Birds: kiwi territory mapping

Version 1.0

This specification was prepared by Hugh Robertson in September 2018.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

Repeated mapping of the territories of kiwi in a defined area, with an associated 'roll call' of marked birds, provides a good method for determining long-term population trends. Kiwi are strongly territorial and often retain the same partner and territory year-round and from year to year. It seems that calls are used to advertise territory ownership and to maintain pair bonds.

The social structure of kiwi varies significantly between species, and even within what are currently regarded as the same species. Most kiwi species normally live as simple pairs and their young disperse from the natal territory within months of hatching (e.g. brown kiwi (*Apteryx mantelli*), little spotted kiwi (*A. owenii*) and Haast tokoeka (*A. australis* 'Haast')). Some retain their young in the natal territory for months or years, but young Rakiura tokoeka (*A. australis lawryi*) can stay in their natal territory well into adulthood and assist with territorial defence and can even assist with incubation. As a result, there can be multiple (up to 7 recorded) adults in a single territory, presumably a pair and their adult offspring.

As populations shrink, remaining territories expand, and conversely territory size shrinks as populations expand until carrying capacity of the area is reached.

The aim of each territory mapping survey is to catch, permanently mark, and radio-tag as many kiwi as possible, and then map their daytime locations and known or projected nocturnal locations from their calls and radio-telemetry signals. The locations of other birds seen or heard are also mapped.

All location records of birds (captures, sightings, projected calls, daytime radio-telemetry locations, and projected telemetry signals) are mapped for each individual, and approximate territory boundaries are drawn using the 'field worker estimate' (MacDonald et al. 1980; McLennan et al. 1987) taking into account radio-telemetry fixes and additional observations by drawing a boundary line around all locations of territory holders rather than around each individual. The boundaries are adjusted to eliminate overlap with adjacent territories and to follow natural geographical features such as streams, spurs and ridges (however, some territories can span these). It is assumed that small gaps of suitable habitat between territories are actually part of one or more neighbouring territories. Where there are few location fixes per territory, especially where there are no clear geographical features to mark territory boundaries, then the central location of each territory is mapped without attempting to delineate territory boundaries.

Despite best attempts, not all resident birds are caught or even detected during a survey period. Having birds permanently marked allows for corrections to be made to earlier maps during subsequent survey periods, assuming that resident birds did not leave the study area and then return.

The data are presented as territory maps and expressed as the change in the number of territories per year. When kiwi live in complex family groups, the change in the minimum number of adult birds can be presented separately. Other measures presented can include the correlation between call rates and population density, and changes in the ratio of adults to subadults/chicks, because this

can point to issues such as recruitment failure or recent breeding success following conservation management programmes. More complicated analyses using capture-mark-recapture and genetic techniques can be added, if required.

Assumptions

- During the survey period, adult kiwi remain in fixed, discrete and non-overlapping territories, regardless of population density.
- Most kiwi species live in simple adult pairs that share and defend the same territory, but note that some species or subspecies (most notably Rakiura tokoeka) can have multiple adult-sized birds share and defend a territory.
- Territories are continuous, with little chance of undetected birds holding a minute territory in an apparent gap between plotted territories.
- There is a reasonable chance of detecting an adult territory holder in any survey period, even if it is not caught and radio-tagged.
- Enough kiwi can be caught and radio-tagged, and enough subsequent locations are accurately plotted in a survey period, to discern the true number and approximate boundaries of occupied territories.
- Capture and handling of birds does not affect their subsequent territorial behaviour or movements.
- Permanent marks are observable and individually distinguishable in the field, and do not harm birds or affect their behaviour.
- Additional birds seen or heard are identified accurately as being different from radio-tagged birds, and they are plotted accurately.
- A constant proportion of the individuals present in the study area is detected each survey.
- Birds are not knowingly double-counted in any survey period (especially for those birds detected only by sight or sound).
- Permanent marks are observable and individually distinguishable in the field, and do not harm birds or affect their behaviour.
- The population remains demographically closed throughout each survey period.

Advantages

- A well-established technique, applicable to all kiwi species.
- Relatively cheap per site per annum. Main costs are hiring experienced dog handlers, helicopter access (if required) and radiotransmitters.
- It provides an intensive snapshot of a population that is invasive for only a short period of time outside the breeding season, with no need to keep transmitters on for long periods nor to monitor (and potentially affect) nesting attempts and chick survival.

- Other biological data can be collected from birds (including from known-aged birds) at the same time (e.g. morphometrics, body condition, disease-screening and behaviour), and pin feathers can be collected for DNA sexing and genetics research.
- Long-term changes in unsolicited call rates can be compared with long-term changes in density estimates.
- The age ratio of the population (determined from measurements) can be calculated each survey, and be related to conservation management or environmental factors in the intervening period.
- Use of permanent marking technologies allow other forms of analysis, and repeated visits to the same study site allows for corrections to be made for birds not detected in a particular survey period.
- Outputs are distribution maps, which are easily compared and understood.
- Outputs also include average territory size and numbers of adults per territory, which can be used for making population estimates for the species.
- Provides opportunities for people to learn new skills that count towards accreditation as kiwi practitioners.

Disadvantages

- The time of year for doing territory mapping is confined to a 5–6-month period when kiwi can be caught and handled. Within that January to May/June period, surveys should be done close to the new moon when it is darker and hence easier to catch birds at night.
- Underlying differences in the ecology and behaviour between and within kiwi species means that prescriptions have to be flexible to accommodate these differences, rather than have one fixed method that can be applied everywhere.
- Multiple mapping visits are required to detect long-term changes in the number of territories and number of resident birds.
- The total number of territories that can be mapped limits the size of study sites, and the chosen study sites may not be representative of changes across the whole distribution range of the species or subspecies concerned.
- Motivated and accredited dog handlers and kiwi catchers are required to form the core of the monitoring team, and these skills are often in short supply.
- Local knowledge of the study areas and the behaviour of study birds is needed to maximise data gathered. Preferably at least two people are needed who are familiar with both the technique and the particular study population.
- Kiwi within a population are not equally detectable. Adult females call less frequently and are less responsive to playback than adult males; subadults call infrequently and are generally not responsive to playback; and kiwi chicks do not call at all and do not approach playback calls.
- Kiwi within a population are not equally catchable. Being less responsive to playback, adult females, subadults and chicks are harder to catch, and some birds become increasingly

difficult to recapture as they learn to be wary of approaching broadcast calls, or run away when approached.

