



Diurnal, seasonal and annual abundance patterns of California quail (*Callipepla californica*) in the Marlborough Sounds, New Zealand, 2010–2019

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Abstract: The California quail was introduced to New Zealand in 1862 as a game bird, and today is held in high regard by recreational hunters. The species is widespread through the North and South Islands, except for the regions of Westland, Fiordland, and Southland. However, it is suspected that populations have been declining in recent decades. Our study focused on the California quail population in the Marlborough Sounds along six road sections between Manaroa, Picton, and Havelock during 2010–2019. Analysis of quail counts using a Generalised Linear Model revealed that year (decline from 2010 to 2019), season (highest in spring, lowest in winter and Autumn) and vehicle traffic (highest at low traffic, lowest at high traffic) all showed significant relationships with the mean number of quail counted per survey. Quail numbers also showed significant relationships with time of day (highest in evening, lowest in afternoon) and road section (highest from Portage to Te Mahia and Te Mahia to Linkwater). The decline in quail counted over the 10-year period was possibly due to loss of suitable habitat through forest regeneration, and perhaps also increased predation by certain introduced mammals. We recommend future research to further investigate the causes of the decline, given that confirmed declines in exotic quail populations may have similar implications for native species that also prefer open habitats within the Marlborough Sounds region.

Keywords: annual abundance, diurnal, Havelock, Manaroa, Picton, road counts, seasonal abundance

Introduction

The California quail (*Callipepla californica*) is native to California, Oregon, and Nevada (USA). Historically in North America, California quail were highly valued by humans as a food source and for recreational hunting. The ability of a population of California quail to persist or thrive is dependent, in part, on the availability of suitable habitat, in particular food, water, and shelter. Their native habitats include chaparral shrubland and conifer and oak forest with particular preference for sparsely-vegetated clearings (Leopold 1985). California quail were successfully introduced to Nelson, New Zealand, in 1862, primarily as a game bird (Westerskov 1985; Walrond 2008). The species has thrived in both the South and North Islands where it is considered a naturalised species (Robertson et al. 2017). It is still found throughout much of the country today, favouring relatively warm and dry regions (mean annual temperature > 10°C, annual rainfall < 1500 mm; Williams 1952).

In New Zealand, this species inhabits native and introduced scrublands, native grasslands (*Poa* and *Festuca* species), the edges of native podocarp forests (Williams 1963), and clear-felled and recently planted exotic pine (*Pinus radiata*) plantations. It has a particular preference for New Zealand's

native mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) scrublands, as well as for tussock grasslands, and can often be observed along roadsides where these adjoin suitable habitats (RG Powlesland, pers. obs.). In contrast, densely forested and intensively farmed habitats are usually avoided (Williams 1952).

A strictly diurnal bird, the California quail is commonly seen during the day feeding on a wide range of vegetation and seeds (Caithness et al. 1989). It is often considered a pest by farmers due to the damage it causes to crops (Simberloff 2019). The California quail is, however, valued in some regions of New Zealand as a gamebird (Fish and Game New Zealand 2020). In addition, these birds provide a means for people to connect with nature, as they visit urban and rural gardens (Rowe & Rowe 2018; RG Powlesland, pers. obs.).

Quail populations in New Zealand are threatened by predation from a wide range of introduced mammalian and avian predators, including feral cats (*Felis catus*), stoats (*Mustela erminea*), ferrets (*Mustela putorius furo*), European hedgehogs (*Erinaceus europaeus*), and the native swamp harrier (*Circus approximans*; Williams 1952). Other threats include subsistence and recreational hunting (Williams 1965; Fish and Game New Zealand 2020) and the conversion of suitable habitat, primarily changing partially cleared land to

completely cleared farmland (Williams 1952). Although some studies suggest that the threats outlined above are likely to have driven a decline in the abundance of quail throughout New Zealand, the evidence is largely anecdotal (Williams 1952; Williams 1965; Fish and Game New Zealand 2020).

To our knowledge, this is the first study on California quail in the Marlborough Sounds region, and the first to analyse a 10-year dataset of their abundance anywhere in New Zealand. Although Bell (2015) also investigated California quail population dynamics, this earlier study was much more limited in scope (a four-year study within the predator-free Zealandia eco-sanctuary, Wellington). The primary aim of our study was to develop an improved understanding of annual trends in abundance of California quail along roadside habitats in the Marlborough Sounds region of New Zealand. The secondary focus was to investigate patterns of seasonal and diurnal activity of this species, and the impact of vehicle traffic intensity on the number of individuals counted.

