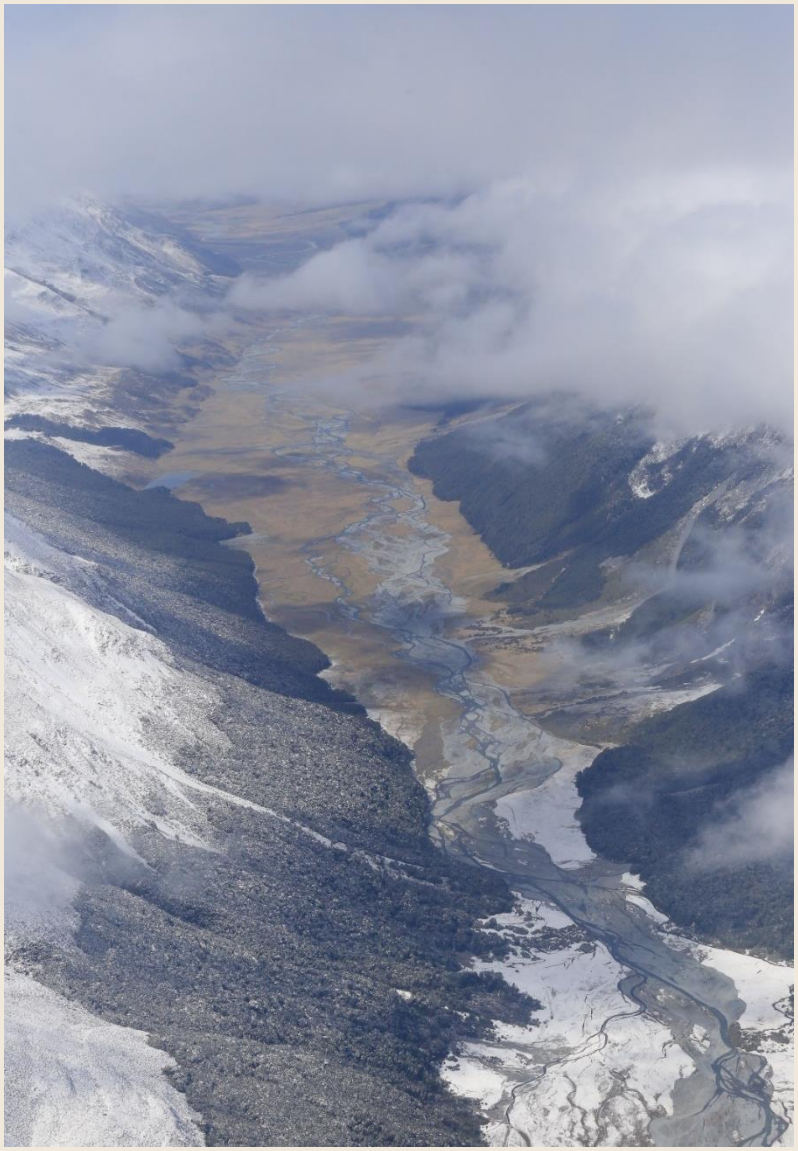
Protocol for best practice in monitoring braided river birds



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1. Introduction

1.1. Braided Rivers

New Zealand is unique in both physical features and wildlife. Relatively young mountains, combined with high erosion, maritime climate, and a strong gradient for rainfall has led to the formation of braided rivers (Wallis & Trewick 2009). For the purpose of this document, a braided river is 'one that, over some part of its length, flows in multiple, mobile channels across a gravel floodplain' (Gray & Harding 2007; O'Donnell et al. 2016). Braided rivers are a rare feature in the world, and only exist in New Zealand, Canada, Alaska, Siberia, and the Himalayas (Caruso 2006). In New Zealand, these rivers flow from the Southern Alps to the eastern and southern coasts, with approximately 60% of the country's rivers flowing through Canterbury (Caruso 2006) and 15% through the West Coast (O'Donnell et al. 2016). Braided river dynamics are driven by floods and high river flow pulses, where gravel bars are exposed during low flow and submerged during high flow (Millar 2000; Caruso et al. 2013).

Braided rivers are complex systems that consist of large-scale interactions between groundwater, floodplain, channels, streams, and springs (Tockner et al. 2010). The transport and deposition of sediments by water creates microhabitats which allows different organisms with specific adaptations to exist in particular areas, such as backwaters or islands (Tockner et al. 2010). The continuous migration of channels and sediment ensures a dynamic environment with plants and invertebrates constantly shifting (Richards et al. 2002). Lateral, vertical, and longitudinal movement of water adds to the complexity of the river ecosystem as the connectivity and interactions between factors at play are difficult to understand (Tockner & Stanford 2002; Tockner et al. 2006).

Numerous unique plant and animal communities consisting of birds, fish, lizards, bats, and invertebrates rely on braided rivers for all or some aspect of their lifecycle thereby making these rivers locally, regionally, and nationally significant (O'Donnell et al. 2016). Many of these plants and animals are now threatened by various factors, such as recreation, water abstraction, introduced predators, weeds, and adjacent land use changes (O'Donnell et al. 2016). Biodiversity values are in decline, but an increase in conservation activities has resulted from an emphasis on raising public awareness (O'Donnell et al. 2016). With a growing interest by numerous conservation groups, agencies, individuals, and businesses in preserving braided river biodiversity values, it is important to create an outline of conservation outcomes and effective management tools (O'Donnell et al. 2016). This document specifically focuses on directing and informing on the monitoring and management of braided river birds.

1.1.1. Birds of braided rivers

More than 80 bird species use braided rivers for their habitat, although some rely on them for only part of their lifecycle (O'Donnell et al. 2016). This document primarily focuses on the threatened endemic and key species but can be applied to all ground nesting river birds in New Zealand. Below is a brief outline of some of the main species and a short summary of important information on their lifecycle and behaviours. Additional details can be found online at www.nzbirdsonline.org.nz. New Zealand Threat Classification Rankings are outlined in further detail by Robertson et al. (2017).

Banded dotterel (tūturiwhatu) ***Charadrius bicinctus***

Endemic to New Zealand, listed as 'Threatened – Nationally vulnerable', solitary breeders. First clutch is laid in late-August or early September through to December but mostly in October and will re-lay after egg loss up to three times. Three eggs are laid in a scrape, and both sexes incubate but females primarily do so during the day and males at night. Incubation period is approximately 25 days. Chicks leave nest within a few hours of hatching and fledge at about 35 days. Chicks may be abandoned by adults before they fledge, but usually they leave as a family group and separate after 2 weeks. Both adults and juveniles usually return to the same general area to breed (Marchant & Higgins 1993).

Black-billed gull (tarāpunga) ***Larus bulleri***

Endemic to New Zealand, listed as 'Threatened – Nationally critical', colonial breeders. First clutch is laid in late September to mid-November and will re-lay after egg loss until end of November. Laying within colony is synchronous with an influx of another set of breeders later in the season. Two or three eggs are laid in a well-formed nest, and both sexes incubate. Incubation period is approximately 22 days. Chicks leave nest within a few days of hatching followed by dispersal away from colony and forming a crèche. Chicks fledge at about 30 days. Chicks continue to be fed for a few months after fledging. Location of colonies may shift between breeding seasons (Higgins & Davies 1996).

