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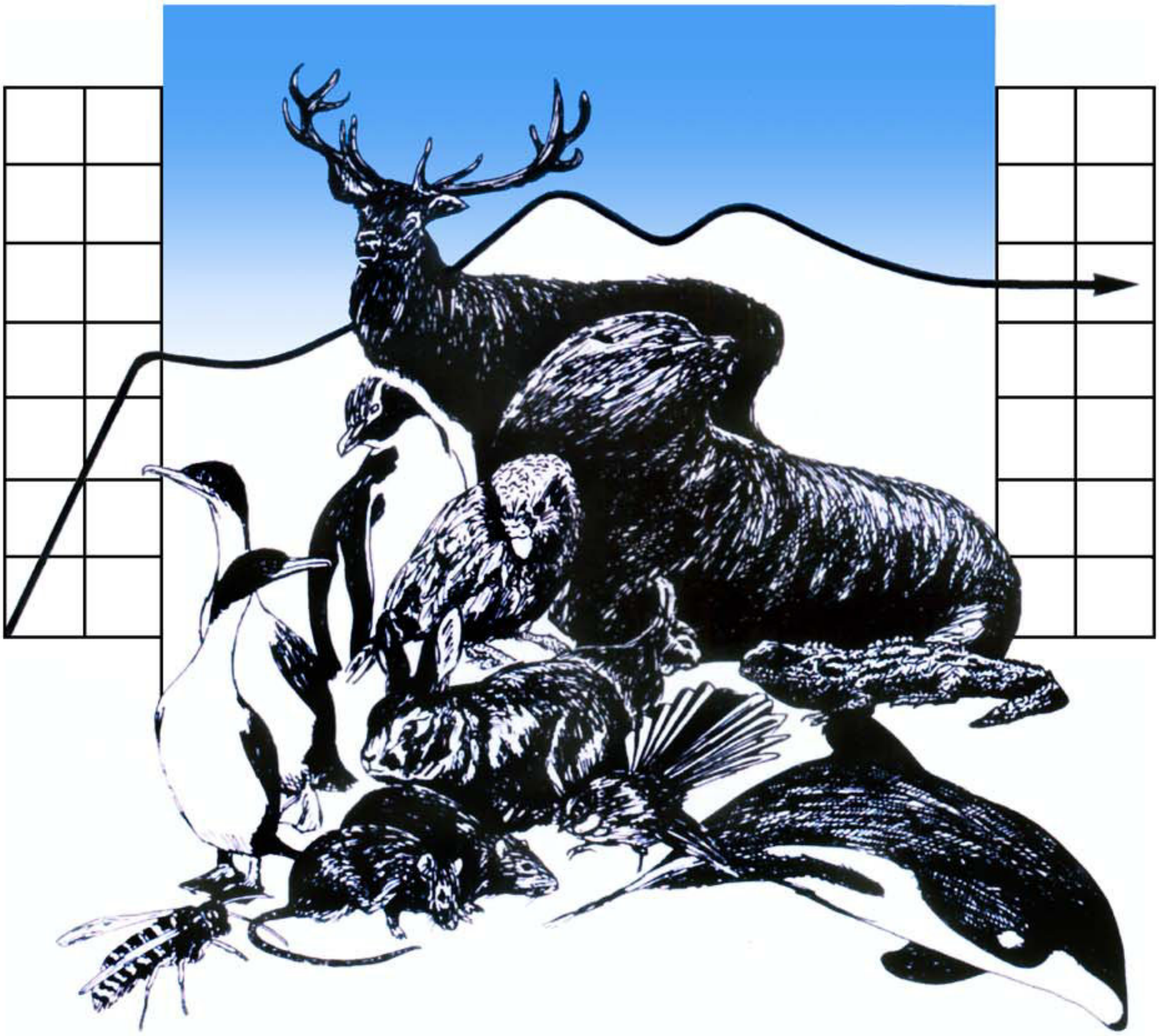

WILDLIFE MANAGEMENT

Influence of population density on breeding parameters of Stewart Island robins on Ulva Island

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Influence of population density on breeding parameters of Stewart Island robins on Ulva Island

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Abstract

Species reintroductions are becoming an increasingly common aspect of conservation efforts. As more reintroduced populations are successfully established, they may be utilised as a source population for future translocations. Understanding how populations change with density is important for estimating population viability, which can be used to assess the suitability of the population as a source for translocations, and the ideal sustainable rate of harvest.

This research was carried out to investigate if nest and territory density had a clear influence on breeding parameters of the Stewart Island robin (*Petroica australis rakiura*, Māori name = toutouwai) on Ulva Island, New Zealand. This reintroduced population is thought to be close to carrying capacity and is showing signs of density dependent processes, but no research has been carried out to quantify the effect of density on reproductive parameters.

Distance to the nearest nest and the number of neighbouring territories that overlapped with a given robin's territory were used as two separate density measures, and the response variable was the success of first clutch nests and their lay date. Data from 442 adult robins was collected during the 2012/13 breeding season on Ulva Island.