Methods

Study area

The study was conducted along three roads in the Marlborough Sounds, where California quail have been observed along the roadside. In this area, forest was converted to pasture between 1860 and 1900, and roads were formed in or around the 1960s (Godsiff 2006). We assessed stability of the quail populations along these roads through an analysis of quail counts across a period of ten years from 2010 to 2019 inclusive. The route was split into six sections: Manaroa to Kenepuru Head (MK), Kenepuru Head to Portage (KP), Portage to Te Mahia (PT), Te Mahia to Linkwater (TL), Linkwater to Picton (LP), and Linkwater to Havelock (LH).

Te Mahia to Linkwater (TL), Linkwater to Picton (LP), and Linkwater to Havelock (LH) (Fig. 1). The MK roadside is primarily regenerating native bush (Eade 2011, Table 1), with some grassland pasture, small areas of mature native forest and pine plantations (SLR Consulting NZ Limited 2018). The KP and PT roadsides consist entirely of native bush. In contrast, along Queen Charlotte Drive (LP and LH), the habitat consists of more modified landscapes such as farmland and residences, and some native forest (Table 1). Finally, TL transitions from primarily forested areas close to Te Mahia, to farmland and residences approaching Linkwater (Table 1).

Data collection

Counts of adult California quail were conducted along each section of road travelled by the same observer (RGP), approximately three times per month from 2010 to 2019. Data were collected opportunistically, each time the route between Manaroa to either Picton or Havelock was travelled (primarily Manaroa Road, Kenepuru Road and Queen Charlotte Drive; Fig. 1). As the sampling method was not randomised or systematic, any inferences made in this paper are limited primarily to the quail populations along the road sections surveyed. In addition to counts, other data recorded included presence of broods, season (spring, summer, winter, autumn), time period (morning [sunrise–1200], afternoon [1201–1700], evening [1701–sunset]), vehicle traffic intensity (low, medium, high), and precipitation (raining, not raining). See Appendix S1 in Supplementary Materials for a description of each variable recorded.

To assess the habitats alongside each road section, Google Maps was used to calculate the distance of each section and to estimate the number of buildings alongside the road (including