Black-fronted dotterel ***Elseyornis melanops***

Native to New Zealand, listed as 'Naturally uncommon', solitary breeders. First clutch is laid as early as August but peak is September to December, and will re-lay up to two times after egg loss or have two broods per season. Two or three eggs are laid in a scrape, and both sexes incubate. Incubation period is approximately 24 days. Chicks leave nest within a few days of hatching and fledge at about 30 days. Chicks from first brood may remain with parents until incubation of the second clutch begins or until they hatch, and chicks from second brood may stay with parents for a few weeks after fledging. Breeders tend to stay near territory all year but shift if conditions change (Marchant & Higgins 1993).

Black-fronted tern (tara piroe) ***Chlidonias albostriatus***

Endemic to New Zealand, listed as 'Threatened – Nationally endangered', colonial breeders. First clutch is laid in mid-October to late November and will re-lay after egg loss until January. Laying within colony is synchronous. Two or three eggs are laid in a scrape, and both sexes incubate. Incubation period is approximately 23 days. Chicks leave nest within a few hours of hatching but stay near it for up to 3 days followed by dispersal throughout the colony but without forming a crèche. Chicks fledge at about 30 days. Chicks continue to be fed for about a month after fledging. Location of colonies may shift between breeding seasons (Higgins & Davies 1996).

Caspian tern (taranui) *Hydroprogne caspia*
Native to New Zealand, listed as 'Threatened – Nationally vulnerable', usually colonial breeders but can be solitary on rivers. First clutch is laid in September to November and will re-lay after egg loss up to two times. Two eggs are laid in a scrape, and both sexes incubate. Laying within colony is synchronous, and incubation period is approximately 24 days. Chicks leave nest within a few days of hatching and fledge at about 35 days. Chicks continue to be fed and remain with parents after fledging for several months. High fidelity to breeding area but some areas not used every year (Higgins & Davies 1996).

Black stilt (kakī) *Himantopus novaezelandiae*
Endemic to New Zealand, listed as 'Threatened – Nationally critical', solitary breeders. First clutch is laid in September to mid-October and will re-lay after egg loss between October and December. Four eggs are laid in a nest lined with some vegetation, and both sexes incubate but males do most of incubating in the first 5 days. Incubation period is approximately 25 days. Chicks leave nest within a few days of hatching and fledge at about 35 days. After chicks fledge, the family remains together until the following breeding season. Both adults and juveniles usually return to the same general area to breed (Marchant & Higgins 1993).

Pied stilt (tōrea) *Himantopus himantopus*
Native to New Zealand, listed as 'At Risk - Declining', solitary breeders. First clutch can be laid in early August but usually in September to October and will re-lay after egg loss between October and December. Usually four eggs are laid in a nest lined with some vegetation, and both sexes incubate but female do more than males. Incubation period is approximately 25 days. Chicks leave nest within a few hours of hatching and fledge at about 30 days. After chicks fledge, the family remains together for weeks or months. (Marchant & Higgins 1993).

Red-billed gull (tarāpunga) *Larus novaehollandiae*
Native to New Zealand, listed as 'At risk – Declining', colonial breeders. First clutch is laid in late September to early-October to late December and will re-lay after egg loss. Laying within colony is synchronous. One to three eggs are laid in a well-formed nest, and both sexes incubate but the same bird incubates through the night. Incubation period is approximately 23 days. Chicks leave nest within a few days of hatching but usually do not form a crèche. Chicks fledge at about 35 days. Chicks continue to be fed for approximately three weeks after fledging. Generally have high fidelity to sites but locations of colonies may shift if breeding in unstable habitats (Higgins & Davies 1996).

South Island pied oystercatcher (tōrea) *Haematopus finschi*
Endemic to New Zealand, listed as 'At risk – Declining', solitary breeders. First clutch is laid in early August and peaks in September and will re-lay up to two times after egg loss usually peaking in October. One to three eggs are laid in a scrape, and both sexes incubate but females moreso at time of hatching. Incubation period is approximately 25 days. Chicks leave nest within a few days of hatching and fledge at about 30 days. Adults have been seen with flying chicks (Marchant & Higgins 1993).

Southern black-backed gull (karoro) *Larus dominicanus*
Native to New Zealand, listed as 'Not threatened', colonial breeders. First clutch is laid in October to November and will up to two times after egg loss until January. Two to three eggs are laid in a well-formed nest, and both sexes incubate but usually females moreso than males. Laying within colony not synchronous, and incubation period is approximately 25 days. Chicks leave nest within a few days of hatching, and do not form a crèche. They fledge at about 53 days and continue to be fed for about a month and remain with parents after fledging for up to 6 months. High fidelity to breeding area but some areas not used every year (Higgins & Davies 1996).

Spur-winged plover *Vanellus miles*
Native to New Zealand, listed as 'Not threatened', solitary breeders. First clutch is laid in early June to late November with a peak in August and will re-lay after egg loss. Three or four eggs are laid in a nest lined with some vegetation, and both sexes incubate but males do most of incubating during the night. Incubation period is approximately 32 days. Chicks leave nest within a few hours of hatching and fledge at about 45 days. After chicks fledge, the family remains together for up to 8 months. Breeders tend to stay near territory all year but shift if conditions change (Marchant & Higgins 1993).

White-fronted tern (tara) *Sterna striata*
Native to New Zealand, listed as 'At risk – Declining', colonial breeders. First clutch is laid in mid-October to late November and will re-lay many times after egg loss until January. Laying within colony is synchronous. One or two eggs are laid in a scrape, and both sexes incubate. Incubation period is approximately 26 days. Chicks leave nest within a few days of hatching followed by dispersal throughout the colony and may form a crèche. Chicks fledge at about 32 days. Chicks continue to be fed for several months after fledging. Location of colonies may shift between breeding seasons (Higgins & Davies 1996).

Wrybill (ngutu pare) *Anarhynchus frontalis*
Endemic to New Zealand, listed as 'Threatened – Nationally vulnerable', solitary breeders. First clutch is laid in late-August or early September but will re-lay after egg loss or potentially have two broods up until late December. Two eggs are laid in a scrape, and both sexes incubate but females do more than males. Incubation period is approximately 30 days. Chicks leave nest within a few days of hatching and fledge at about 35 days. Once chicks fledge, adults become aggressive towards them causing the young to leave. Both adults and juveniles usually return to the same general area to breed (Marchant & Higgins 1993).

1.2. Aims and Structure of Plan

The primary aim of this document is to serve as a 'best practice' guide for general surveying and monitoring protocols of braided river birds. This document is meant to be used by a variety of braided river bed practitioners and for a range of project sizes.