Neither an increase in territory density nor distance to the nearest nest resulted in significant changes to nesting success or date of first lay. This may be due to other factors, such as habitat quality or food availability, being more important than density when territories are established. Indeed, robin territories and nests appeared to be more concentrated around coastal areas, which have been shown to be preferable habitats, even at low robin densities. Further research on reproductive success in different habitat types may clarify if this is the case.

Key words: Density dependence; carrying capacity; reintroductions; *Petroica australis rakiura;* Ulva Island.

Introduction

Species reintroductions are beginning to play a more common role in conservation efforts, due to a range of recent advances enabling higher likelihoods of successful establishment (Armstrong & Seddon 2008; Jamieson 2010). Improved poison bait and its deployment, along with development of effective predator exclusion fences, enable better protection of reintroduction sites by removing predators and limiting reinvasion events (Towns & Broome 2003; Speedy et al. 2007). As well as reducing predation impacts on reintroduced species, this also allows for habitat regeneration through reduced browsing by some predators. In turn, a more pristine habitat with greater food availability is beneficial for reintroduced birds, as it reduces the chances of dispersal in search of food and can increase reproductive success (Molles et al. 2008; Robb et al. 2008).

Reintroductions to island or predator-proof fenced sites are typically carried out with a small number of individuals (Armstrong et al. 2004; Jamieson 2010). This can be due to small release sites with limited carrying capacities (Jamieson 2010), or because the logistics of transporting large numbers of animals to or from an island can be difficult. A small initial founder population provides an opportunity to study the reintroduced population's dynamics over time, such as density dependence (Armstrong et al. 2004).

From a metapopulation conservation point of view, the harvest rate of a source population is an important question (Armstrong & Seddon 2008). Determining the ideal sustainable rate of harvest require knowledge of the populations' increase in survival and/or reproduction following a reduction in density (Armstrong & Seddon 2008). Where a reintroduction is successful and the population is at a healthy level, it can act as a source population for future translocations and reintroductions without being at risk of declining over the long term. Further monitoring of a harvested source population can also provide insight to sensible harvesting regimes, and thus guide future translocations (Armstrong et al. 2004). This allows for adaptive management, as information gained from each harvest increases the confidence in determining the optimum harvest rate and quantity (Armstrong & Seddon 2008). Knowing when a population is at carrying capacity and influenced by density dependent processes is also important for justifying harvesting from a source population which has economic and sentimental value to stakeholders; if they can be shown that the population can quickly recover from harvests then there may be less opposal to planned removals.

New Zealand has numerous populations of bird species reintroduced to predator free offshore islands (Armstrong et al. 2002; Armstrong et al. 2004). As of March 2002, there have been 188 documented reintroductions of native animals to New Zealand islands (Armstrong et al. 2002). This number has undoubtedly increased, but by how much is not clear. Reintroduced bird populations on predator free islands, such as Ulva Island, located in Paterson Inlet of Stewart Island, have begun to be harvested for reintroduction to mainland sites where predator numbers are controlled (e.g. Masuda & Jamieson 2012). Harvesting of source populations is likely to increase, and may continue to do so if mainland sites do not establish and become 'sinks' (Armstrong et al. 2004). In this case, knowledge of density dependent processes on source populations is vital for ensuring they can be sustainably harvested without risking their decline along with losses from translocated individuals.

In this report I assess the influence of density on reproductive parameters of the Stewart Island Robin on Ulva Island, New Zealand, using data collected from the 2012/2013 breeding season. This will be done by evaluating the effect of distance to the nearest neighbouring robin nest, and the number of territories overlapping with a pairs territory, on the lay date and nesting success of first clutches. Other studies on passerines have observed lower reproductive success at higher densities (e.g. Armstrong et al. 2004). Additionally, the Ulva Island robin population is currently showing signs of density dependent pressure (Department of Conservation 2012; see '*Study site and population*'). Therefore, I predict that increased number of overlapping robin territories and distance to the nearest neighbouring nests will result in later lay dates and lower success rates of first clutches.

Materials and Methods

Species and study site

Stewart Island robins, a subspecies of South Island robins, were once widespread on Stewart Island, but have become confined to areas where densities of rats and feral cats are low relative to other areas on the island (Michel et al. 2010). They are territorial all year around, and typically rear two broods per season, although early nesters may rear a third brood (Powlesland 1997).

Ulva Island (46°55.9' S, 168°07.7' E, Paterson Inlet, Stewart Island, New Zealand) is an 'open sanctuary', managed by the Department of Conservation (Michel et al. 2010; Department of Conservation 2012). The 256 hectare island is predominantly covered by dense podocarp forest of *Dacrydium cupressinum* (rimu), *Podocarpus hallii* (Hall's tōtara) and *Prumnopitys ferruginea* (miro; Michel et al. 2010). The angiosperms *Metrosideros umbellata* (southern rātā), *Griselinia littoralis* (broadleaf), *Weinmannia racemosa* (kāmahi) and *Dicksonia squarrosa* (tree fern) make up the surrounding coastal forest, and a narrow fringe of coastal scrub consisting mainly of *Olearia colensoi* (leatherwood), *Brachyglottis rotundifolia* (muttonbird scrub) and *Dracophyllum longifolium* (inaka) borders the coastline (Michel et al. 2010; Department of Conservation 2012).