Suitability for inventory

Territory mapping concentrates on only a single species of kiwi at a site over a long period of time, often over decades. Although species lists of plants and other animals can be compiled at the time of doing territory mapping, it is not a technique that can be recommended for compiling simple species inventories.

Suitability for monitoring

Territory mapping of permanently marked kiwi can provide useful information on changes in the status and trend of the kiwi population. Because kiwi are generally long-lived (mean life expectancy of 40+ years) and have low productivity, population changes are often slow, and so it is likely to take 10 or more years to detect meaningful changes in the number of territories and the total number of kiwi in a defined area, including juveniles, subadults and helpers (where applicable). Given likely rates of population turnover and change, repeated measures of the number, shape and occupants of territories is usually done at intervals of 5 years, or longer in situations where a population has been recently established.

Because the technique is labour-intensive, it is usually possible to map only a limited number of territories at a given site. The protocols are flexible, but the aim is to map a minimum of 15 territories per study site, except on Stewart Island, where there can be multiple adults in a territory, the aim is to map and determine the membership of at least 10 territories. The size of study sites depends on the density of kiwi, terrain and the accessibility of the study area. In practice, established study sites range from 110 ha to nearly 2000 ha. For studies of island and fenced mainland populations of little spotted kiwi, the aim is to determine the total number of territories and to make a population estimate for the entire site.

To create a territory map, the aim is to plot a minimum of five separate locations per radio-tagged individual, being a mixture of daytime fixes to within a few metres of accuracy plus nocturnal fixes from sightings of birds with reflective tape on their leg bands, projected calls or projected telemetry signals. Other records of birds seen or heard calling are added to the radio-telemetry data. GPS locations of birds are plotted on maps and approximate territory boundaries are drawn using the ‘field worker estimate’ to encompass all records of territory owners, initially using a maximum convex polygon and then reduced to prevent overlap of neighbouring territories and/or expanded to take into account geographical features that typically form territorial boundaries of kiwi.

Catching and permanently marking individuals allows other forms of analysis to be conducted, including:

- Assessment of the age structure

- Capture-mark-recapture estimates
- Genetic estimates of effective population size
- Genetic identification of individuals and relationships between birds
- Changes in weights and conditions of individuals
- Time to reach adult size
- Age of dispersal from the natal territory

Skills

Territory mapping of kiwi requires a core team of skilled and accredited kiwi handlers, often using conservation dogs certified to work on that species of kiwi. The core team must:

- Be familiar with the relevant design issues for territory mapping and know the boundaries of the study area
- Have an understanding of the behaviour and spatial distribution of the target species of kiwi

Other field observers must be:

- Comfortable operating in remote backcountry locations and working at night
- Proficient at map-reading, radio-tracking, plotting locations on GPS and, if necessary, be trained to use the ‘sight ’n go’ function of GPS units
- Trained to catch and handle kiwi under supervision until accreditation standards have been reached
- Trained to distinguish male and female kiwi calls from other nocturnal sounds, be able to estimate distance, and determine direction using GPS or a compass

Those responsible for analysis must preferably have been part of the field team and know the study area, and understand the:

- Limitations of the data collected
- Protocols for drawing territory boundaries using the ‘field worker estimate’
- Most appropriate analyses and reporting format

Resources

Territory mapping of kiwi is relatively straightforward in the field, but it requires some specialist skills, training and equipment. The resources required are:

- Accredited kiwi practitioners capable of catching, handling, permanently marking, and radio-tagging the particular species of kiwi concerned

- Certified kiwi dogs, which are an advantage at all kiwi densities, and night-certified 'indicator' dogs, which are especially useful in low-density populations, where most encounters are of birds at night
- Assistants willing to be trained in catching and handling skills, and capable of radio-tracking
- A copy of the *Kiwi Best Practice Manual* (Robertson & Colbourne 2017), or its electronic updates
- Laminated maps of the study area boundaries and known hazards
- Lists and general locations of all marked birds that could be encountered
- GPS locations of key sites previously used by study birds, especially well-used daytime dens and nests
- Good torches and batteries, and spares
- Playback equipment and amplifying speakers, with a good range of calls to broadcast
- Hand-nets and fast runners
- Kiwi handling and measuring gear
- Metal leg bands, transponders and wing-tags and appropriate equipment for attaching them
- Radiotransmitters, baby bracelets for attaching them temporarily, and radio-tracking equipment and spares (including back-up receivers and aerials and batteries)
- Reflective tape for colour combination on leg bands and transmitters, for marking hazards, and for marking safe routes to catching sites
- Flagging tape or safety tape for marking daytime sites and routes to catching sites
- Mirror, pruning saw, small spade for burrow checks
- Waterproof field notebooks, pens, highlighters, and field data sheets (see Figure 1)
- Zip-lock plastic bags for storing pin feathers
- GPSs for recording kiwi locations
- GPSs/compasses for plotting locations of kiwi calls and radio signals
- Appropriate personal protective equipment (emergency position-indicating radio beacon (EPIRB), clothing, footwear, first aid) and safety and first-aid procedures

Minimum attributes

Consistent measurement and recording of these attributes are critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to 'Full details of technique and best practice'.

