matahina	0	0.423 (0.08) CDEF	0.108 (0.05) AB	0.145 (0.06) AB	0.094 (0.05) A	0.394 (0.08) CD
Matahina	4	0.7 (0.09) EFGH	0.208 (0.08) ABCD	0.143 (0.06) AB	0.29 (0.09) ABC	0.052 (0.04) AB
Matahina	8	0.321 (0.07) BCDE	0.364 (0.08) BCD	0.195 (0.06) ABC	0.191 (0.06) AB	0.09 (0.04) ABC
Matahina	16	0.347 (0.08) CDE	0.558 (0.08) DE	0.245 (0.07) ABC	0.094 (0.05) A	0.162 (0.06) ABCD
Matahina	20	0.551 (0.08) DEFG	0.18 (0.06) ABC	0.525 (0.08) C	0.191 (0.06) AB	0.022 (0.02) A
Kaingaroa North	Native	1 (0) H	0 (0) A	0.448 (0.08) BC	0.858 (0.05) E	0.044 (0.03) AB
Kaingaroa North	0	0 (0) A	0.041 (0.03) A	0.121 (0.05) AB	0 (0) A	0.288 (0.07) BCD
Kaingaroa North	4	0.296 (0.07) BCD	0.53 (0.08) CDE	0.048 (0.03) A	0.046 (0.03) A	0.186 (0.06) ABCD
Kaingaroa North	8	0.296 (0.07) BCD	0.18 (0.06) ABC	0.295 (0.07) ABC	0.142 (0.05) AB	0.262 (0.07) ABCD
Kaingaroa North	16	0.321 (0.07) BCDE	0.085 (0.04) AB	0.22 (0.07) ABC	0.094 (0.05) A	0.044 (0.03) AB
Kaingaroa North	20	0.829 (0.06) GH	0.231 (0.07) ABCD	0.448 (0.08) BC	0.578 (0.08) CDE	0.137 (0.05) ABC
Kaingaroa South	Native	0.779 (0.07) FGH	0.156 (0.06) AB	0.346 (0.08) BC	0.473 (0.08) BCD	0.022 (0.02) A
Kaingaroa South	0	0 (0) A	0 (0) A	0.17 (0.06) AB	0 (0) A	0.113 (0.05) ABC
Kaingaroa South	4	0.048 (0.03) AB	0.132 (0.05) AB	0.22 (0.07) ABC	0 (0) A	0.162 (0.06) ABCD
Kaingaroa South	8	0.221 (0.07) ABCD	0.77 (0.07) E	0.372 (0.08) BC	0.07 (0.04) A	0.501 (0.08) D
Kaingaroa South	16	0.146 (0.06) ABC	0.132 (0.05) AB	0.245 (0.07) ABC	0 (0) A	0.315 (0.08) BCD
Kaingaroa South	20	0 (0) A	0.108 (0.05) AB	0.27 (0.07) ABC	0 (0) A	0.044 (0.03) AB