Ulva Island has been free from introduced mammalian predators since 1996 (Michel et al. 2010). Between September 2000 and December 2001, 25 Stewart Island robins were translocated from Freshwater Flats on Stewart Island to Ulva Island, of which 12 survived and started breeding in 2001 (Michel et al. 2010). Their number has increased rapidly, and was near carrying capacity prior to the invasion and subsequent eradication of Norway rats (*Rattus norvegicus*) in 2011 (Department of Conservation 2012). The rat invasion and eradication led to a 31.5% decline in robin numbers, but the population has since recovered, with 220 fledglings produced the following breeding season (Department of Conservation 2012). The population is once again thought to be approaching carrying capacity, showing evidence of density dependent population pressure such as robin pairs having single clutches of nests each year (Jamieson 2010; Department of Conservation 2012).

Field sampling and data collection

442 adult robins were monitored during the 2012/13 breeding season, consisting of 171 breeding pairs, 44 non-breeding pairs, and 12 unpaired individuals (Ian Jamieson, unpublished data). These numbers were not solid throughout the breeding season due to deaths, divorces, and discovery of new birds and pairings.

Nearly all of the Ulva Island robin population are individually colour banded, allowing identification of each individual bird and pair, and therefore accurate data collection on where individuals and pairs are known to have a territory. Ulva Island is crossed with parallel tracks running approximately magnetic north-south 100 metres apart, and approximately 100 metres along each line is an alphabetically labelled bait station (see figure 1). This location system allowed us to easily record the location of specific robins in relation to the nearest bait station. When a pair appeared to be defending an area which was not previously known to be in their territory this location was also recorded.

Observations were carried out during one breeding season, from early October 2012 to early January 2013. Sweeps of the island were carried out from east to west, sequentially checking all known robin territories and recording locations of any nests, along with numbers of eggs, chicks and fledglings from each pair. GPS coordinates of all nests were recorded, with an estimated positional error (EPE) of less than 7m where possible. The same data was collected for any new pairs found throughout the breeding season. Each territory was checked approximately every five days. While data on all pairs was collected during the field season, only first clutches were used for this study.

Statistical analyses

Distance to nearest neighbour was calculated for each breeding pair, using the GPS location for the first nest established in the breeding season. Distances were determined using Geospatial Modelling Environment (Version 0.7.2.0) and ESRI® ArcMap ™10.0 (Service Pack 4, build 4000). Nests were considered to be successful if at least one chick fledged.

Territory density estimation

For each robin pair, territory density was calculated by counting the number of other robin pairs that were also known to be found at at least one bait station in their territory. This gave the number of unique neighbouring territories that overlapped at least one bait station within a given territory. Information on robin pair locations was based on known locations from the field season, accurate to the end of December 2012.

Lay date estimation

Lay date was estimated by: (1) If the age of chicks could be determined, then the lay date was back-calculated from this age, assuming eggs are incubated for 18 days, and nestlings fledge 21 days after hatching as per Powlesland (1997). (2) If chick age is not known, then the middle date between when the pair was last known to not be incubating, and when the pair was first known to be incubating was used. The accuracy of this estimated lay date was improved by taking into account the life history stages of the young at future checks.

If there were conflicting estimates of lay date when both methods were available then back calculating from known chick ages was given priority, as it is possible that pairs could be incorrectly recorded as not breeding, when in fact they were. Confidence in field observations was taken into account when choosing the intermediate lay date if the day was not clear (e.g. between 12th or 13th of a month). Once the lay dates were calculated, the date of the first lay event of the 2012/13 breeding season was determined. Lay dates of subsequent nests were converted to the number of days since the first lay event of the breeding season.

Two methods for quantifying robin density were used to investigate robin nesting success and their estimated lay date. Influence of territory density on nesting success and first lay date was investigated by using generalised linear models to carry out linear and logistic regressions, respectively. Similarly, influence of distance to the nearest neighbouring nest on nesting success was investigated by using generalised linear models to carry out a logistic regression. A linear model was used to carry out regression to investigate the influence of distance to nearest neighbour on first clutch lay date. Effect statistics for these differences were calculated, with a Cohen's d value of 0.2

considered a weak effect, 0.5 medium and 0.8 strong as per Cohen (1992). All statistical and graphical analyses were carried out using R, version 2.15.2 (R Core Team 2012). Identical data points for first lay date graphical analyses were offset using the *jitter* function in R to aid interpretation.

Results

Data from 168 first clutch nests were collected, although at the end of the field season two of these were still active so their outcome was unknown; these nests were therefore not included in the analyses on nesting success. Figure 2 shows a map of Ulva Island overlaid with the GPS locations for all first clutch nests from the 2012/13 breeding season (N = 168). Figure 2 shows the nest locations, which do not appear to be uniformly distributed across Ulva Island; there is clustering of nests along the south-western coast, and also on the north-western coast. Nest density also appears to be higher near the eastern end of the island compared to the interior. Territory density also appeared to show a similar spatial trend (Leon Berard, pers. obs.).

The mean distance to the closest neighbouring nest was 82.13 metres (SD 30.34, table 1). The mean number of overlapping neighbouring robin territories was 2.63 (SD 1.66, table 2). Mean nesting success of first clutch nests was 50% (SD 0.50), and mean lay date of first clutch was 44.32 (SD 18.72) days since the first lay event of the 2012/13 breeding season (28th October 2012, tables 1 and 2). First lay date of the season was the 14th of September 2012.