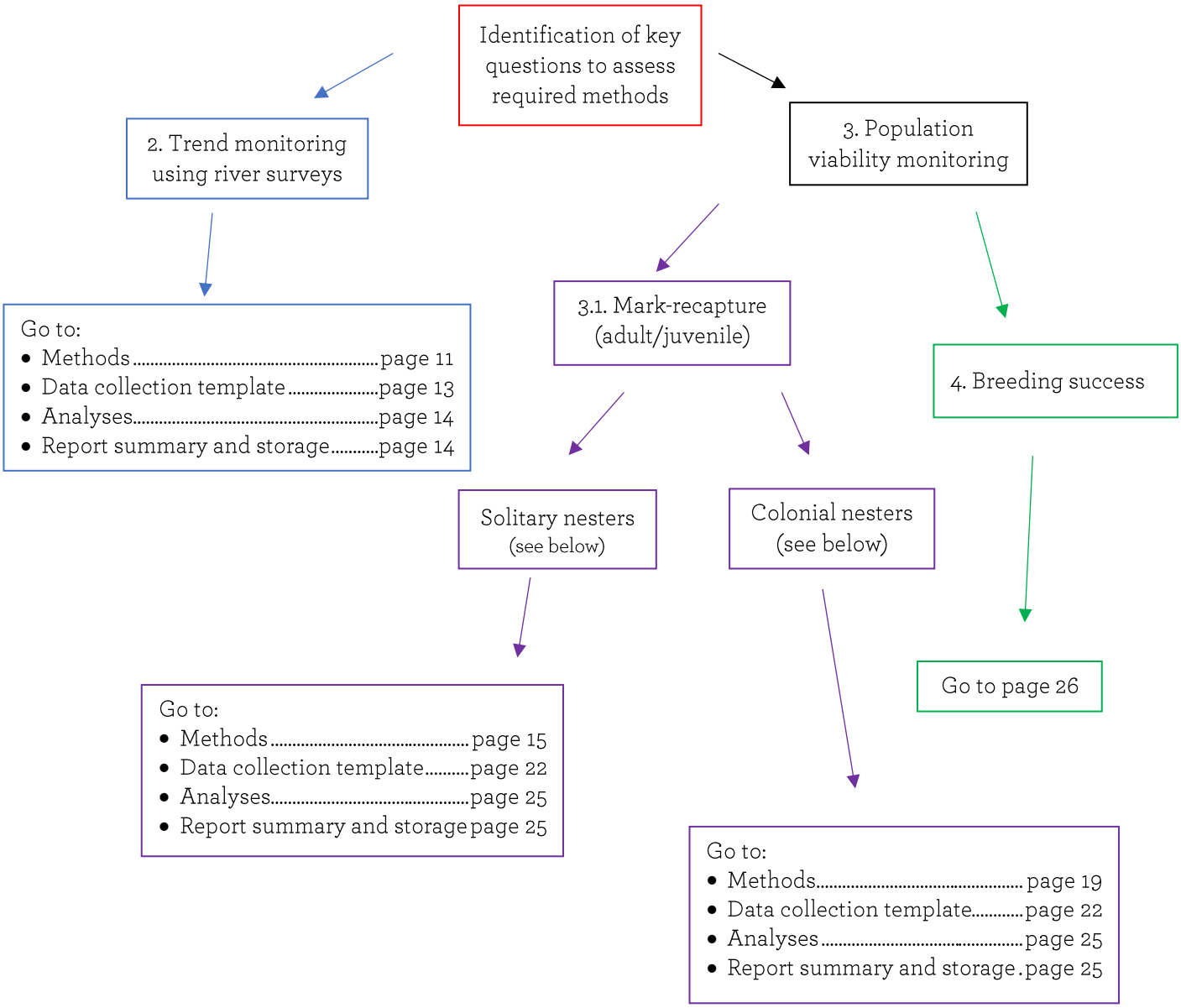
With an increase in braided river bird monitoring throughout regions by conservation groups, agencies, individuals, and businesses, it is important to try and reduce or avoid inconsistencies in monitoring methods. This is to ensure that comparisons across sites and time periods can be made, to measure successes of management actions, and to provide a set of efficient generic methods rather than different methods at each site.

The document uses the following structure:

- Key questions to be answered need to be identified
- Possible methods that can be used to answer key questions are outlined
- Best practice protocols for *some* of the possible methods are provided in this document.

Please note that there are an infinite number of questions that can be identified, and hence methods need to be adjusted according to the desired level of detail and scale. It is not possible to provide a protocol for every single question, and it is therefore recommended that anyone interested in fine scale studies gather additional assistance and insights from experts in the field. It should also be noted that the Data Collection Template section is for raw data storage, and not a summary. The format is set up to allow quick and easy analyses, such as for coding.

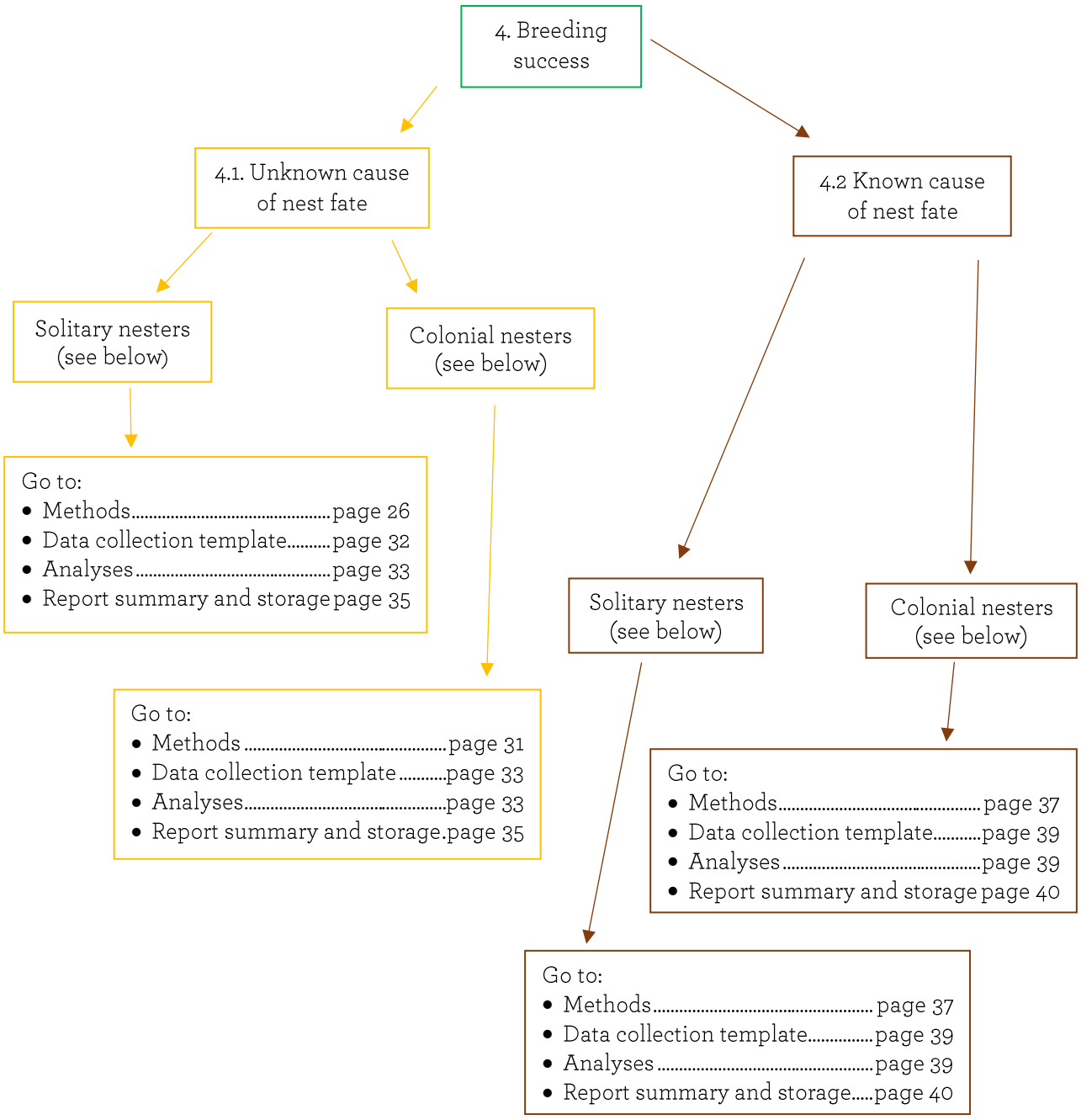
The present document is structured to allow the user to easily identify and locate the protocols for the potential methods to be used to answer the identified key questions. The flowchart (Fig. 1) provides guidance to locate the appropriate pages for methods, data collection, analyses, and reporting. Colonial versus solitary breeding species are also separated with a list of species falling into the respective category shown below the flowchart. Solitary breeders are considered to nest individually or in loose aggregations of nests, whereas colonial breeders nest in tighter aggregations than solitary. Table 1 outlines the potential methods that can be used to answer key questions, along with required resources, limitations, knowledge gained, and additional resources. Table 1 should be used alongside the flowchart (Figure 1). Table 2 highlights the minimum amount of effort that needs to be invested in regards to how often to do surveys/check, data to record, and analyses that can be conducted on a basic level. The continuum (Figure 2) provides guidance for choosing target species and determining the desired level of monitoring intensity, and can be used in addition to Table 2.