DOC staff must complete a 'Standard inventory and monitoring project plan' (doccm-146272).[1]

Minimum attributes to record:

[1] http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-standard-inventory-and-monitoring-project-plan.doc

- Record metadata, including observers' names and contact details, number and names of dogs used, date of survey, time over which survey conducted (start/finish dates) and note if inclement weather or other factors significantly reduced search effort.
- Record and map location (polygons) of survey area.
- Record the identity, age and gender, date of capture and method of capture (e.g. night catch, dog find, with transmittered partner, in a previously used burrow) of all permanently marked kiwi, and which territory they were assigned to.
- For DOC staff, record the DOCCM number of the data file that holds all locations of each bird in the survey period.
- For DOC staff, record the DOCCM number of the written report of the survey.

Data storage

A list of kiwi captured and their transmitter frequencies is maintained in the field (Figure 1) so that each day a group of nearby birds can be allocated to team members to check. Observers maintain full records of all kiwi caught, measurements, locations, etc in field notebooks and/or on GPS units.

CAPTURE DATA FOR KIWI TERRITORY MAPPING Site: _____

C/R	Band	Old mark	Age	Sex	Date	East	North	Bill	TarW	TarD	TarL	Wt	Cond	Col	Tx	Terr	Detect	Notes

Key

C/R:	Capture/ Recapture	**Cond:**	Excellent/ Very Good/ Good/ Moderate/ Poor, or intermediate combinations, e.g. MP
Age:	Adult/ Subadult/ Chick (<800g)	**Detect:**	Night capture/ Dog find/ Night dog/ with a Tx bird/ Previously used site/ Day capture
Sex:	Female/ Male/ Unknown		

Figure 1: Sample field sheet for recording captures of kiwi.[2]

[2] 'Kiwi territory mapping field sheet' (docCM-5597554): http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-birds-kiwi-territory-mapping-field-sheet.xlsx

Preferably immediately on return from the field, download GPS locations from the various GPS units and from field notebooks into standard Excel files and consolidate and store survey information securely. DOC staff should keep a copy of the data on DOCCM. The key steps here are data entry, data checking, storage and maintenance for later analysis, followed by copying and backing the data up for security. If data storage is designed well at the outset, it will make analysis and interpretation much easier. Before storing data, check for missing information and errors, and ensure metadata are recorded.

Record daily locations of each bird in a file such as the one shown below in Figure 2. Highlight any special locations worthy of checking during future surveys (e.g. nests or well-used burrows).

Band	Old mark	Age	Sex	Date	East	North	Col	Tx	Terr	Detect	Note
RA 3015		**A**	**F**	**10/02/2018**	**1204343**	**4790421**	**R**	**32**	**11**	**Night**	**Main track**
RA 3015		A	F	11/02/2018	1204444	4790305	R	32	11		bracken
RA 3015		A	F	12/02/2018	1204542	4790310	R	32	11		flax & reeds
RA 3015		A	F	13/02/2018	1204329	4790270	R	32	11		flax & tussock
RA 3015		A	F	13/02/2018	1204191	4790322	R	32	11		night sighting
RA 3015		A	F	14/02/2018	1204448	4790300	R	32	11		bracken tunnel
RA 3015		A	F	15/02/2018	1204479	4790310	R	32	11		reed/tussock
RA 3015		A	F	16/02/2018	1204504	4790321	R	32	11		With tx 35; tussock
RA 3015		A	F	17/02/2018	1204230	4790408	R	32	11		flax & bracken
RA 3015		A	F	18/02/2018	1204444	4790308	R	32	11		scrub near old nest #610
RA 3015		A	F	19/02/2018	1204542	4790310	R	32	11		flax & reeds
RA 3015		A	F	20/02/2018	1204444	4790308	R	32	11		Tx removed
WT S2243		**S**	**U**	**15/02/2018**	**1204076**	**4790270**		**35**	**11**	**Night**	**Track to Hunters Camp**
WT S2243		S	U	16/02/2018	1204504	4790321		35	11		With tx 32; tussock
WT S2243		S	U	17/02/2018	1204560	4790406		35	11		feeding by day
WT S2243		S	U	19/02/2018	1204631	4790421		35	11		tussock

Figure 2: Sample of an Excel file[3] recording daily locations of kiwi. Age: A = adult; S = subadult; C = chick (< 800 g). Sex: F = female; M = male; U = unknown. Detect options are: Day find; Dog find; Night capture; Night dog detect; Prev = previously used site; Tx bird = with a transmittered bird.

Analysis, interpretation and reporting

Plot capture and radio-telemetry locations onto maps, either using ArcView or manually. Generally Topo50 maps do not align very well with GPS locations and so manually plotting locations on the map in relation to topographical features (e.g. streams or bush edge) is often far more accurate than relying on computer programs. For manually drawn maps, create a scanned copy (e.g. PDF) and save and label the file so it is saved within an electronic folder structure so it is not lost for future reference. For DOC staff this is the DOCCM system.

Add to the map records of other kiwi seen or heard.

[3] 'Kiwi territory mapping data sheet' (docCM-5597563): http://www.doc.govt.nz/documents/science-and-technical/inventory-monitoring/im-toolbox-birds-kiwi-territory-mapping-data-sheet.xlsx

Draw a convex polygon connecting the outermost records of each pair of birds, or clusters of family members where more than pair share the same home range, and then draw approximate territory boundaries to remove overlap between adjacent convex polygons, and follow topographical features such as streams, ridges and spurs that often form territory boundaries. Consider whether suitable, apparently vacant, adjacent habitat within the same topographical boundary (e.g. on the same side of a stream) is part of the territory. Bear in mind that most kiwi territories are approximately the same size in a study area but can vary hugely from site to site, and from species to species. In cases where there are few clear topographical boundaries, few fixes per territory, and/or many birds were detected but not captured, simply plot the approximate central location of each pair without attempting to define where the exact territory boundaries are. The total number of pairs and estimated total population are the two most important measures of population change rather than delineating territory boundaries.