Territory density and distance to the nearest neighbouring nest did not have a significant impact on either nesting success or first lay date ($P > 0.05$, see tables 1 and 2). Probability of successful nesting appeared to increase slightly in areas with more overlapping territories, although the relationship was weak (Figure 3, table 1, $P = 0.741$, $d = 0.052$, $n = 166$). First lay date appeared to be slightly later in higher density territories, although again this was a weak and insignificant trend (Figure 4, table 1, $P = 0.273$, $d = 0.171$, $n = 168$).

Probability of successful nesting decreased insignificantly as distance to the nearest neighbouring nest increased (Figure 5, table 2, $P = 0.276$, $d = 0.171$, $n = 166$). Finally, a larger distance to the nearest neighbouring nest appeared to result in a marginally earlier date of first lay, but this was also insignificant (Figure 6, table 2, $P = 0.563$, $d = 0.09$, $n = 168$).

Discussion

Relationships between density and reproductive parameters were too insignificant to infer that territory density and distance to the nearest neighbouring nests had an influence on lay date and success of the Stewart Island robins' first clutches. It is not surprising that first lay date and hatching success responded similarly to different measures of density. If a territory is in a high density area, then any nests in the high density area are likely to be close to neighbouring nests. However, the observed slight decrease in nesting success as distance to nearest nest increased was interesting, as a similar change in nesting success was not observed when measuring it against territory density. This may be due to the more exact measurements of distance to nearest nest; locations were calculated using GPS coordinates, while territory density was calculated using field observations over several months. This variation may also be simply due to the huge amount of variation observed in both predictor and response variables. Further comparisons of density measures would need to be carried out before making conclusions about the accuracy of these density measures. These findings contradict my hypotheses, but there are several possible causes for the observed lack of a trend.

Figure 2 indicates that nest clusters occur on Ulva Island. This, combined with the lack of clear trend in my analysis, suggests that there is another factor which influences density. In fact, my findings that nesting success is marginally higher (albeit insignificantly) for nests closer to their neighbours reinforces this. Habitat selection is influenced by availability of food and breeding sites, along with intra- and inter-specific competition (Steffens et al. 2005). Higher quality habitats also provide additional roost sites and shelter (Michel et al. 2010). It is possible that the benefits of a high quality habitat override any possible negative effect of having a territory in a high density area. Based on the concentration of territory and nest sites around coastal areas versus inland forest areas, it is unlikely that habitat selection of the robins is being influenced by interspecific competition for nesting sites and/or food resources.

Food competition

Mackintosh & Briskie (2005) investigated food competition in the South Island robin (*Petroica australis*) on Motuara Island to determine if the high robin density compared to mainland populations was responsible for the higher hatching failure in the robin population. They found that food supplements equivalent to approximately 50% of robin's daily needs had no effect on hatching success (Mackintosh & Briskie 2005). However, the Ulva Island robin population is at considerably lower densities than the Motuara Island population (1.73 robins/ha vs. ca. 5.1 robins/ha; Heber 2012), and is already considered to be near carrying capacity (Jamieson 2010; Department of

Conservation 2012). Furthermore, differences in population dynamics between the two sub-species are not known, which may explain their reproductive responses to food availability.

The high density of robins on Ulva Island could lead to food competition and food limitation, resulting in lower clutch size and fewer clutches per season (Mackintosh & Briskie 2005). To further investigate this, a study using supplementary feeding could be carried out to evaluate the influence of additional food availability on hatching success as per Mackintosh and Briskie (2005). Additionally, while food intake may not be a significant enough factor to influence hatching success, areas with high food availability and foraging habitat may still be preferred, and influence the density and distribution of robin territories.

Habitat preferences

Studies on habitat selection of the Ulva Island robin population have found that following their release, robin territories were initially established in the western coastal part of the island, and progressively settled towards the eastern end of the island but still favoured coastal areas (Steffens et al. 2005; Michel et al. 2010). This is evident in figure 2, which shows first clutch robin nests predominantly distributed around the coastline of Ulva Island. Mature podocarp forests found further inland, especially those with moss cover, were least favoured for territory establishment due to the lower food availability and foraging difficulty associated with these areas (Steffens et al. 2005; Michel et al. 2010). Additionally, tree cavities on Ulva Island are more abundant in coastal fringe areas than mature podocarp forests found further inland (Steffens et al. 2005). As robins are partial cavity nesters, this represents increased options for nesting sites, although this may not be a significant benefit as robins are highly flexible with nest choice (Michel et al. 2010).

Steffens et al. (2005) proposed two hypotheses why coastal habitat is preferred to mature forests further form the coast. Firstly, coastal scrub habitats may represent an ‘ecological trap’, where the habitat is not necessarily better quality, but is preferred due to evolutionary familiarity (Steffens et al. 2005). It can be difficult to demonstrate the existence of an ‘ecological trap’ on Ulva Island as forest composition and structure influences the invertebrate abundance and diversity (Michel et al. 2010). As such, quantifying a ‘better quality’ habitat based predominantly on invertebrate composition will invariably be confounded by the associated vegetation. However, Stewart Island robin species were once abundant in mixed podocarp–broadleaved forest types found on the mainland (Michel et al. 2010). This suggests that appeal of coastal habitats is due to the increased food and nesting availability, rather than familiarity.