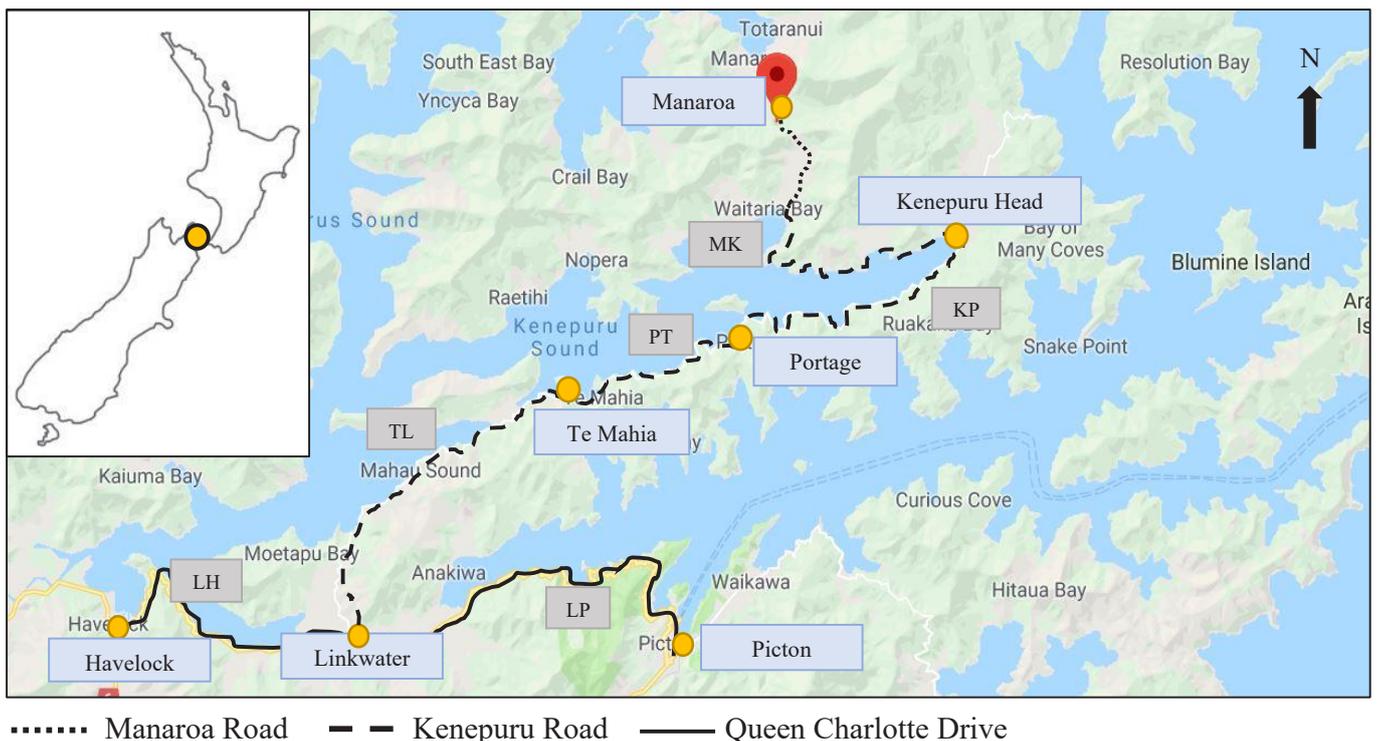


Figure 1. Roads travelled between Manaroa and Picton or Havelock along which counts of California quail were made during 2010–2019. Initials refer to the road sections: Manaroa to Kenepuru Head = MK, Kenepuru Head to Portage = KP, Portage to Te Mahia = PT, Te Mahia to Linkwater = TL, Linkwater to Picton = LP, and Linkwater to Havelock = LH.

Table 1. Summary of variables describing the roadside habitat of six road sections between Manaroa and Picton or Havelock, including length, number of buildings (including houses, camping sites, farm sheds, and shops) and percentages of road with dense forest, open clearing and farmland, and residential areas alongside. Initials refer to the road section: Manaroa to Kenepuru Head = MK, Kenepuru Head to Portage = KP, Portage to Te Mahia = PT, Te Mahia to Linkwater = TL, Linkwater to Picton = LP and Linkwater to Havelock = LH. Total number of buildings along the LH and LP sections do not include the towns of Picton or Havelock.

Variables	MK	KP	PT	TL	LH	LP
Length of road section (km)	21.7	13.0	8.9	19.7	12.7	20.8
Number of buildings	8	57	124	119	125+	190+
Percentage of road surrounded primarily by dense native forest	83%	100%	100%	66%	34%	58%
Percentage of road surrounded primarily by open areas or farmland	17%	0%	0%	23%	40%	26%
Percentage of road primarily next to a residential area	0%	0%	0%	11%	26%	16%
Building density per km	0.4 km ⁻¹	4.0 km ⁻¹	14.0 km ⁻¹	6.0 km ⁻¹	9.7 km ⁻¹	9.1 km ⁻¹

houses, shops, farm sheds and campsites). From these data, the density of buildings per km of road was calculated. Using the Google Maps distance calculator, the road distances of each habitat type (primarily dense forest, open clearings, farmland and housing) beside the road for each of the six sections were measured (Table 1).

Data analysis

Exploratory analyses indicated that the quail count data had a Poisson distribution and were over-dispersed, therefore the data were analysed using a generalised linear model (GLM) with a quasi-poisson family and log link. The analysis was completed using R (version 3.4.1; R Core Team 2016). The model included all predictor variables of interest (Appendix S1):

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glm(Quail Counts ~ Road section + Year + Vehicle traffic intensity + Time period + Season + Precipitation, family=quasipoisson(link="log"), data=Quail) (1)
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Year was analysed as a continuous predictor variable; the other variables were categorical predictors.

Only two-way interactions that made good biological sense were initially considered, rather than all possible interactions. Further, some combinations of predictor variable levels were missing (e.g. surveys were not conducted during winter at high vehicle traffic), and therefore could not be tested. Thus, the interaction between rainfall and season was the only interaction initially included in the candidate models. However, collinearity checks showed this interaction term was highly

collinear (variance inflation factor (VIF) > 40); therefore it was not retained in the model. All factors in the model had VIF < 2. Residuals were checked and significant results plotted.

The key assumption made in the analysis is that quail counts from one road section were independent from those made in other sections.