When reporting, compare the total number of territories in the study area with the original number detected, and with the number observed in the previous survey, and then calculate an annual rate of change. Although the catchability of birds can change over time, the number of territories is usually easy to identify, except in cases where multiple adults occupy a territory. In some instances, the number of territories has to be re-interpreted based on greater knowledge. For example, at Port Adventure on Stewart Island/Rakiura, Colbourne & Robertson (2011) identified two Rakiura tokoeka territories from short-term radio-telemetry records from birds in one area, and a sighting of 3–4 adult birds in a nearby area; however, from more radio-telemetry fixes in 2017, it was discovered that seven adult birds occupied a single territory spanning these two areas (Robertson et al. *in press*).

For species that have more than a simple pair per territory, also report on the minimum number of birds alive in the study area, and the annual rate of change. Also report on the age structure and sex ratio of birds caught or otherwise observed, and report on the number of birds first encountered in different ways (e.g. found with dogs in the day, caught at night, or found with a radio-tagged bird) because this can help plan how time is best allocated on future surveys.

Interpretation can include consideration of the reasons why the population is increasing or decreasing, and whether there has been a change in the rate of growth over time—for example, as carrying capacity of the site is approaching, as a result of recent management, or because the survey was done differently to previous surveys. Could the observed annual rate of population growth trigger a change in the threat classification of the species if the results can be applied widely?

Case study A

Case study A: Little spotted kiwi on Tiritiri Matangi Island in 2017

Synopsis

Five pairs of little spotted kiwi (*Apteryx owenii*) were introduced to Tiritiri Matangi Island from Kapiti Island in July 1993, but two males died before they had bred. A further two pairs and two males

were added in July 1995 (Colbourne & Robertson 1997). Territory mapping surveys have been done every five years since 1997, to measure the rate of growth of this new population of the second rarest of the five kiwi species. In 2008, as the result of territory mapping showing that the population on Tiritiri Matangi Island and several other recently introduced populations were increasing, and the Kapiti Island population was stable despite removal of birds for translocations, the conservation status of little spotted kiwi was improved from 'Nationally Vulnerable' to 'At Risk: Recovering' (Miskelly et al. 2008). Colbourne & Robertson (1997) had estimated that the carrying capacity of Tiritiri Matangi Island would be about 110 birds if they reached the same density (1 pair per 4 ha) as they do on Kapiti Island, and this would be reached by 2012 if the estimated 11% per annum growth between 1993/95 and 1997 was maintained. Subsequent 5-yearly surveys in 2002 to 2012 showed ongoing strong population growth, but the rate of growth slowed between 2007 and 2012 as the estimated population approached the predicted carrying capacity of the island (see Table 1).

Table 1: Estimated population of little spotted kiwi on Tiritiri Matangi Island, 1997–2012.

Year	Number of birds caught	Estimated population	Midpoint of estimate	Annual growth since last survey
1997	11	20–25	22.5	11.0%
2002	15	30–40	35	9.2%
2007	27	60–70	65	13.2%
2012	32	80–100	90	6.7%

Objectives

The territory mapping survey aimed to assess total population size in 2017, and also prepare for the transfer of 10 females to nearby Shakespear Open Sanctuary and the arrival of 10 new females from Kapiti Island to improve the genetic diversity of the Tiritiri Matangi Island population.

Sampling design and methods

A team of four dog handlers, a rotating roster of 13 volunteers from the Supporters of Tiritiri Matangi, and four Auckland Council or DOC officers caught and radio-tagged little spotted kiwi between 17 and 30 April 2017. On the first two nights, the team recorded the time, gender, estimated distance and estimated direction of unsolicited calls in the first hour of darkness from sites that gave good coverage of the island. Once the call counts were finished, and on all other nights, recorded calls were played to attract kiwi, and any birds that approached the 'intruder' were caught by hand or in hand-nets. A night-certified kiwi dog was used to indicate the presence of kiwi near tracks or any birds that were cautiously approaching the recorded calls, which we also attempted to catch by hand.

All of the captured birds were banded, measured and weighed, and their body condition was scored following the methods of Robertson & Colbourne (2017). Most of the captured birds were radio-tagged with an 11-g Sirtrack transmitter that was temporarily attached using a single baby

identification bracelet. These birds were tracked on most days to see if they were with a partner, and their positions were recorded by GPS. Four certified kiwi dogs were used during the day to search for new birds or to pinpoint the location of radio-tagged birds.

The daytime and approximate night-time locations of all radio-tagged birds were plotted, and then this information was combined with the known or projected locations of other birds that were seen or caught but not radio-tagged, or heard calling, to estimate the number and approximate locations of territories on the island.

Results

A total of 31 little spotted kiwi were caught on Tiritiri Matangi Island, comprising 17 adult males, 11 adult females, 2 subadults and 1 chick from the 2016/17 season. Two of these birds (1 male and 1 female) were among the original founders brought to the island in the mid-1990s, 9 (6 males and 3 females) were island-bred birds that had been banded between 1997 and 2012, and 20 were new birds (Robertson et al. *in press*).

The majority of captures (21/31) were made at night; however, 4 birds were found by dogs during the daytime and 6 were found with their radio-tagged partners. This last method of encounter, which particularly improved the capture rate of females, was higher than usual because we spent longer on the island than during previous visits and so had more opportunities to find birds sharing a daytime site (Robertson et al. *in press*).

A plot of the radio-telemetry locations was combined with the capture sites of birds that were not radio-tagged, sightings, and the projected locations of calling birds to give an overall picture of the distribution and number of birds on the island (Figure 3). There were at least 25 pairs, as well as 1 apparently unpaired adult male, 2 subadults and 1 chick on the island in April 2017. Based on an expectation that some adults (particularly females) and most juveniles and subadults will have gone undetected, the total population in April 2017 was estimated to be 60–80 birds (Robertson et al. *in press*).