Colonial nesters – black-billed gull, black-fronted tern, Southern black-backed gull, white-fronted tern
Solitary nesters – banded dotterel, black stilt, black-fronted dotterel, Caspian tern*, pied stilt, South Island pied oystercatcher, spur-winged plover, wrybill.

*Caspian tern are included here as solitary since they usually do not nest in colonies on braided rivers. They nest in association with Southern black-backed gulls, and data on Caspian terns can therefore be collected as part of the colonial Southern black-backed gulls.

Figure 1. Flowchart providing guidance to methods, data collection template, analyses, and report summary and storage and the associated pages.



Colonial nesters – black-billed gull, black-fronted tern, Caspian tern, Southern black-backed gull, white-fronted tern.

Solitary nesters – banded dotterel, black stilt, black-fronted dotterel, pied stilt, South Island pied oystercatcher, spur-winged plover, wrybill.

Figure. 1. (continued) Flowchart providing guidance to methods, data collection template, analyses, and report summary and storage and the associated pages.

Table 1. Potential methods to be used to answer key questions, outlining the required skills and resources, key information gained, limitations, and additional references for further information. Bold (within Methods column) indicates protocols outlined in current document.

Question	Method	Skills and resources	Key information gained	Key limitations	Additional References
Population index - Not concerned about productivity	Trend monitoring using river surveys - Ground - Aerial	- Observers trained in river crossings and bird id skills - Plane hire (aerial) - Ability to count birds using computer software (aerial)	- Abundance - Presence and/or absence - Fast and efficient (aerial) - Accurate numbers for certain species (aerial)	- Can be time consuming with numerous people - Weather dependent - Can miss cryptic species - Unable to use aerial for all species (i.e. dotterels, wrybill)	- O'Donnell (unpub) - Mischler (2018)
Adult survival, juvenile recruitment - Can also be used for pair bonds, adult and juvenile site fidelity	Population viability monitoring - Mark-recapture (juvenile/sub-adult/adult)	- Long-term time investment - Time spent banding and searching for banded birds - Banding permits, Wildlife Act	- Adult survival and juvenile recruitment - Pair bonds - Site fidelity - Identify if birds survive winter	- Huge time investment as it takes years to build up sufficient number of banded birds and resights - Huge effort to search large areas for banded birds	- Lettink & Armstrong (2003) - Pryde (2003) - Banding office (www.doc.govt.nz; Bird banding) - Bulling (2008)
Productivity - Hatching and/or fledging success - Not concerned about cause of nest failure	Population viability monitoring - Breeding success	- Ability to find nests - Frequency of checks can be adjusted - need statistically significant no. of nests	- Hatching/fledging success is known which can highlight problem stages - General overview of breeding success in an area	- Time and effort to find nests and do checks	
Productivity - Hatching and/or fledging success - Also concerned about identifying cause of nest failure	Population viability monitoring - Breeding success (with use of remote cameras)	- Ability to find nests - Frequency of checks can be adjusted but needs to suit camera requirements - Need statistically significant no. of nests - Cameras, solar panels, batteries, stands very expensive	-Hatching/fledging success is known which can highlight problem stages - General overview of breeding success in an area - Identification of problems	- Time and effort to find nests and do checks, camera set up - Camera use is limited to incubation period as chicks move around too much - Time consuming to check photos/videos	- Mischler & Bell (2016) - Bell (2017) - Sanders & Maloney (2002) - Steffens et al. (2012)

Table 2. Table highlighting the minimum amount of effort that needs to be invested in regards to how often to do surveys/check, data to record, and analyses to be conducted on a basic level.

Method		Timing	Key data to record	Key analyses
Trend monitoring using river surveys	River survey on ground	- minimum of once per breeding season, but does not have to be repeated every year - for repeat surveys, sections of river and no. of observers need to remain consistent	- No. of birds per species per section - section(s) surveyed - No. of observers - general weather conditions	- trends over a given time period
Population viability monitoring	Mark-recapture	- not recommended unless willing and able to commit at least 5 years of intense monitoring and resighting	- band combinations - location of when and where banded - location of when and where seen - age at banding	- survival of adults and juveniles/recruitment - survival during breeding vs non-breeding season - pair bonds - site fidelity
	Breeding success – hatching only	- statistically significant number of nests (i.e. 30 nests) - check once a week, daily around hatching time	- location of nest and species - date found - status of nest – active with eggs, failed, chicks hatched, etc. - whether parents are banded (if yes, band combinations)	- hatching success
	Breeding success – hatching and fledging	- statistically significant number of nests (i.e. 30 nests) - check once a week, daily around hatching time, back to once a week, three times per week around fledging	- location of nest and species - date found - status of nest – active with eggs, failed, chicks hatched, etc. - whether parents are banded (if yes, band combinations)	- hatching success - fledging success
	Breeding success with identifying nest fate (remote cameras)	- statistically significant number of nests (i.e. 30 nests) - check twice per week, daily around hatching time (cameras removed after chicks leave nest, so see above for fledging if continuing monitoring)	- location of nest and species - date found - status of nest – active with eggs, failed, chicks hatched, etc. - whether parents are banded (if yes, band combinations) - location of cameras, and settings of cameras	- hatching success - fledging success - time cameras at nest (actual recording, no flat batteries or malfunctions) - predation or scavenging or abandonment events and identification