The second hypothesis put forward by Steffens et al. (2005) suggests that the coastal and mature podocarp habitats represent a source and sink population dynamic. The coastal habitat is superior in terms of nesting sites, litter cover and food availability, and was colonised preferentially compared to inland podocarp forests (Steffens et al. 2005; Michel et al. 2010). As territories in these areas become denser, robins are forced to settle in the inferior sink habitats of the podocarp forests. This is a more likely explanation for the pattern of territory and nesting establishment evident on Ulva Island since the reintroduction of the robin population (Steffens et al. 2005).

Due to the large amount of data available on the Ulva Island habitat and robin population, it would be feasible to investigate how reproductive parameters such as nesting success vary in different types of habitat, while accounting for density and cohort. This would serve to quantify the reproductive benefits of establishing a territory in the preferred coastal area, and also help predict population and reproductive dynamics of future translocated populations.

Limitations

Ideally, territory density would have been quantified by estimating the calculating home ranges of each robin pair, rather than which bait stations they were known to be found at. A 95% Minimum Convex Polygon (MCP) could then be calculated as per Steffens et al. (2005), and the true number of overlapping territories could be used as a measure of density. Collecting enough location data to accurately estimate home range would not have been feasible on Ulva Island, as the workload during the field season would not have permitted recording the required amount of sighting data. To be confident that the home range was accurately estimated, incremental area analysis would have to show the estimate was stable, and too few locations would result in the home range being unlikely to be fully revealed, or to be overestimated (Kernohan 2001; de Almeida Jácomo et al. 2009). However, while the MCP method would likely result in more precise estimates of territory locations, the distinctly insignificant influence of territory density on reproductive parameters indicates that the change would likely be too small to reveal a significant trend.

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Tables and Figures

Table 1. Mean and standard deviation (SD) of breeding parameters and territory density of Stewart Island robins (*Petroica australis rakiura*) during the 2012/13 breeding season on Ulva Island, New Zealand. First lay date of the season was 14th September 2012.

	Mean	SD	N	P-value
Number of overlapping neighbouring territories	2.63	1.66	168	-
Nesting success (%)	0.50	0.50	166	0.741
First clutch lay date (days since first lay)	44.32	18.72	168	0.273

Table 2. Mean and standard deviation (SD) of breeding parameters and distance to nearest nest of Stewart Island robins (*Petroica australis rakiura*) during the 2012/13 breeding season on Ulva Island, New Zealand. First lay date of the season was 14th September 2012.

	Mean	SD	N	P-value
Distance to nearest nest (m)	82.13	30.34	168	-
Nesting success (%)	0.50	0.50	166	0.272
First clutch lay date (days since first lay)	44.32	18.72	168	0.563

Figure 1. Locations of trap lines on Ulva Island, New Zealand, which are used to navigate and record estimated Stewart Island robin (*Petroica australis rakiura*) territory locations. Circles denote bait station locations along each trap line. Trap lines and bait stations are spaced at approximate 100m intervals.

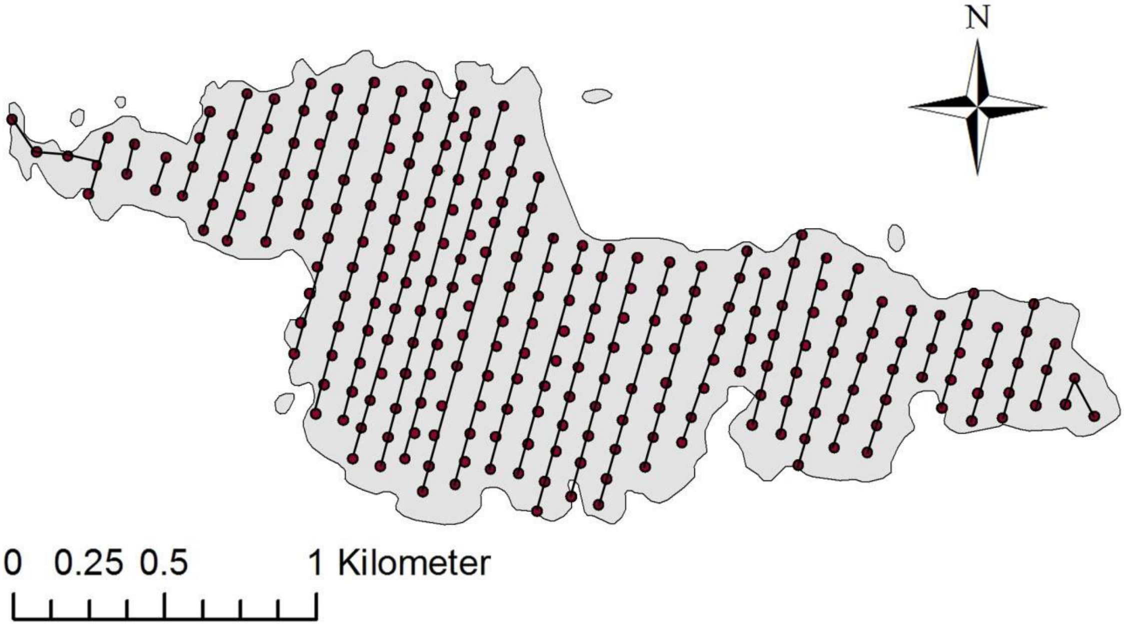

Figure 2. GPS locations of Stewart Island robin (*Petroica australis rakiura*) first clutch nests from the 2012/13 breeding season on Ulva Island, New Zealand. N = 168.