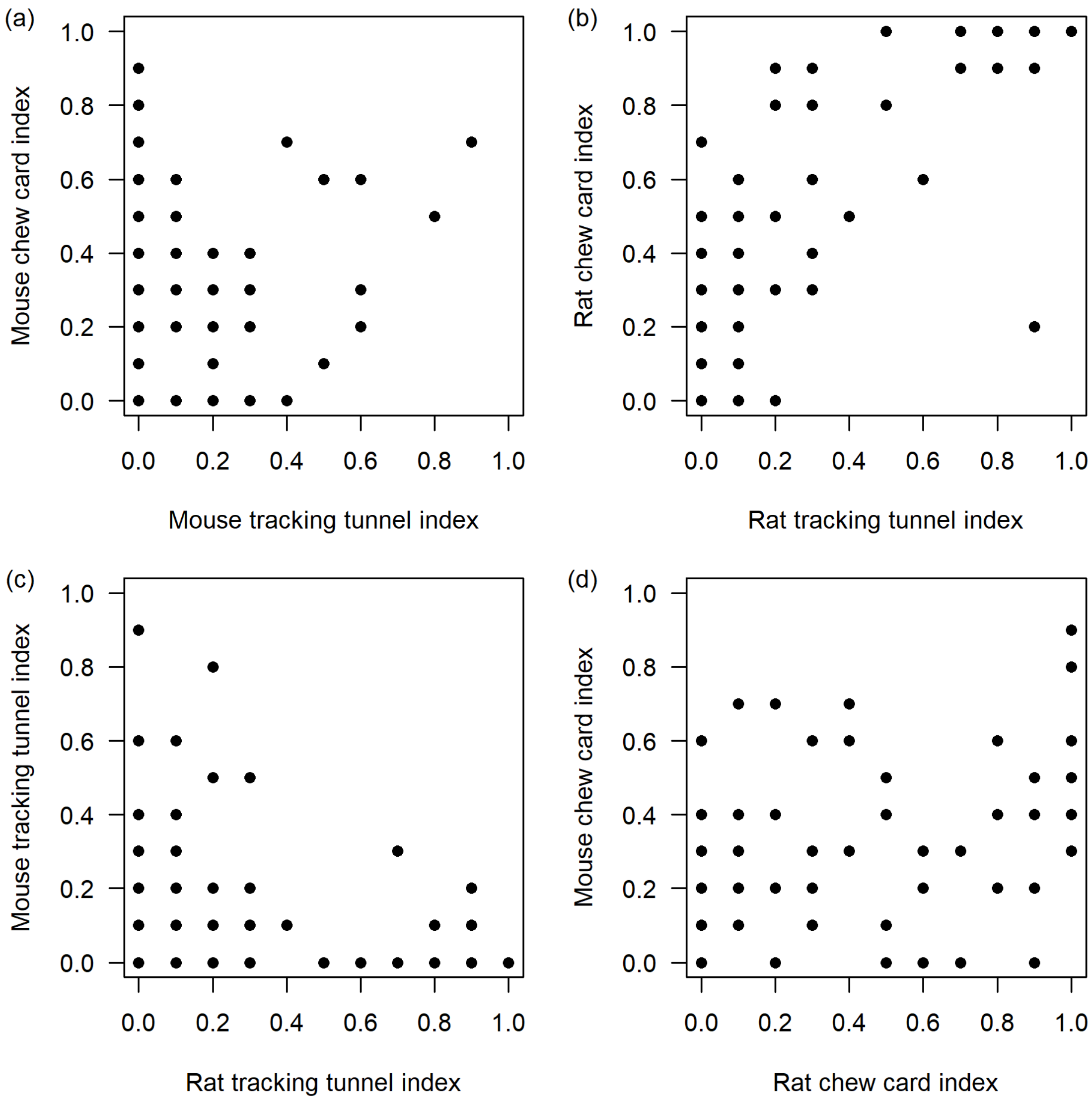

Fig. 3: Comparison of tracking tunnel and chew card indices (the proportion of cards chewed or tunnels visited on each transect during the study) for (a) mice *(Mus musculus),* and (b) rats (*Rattus* spp.) across all monitoring stations; and comparison of mouse and rat indices for (c) tracking tunnels and (d) chew cards at the same sites.

Camera traps

The total camera trap effort was 1512 (4×7×54) trap nights. A total of 54 613 images were recorded, of which 41 287 were ‘positive’ images (i.e. recorded mammals and birds rather than people, vehicles, or windblown vegetation). After applying a 30 minute time-based filter to ensure images were independent, we recorded a total of 25 cats, 205 hedgehogs, 536 possums, 1 154 rodents, and eight mustelids, with the Matahina forest having the highest number of predator observations during the study (Table 3). Rodents were the most frequently observed mammal at all forest sites.

Table 3: Number of independent observations (camera triggers > 30 minutes apart) of predators over the course of the study (1512 trapping nights) at the three study sites. Note: rodent includes *Rattus* spp. and *Mus musculus*.

	Cat	Hedgehog	Possum	Rodent	Mustelid	**Total**
Matahina	12	60	280	665	2	**1 019**
Kaingaroa North	4	88	96	305	4	**497**
Kaingaroa South	9	57	160	184	2	**412**
Total	**25**	**205**	**536**	**1 154**	**8**	**1 928**

For cats, hedgehogs, and mustelids, we had insufficient data to undertake subsequent analysis. For these animals, there were no clear patterns with respect to their relative abundance in the different habitats. Of the independent 25 images of cats, four were in native forest habitats while the remainder were in plantation sites: one in a cutover (0 years) forest, five in four-year-old stands, 10 in eight-year-old stands, two in 16-year-old stands, and 3 in 20-year-old stands. Of the independent hedgehog images, 15 were in native forest habitats, 13 in cutover plantation, 23 four-year-old stands, 87 in eight-year-old stands, 41 in 16-year-old stands, and 26 in 20-year-old stands. For the eight independent mustelid images, two were in native forest and six were in 16-year-old plantation stands.

For possums, there were significant differences in the number of observations among habitat types for all three sites (P < 0.001). At Matahina, the native forest and 16-year-old plantation had significantly higher numbers of possum observations than the other habitats, while in Kaingaroa South the native forest had significantly higher numbers of observations than all other habitats, except the eight-year-old stand (Table 4; Fig. 4). For Kaingaroa North, differences were less apparent, with no significant difference in numbers of observations among plantation habitats aged 4 – 20 years. The native and the cutover habitats did not differ from each other and were both significantly lower than the eight-year-old habitat.

When comparing the possum observations among the four sampling periods, there were significant differences among season for both Kaingaroa sites. For these sites the highest number of observations (and thus the highest possum activity levels) were in March 2025 (Table 5; Fig. 4). This sampling period was significantly higher than all other periods for Kaingaroa South, and significantly higher than June and September 2024 for Kaingaroa North.