Results

A total of 2557 quail count surveys were conducted between 2010 and 2019 (Appendix S1). During this period, California quail were observed along all road sections between Manaroa and Havelock or Picton, throughout the day, and during all four seasons. On average, 1.7 quail (SE 0.076) were counted per road section survey. Quail were observed in 35.5% of surveys. The highest average quail count of 6.9 occurred in 2010 and the lowest of 0.53 in 2018.

The McFadden's pseudo R² value (McFadden 1974) for the GLM model was 35.8%, indicating a relatively good fit to the data. Mean California quail counts per survey were significantly related to the following predictors: road section, time period, season, vehicle traffic intensity, and year (Table 2).

Quail counts decreased significantly over the 10-year period from 2010 to 2019 (using year as a continuous predictor; estimate = -0.21, SE = 0.015, p < 0.001; Fig. 2). After the high mean counts in 2010, numbers generally decreased further between 2011 and 2019 (Fig. 2).

Table 2. Summary of Generalised Linear Model of relationships between mean California quail counts and time period, road section, year, vehicle traffic intensity, season and precipitation predictor variables. The degrees of freedom, F value and p value are included. * represents a statistically significant effect (p < 0.05).

Predictor variable	Degrees of freedom	F value	p value
Time period	2	77.4	< 0.001*
Road section	5	44.7	< 0.001*
Year	1	229.7	< 0.001*
Vehicle traffic intensity	2	13.6	< 0.001*
Season	3	43.6	< 0.001*
Precipitation	1	3.0	0.083

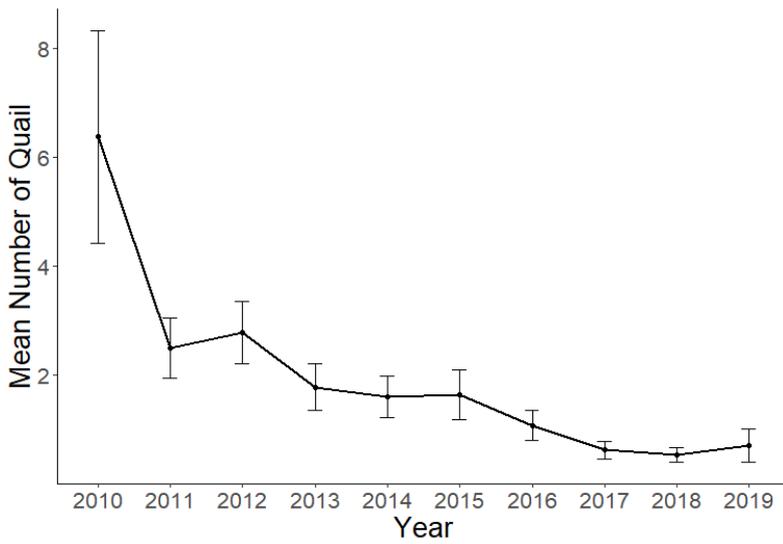


Figure 2. Annual mean California quail counts per survey across 10 years between October 2010 and March 2019. Bars represent 95% confidence intervals.