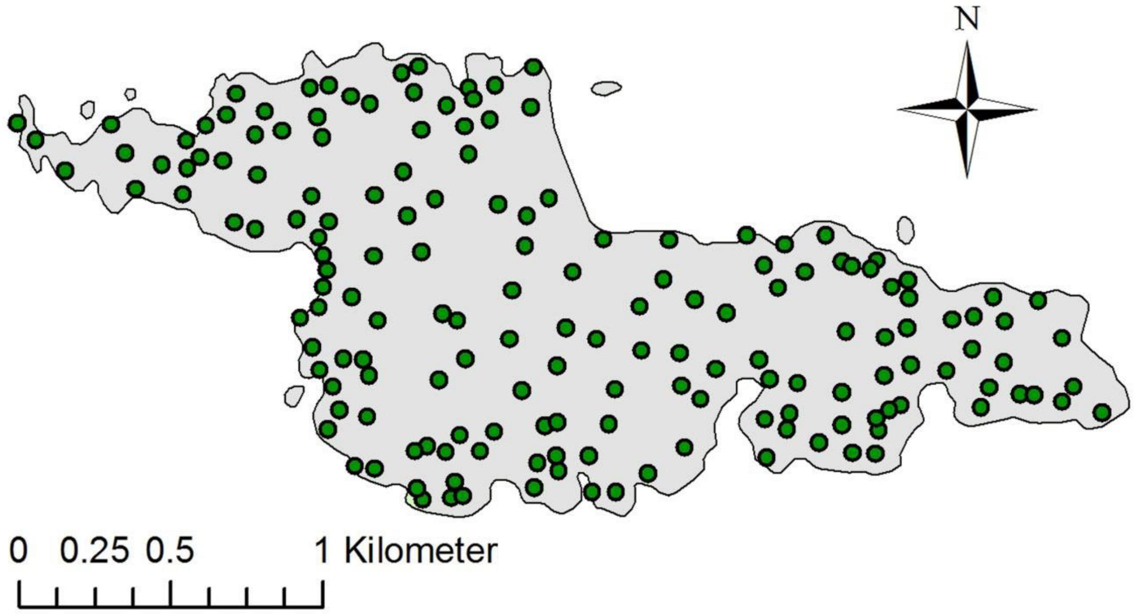

Figure 3. Relationship between territory density and the probability of Stewart Island robins (*Petroica australis rakiura*), successfully nesting during the 2012/13 breeding season on Ulva Island, New Zealand. First lay date of the season was 14th September, 2012. N = 166.