	Key Question	Method
Low intensity	- Change in population over time surveys	- Trend monitoring using river - Section of river, one-off
	- Productivity	- Breeding success determined by monitoring hatching success (without determining cause of nest fate) - up to 30 (needs to be statistically robust) nests per species - Species: banded dotterel/wrybill (solitary), black-fronted tern (colonial)
Medium intensity	- Change in population over time surveys	- Trend monitoring using river - Section of river, annually for 3 consecutive years
	- Productivity	- Breeding success determined by monitoring hatching *and* fledging success (without determining cause of nest fate) - up to 30 (needs to be statistically robust) nests per species - Species: banded dotterel/wrybill (solitary), black-fronted tern (colonial)
High intensity	- Change in population over time surveys	- Trend monitoring using river - Section of river, annually for 3 consecutive years, then annually continued or every 3 or 5 years
	- Productivity	- Breeding success determined by monitoring hatching *and* fledging success (*with* determining cause of nest fate) - up to 30 (needs to be statistically robust) nests per species - Species: as many as desirable
	- Survival	- Mark-recapture study using banded adults and chicks for solitary nesting species

Figure 2. Continuum showing desired level of intensity associated with key questions and suggested methods.

2. Trend Monitoring Using River Surveys

River surveys are used as an index of relative abundance to determine trends over the period of years. These surveys will not provide a total population estimate because some birds will not be detected during counts or are not present on the river, and it is therefore assumed that the counts are *representative* of the total population using the river (O'Donnell & Hoare 2011). Surveys can be done for any number of species and do not have to be repeated every year, and can either be conducted over the length of an entire river (if feasible) or several rivers or sections of a river. However, timing of surveys and river sections should be kept consistent between surveys to allow for trend analyses. As a general rule, the same section at the same time of year should ideally be repeated over a period of three years.

There are also other methods that can be used for trend monitoring, such as aerial river surveys. The protocol for ground surveys is outlined below, whereas a detailed example of an aerial black-billed gull census has been published by Mischler (2018). Drones, helicopters, or fixed wing aircraft can be used to cover large areas/multiple rivers in one season (for colonial nesters). Jet boats can be used for a rapid survey of long stretches of river for colonial nesters where colonies are located by boat and then counted afterwards. If detailed questions about habitat preference or bird densities are identified, dividing the river into small sections (ex. 1 km grids) and using detailed maps would be appropriate methods. For further information, consult Maloney et al. (1997), Maloney (1999), and McArthur & Burgin (2017).

2.1. Prior to the survey

Timing

Conduct surveys between mid-October and mid-December, preferably in mid- to late November. The timing of the survey should reflect the timing of breeding, particularly for projects where multiple rivers are being surveyed in one season. For example, surveys should be conducted earlier for rivers at low altitudes as birds arrive and breed before birds on rivers at high altitudes (Maloney et al. 1997).

Weather conditions and river flows

Choose a day with dry weather, and monitor river flows a week or two before the survey to ensure choosing a day when river flows are relatively normal (give or take). Refer to www.ecan.govt.nz/data/riverflow for river flow data in Canterbury to gain an understanding of average flows for the river in question. For big rivers with large flows (80-100 m^3/sec), a jet boat is required as part of the survey to transport observers across braids that are too swift to safely cross on foot. Also, do *not* survey after a significant flood – wait approximately 7-10 days to give the birds a chance to return to the river.

Sections of river

Survey the same sections of river each time the count is being conducted. GPS units should be carried by all observers with each track recorded. The river length is divided into sections of approximately 10-20 km lengths based on easy access points (for ease of observer drop-offs and pick-ups) and geographical features, such as gorges. GPS units should be used to mark the start and end points of each section. Also, section boundaries need to be easily identifiable to all observers (providing a printout of a map showing sections is advisable to give to observers for use in the field). The width of the section surveyed is the area of active riverbed. This includes open gravel and cobble as well as vegetated islands that occasionally flood but excludes stable vegetated islands and banks. Different sections can be surveyed simultaneously by different groups of observers. If surveyors are covering more than one survey section, then they must record data from each section separately, i.e. field data must be clearly delineated for separate sections. Although surveys should be done over as short a time period as possible, surveying

over a period of multiple days is acceptable if river sections are very long. This is assuming that river conditions remain the same over this time period (i.e. no major weather changes or floods). For most of the rivers, survey sections have already been established, and these established sections should be used. Section data is available from DOC (agrant@doc.govt.nz) or individuals maintaining the data from those rivers.

Observers

Use the same number of observers during each survey, and ensure that they have river crossing knowledge and excellent river bird identification skills, both by sound and sight, in order to minimize observer bias or inconsistencies. The number of observers depends on the width of the river sections being surveyed. Observers have to be spaced far enough apart to avoid double counting but close enough to allow communication, usually at intervals of approximately 50-150 m. It is important to note that the key with the number of observers is that there are sufficient surveyors to locate cryptic small species such as wrybill and dotterel which are predominately on the ground. Communication is needed to ensure that the more conspicuous flying species and large colonies are only recorded once.

During the survey

Once sections have been assigned, observers will space themselves evenly across the width of the riverbed at approximately 50-150 m intervals. They will walk downstream in a straight line with other observers perpendicular to the water flow, maintaining the same speed and a swift constant pace (approximately 3km/hr). Stopping should only be done at the end of sections as frequent stopping will cause errors in counts due to birds moving around. When walking, all birds that have moved upstream past the observers as well as birds that have moved from the riverbed away to either side are identified and counted, using binoculars. If a bird flies downstream without circling back and is unlikely to end up in a lower section, it is counted. If any observer is unsure whether or not a bird was seen by an adjacent observer, communication such as predetermined hand signals, 2-way radios, or verbalizing will be used to avoid double counting. Counts are recorded on a datasheet by each observer, and additional notes such as the location of gull or tern colonies as well as any juveniles/immatures and chicks can also be noted. GPS devices should be used to record colony locations, or any other species of interest, such as wrybill.

Species to be counted should be agreed upon before starting the survey, and as many wetland species as possible should be included. Suggested species are Australasian harrier, banded dotterel, black-fronted tern, black shag, black stilt, black-billed gull, Canada goose, Caspian tern, grey duck, grey teal, hybrid stilt, little shag, mallard, New Zealand shoveler, paradise shelduck, pied stilt, South Island pied oystercatcher, Southern black-backed gull, spur winged plover, unidentifiable duck spp. (mallard or grey), white-faced heron, black-fronted dotterel, New Zealand pipit, and wrybill.

2.2. Data Collection Template

Key information needed is the count of birds as well as breeding colonies and their size. Survey data from all observers should be collated and summarized into a table as soon as possible after conducting the survey. Figure 3 outlines how data should be collected.