The estimated population was lower than expected, and the results suggested that the population had declined or, at best, had stabilised since 2012. Although a disease outbreak cannot be ruled out, it seemed more likely that that many birds died during the severe drought that affected the island in early 2013 (Robertson et al. *in press*). A MetService automated weather station located 5 km from the island on the tip of Whangaparaoa Peninsula recorded a total of 11.6 mm of rainfall in the first 2.5 months of 2013, which was about 7% of the 30-year (1981–2010) average of 160 mm for this period (Robertson et al. *in press*). Unusually, at the height of the drought, two unbanded island-bred birds were discovered active in daylight, and both subsequently died at Auckland Zoo of complications from severe dehydration. These two birds may have just been the tip of the iceberg and many others died without being found (Robertson et al. *in press*).

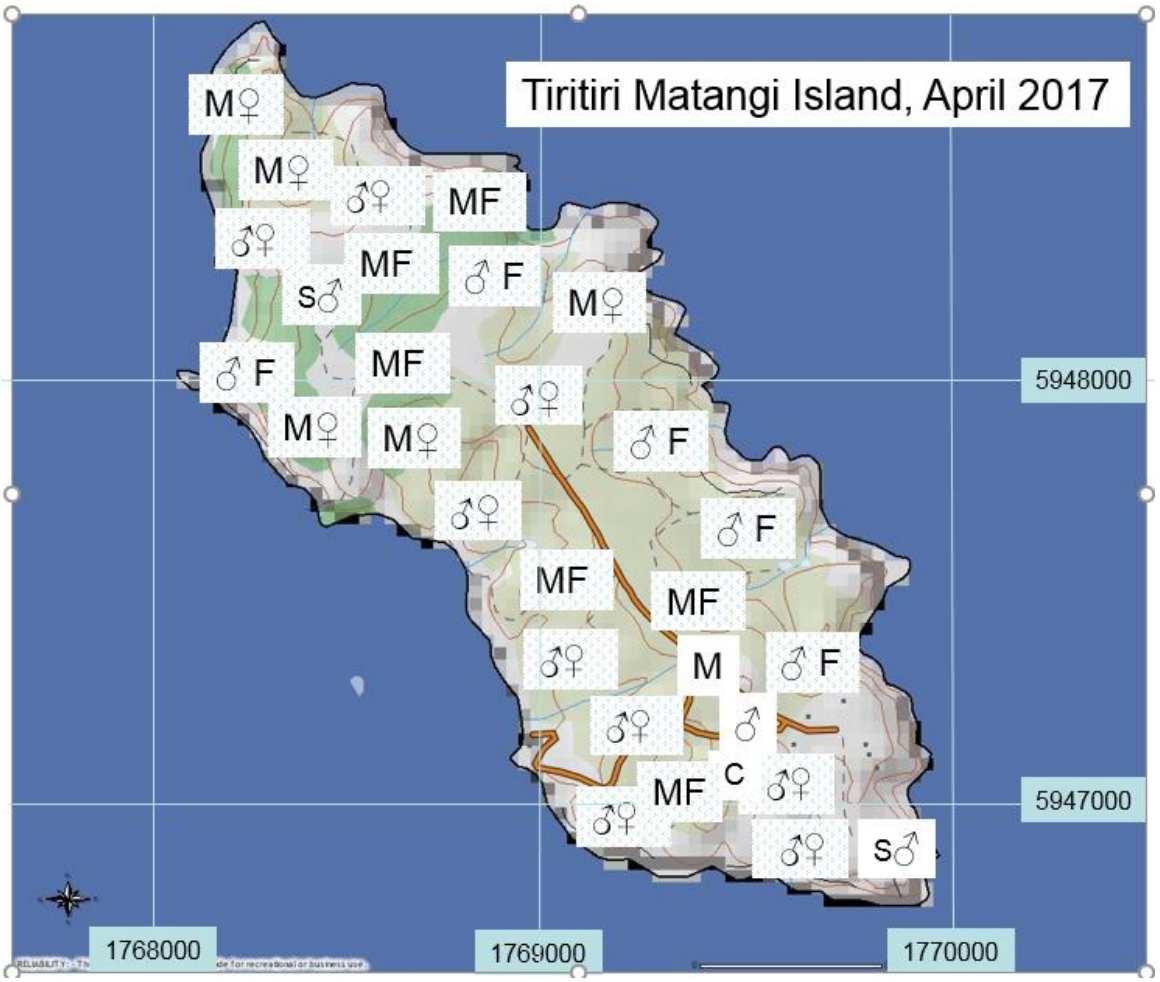

Figure 3. Map of Tiritiri Matangi Island showing the locations of little spotted kiwi (*Apteryx owenii*) in April 2017. ♂ = adult male caught; ♀ = adult female caught; M = male heard; F = female heard; S♂ = subadult male; C = chick (from Robertson et al. *in press*).

Limitations and points to consider

During each territory mapping period, the total number of birds caught and radio-tracked was less than 50% of the estimated total population. Females are less responsive to playback than males, and subadults and chicks do not approach broadcast calls, nor do they share daytime dens with partners, and so their capture relies on chance encounters at night or by day with dogs. From the estimated number of pairs, which is likely quite accurate, a further c.30% of birds was added to make up the total population estimate and this is expressed with wide limits of about 10–50% extra birds. For example, in 2017, 54 birds were detected or believed to be in pairs, and the final rounded estimates of 60–80 birds represents another 11–48% birds that were assumed to have gone undetected. This estimate could be refined by lengthening the survey period and so increasing the opportunity for random encounters, but this additional cost is not warranted for a species that is classified as At Risk: Increasing (Robertson et al. 2017).