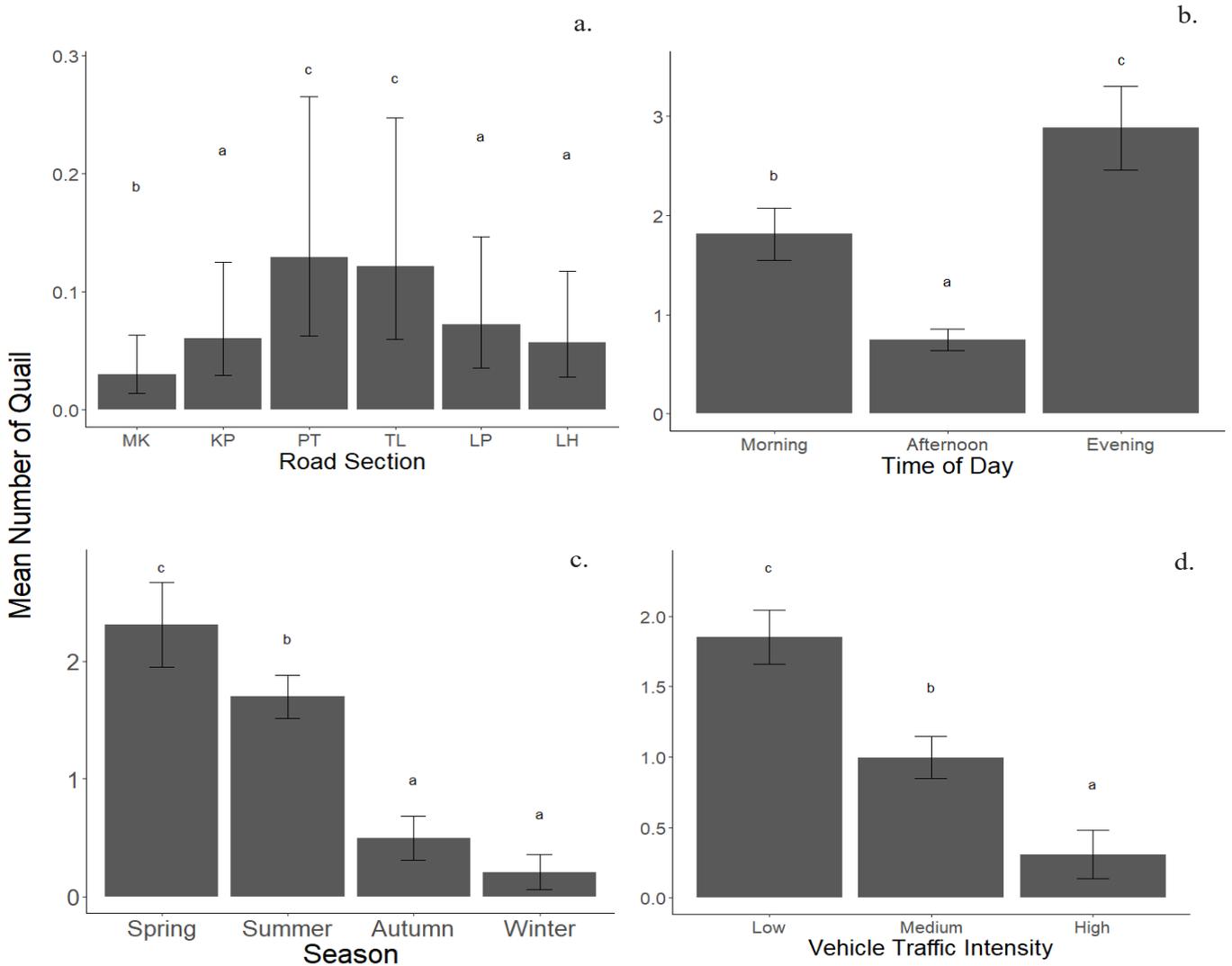


Figure 3. Mean California quail counts on six road sections between Manaroa and Picton or Havelock (a), for the three time periods (b), in four seasons (c), and at different vehicle traffic intensities (d). Manaroa to Kenepuru Head = MK, Kenepuru Head to Portage = KP, Portage to Te Mahia = PT, Te Mahia to Linkwater = TL, Linkwater to Picton = LP, and Linkwater to Havelock = LH. Morning = sunrise–1200, afternoon = 1201–1700 pm, and evening = 1701–sunset. Low vehicle traffic = 0–10 vehicles, medium = 11–30 vehicles and high > 30 vehicles. Winter quail counts were recorded only during 2017, 2018, and 2019. Figure 3a. uses the adjusted mean number of quail. Bars represent 95% confidence intervals.

For all years combined, the highest mean counts were obtained from section PT and TL, and mean counts were lowest in section MK (Fig. 3a; see Appendix S2 for detailed pair-wise post-hoc test results).

Quail counts in the morning, afternoon and evening all differed significantly from one another (see post-hoc tests in Appendix S3), with the highest mean count occurring during the evening (1700 hrs until sunset) and the lowest counts during the afternoon (Fig. 3b). Quail counts were highest in spring, intermediate in summer, and lowest in autumn and winter (Fig. 3c). See Appendix S4 for season post-hoc test results.

The intensity of vehicle traffic during surveys affected the number of quail counted. The greatest mean counts were recorded during low traffic intensity, intermediate during medium intensity, and the lowest during high traffic intensity (Fig. 3d; see Appendix S5 for post-hoc test results).

Broods were seen every year, during a total of 447 surveys. Broods were evident between November and April, but most were seen between December and February. Recently hatched broods were observed almost all when broods were evident. The months when broods and recently-hatched broods were observed did not change substantially over the ten-year study period (Table 3).