						Section start		Section end				Colony location		
Season	Survey date	Observer	River	River section	NZTM E	NZTM N	NZTM E	NZTM N	Species	No. seen	NZTM E	NZTM N	Weather	Comments
2018/19	16-Nov-18	Jane Smith	Ashburton River	SH1 bridge to rivermouth	1498739	5137266	1504179	5121532	Banded dotterel	7	N/A	N/A	Hot, sunny, calm	At least two pairs with one chick each
2018/19	16-Nov-18	Jane Smith	Ashburton River	SH1 bridge to rivermouth	1498739	5137266	1504179	5121532	Pied stilt	12	N/A	N/A	Hot, sunny, calm	N/A
2018/19	16-Nov-18	Jane Smith	Ashburton River	SH1 bridge to rivermouth	1498739	5137266	1504179	5121532	SI pied oystercatcher	15	N/A	N/A	Hot, sunny, calm	N/A
2018/19	16-Nov-18	Jane Smith	Ashburton River	SH1 bridge to rivermouth	1498739	5137266	1504179	5121532	Black-billed gull	5580	1498958	5136912	Hot, sunny, calm	Colony directly downstream of bridge
2018/19	16-Nov-18	Jane Smith	Ashburton River	SH1 bridge to rivermouth	1498739	5137266	1504179	5121532	Black-fronted tern	260	1503592	5123580	Hot, sunny, calm	N/A

Fig. 3. Image showing the data collection template that should be used for river surveys, completed with hypothetical data.

Clarification of headings are as follows:

- Observer – counts should be listed for each observer, and then combined at the end as a total,
- River section – include GPS points (under Section start and Section end), particularly if section boundaries have the potential to be unclear,
- No. seen – should be adult birds only. If chicks and/or juveniles are seen, this should be listed in a separate column (if agreed prior to survey) or in the comments section,
- Colony location – GPS point of any gull or tern colonies found during the survey,
- Weather – vague, general idea of conditions.

This template can be copied, or directly downloaded as an Excel file (RiverSurveyDataTemplate.xlsx) from www.braid.org.nz. Descriptions of headings are also shown in a separate worksheet in the Excel file.

There are several analyses that can be done with river survey data. For example, comparisons of river bird densities (Maloney et al. 1997, Maloney 1999), linear regression for trends (Spurr & Ledgard 2016), and determining factors that influence trends (O'Donnell & Hoare 2011). However, a basic but very useful analysis is comparing the minimum number of birds, as shown in Table 3. This simple comparison can be used as an index of relative abundance to determine trends over the period of years. Equally, a simple bar graph as shown in Fig. 4 can be drawn for any number of species.

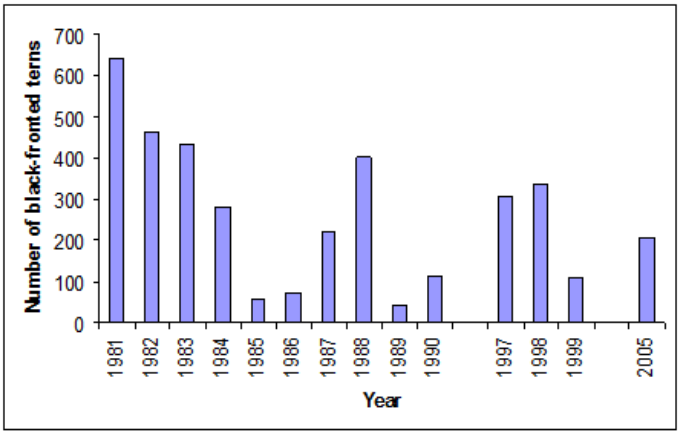


Fig. 4. Sample bar graph showing number of black-fronted terns as counted in given years on the Ashburton River (adapted from O'Donnell (unpub)).

2.3. Report Summary and Storage

The most effective format for a report summary is shown in Table 3, with the emphasis placed on showing multiple years in the table. This allows ease of comparison between years and analyses. A copy of annual river survey count data should also be submitted to one place by all parties. For example, Andy Grant (DOC Christchurch; agrant@doc.govt.nz) will collate the information in a database. Equally, copies can be made available via the BRaid website (www.braid.org.nz).

Future standards of report summary and storage will be electronic datalogger (ipads or phone apps) type capture of all species automatically linked to GPS locations and uploaded into data templates. For the present time, data should be submitted to Andy Grant as DOC is reviewing how data can be securely stored, displayed, and made accessible in the long-term (which may include public websites such as eBird and the DOC website).

Table 3. Table showing species numbers from river surveys across several years on the Tasman River, shown as an example (adapted from Leseberg et al. 2005).

Species	1992	1993	1994	2004	2005	2006	2007	2008	2009	2010	2012	2013	2014	2015	2016
Banded dotterel	599	572	523	837	569	778	858	847	743	395	452	570	533	691	652
Black stilt	5	1	1	2	8	9	15	15	32	2	5	3	19	20	10
Black-backed gull	537	608	609	258	151	95	154	127	243	228	413	366	363	232	160
Black-billed gull	25	8	7	32	7	10	37	5	6	11	22	6	113	48	165
Black-fronted tern	110	175	79	217	121	47	92	101	143	155	131	173	188	244	318
Caspian tern	2	2	2	0	3	0	0	0	3	0	0	1	2	2	4
Harrier	11	3	0	3	3	1	9	7	1	1	2	1	3	2	2
Hybrid stilt	9	1	1	8	9	4	10	4	1	1	0	2	4	0	2
Pied stilt	21	12	18	17	54	12	9	2	0	0	2	2	9	4	13
SIPO	76	59	46	100	61	86	69	64	52	65	53	109	65	57	71
Spurwing plover	23	17	18	25	31	21	37	23	12	5	7	23	19	14	12
Waterfowl and shags	357	407	334	702	382	345	842	377	336	205	177	295	401	343	208
White-faced heron	1	2	2	0	3	2	0	0	2	1	3	0	3	4	1
Wrybill	151	128	120	86	99	32	111	143	156	92	84	165	133	91	85
TOTAL	1927	1995	1760	2287	1501	1442	2243	1715	1730	1161	1351	1716	1855	1752	1703

3. Population Viability Monitoring

This section outlines protocols for population viability monitoring, and encompasses several different aspects. It is divided according to the methods and species being monitored. The methods include mark-recapture (for survival questions), breeding success without identifying the cause of nest fate (for productivity questions), and breeding success with identifying the cause of nest fate (for productivity questions). Species are separated based on whether they are solitary or colonial nesters as methods used differ.

3.1. Mark-Recapture (Survival, adult and juvenile)

Understanding adult survival is important because it is the breeding birds that contribute the most to the overall population. Adult survival is best monitored by banding breeding birds. This also allows other demographic aspects to be studied, such as pair bonds (i.e. do pairs stay together every season, do they find a new partner if the nest fails) and nest site fidelity (i.e. do the same birds return to the same area to breed every season, do pairs re-lay in the same area if their nest fails). Understanding juvenile survival is also important as new recruitment into the population is necessary to maintain or increase numbers. Banded juveniles are useful to determine fidelity to the site from which the chicks fledge, and can also provide information on different stages of life since banded juveniles are known-age birds. If adult and juvenile survival are low during the non-breeding season, it can be indicative of problems in areas away from the breeding site. Estimates of survival are best achieved by banding adults unless catching adults causes too much disturbance in which case chicks should be banded. Chick survival is generally low and they may not return to their natal site; consequently, using chicks for survival studies is problematic. Regardless, survival studies are a multi-year effort, and require *high levels* of repeat surveys and intense searching for banded birds.