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Case study B

Case study B: Rakiura tokoeka at Mason Bay, Stewart Island, in February 2018

Synopsis

Long-term monitoring of Rakiura tokoeka at Mason Bay started in 1993, taking advantage of having a large number of banded birds in 11 territories marked during an ecological and behavioural study conducted in 1988–1990 (Colbourne 1991). In 1993, the study area was expanded to include six extra territories to the north and east of the original scientific study area. During subsequent 5-yearly territory mapping surveys, the number of territories progressively declined from 17 in 1993 to 11 in 2013, at a rate of 2.2% per annum. If the generation time of Rakiura tokoeka is 20 years, this decline rate would equate to a 73% decline over three generations and therefore trigger a threat classification of 'Nationally Critical' (Townsend et al. 2008). In 2012, the expert panel assessing the conservation status of birds changed the status of Rakiura tokoeka from 'Nationally Vulnerable' (Miskelly et al. 2008) to 'Nationally Endangered' (Robertson et al. 2013). This status was designated instead of 'Nationally Critical' due to the possibility that the Mason Bay study site was not representative of the island as a whole because it was undergoing rapid habitat change from rough farmland to scrub, flax and tussock communities following de-stocking in the 1980s. The 2018 territory mapping survey was the sixth in the series of 5-yearly surveys, which cover a span of 25 years.

Objectives

The objective of the 2018 territory mapping survey was to catch and radio-tag as many Rakiura tokoeka as possible in the study area, and then plot the number and distribution of territories, and also to determine the number of adults per territory and the ratio of adults to subadults in the population. Manaaki Whenua—Landcare Research scientists collected faecal samples from the study area to assess the utility of developing genetic techniques to identify individuals and estimate population size.

Sampling design and methods

The survey ran from 5 to 22 February 2018, at the same time of year as all surveys done since 1993. A core team of four dog handlers were present the whole time and 11 others from DOC, Manaaki Whenua—Landcare Research, Ngāi Tahu or Massey University assisted for shorter periods. Tokoeka were caught at night, in daytime searching with certified kiwi dogs, and in daytime locations with a radio-tagged family member. All subadults caught were permanently marked with wingtags, and adults were banded with a uniquely numbered leg band that was temporarily colour-coded with reflective tapes to allow quick recognition at night.

All but two birds caught towards the end of the survey were radio-tagged, and their locations were plotted daily. A visual inspection of each radio-tagged bird was attempted each day to see if they were sharing their daytime den with any other family member, and well used daytime sites were re-visited to see if they were being used by other family members. Locations of radio-tagged birds were checked at night, especially to determine if a bird that was heard calling was radio-tagged or untagged, and their projected location was mapped.

From all of the records of captures, sightings, radio-tracking locations and projected calls, territory maps were prepared by using the ‘field workers estimate’ of drawing a maximum convex polygon that encompassed the locations of all family members (determined by being together by day or night, or from their from overlapping distributions), and the territory boundaries were modified to eliminate overlap between adjacent territories and followed geographical features (e.g. streams), where appropriate.

Results

A total of 27 Rakiura tokoeka were caught in the 125-ha study area and at least 11 other birds were recorded and assigned to territories. The 27 birds caught comprised 11 adult males, 9 adult females, 6 subadults and 1 chick from the 2017/18 season. Five of the adults were originally banded during 1988–1990, 13 had been banded during surveys from 1993 to 2013, and 2 were caught for the first time on this survey.

Fourteen of the birds were caught at night (mainly in random encounters because the birds did not seem to be very responsive to play-back calls), 8 were found by dogs during the day, 4 were found with radio-tagged family members, and 1 was caught as it foraged in daylight.

A plot of the capture sites and radio-telemetry locations of 27 birds was combined with sightings of birds and the projected locations of calling birds to provide an overall picture of the distribution and number of birds in the study area (Figure 4). All the birds fitted neatly into 1 of 12 territories identified except for a small overlap between locations of birds in Territory 2 and Territory 16, a very minor incursion of a bird from Territory 13 into Territory 5, and a subadult bird moved several hundred metres southward from Territory 11 to the very edge of our study area after being recorded at 4 locations in Territory 11, including once sharing a daytime den with its probable mother.