Discussion

Due to the opportunistic nature of our data collection, interpretations of our findings are limited primarily to the road sections surveyed and can only be extrapolated tentatively to the wider Marlborough Sounds area. Our results confirm that California quail are frequently observed in roadside habitats within the study area. This is likely due to the patches of open habitat that roadsides provide, which provide nesting sites (Leopold 1985), and also potential easy access to food resources. Several potential reasons for the observed quail population decline between 2010 and 2019 will be discussed below. Further, in our study the highest quail numbers were seen during times of low traffic intensity (0–10 vehicles), in the evening (1700 hrs until sunset), and during spring. This information may be useful to bird spotters or recreational hunters to maximise their chances of finding the birds.

Quail abundance patterns from 2010–2019

To our knowledge, this study represents only the second

multi-year data set on California quail populations in New Zealand. Bell's (2015) study in the fenced Zealandia wildlife sanctuary found year had no significant effect on quail counts (heard or seen), whereas in our study, quail counts decreased significantly across the ten-year observation period. Possible drivers behind this decline are forest regeneration leading to a loss of suitable quail habitat, and perhaps also an increase in predation pressure.

Forest regeneration

The ongoing regeneration of native forest along several of the studied road sections, in particular MK (Eade 2011), may have contributed to the observed decline in mean annual quail counts, by reducing the availability of the semi-open habitat preferred by quail. Beech and podocarp forest have historically dominated the native forest in the Sounds district of North Marlborough (Walls & Eade 2009; Avis 2019), and today the area consists of slowly expanding remnants of this native forest following mass clearances. Large-scale agricultural practices, in particular sheep farming and forestry, developed around Kenepuru Sound since the 1860s, resulting in significant changes to the surrounding environment including substantial deforestation and conversion of land to pasture. During 1900–1960, an estimated two thirds of 1480 km² of native bush was removed and burnt to make space for pasture (Handley et al. 2017). Forest regenerating during 2010–2019 has been primarily k nuka (*Kunzea ericoides*), m nuka (*Leptospermum scoparium*), tauhinu (*Ozothamnus leptophyllus*), and several broadleaved species (Eade 2011; RG Powlesland, pers. comm.).

Habitat availability

With the loss of semi-open habitat in mind, as expected, the road section undergoing the most forest regeneration (MK; Eade 2011) had the lowest mean quail count (Fig. 2; Appendix S2). In addition, most open country in the MK section is grazed pasture. Although California quail prefer semi-open habitat and inhabit agricultural land, adequate cover is essential and intensive farmland is avoided (Emlen 1939; Williams 1952). Hence, neither densely forested nor open habitat may be ideal for California quail populations in the long-term.

Quail counts in LH did not differ significantly from either KP or LP. This similarity between the LP and LH sections can most likely be attributed to the proportion of suitable quail habitat in both sections, with the highest proportions (42%

Table 3. Timing of California quail brood detection observed along the road between Manaroa and Picton or Havelock each year, including the months when surveys were carried out, the number of surveys, and the months when broods and recently-hatched broods were seen.

Year	Timing of surveys	Number of surveys	Broods evident	Recently-hatched broods
2010–2011	November–March	44	December–March	December–February
2011–2012	August–May	51	November–April	November–February
2012–2013	September–March	55	December–February	December–January
2013–2014	September–March	57	November–February	November–February
2014–2015	September–March	37	December–January	December
2015–2016	September–March	56	December–March	December–February
2016–2017	September–March	44	December–February	Unknown
2017–2018	September–March	53	December–March	December–March
2018–2019	September–March	50	December–February	Unknown

and 66%) of road being surrounded mainly by farmland and housing, the latter quite dense, especially close to Havelock (population 588; Statistics NZ 2018) and Picton (population 4730; Statistics NZ 2020). Some residential areas may provide more quail habitat in terms of clearings (lawns, gardens) surrounding the buildings. However, we suspect the relatively high density of buildings in LP and LH may not provide adequate cover to support high numbers of quail. KP likely provides a similar proportion of suitable quail habitat despite the vastly different roadside environment, with 100% of the road surrounded primarily by dense native forest and less than half the number of buildings. It is possible that the lack of clearings in this section is having a similar influence on quail counts as the low proportion of suitable habitat has on counts in the LH and LP sections.