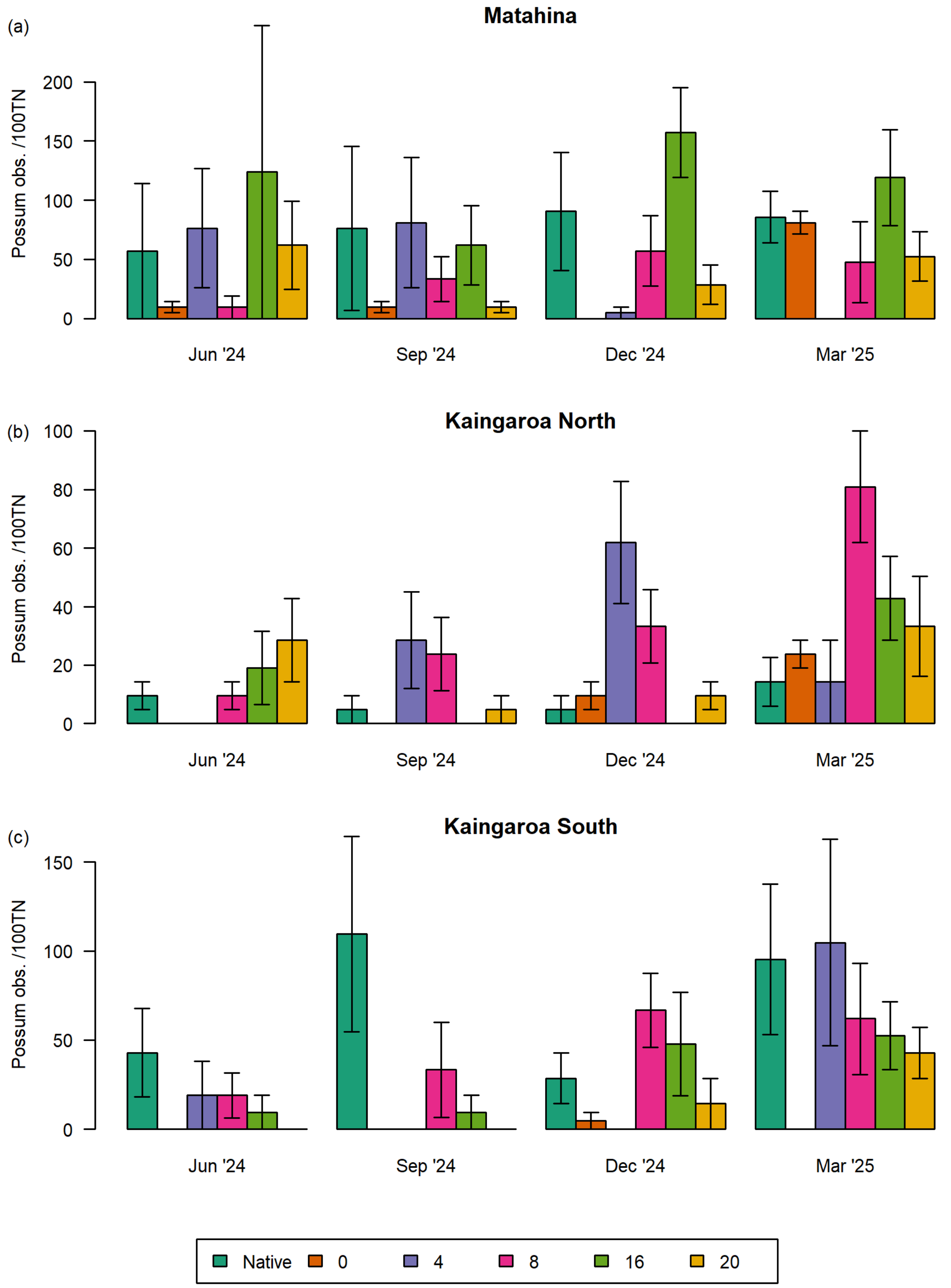

Fig. 4: Mean number of independent observations of possums (*Trichosurus vulpecula*) at the three forest sites, separated by observation period and habitat type (native, or pine plantation ranging from cutover [0] to 20-year-old stands). Observations are standardised to number of observations per 100 trap nights, with a single trap night equalling one active camera for one night. Error bars are the standard error of the mean.

Table 4: Relative differences among habitats of camera trap possum observations over the seven trapping nights per sampling period. These are the model-adjusted means (± 95% confidence intervals), which take into account the other variables in the model (sampling period and the random factor of camera location on transect) and represent the expected value of the response variable for each habitat, averaged over the other factors in the model. Models are generalised linear mixed models with a Poisson error distribution. Different letters signify significant differences between habitat types per site (*P* < 0.05). *** = *P* < 0.001.

	Native	0	4	8	16	20
Matahina	5.30	1.71	2.77	2.53	7.90	2.61
***	(3.88-7.23)	(1.07-2.74)	(1.88-4.08)	(1.69-3.78)	(5.98-10.44)	(1.75-3.88)
	B	A	A	A	B	A
Kaingaroa North	0.511	0.511	1.606	2.262	0.949	1.168
***	(0.24-1.09)	(0.24-1.09)	(1.02-2.52)	(1.53-3.34)	(0.54-1.68)	(0.70-1.96)
	A	A	AB	B	AB	AB
Kaingaroa South	4.264	0.074	1.911	2.79	1.838	0.882
***	(3.26-5.58)	(0.01-0.52)	(1.29-2.83)	(2.01-3.88)	(1.23-2.74)	(0.50-1.56)
	D	A	BC	CD	BC	AB

Table 5: Relative differences among sampling periods the camera trap possum observations over the seven trapping nights per sampling period. These are the model-adjusted means (± 95% confidence intervals), which take into account the other variables in the model (habitat type and the random factor of camera location on transect) and represent the expected value of the response variable for each sampling period, averaged over other factors in the model. Models are generalised linear mixed models with a Poisson error distribution. Different letters signify significant differences between habitat types per site (*P* < 0.05). *** = *P* < 0.001; NS = p > 0.05.

	June 2024	September 2024	December 2024	March 2025
Matahina	3.38	2.71	3.38	3.86
NS	(2.48-4.61)	(1.95-3.78)	(2.48-4.61)	(2.86-5.20)
Kaingaroa North	0.667	0.620	1.192	2.097
***	(0.38-1.16)	(0.35-1.10)	(0.78-1.83)	(1.49-2.96)
	A	A	AB	B
Kaingaroa South	0.636	1.071	1.138	2.510
***	(0.37-1.11)	(0.67-1.72)	(0.71-1.81)	(1.69-3.73)
	A	A	A	B

For rodents, there were also significant differences in the number of observations among habitat types for all three sites (P < 0.001). For all sites, the number of observations in the native habitat was significantly higher than in any of the plantation habitats (Table 6; Fig. 5). The oldest pine stands had consistently more rodents than other plantation habitat, however there was no consistent trend of increasing rodent numbers as a function of stand age (Table 6; Fig. 5).