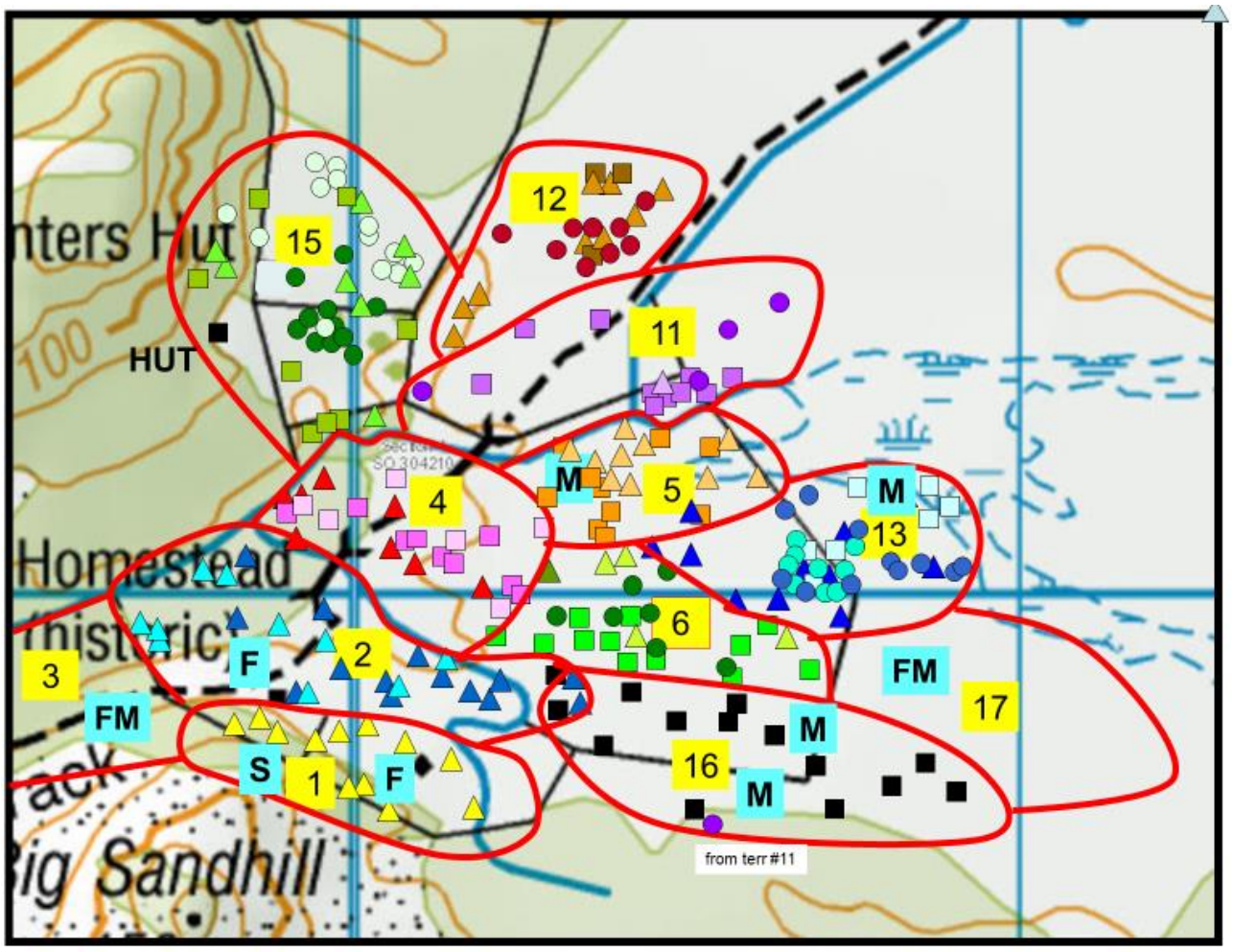

Figure 4: Capture and radio-telemetry locations of Rakiura tokoeka in the Mason Bay study area in February 2018. Each different-coloured shape represents a different bird: females (squares), males (triangles) and subadults or chicks (circles). Additional birds seen or heard are shown with approximate locations: adult female (F), adult male (M) and subadult (S).

One territory had been lost since 2013, but two territories had split in two, thus producing a net gain of one territory to 12 altogether. The overall decline over the 25 years from 1993 to 2018 was 1.4% per annum, rather than 2.2% per annum recorded in the 20 years up to 2013, and so the three generation (60-year) decline rate is now estimated to be 57%. This would trigger a conservation status of 'Nationally Vulnerable' rather than the 'Nationally Critical' status from results up to 2013. We observed that over the last 5-year period, large areas of flax had died, consistent with being

affected by yellow-leaf disease caused by a phytoplasma bacterium, and this dieback may have increased the area available for tokoeka to feed.

Limitations and points to consider

During each territory mapping survey, the number of territories is reasonably easily identified, but with the complicated social system of Rakiura tokoeka, the number of resident birds is less accurate because only about 60–80% of resident birds are caught and radio-tracked in any one mapping survey. For example, in February 2018, we caught 27 birds but at least 11 additional birds were detected, including pairs in two territories in which we did not manage to catch any adults. Even though the time of year of recent surveys has remained constant, on this territory mapping survey adult birds were remarkably unresponsive to playback. Generally adult males respond better to playback than females, and subadults and chicks do not approach broadcast calls and so are under-reported. The estimate of resident birds could be refined by lengthening the survey period and so increasing the opportunity for random encounters, but this additional cost is probably not warranted given that the change in the number of territories is probably the most important measure of population change.

References for case study B

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Full details of technique and best practice

There is no single generic best practice approach for territory mapping of kiwi because the methods have to be adapted to the situation. The size of study areas varies according to the social systems of different kiwi species; the density, catchability and accessibility of birds in the chosen study area; and the topography of the study site. Nevertheless, there are some general best-practice points to keep in mind.

Planning

- Some sort of pilot study is essential to determine whether sufficient numbers of the target kiwi species are living in a clearly defined and safely workable study area. The aim should be to have safe access (preferably with well-marked tracks radiating from a hut or a suitable location for a base camp) to catch or identify 25–40 birds in a minimum of 15 territories, except that with kiwi that have social systems with pairs plus additional territorial adults ('helpers') in a territory (e.g. Rakiura tokoeka), the minimum number of territories should be 10.
- Acoustic recorders can be used to first determine if kiwi are present in a potential territory mapping site, but the pilot study should be done by experienced kiwi practitioners who can assess the approximate number of safely accessible territories by using playback to solicit responses from territorial birds. No attempt should be made to catch any birds during the pilot study because the birds will be harder to catch during subsequent monitoring.
- The size of a study site will depend on the density of kiwi, terrain and the accessibility of the study area. In practice, established territory mapping study sites range from 110 ha to nearly 2000 ha. For studies of island and fenced mainland populations of little spotted kiwi, the aim is to determine the total number of territories and to make a population estimate for the entire site.
- If a new study site builds on a previous kiwi project—for example, where birds have been marked during a research programme—obtain as much background information as possible on the individual marking system used and the favoured locations of those marked birds.
- Sufficient resources must be available to catch and mark a large percentage of the resident kiwi during each survey period, and to repeat the survey preferably at 5-year intervals so there is measurable turnover in the population between successive visits, but not so much turnover that the picture becomes confusing.
- Consideration should be given to ensuring that there is secure long-term access to potential study sites for a period of > 25 years, and so a study site on public land is preferable to one on private land.
- The permanent marks and radiotransmitters used on a given kiwi species must be clearly observable and individually distinguishable in the field by all field workers. Marks must not harm birds or affect their behaviour, and they should be attached according to the *Kiwi Best Practice Manual* (Robertson & Colbourne 2017).
- Because the monitoring programme needs to be maintained for a long time period, a mark replacement programme may be required, so that mark loss does not affect interpretation of results.