The PT and TL sections had the highest mean quail counts of the six road sections, despite the fact that the roadsides consist of entirely (PT) or primarily (TL) regenerating native bush (like KP). However, our habitat analysis identified that PT has 2–15 times more buildings along the roadside than MK and KP (densely forested roadsides with low mean quail counts). In addition, the buildings in PT (unlike those in LP and LH) are relatively sparsely spaced and may therefore provide more suitable quail habitat and potentially more opportunities for finding food (primarily seeds, leaves, shoots, berries and insects; Crispens et al. 1960) than other road sections. The high mean quail counts recorded in the TL section on the other hand, may be driven by the cover that patches of regenerating forest can provide, in addition to the suitable habitat and foraging opportunities provided by open farmland and a sparsely populated residential area.

A key assumption of our study was that the quail counts in different road sections were independent. California quail can travel up to 1.6 km a day, and feed within 1–8 ha (up to 0.08 km²) around the nest site (Emlen 1939). Therefore, there is the potential for some individuals to travel between road sections, which would violate our assumption. However, as the road sections were at least 8.9 km long, seasonal and daily movement of individuals was unlikely to have greatly influenced the observed trends in our study.

Predation pressure

Regeneration of native forest could also have increased the risk of predation by some introduced mammals. Many predatory native and exotic animal species are present within the North Marlborough region (Walls & Eade 2009). These include three native birds: weka (*Gallirallus australis*), known to prey on quail chicks (P Todd, formerly Department of Conservation, pers. comm.), swamp harrier (*Circus approximans*) (Williams 1952), and New Zealand falcon (*Falco novaeseelandiae*) (Kross et al. 2013). Based on their known habitat preferences and distributions across New Zealand, a wide range of introduced mammalian predators are also likely to be present throughout the study region. These mammals include feral cats (*Felis catus*; Gillies & van Heezik 2021), stoats (*Mustela erminea*) and ferrets (*M. putorius furo*) (King et al. 2021), European hedgehogs (*Erinaceus europaeus*; Jones 2021), brushtail possums (*Trichosurus vulpecula*; Cowan & Glen 2021), Norway rats (*Rattus norvegicus*), ship rats (*R. rattus*), and house mice (*Mus musculus*; Wilmshurst et al. 2021).

As a ground-nesting species and with chicks unable to fly for the first ten days (Heather & Robertson 2015), the California quail is particularly vulnerable to egg and chick predation by various species, especially by cats, mustelids,

and hedgehogs (Williams 1952), and also by the above avian predators (P Todd, formerly Department of Conservation, pers. comm.; Williams 1952; Kross et al. 2013). Although there is no published evidence of increased predator abundance from 2010 to 2019 in our study area, possums, ship rats, mice and stoats often inhabit forested areas in considerable numbers (Elliott & Kemp 2016; King & Forsyth 2021). Therefore, as the native forests regenerate within the Sounds district, including in three of the six road sections surveyed in our study (MK, KP, and PT), this regeneration could lead to shifts in the composition and densities of the suite of mammalian predator species present, and these shifts might contribute to the observed decline in the quail population studied. The increasing density of vegetation may also enable greater hunting success by some predators.

Additional potential causes for the declining quail numbers from 2010–2019 could include disease, degradation of food resources or food quality, or a reduction in quail breeding success (which can be reduced, enhanced or delayed by climatic factors, in particular rainfall; Francis 1970). Finally, hunting of quail by people in the Marlborough Sounds is not common (RG Powlesland, pers. obs.), so it is unlikely the decline is due to unsustainable hunting. Clearly, further research is required to identify the causes of the decline.

Diurnal and seasonal abundance patterns

As strictly diurnal feeders, most of a California quail's diurnal activity involves foraging. In another New Zealand study, California quail in the Kaingaroa State Forest exhibited a bimodal feeding pattern, peaking in mid-morning and evening from mid-summer to early autumn, but with relatively consistent feeding effort throughout the day from late autumn to early summer (Caithness et al. 1989). This seasonal change in daily feeding pattern is thought to be due to opportunistic feeding behaviour during the breeding season, and shorter day lengths during winter. Given the influence of season on California quail activity, a bias in diurnal activity towards a bimodal pattern could be expected in our study, as more surveys were conducted in summer (1113) compared to in autumn (421), winter (193), and spring (830). Indeed, the pattern of quail abundance from our counts in the Marlborough Sounds does show a bimodal pattern of activity, with peaks in the morning and evening. Our particularly high evening counts may have also been the result of fewer vehicles on the roads at that time, because quail counts decreased steadily as vehicle traffic increased.