When comparing the rodent observations among the four sampling periods, there were significant differences among all sites (Table 7; Fig. 5). For Matahina, rodent observations were lowest in December 2024; for Kaingaroa North observations in June 2024 were significantly higher than any other sampling period; and for Kaingaroa South observations were significantly highest in September 2024.

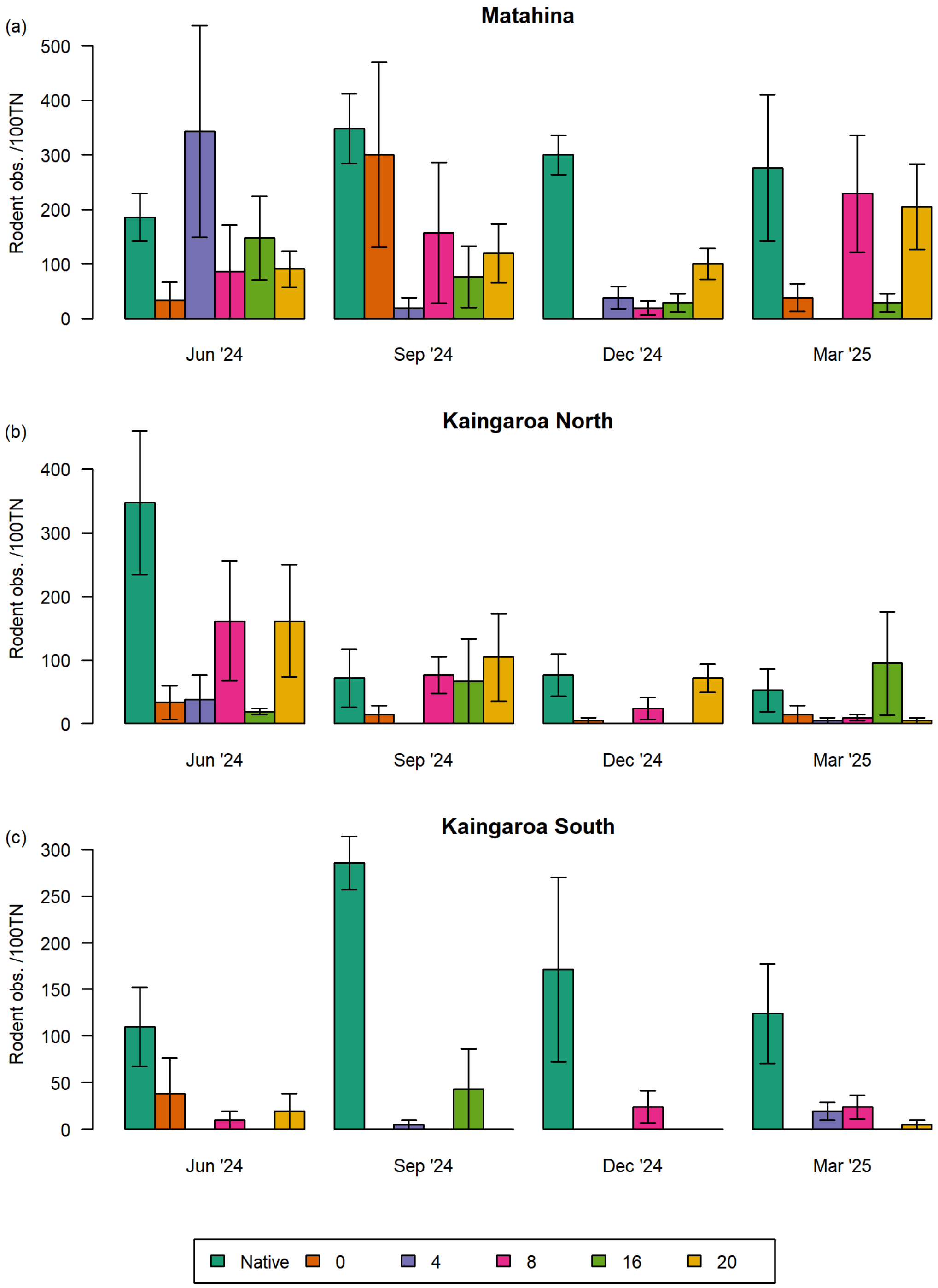

Fig. 5: Mean number of independent observations of rodents (*Rattus* spp. and *Mus musculus*) at the three forest sites, separated by observation period and habitat type (native, or pine plantation ranging from cutover [0] to 20-year-old stands). Observations are standardised to number of observations per 100 trap nights, with a single trap night equalling one active camera for one night. Error bars are the standard error of the mean.

Table 6: Relative differences among habitats the camera trap rodent observations over the seven trapping nights per sampling period. These are the model-adjusted means (± 95% confidence intervals), which take into account the other variables in the model (sampling period and the random factor of camera location on transect) and represent the expected value of the response variable for each habitat, averaged over the other factors in the model. Models are generalised linear mixed models with a Poisson error distribution. Different letters signify significant differences between habitat types per site (*P* < 0.05). *** = *P* < 0.001.