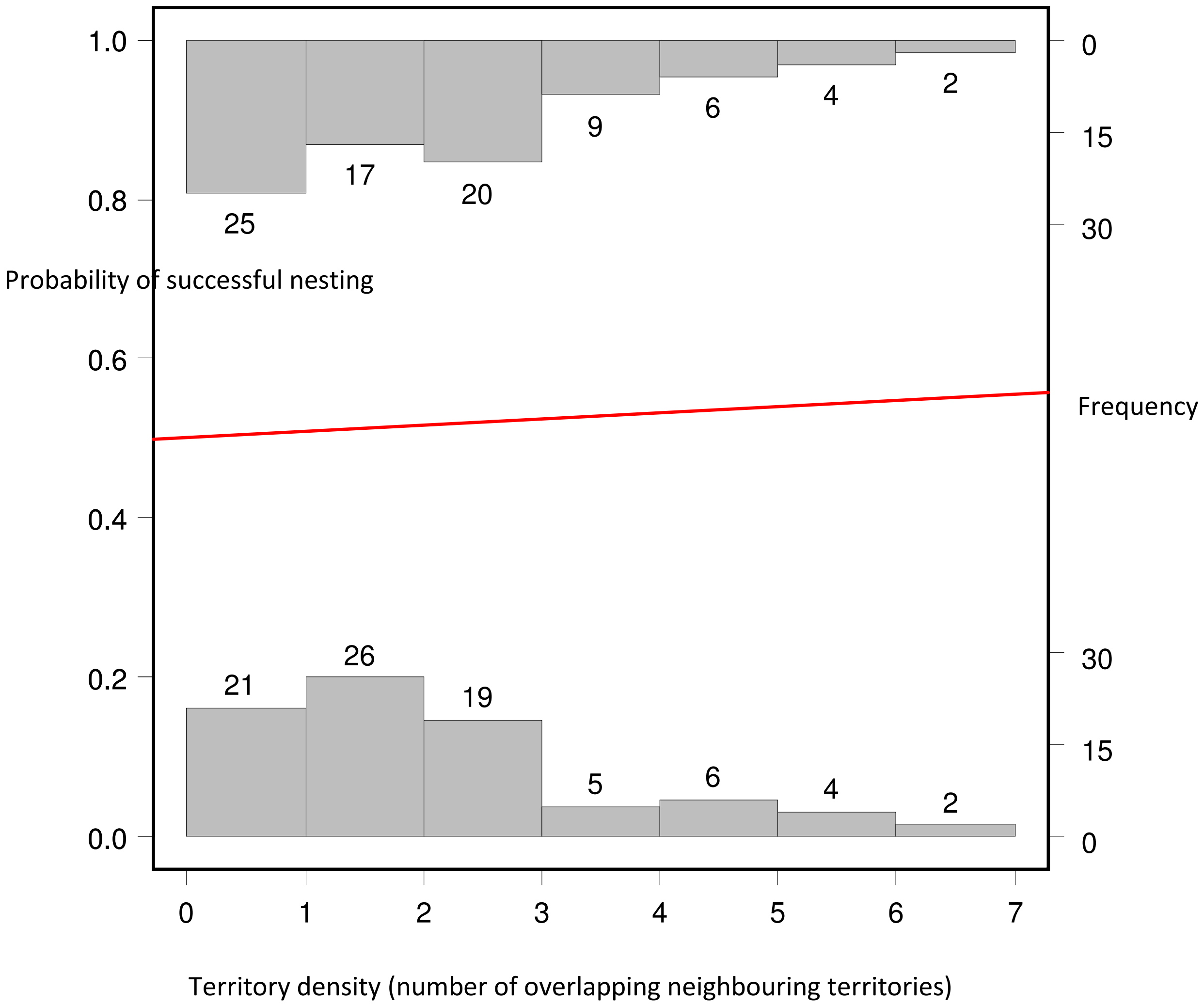

Figure 4. Relationship between territory density and first clutch lay date of Stewart Island robins (*Petroica australis rakiura*) during the 2012/13 breeding season on Ulva Island, New Zealand. First lay date of the season was 14th September, 2012. N = 168