Field methods

- Usually, for the first two hours of darkness on the first night or two in a survey period, in order to get a feel for the distribution of birds, and to record unsolicited call rates before disturbing the birds, observers record the gender, distance and direction of kiwi calls from

the same fixed listening stations that give a good coverage of the study area. Data are entered on Kiwi Call Scheme cards (see Robertson & Colbourne 2017).

- Catching effort moves progressively away from the hut or base camp so that continuous and nearby territories are targeted first to avoid ending up with a patchwork of territories.
- Details of kiwi caught are entered on a field data sheet (Figure 1), which is updated daily.
- Most birds are caught at night, either as randomly encountered or, more often, when they approach in response to playback of kiwi calls from a broadcast speaker. Night-certified 'indicator' dogs assist in detecting the nearby presence of kiwi, and playback is generally more successful when calls are played to a nearby bird rather than at a random location in a territory.
- All birds caught are permanently marked with either a uniquely numbered leg band of appropriate size, a transponder, or a wing tag in accordance with the *Kiwi Best Practice Manual* (Robertson & Colbourne 2017). Distinctive combinations of reflective tape are added to leg bands to aid subsequent identification at night.
- A two-stage radiotransmitter is attached to most birds, especially those caught early in the survey period and in territories where there is little other information from other birds. Only a single hospital identification bracelet is used without any electrical tape, so that the transmitter falls off the bird within months (rather than years) if the bird is not recaptured.
- At night, one person in each catching group is assigned the task of plotting origins of calls using 'Sight 'N Go' functions on GPS, for using telemetry gear to determine if calls are likely to be from radio-tagged or untagged birds, and for plotting approximate fixes of radio-tagged birds from a rapid triangulation of signals taken from a number of points (e.g. along a track).
- Dogs are also used by day to search for new birds, and to quickly identify the exact location of radio-tagged birds in daytime shelters.
- On each successive day, radio-tagged birds are tracked to their daytime location and a careful visual check is made to see if they are sharing the site with their partner (or another family member) and the waypoint is recorded on GPS. The site is marked with flagging tape or safety tape for re-inspection on subsequent days in case the same site is used by the partner (or another family member).
- The target is to obtain a minimum of 5 different locations per bird and 10 different locations per territory, being a mixture of daytime fixes to within a few metres of accuracy, plus nocturnal fixes from sightings of birds with reflective tape on their leg bands, projected calls or projected telemetry signals. When birds regularly use a single daytime den, then more effort is needed to obtain nocturnal fixes to make up the target numbers of total fixes.
- In very tight vegetation, where the chances of seeing the radio-tagged bird before it bolts is very low, then an approach to the point where the transmitter can be detected on a receiver without an aerial (c.20 m) is sufficient, and the bird's position can then be projected.
- If a bird is in a burrow, hollow log, or under a hollow tree, block all entrances and try to get a direct visual or a view with a hand mirror to see if the bird is by itself or with another. If necessary, cut or dig shafts to gain better access to see the radio-tagged bird and/or to extract un-tagged bird(s).

- Suitable sites (e.g. well-formed burrows or hollow logs) used in the same or previous survey periods are checked and, if necessary, a small palisade of sticks is placed at the entrance to identify if the site is still being used.
- Other tools can be used to determine the presence of previously undetected birds. Camera traps can identify birds without transmitters and/or bands and, in low density and unresponsive populations, acoustic recorders can identify the presence of birds in a territory where no birds had hitherto been recorded.
- Towards the end of the usual 14–18-day survey period, as many transmitters as possible are retrieved from birds, starting with birds in territories with the greatest amount of location data. Sometimes local staff or volunteers are able to retrieve the dropped transmitters from the remaining birds about a month after the study period finished.

Analysis

- All GPS location records of birds (captures, sightings, projected calls, daytime radio-telemetry locations, and projected telemetry signals) are transferred from GPS units and field notebooks to standard Excel data files (e.g. Figure 2) or stored in ArcView files, and then the locations are mapped using different symbols (by shape and/or colour and/or letters) for each individual.
- Where there are few location fixes per territory, especially where there are no clear geographical features to mark territory boundaries, then the central location of each territory is mapped without attempting to delineate territory boundaries.
- When there are good data, approximate territory boundaries are drawn using the ‘field worker estimate’ as a maximum convex polygon around all locations of territory holders rather than around each individual, but reduced to eliminate overlap with adjacent territories, and further reduced or expanded to follow natural geographical features such as streams, spurs and ridges (however, some territories can span these) and to assume that small gaps are part of a known territory if it is suitable habitat within the same geographical feature—for example, a set of plotted locations between two major streams may not have had any points fall within 20 m of the streams, but the territory boundary is drawn as being the stream.
- Outputs can include average territory size, and numbers of adults per territory, which can be used for making broader population estimates for the entire species, bearing in mind that sites chosen for territory mapping are not random.
- Outputs can also include a comparison of long-term changes in call rates from the same fixed listening stations with long-term changes in population density.
- Report the age ratio of kiwi caught or otherwise detected, and then compare this with the age ratios obtained on previous territory mapping surveys at the site and at other sites. If possible, relate the changes or differences in age ratios to the presence and timing of conservation management.
- Catching and permanently marking individuals allows other forms of analysis to be conducted, including mark-recapture estimates, genetic estimates of effective population size, changes in weights and conditions of individuals, and determining the minimum age of

dispersal from the natal territory. Some of these measures may be related to carrying capacity issues.

References and further reading

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Appendix A

The following Department of Conservation documents are referred to in this method:

doccm-5597563	Kiwi territory mapping data sheet
doccm-5597554	Kiwi territory mapping field sheet
doccm-146272	Standard inventory and monitoring project plan