	Native	0	4	8	16	20
Matahina	18.73	6.27	6.75	8.28	4.74	8.68
***	(16.5-21.3)	(5.0-7.8)	(5.5-8.4)	(6.8-10.1)	(3.7-6.1)	(7.2-10.5)
	C	AB	AB	B	A	B
Kaingaroa North	7.892	0.961	0.618	3.912	2.608	4.941
***	(6.36-9.80)	(0.56-1.64)	(0.32-1.20)	(2.94-5.20)	(1.86-3.66)	(3.82-6.40)
	D	A	A	BC	B	C
Kaingaroa South	11.007	0.607	0.380	0.911	0.683	0.380
***	(7.30-16.60)	(0.28-1.33)	(0.15-0.98)	(0.46-1.80)	(0.32-1.45)	(0.15-0.98)
	B	A	A	A	A	A

Table 7: Relative differences among sampling periods the camera trap rodent observations over the seven trapping nights per sampling period. These are the model-adjusted means (± 95% confidence intervals), which take into account the other variables in the model (habitat type and the random factor of camera location on transect) and represent the expected value of the response variable for each sampling period, averaged over other factors in the model. Models are generalised linear mixed models with a Poisson error distribution. Different letters signify significant differences between habitat types per site (*P* < 0.05). *** = *P* < 0.001.

	June 2024	September 2024	December 2024	March 2025
Matahina	9.33	10.73	5.11	8.17
***	(8.1-10.8)	(9.4-12.3)	(4.2-6.2)	(7.0-9.6)
	BC	C	A	B
Kaingaroa North	6.31	2.76	1.46	1.50
***	(5.09-7.83)	(2.09-3.65)	(1.02-2.08)	(1.06-2.13)
	C	B	A	A
Kaingaroa South	0.768	1.454	0.851	0.748
***	(0.44-1.33)	(0.88-2.40)	(0.50-1.46)	(0.43-1.30)
	A	B	A	A

Discussion

New Zealand has a range of introduced mammals that eat an omnivorous diet that includes insects, reptiles, birds, small mammals and in some cases vegetation, e.g., possums. This study aimed to understand the abundance of key potential predators of forest birds in *P. radiata* plantations. The use of peanut butter and dried rabbit bait was designed to attract rats, mice, stoats, cats, possums, mustelids, and hedgehogs. Rodents accounted for 60% of camera images and possums a further 28%. Collectively hedgehogs, cats, and mustelids making up the remainder. It is likely that the composition of the introduced mammalian fauna will vary regionally due to broad scale factors like climatic, here in the central North Island it was dominated by rodents and possums.

We found that rodent (*Rattus* spp. and *Mus musculus*) density was consistently higher in native forest fragments than *P. radiata* stands. This was consistent across mean chew card and tracking tunnel indices and camera trap rodent observations at all three sites. No clear trend in abundance as a function of increasing *P. radiata* stand age was observed, however rodents were most abundant in 20+ year-old stands at the two most northern sites, particularly Kaingaroa North. Separating rats from mice was not possible with the current camera arrangement. However, mice were observed by both chews and tracking tunnels in all sampled plantation stands irrespective of age, whereas rats were not recorded in two of the three clear-felled stands by these methods. Tracking tunnels indicated that mice tended to be more consistently detected in stands <8 years and low in mature *P. radiata* and native forest. However, there were no obvious trends in mouse occupancy across different stand ages using chew cards. Brosnahan (2025) detected mice in 4 out of 5 stands (*P. rad*, aged 26 to 33 years) with tracking tunnels and all 5 stands with trails cameras where mice abundance (by trail camera) was highest in the oldest stand, but rats were not recorded. In comparison we found that rodents were more abundant in the older *P. radiata* stands in 2 of the 3 sites with mice present in all habits at all sites and rats absent from one mature and one clearfell stand. Brosnahan (2025) also made a comparison between Kaingaroa Forest and the nearby native forest (Whirinaki Ecological Management Zone) and found ship rats to be approx. 5.5 detections per 1,000 camera hours and absent in the plantation. Our results show a similar pattern where rat abundance was consistently higher in native forests compared to plantation stands irrespective of age.

Rat population density is known to be influenced by a range of factors, such as climate (influenced by elevation) and food availability (Carpenter et al., 2022; Christie et al., 2017). In a plantation context these factors are not independent as the density of fruiting understorey plant species (which is known to influence rat density (King et al., 1996)) is linked to climatic factors, such as temperature and rainfall, stand age (Brockerhoff et al., 2003), and available seed sources, i.e., proportion of native remnants in the landscape (Marshall et al., 2025). Measurements of food availability (e.g., fruiting understorey) and climatic suitability was beyond the scope of this study, however from what is known (Allen et al., 1995; Brockerhoff et al., 2003; Ogden et al., 1997) and personal observation, the density and diversity of fruiting understorey shrubs is lower in Kaingaroa South than Kaingaroa North and Matahina. These northern sites are warmer (~200m lower altitude) and in Matahina there is a greater proportion of indigenous forest remnants in the region that can act as a source for bird dispersed fruiting tree species. Hence, the higher rat density in Matahina stands is potentially linked to understorey vegetation.

Ascertaining any generalities with respect to mice or rat density in *P. radiata* stands is difficult as comparisons with past studies is confounded by either tree species and/or sampling method, e.g., snap traps, Fenn traps, and tracking tunnels in two of the three known studies. Furthermore, this is the only known study to sample a broad range of *P. radiata* stand ages. We can compare with McArthur et al. (2019) who also used tracking tunnels in ~20-year-old *P. radiata* stands and found a mean rat occupancy of 0.11. In our study rat occupancy varied between 0 and 0.58 in similar aged forests. Kaingaroa South was the closest and most climatically similar location to the McArthur et al. (2019) study and had the most similar rat abundance, with zero occupancy. Similar to McArthur et al. (2019) the abundance of rodents was lower in *P. radiata* than native forest remnants in plantation or ungrazed native fragments amongst pasture. Rodent abundance was high in the Kaingaroa Nth 20+ year old stand and from Clout (1980) it is known that rat abundance can sometimes be high in *P. radiata* stands.