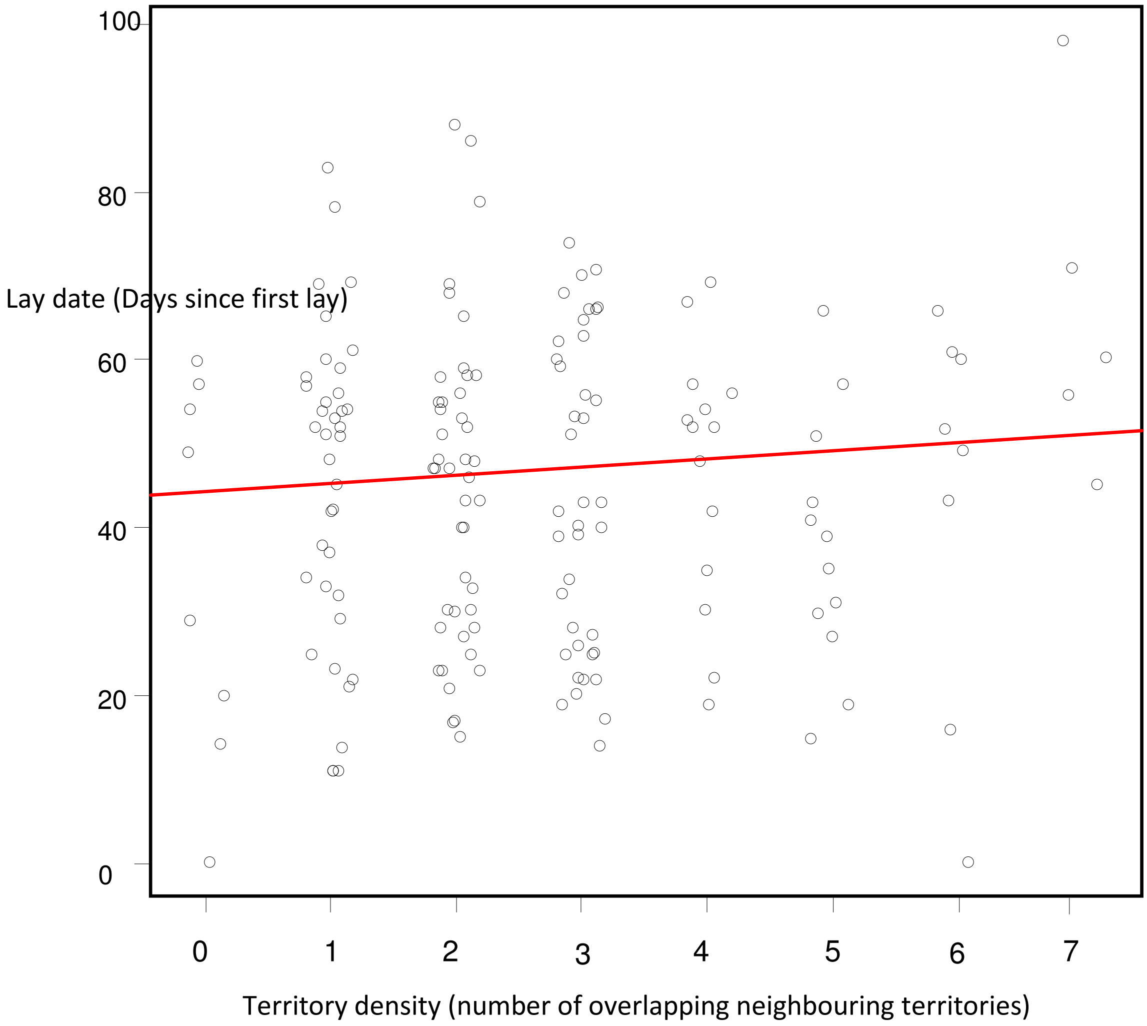

Figure 5. Relationship between distance to the nearest neighbouring nest (in metres) and probability of first clutch nesting success of the Stewart Island robin (*Petroica australis rakiura*) during the 2012/13 breeding season on Ulva Island, New Zealand. N = 166.

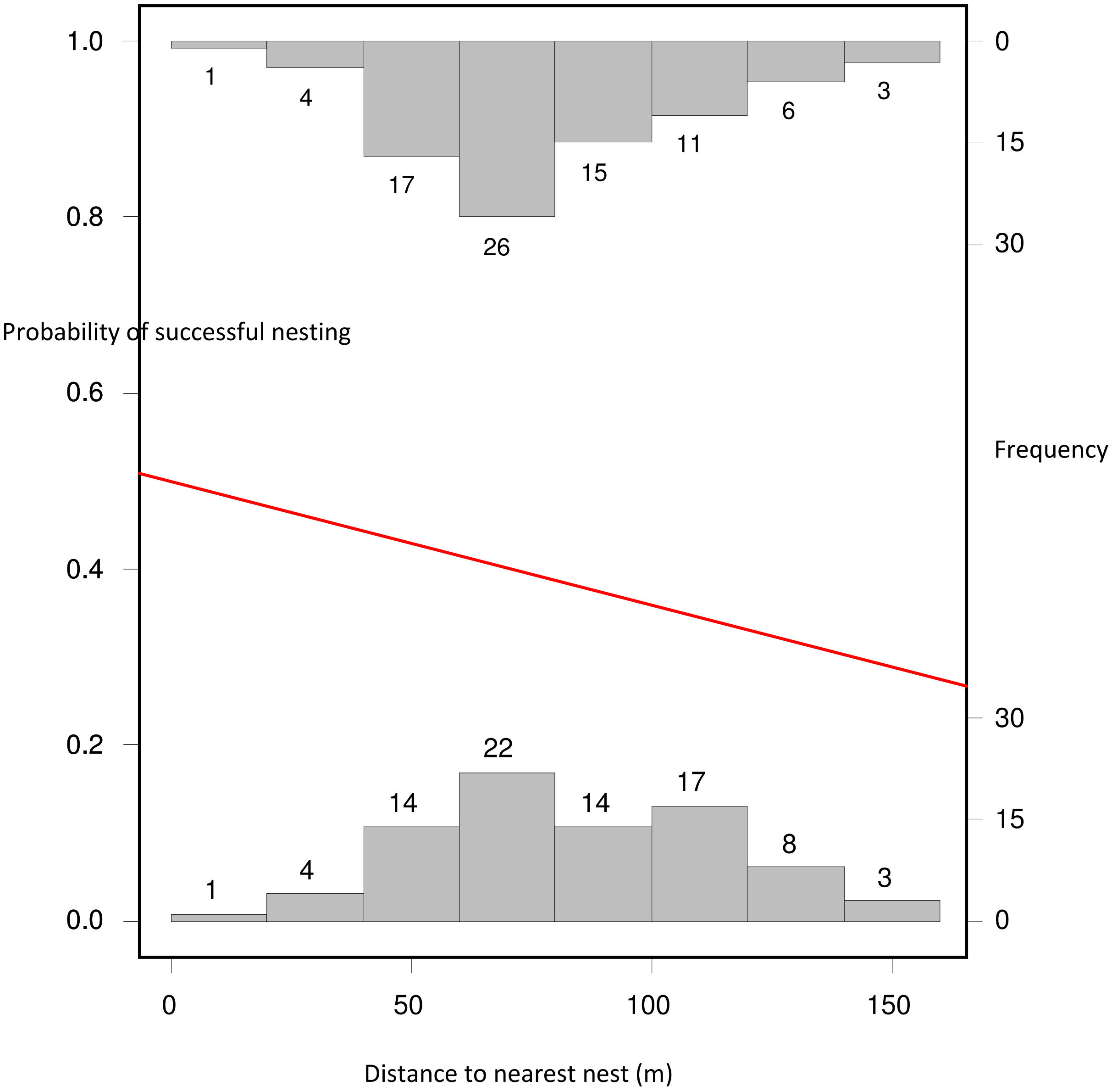

Figure 6. Relationship between distance to the nearest neighbouring nest (in metres) and first clutch lay date of Stewart Island robins (*Petroica australis rakiura*) during the 2012/13 breeding season on Ulva Island, New Zealand. First lay date of the season was 14th September, 2012. N = 168.