The seasonal patterns seen, with mean quail counts highest in spring followed by summer and lowest autumn and winter, were probably linked to the breeding season, as hatching in California quail in Central Otago and in the central North Island has been previously recorded between November and February (late spring to late summer) (Williams 1959; Williams 1967). We observed a similar breeding season, with recently hatched broods seen between November and March each year, but primarily during summer (December to February; Table 3). In addition, seasonal growth may lead to increased abundance of preferred food resources (such as seeds, shoots, leaves and berries along roadsides in summer).

Interestingly, Bell (2015) found no statistically significant relationship between sampling season and California quail counts in the Zealandia wildlife sanctuary between 2011 and 2015, even though counts tended to be higher in summer (3.8 ± 0.8 SE) than in winter (1.7 ± 0.6), spring (1.6 ± 0.5) or autumn (1.1 ± 0.5). Assuming that Bell's interpretation

of no seasonal pattern in Zealandia is robust, this apparent difference from our findings might be explained by the different climate in Wellington, restriction of birds' seasonal movements by Zealandia's fence, or effects of mammalian predator exclusion. In addition, Bell's surveys were always conducted at the same time of day, whereas time of day (time period) varied in our study. The significant seasonal effect in our study could therefore have been influenced by diurnal differences in quail detection across surveys. In our study, most surveys were conducted in the morning during spring and winter and in the evening during autumn and summer. Detectability is expected to be lowest during periods of high traffic volume (most common during afternoon surveys) and sub-optimal foraging conditions, when birds are likely to be hiding or resting and therefore present along the roadside but not detectable. Our results suggest that detectability was low in the afternoon, i.e. between 1201 and 1700. Diurnal differences in detectability are also likely to change between seasons as the air temperature and number of sunlight hours differ.

Our study provides evidence of a significant decline in the average number of California quail counted alongside roads from Manaroa to Havelock and Picton between 2010 and 2019. This decline gives cause for concern about the long-term stability and viability of these quail populations, but the cause of the decline is currently uncertain. Although, as an introduced bird, California quail are of no immediate interest to regional conservation managers, we believe there is a need to identify the drivers behind the observed population decline. Improving our understanding of changes in predator abundance within the Marlborough region over the last decade is an important first step for future studies. If the observed quail population decline turned out to be driven by increased mortality due to rising predation pressure, a similar decline might be reflected in native open-habitat species of much greater value to the region. For example, the pipit (*Anthus novaeseelandiae*) is another ground-nesting bird known to occupy semi-open habitat and be highly vulnerable to predation by introduced predators (O'Donnell et al. 2015; Beauchamp 2019), similar to the California quail.

Finally, to maximise detection probability, we recommend that future surveys of California quail along roadsides are conducted during their peak activity periods (morning or evening) and, if possible, in areas with low vehicle traffic intensity.

Acknowledgements

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Data and Code Availability

The data and code from this article are not openly available online.

Author Contributions

RP conceived the idea, developed the methodology and collected the data while ER, SG and CM conducted the data analysis. ER wrote the manuscript alongside editorial contributions from SG, CM and RP.

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Supplementary material

Additional supporting information may be found in the supplementary material file for this article:

Appendix S1. A summary and description of the levels within the road section, season, time period, vehicle traffic intensity, precipitation variables, and an overview of the number of quail surveys undertaken each year in each road section, season, time period, and precipitation status.

Appendix S2. Summary of general linear hypothesis tests (pair-wise post-hoc tests) run in R on the predictor variable 'Section' to determine which individual road sections differed significantly in their quail counts.

Appendix S3. Summary of general linear hypothesis tests (pair-wise post-hoc tests) run in R on the predictor variable 'Time Period' to determine which individual time periods differed significantly in their quail counts.

Appendix S4. Summary of general linear hypothesis tests (pair-wise post-hoc tests) run in R on the predictor variable 'Season' to determine which individual seasons differed significantly in their quail counts.

Appendix S5. Summary of general linear hypothesis tests (pair-wise post-hoc tests) run in R on the predictor variable 'Vehicle Traffic' to determine which individual traffic categories differed significantly in their quail counts.

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