Possums are omnivorous whose diet changes seasonally. Possums consume pine needles, female and male (pollen) cones seasonally, potentially when other sources of food are not available (Clout, 1977). Possums are known to consume invertebrates in plantation, particularly the gregarious bibionid (*Philia nigrostigma*) larvae in winter and spring. The extent of possum predation on nesting birds is not well documented in plantations, but they are known nest predators in native forest systems. For example possums were responsible for 15% of kokako nest predation on average in Rotoehu Forest (Innes et al., 1996). Differences in possum abundance as a function of stand age have not been studied in detail. Possums cause commercially significant damage to trees in plantations, particularly trees < 3 years (Jacometti et al., 1998). However, damage to trees does not necessarily correlate with abundance. In this study we found differences between habitat types, but these were not consistent across all sites. Seasonal effects varied by site, in the most northern site (Matahina) there was no detectable difference in possums between seasons. However, March was the most active period for possums in Kaingaroa (both Nth and Sth). Brosnahan (2025) did compare between summer (December to February) and winter (July and August) and found not difference in possum detection using trail cameras in 26- to 33-year-old *P. radiata* stands.

This study has demonstrated that key predators, particularly rodents, of forest birds are less abundant in *P. radiata* plantation forest stands compared to adjacent native forest. This effect was consistent, irrespective of stand age. Rodents and possums were the main predators observed that are likely to predate birds. Hedgehogs (205 images) were more common than cats (25) and mustelids (8). Although clear trends were no apparent for these species hedgehogs appear to mid-rotation stand prior to canopy closure and mustelids were only found in 16 year old stands and native remnants. Their observation in stands that have full canopy closure is similar to that observed by King et al. (1996).

Camera traps clearly provide more robust data, but a more standardised approach to the camera field of view is required to allow suitable discrimination between different species of rats and mice. The population abundance of predatory mammals will differ regionally in response to climatic factors, both directly and indirectly via the influence of climate on understorey vegetation and the abundance of fruit/seed bearing understorey plants. Hence, studies in additional regions will be required to determine the general habitat use by predators throughout New Zealand. Given the importance of understorey plants as food sources these additional surveys should include an assessment of understorey vegetation. Understanding resource use would also benefit from an assessment of diet.

Managing predatory mammal populations to improve biodiversity outcomes requires knowledge of the habitat use (i.e., different aged stands) as done here but also needs an understanding of predator movement between habitat types. Understanding seasonal habitat utilisation and movement in plantations will facilitate more strategic application of broadscale control tools (e.g., aerial 1080) to first eliminate and then prevent reinvasion, ultimately reducing long-term management control costs and improving biodiversity outcomes.

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Appendix A.

Table 1: Coordinates of each sampling site. Tracking tunnels and chew cards were placed at all locations at each site with cameras assigned to A, F, and I, unless moved as per discussion in methods.

Site	Habitat	Replicate	NZTM East	NZTM North
Kaingaroa Nth	Clearfell	A	1914783.682	5749122.925
Kaingaroa Nth	Clearfell	B	1914736.209	5749138.619
Kaingaroa Nth	Clearfell	C	1914688.736	5749154.314
Kaingaroa Nth	Clearfell	D	1914641.263	5749170.008
Kaingaroa Nth	Clearfell	E	1914593.790	5749185.702
Kaingaroa Nth	Clearfell	F	1914546.317	5749201.396
Kaingaroa Nth	Clearfell	G	1914498.844	5749217.091
Kaingaroa Nth	Clearfell	H	1914451.371	5749232.785
Kaingaroa Nth	Clearfell	I	1914403.898	5749248.479
Kaingaroa Nth	Clearfell	J	1914356.425	5749264.173
Kaingaroa Nth	*P.rad* 16	A	1915036.441	5747289.718
Kaingaroa Nth	*P.rad* 16	B	1915086.418	5747288.189
Kaingaroa Nth	*P.rad* 16	C	1915136.395	5747286.661
Kaingaroa Nth	*P.rad* 16	D	1915186.371	5747285.133
Kaingaroa Nth	*P.rad* 16	E	1915236.348	5747283.604
Kaingaroa Nth	*P.rad* 16	F	1915286.325	5747282.076
Kaingaroa Nth	*P.rad* 16	G	1915336.301	5747280.548
Kaingaroa Nth	*P.rad* 16	H	1915386.278	5747279.019
Kaingaroa Nth	*P.rad* 16	I	1915436.255	5747277.491
Kaingaroa Nth	*P.rad* 16	J	1915486.231	5747275.962
Kaingaroa Nth	*P.rad* 20	A	1913428.069	5748060.762
Kaingaroa Nth	*P.rad* 20	B	1913477.976	5748063.807
Kaingaroa Nth	*P.rad* 20	C	1913527.884	5748066.851
Kaingaroa Nth	*P.rad* 20	D	1913577.791	5748069.896
Kaingaroa Nth	*P.rad* 20	E	1913627.698	5748072.941
Kaingaroa Nth	*P.rad* 20	F	1913677.605	5748075.986
Kaingaroa Nth	*P.rad* 20	G	1913727.512	5748079.030
Kaingaroa Nth	*P.rad* 20	H	1913777.420	5748082.075
Kaingaroa Nth	*P.rad* 20	I	1913827.327	5748085.120
Kaingaroa Nth	*P.rad* 20	J	1913877.234	5748088.164
Kaingaroa Nth	*P.rad* 4	A	1914237.224	5745983.385
Kaingaroa Nth	*P.rad* 4	B	1914282.316	5746004.988
Kaingaroa Nth	*P.rad* 4	C	1914327.408	5746026.591
Kaingaroa Nth	*P.rad* 4	D	1914372.500	5746048.194
Kaingaroa Nth	*P.rad* 4	E	1914417.593	5746069.797
Kaingaroa Nth	*P.rad* 4	F	1914462.685	5746091.400
Kaingaroa Nth	*P.rad* 4	G	1914507.777	5746113.003
Kaingaroa Nth	*P.rad* 4	H	1914552.869	5746134.606
Kaingaroa Nth	*P.rad* 4	I	1914597.961	5746156.210