Methods for banding are outlined below according to the nesting habit of species, solitary or colonial. The most effective way to band adults is by locating nests and capturing incubating birds. Nests of solitary species are generally more difficult to find than those of colonial species.

3.1.1. Methods for solitary nesters

Solitary nesters include: Banded dotterel, black stilt, black-fronted dotterel, Caspian tern, pied stilt, South Island pied oystercatcher, spur-winged plover, wrybill.

Locating nests

Nests of solitary breeders can be difficult to find. To locate nests, it is most efficient to walk the section of river that is of interest. Suitable habitat needs to be pinpointed by using a map and searched. Areas of interest may need to be searched several times between September and December, particularly if individuals are present but nests are not found, or if birds are absent from areas where they would be expected to occur. Laying may not have started, or birds may not have arrived hence subsequent searches are required.

To find solitary nests, the observer must pay attention to both behaviours and sounds of birds. Please note that not all individuals and species will behave in the same way, and that observer discretion is required. Generally, breeding birds will appear agitated and call frequently. When a bird with breeding behaviour is located, the observer should move between 100-300 meters away as quickly as possible to find a vantage point from which as large of an area as possible can be seen. Do not hide, but rather keep to an open area and try to find a slightly raised bank while keeping an eye on the bird. Relocate the bird with binoculars and observe. If the bird continues to appear agitated and bothered by the observer's

presence, back away a further 50 meters. Only once the observer no longer poses a threat will the bird return to the nest. Once the bird has settled on its nest, the observer must note down nearby features such as clumps of tussock or unique rocks to pinpoint the exact location of the nest bowl. Choosing a distant feature to maintain the line is also useful. Begin swiftly walking towards the nest without ever looking away from the nest. Once the observer approaches the general area of the nest, it is best to move either slightly right or left to avoid trampling on the eggs. Extreme care must be taken as the eggs are cryptic and very difficult to see, particularly for banded dotterel and wrybill.

Use the following along with Table 4:

- For banded dotterels, females incubate the nest during the day and males at night. Consequently, if agitated females are observed which are calling and displaying 'head-bobbing', that bird needs to be observed in order to find the nest. The male will usually be nearby and will arrive into the territory.
- Wrybills leave their nest at a later stage than dotterels and may be seen running from their nest. They may also do a broken-wing display only 1-2 meters from the nest thereby indicating that the nest is within close proximity. It may, however, still be better to retreat 50-100 meters and wait for the bird to return rather than risk trampling on the eggs.
- Stilts may fly straight up and off the nest without running, followed by some circling around above the observer. Or they may walk/sneak off the nest.
- Oystercatchers sneak away like dotterels and frequently false brood. They can often be seen sitting on the nest from a distance (the birds are not cryptic) if the observer is actively looking for them.
- All the species tend to return to the nest by either running in a straight line towards it and keeping a low and crouching posture or flying a short distance and then running or casually walking back towards it.

Different species and individuals react differently to disturbance when breeding. Several factors that affect behavior and will influence search time are weather conditions (wind and temperature – is it too hot or too cold), and the amount of disturbance the birds encounter on an everyday basis (if at a river mouth or at a readily accessible access point near a populated place, the normal day to day disturbance may be quite high). Experienced observers should be able to find nests quicker than new operators; however, solitary nests should be found within 15-20 minutes, and colonies should be covered within 15 minutes in order to prevent excess disturbance and potential abandonment.

Once nests have been located, a GPS point is taken. A small rock cairn can be built 1 or 2 meters away from the nest. Ensure that the cairns are placed in the same direction for every nest, for example upstream, to make locating the nest again easier. If a nest is found at early chick stage, exclude this nest from monitoring (due to introducing bias).

Table 4. Key factors to help locate nests of solitary breeders. Note that not all species and individuals will follow these guidelines.

Species	Nest/scrape	Nesting behaviour
Banded dotterel	Scrape	Agitated, calling, head-bobbing, female incubates during the day – observe her to find nest
Black stilt	Minimal vegetation	Run, or fly straight upwards from nest, fly quietly around in a circle above observer, may fly away before returning
Black-fronted dotterel	Scrape	Agitated, calling, leaves nest from a very long distance so incredibly difficult to find, also do a 'fake' settling onto random spot where no nest is located
Caspian tern	Scrape	Flying birds, agitated calls, dive-bombing, generally associated with Southern black-backed gull colonies when nesting on braided rivers
Pied stilt	Minimal vegetation	Fly straight upwards from nest without running, fly quietly around in a circle above observer, may fly away before returning, sneak off nest
South Island pied oystercatcher	Minimal vegetation	Agitated, calling, nervous running and flying around, can be seen sitting on nest if looking carefully since bird is not cryptic, also do a 'fake' settling onto random spot where no nest is located
Spur-winged plover	Minimal vegetation	Agitated, calling, nervous running and flying around, leaves nest early on
Wrybill	Scrape	Agitated, calling, leave nest quite late so may be able to see it run off, broken wing display if within 1 or 2 meters of nest. Nest bowls often used between years.

Banding adults

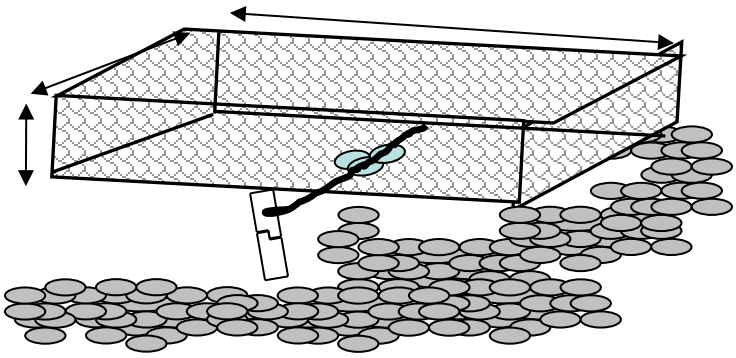
It is important that no catching or banding of birds is conducted without the appropriate permits. For all information in regards to this, contact the DOC Banding Office (bandingoffice@doc.govt.nz) or check online at www.doc.govt.nz (Bird banding section). This includes finding the appropriate people to support catching and banding. Additional methods for catching birds, such as noose mats or walk-in traps, are outlined in the New Zealand National Bird Banding Scheme (NZNBBS) manual. For all colour banding of shorebirds, there are designated coordinators to ensure the same combination is not used twice. For a list of the most recent coordinators, contact the Banding Office.

Breeding adults can be trapped on the nest using a rectangular or square drop trap. Ensure that the weather is warm and dry, that hands are dry when handling birds, and that no more than 20 minutes is spent on attempting to catch one particular bird. One incubating adult is caught at a time with a light-weight wire frame covered with thin plastic netting (Figure 5). The trap is placed over the nest with the eggs in the middle of the trap, and held open at an angle of approximately 45° by two interlocking wooden sticks. Ensure that the trap is open high enough to prevent the bird from having to duck underneath it or touching it, and check that the trap base drops as flat as possible. If there are large

stones under the base when it drops, the bird may be able to escape. To trigger the trap use either: 1) a thin nylon line which is attached to the sticks and the opposite side of the frame from the sticks, the line should run over the eggs. Or 2) use the electronic trigger to release the trap. After setting the trap, back away until the bird returns to the nest (at least 50-100 meters). Make sure the trap can be seen at all times. When the bird returns and walks under the trap and sits down on the eggs, the line is depressed by the bird and pulls the two sticks apart and the drop trap falls down over the bird.