Kaingaroa Nth	*P.rad* 4	J	1914643.054	5746177.813
Kaingaroa Nth	*P.rad* 8	A	1914244.012	5746969.726
Kaingaroa Nth	*P.rad* 8	B	1914211.811	5747007.976
Kaingaroa Nth	*P.rad* 8	C	1914179.610	5747046.226
Kaingaroa Nth	*P.rad* 8	D	1914147.409	5747084.477
Kaingaroa Nth	*P.rad* 8	E	1914115.207	5747122.727
Kaingaroa Nth	*P.rad* 8	F	1914083.006	5747160.977
Kaingaroa Nth	*P.rad* 8	G	1914050.805	5747199.227
Kaingaroa Nth	*P.rad* 8	H	1914018.603	5747237.477
Kaingaroa Nth	*P.rad* 8	I	1913986.402	5747275.727
Kaingaroa Nth	*P.rad* 8	J	1913954.531	5747313.586
Kaingaroa Nth	Native	A	1920152.913	5744436.825
Kaingaroa Nth	Native	B	1920103.721	5744427.873
Kaingaroa Nth	Native	C	1920054.529	5744418.921
Kaingaroa Nth	Native	D	1920005.336	5744409.969
Kaingaroa Nth	Native	E	1919956.144	5744401.017
Kaingaroa Nth	Native	F	1919906.952	5744392.065
Kaingaroa Nth	Native	G	1919857.760	5744383.113
Kaingaroa Nth	Native	H	1919808.568	5744374.16
Kaingaroa Nth	Native	I	1919759.376	5744365.208
Kaingaroa Nth	Native	J	1919710.184	5744356.256
Kaingaroa Sth	Clearfell	A	1902467.958	5717123.297
Kaingaroa Sth	Clearfell	B	1902507.822	5717093.117
Kaingaroa Sth	Clearfell	C	1902547.687	5717062.937
Kaingaroa Sth	Clearfell	D	1902587.551	5717032.757
Kaingaroa Sth	Clearfell	E	1902627.415	5717002.578
Kaingaroa Sth	Clearfell	F	1902667.280	5716972.398
Kaingaroa Sth	Clearfell	G	1902707.144	5716942.218
Kaingaroa Sth	Clearfell	H	1902747.009	5716912.038
Kaingaroa Sth	Clearfell	I	1902786.873	5716881.858
Kaingaroa Sth	Clearfell	J	1902826.738	5716851.678
Kaingaroa Sth	*P.rad* 16	A	1909391.923	5716109.144
Kaingaroa Sth	*P.rad* 16	B	1909364.231	5716150.775
Kaingaroa Sth	*P.rad* 16	C	1909336.540	5716192.406
Kaingaroa Sth	*P.rad* 16	D	1909308.848	5716234.038
Kaingaroa Sth	*P.rad* 16	E	1909281.156	5716275.669
Kaingaroa Sth	*P.rad* 16	F	1909253.464	5716317.300
Kaingaroa Sth	*P.rad* 16	G	1909225.772	5716358.931
Kaingaroa Sth	*P.rad* 16	H	1909198.081	5716400.563
Kaingaroa Sth	*P.rad* 16	I	1909170.389	5716442.194
Kaingaroa Sth	*P.rad* 16	J	1909142.697	5716483.825
Kaingaroa Sth	*P.rad* 20	A	1904089.614	5718957.492
Kaingaroa Sth	*P.rad* 20	B	1904040.375	5718966.181
Kaingaroa Sth	*P.rad* 20	C	1903991.136	5718974.871
Kaingaroa Sth	*P.rad* 20	D	1903941.896	5718983.560
Kaingaroa Sth	*P.rad* 20	E	1903892.657	5718992.249

Kaingaroa Sth	*P.rad* 20	F	1903843.418	5719000.938
Kaingaroa Sth	*P.rad* 20	G	1903794.179	5719009.628
Kaingaroa Sth	*P.rad* 20	H	1903744.940	5719018.317
Kaingaroa Sth	*P.rad* 20	I	1903695.700	5719027.006
Kaingaroa Sth	*P.rad* 20	J	1903646.461	5719035.695
Kaingaroa Sth	*P.rad* 4	A	1905342.853	5718804.837
Kaingaroa Sth	*P.rad* 4	B	1905302.166	5718833.898
Kaingaroa Sth	*P.rad* 4	C	1905261.479	5718862.960
Kaingaroa Sth	*P.rad* 4	D	1905220.793	5718892.022
Kaingaroa Sth	*P.rad* 4	E	1905180.106	5718921.084
Kaingaroa Sth	*P.rad* 4	F	1905139.419	5718950.146
Kaingaroa Sth	*P.rad* 4	G	1905098.733	5718979.208
Kaingaroa Sth	*P.rad* 4	H	1905058.046	5719008.270
Kaingaroa Sth	*P.rad* 4	I	1905017.359	5719037.332
Kaingaroa Sth	*P.rad* 4	J	1904976.673	5719066.394
Kaingaroa Sth	*P.rad* 8	A	1904274.125	5718681.858
Kaingaroa Sth	*P.rad* 8	B	1904312.786	5718650.151
Kaingaroa Sth	*P.rad* 8	C	1904351.448	5718618.445
Kaingaroa Sth	*P.rad* 8	D	1904390.109	5718586.738
Kaingaroa Sth	*P.rad* 8	E	1904428.770	5718555.032
Kaingaroa Sth	*P.rad* 8	F	1904467.432	5718523.325
Kaingaroa Sth	*P.rad* 8	G	1904506.093	5718491.619
Kaingaroa Sth	*P.rad* 8	H	1904544.755	5718459.913
Kaingaroa Sth	*P.rad* 8	I	1904583.416	5718428.206
Kaingaroa Sth	*P.rad* 8	J	1904622.077	5718396.500
Kaingaroa Sth	Native	A	1911083.419	5714123.018
Kaingaroa Sth	Native	B	1911077.187	5714172.629
Kaingaroa Sth	Native	C	1911070.956	5714222.239
Kaingaroa Sth	Native	D	1911064.725	5714271.849
Kaingaroa Sth	Native	E	1911058.494	5714321.459
Kaingaroa Sth	Native	F	1911052.262	5714371.069
Kaingaroa Sth	Native	G	1911046.031	5714420.680
Kaingaroa Sth	Native	H	1911039.800	5714470.290
Kaingaroa Sth	Native	I	1911033.569	5714519.900
Kaingaroa Sth	Native	J	1911027.338	5714569.510
Matahina	Clearfell	A	1927521.909	5767439.033
Matahina	Clearfell	B	1927553.695	5767400.437
Matahina	Clearfell	C	1927585.480	5767361.840
Matahina	Clearfell	D	1927617.265	5767323.244
Matahina	Clearfell	E	1927649.051	5767284.647
Matahina	Clearfell	F	1927680.836	5767246.050
Matahina	Clearfell	G	1927712.621	5767207.454
Matahina	Clearfell	H	1927744.407	5767168.857
Matahina	Clearfell	I	1927776.192	5767130.261
Matahina	Clearfell	J	1927807.978	5767091.664
Matahina	*P.rad* 16	A	1925300.660	5763261.057

Matahina	*P.rad* 16	B	1925280.401	5763306.768
Matahina	*P.rad* 16	C	1925260.143	5763352.480
Matahina	*P.rad* 16	D	1925239.884	5763398.192
Matahina	*P.rad* 16	E	1925219.625	5763443.904
Matahina	*P.rad* 16	F	1925199.367	5763489.616
Matahina	*P.rad* 16	G	1925179.108	5763535.328
Matahina	*P.rad* 16	H	1925158.849	5763581.040
Matahina	*P.rad* 16	I	1925138.590	5763626.752
Matahina	*P.rad* 16	J	1925118.332	5763672.464
Matahina	*P.rad* 20	A	1924019.780	5763222.428
Matahina	*P.rad* 20	B	1924063.125	5763247.352
Matahina	*P.rad* 20	C	1924106.470	5763272.275
Matahina	*P.rad* 20	D	1924149.816	5763297.199
Matahina	*P.rad* 20	E	1924193.161	5763322.122
Matahina	*P.rad* 20	F	1924236.506	5763347.046
Matahina	*P.rad* 20	G	1924279.852	5763371.970
Matahina	*P.rad* 20	H	1924323.197	5763396.893
Matahina	*P.rad* 20	I	1924366.542	5763421.817
Matahina	*P.rad* 20	J	1924409.888	5763446.740
Matahina	*P.rad* 4	A	1930116.396	5761195.692
Matahina	*P.rad* 4	B	1930071.443	5761217.584
Matahina	*P.rad* 4	C	1930026.491	5761239.477
Matahina	*P.rad* 4	D	1929981.539	5761261.369
Matahina	*P.rad* 4	E	1929936.586	5761283.262
Matahina	*P.rad* 4	F	1929891.634	5761305.154
Matahina	*P.rad* 4	G	1929846.681	5761327.046
Matahina	*P.rad* 4	H	1929801.729	5761348.939
Matahina	*P.rad* 4	I	1929756.776	5761370.831
Matahina	*P.rad* 4	J	1929711.824	5761392.724
Matahina	*P.rad* 8	A	1923007.167	5764996.054
Matahina	*P.rad* 8	B	1923045.293	5764963.705
Matahina	*P.rad* 8	C	1923083.418	5764931.356
Matahina	*P.rad* 8	D	1923121.544	5764899.007
Matahina	*P.rad* 8	E	1923159.669	5764866.658
Matahina	*P.rad* 8	F	1923197.795	5764834.310
Matahina	*P.rad* 8	G	1923235.920	5764801.961
Matahina	*P.rad* 8	H	1923274.045	5764769.612
Matahina	*P.rad* 8	I	1923312.171	5764737.263
Matahina	*P.rad* 8	J	1923350.296	5764704.914
Matahina	Native	A	1924663.370	5762525.448
Matahina	Native	B	1924698.230	5762489.604
Matahina	Native	C	1924733.090	5762453.761
Matahina	Native	D	1924767.951	5762417.917
Matahina	Native	E	1924802.811	5762382.073
Matahina	Native	F	1924837.671	5762346.230
Matahina	Native	G	1924872.531	5762310.386

Matahina	Native	H	1924907.391	5762274.542
Matahina	Native	I	1924942.251	5762238.699
Matahina	Native	J	1924977.112	5762202.855