Once caught, move towards the nest as quickly as possible to ensure the eggs are not damaged. The bird is carefully retrieved from the trap, and the trap is removed from the nest, and any rocks that were shifted are replaced in their original positions. To avoid too much disturbance at the nest (by leaving scent and tracks), the bird is banded at least 50 meters away. This also allows the partner (if nearby) to continue to incubate the eggs. Ensure other birds nesting nearby are able to return to their nest. To band birds, an individual with the necessary banding authority (graded according to skill and experience) must be present to carry out and/or supervise the work. In addition, an appropriate Wildlife Act Authority is necessary from DOC for any person carrying out research and handling or disturbing protected species (DOC employees are excluded from this). Any research project requires an Animal Ethics Committee approval, a requirement of the Animal Welfare Act. All birds must be banded with the appropriately sized stainless steel band. It is also recommended that a unique combination of coloured plastic double wrap-around bands are used for each bird to allow resighting without having to recapture the birds. There are also other band options, such as engraved darvic bands or flags. The number of adults banded will depend on the number of pairs breeding in an area and the amount of time and resources that are available for the nest searching and the banding process.

Fig. 5. Drop trap placed over nest to catch breeding adults for banding (Leseberg et al. 2005). Dimensions need to be adjusted according the size of species being captured.



Banding chicks

Chicks should be banded as late as possible before they fledge. For species such as the banded and black-fronted dotterel, finding the chicks can be very challenging and time consuming as they are cryptic and are well hidden amongst stones or vegetation. Banding chicks for these species should therefore be opportunistic and carried out whenever a chick is seen and caught. It is also possible to band the chicks at 3 days of age if they are still at or near the nest; however, colour banding is not recommended at this early age as the bands are too large. For other species, such as stilts, wrybill, and oystercatchers, chicks are often readily visible before fledging because of their size or due to behaviours such as congregating near water. Chicks are chased and caught using a small, long-handled butterfly net and then banded in the same manner as adults. If on an island, chase chicks upstream to prevent them from going in the current downstream. Also, wet chicks should not be handled. If possible, all chicks of a clutch should be

caught at once and then banded to avoid a long banding process and splitting up siblings. The number of chicks banded will depend on the number of successful pairs breeding in an area and the amount of time and resources that are available for nest searching, monitoring, and the banding process.

Please note that due to high mortality and dispersal from natal sites, care needs to be taken in determining numbers of chicks banded in order to ensure results are statistically robust. Power analyses can be conducted to determine if the level of chick banding can be reached to achieve the aims of the survival study. It is vitally important to have a purpose for banding to answer original research questions, and the result must be written up in a timely manner to avoid overuse of banding or disturbance. A considerable amount of resighting is required to attain a meaningful result, and if resighting cannot be thoroughly followed through banding must *not* be done.

Resighting

Data on adult survival and recruitment should be collected as often as possible and in as many areas as possible. Take note of the species and colour combination/inscription on the band. A GPS point should be taken at the locations where banded birds are seen. Send resighting information to the Banding Office. Raising awareness about the presence of banded birds to the public may also help in more birds being spotted in and outside of the breeding season.

3.1.2. Methods for colonial nesters

Colonial nesters include: Black-billed gull, black-fronted tern, red-billed gull, Southern black-backed gull, white-fronted tern)

Locating nests

Nests of colonial breeders are generally easier to find than those of solitary breeders. This is due to the large concentration of birds present in a colony. To locate nests, it is most efficient to walk the section of river that is of interest. Suitable habitat needs to be pinpointed by using a map and searched. For colonial breeders, it is also possible to look for flocks of flying or hovering birds as these birds may be traveling to or from, or are directly above, the colony. Areas of interest may need to be searched several times between September and December, particularly if colonies are absent and hence may form later.

Use the following along with Table 5:

- For gulls (black-billed, red-billed, and Southern black-backed gulls), colonies are obvious in that there are large numbers of birds in one area, and they will appear agitated by calling out with some individuals flying towards the observer(s) while others may remain focused on one area. Gull nests are also generally quite large and very well formed with vegetation and hence can easily be seen.
- Black-billed and red-billed gulls nest in very dense colonies. These two species can mix into the same colony, as well as with white-fronted terns (particularly at river mouths).
- Southern black-backed gull colonies are generally less dense than black-billed and red-billed gull colonies, and can be spread over many kilometers.
- Terns (white-fronted and black-fronted) generally lay their camouflaged eggs in a scrape and can be difficult to find.
- White-fronted terns breed in high density colonies (at river mouths), and scrapes are therefore close together. Once a white-fronted tern colony has been located, nests can be readily seen.
- Black-fronted terns nest in low density colonies with scrapes spread out over large areas (can be >50 meters apart). Once the observer(s) has entered a colony, birds will be agitated and will fly overhead or potentially dive-bomb. To find nests, a systematic search of the non-vegetated area

where birds are present (island or bank) is required. This involves walking slowly and looking for eggs about 2 meters on either side, being careful not to tread on any eggs. For small colonies (<10 pairs), it is possible to sit approximately 100 meters away and allow the birds to settle, followed by a brisk walk back towards the colony and noting the precise location where birds are flushing from.

Once colonies have been located, a GPS point is taken. For Southern black-backed gull nests, each nest needs to have a GPS point taken (due to the low density of colonies), and an additional marker (wooden stake, for example) may need to be placed next to the nest for ease of finding it again. For black-fronted terns, each nest needs to have a GPS point taken (due to the low density of colonies), and a small rock cairn can be built 1 or 2 meters away from the nest. Ensure that the cairns are placed in the same direction for every nest, for example downstream, to make locating the nest again easier.

Table 5. Key factors to help locate nests of colonial breeders.

Species	Nest/scrape	Colony density	Nesting behaviour
Black-billed gull	Formed nest	High	Flying birds, agitated calls, large congregation of individuals, dive-bombing
Black-fronted tern	Scrape	Low	Flying birds, agitated calls, many individuals present but may be spread out over large area, search systematically, dive-bombing
Red-billed gull	Formed nest	High	Flying birds, agitated calls, large congregation of individuals, dive-bombing
Southern black-backed gull	Formed nest	Low – medium	Flying birds, agitated calls, many individuals present but may be spread out over large area, search systematically, dive-bombing
White-fronted tern	Scrape	High	Flying birds, agitated calls, large congregation of individuals, generally at river mouth

Banding adults

It is important that no catching or banding of birds is conducted without the appropriate permits. For all information in regards to this, contact the DOC Banding Office (bandingoffice@doc.govt.nz) or check online at www.doc.govt.nz (Bird banding section). This includes finding the appropriate people to support catching and banding. Additional methods for catching birds, such as noose mats or walk-in traps, are outlined in the New Zealand National Bird Banding Scheme (NZNBBS) manual.

Adults of colonial nesters can be captured and banded using the same methods as outlined above (Section 2.1) for solitary breeders. A drop trap can be placed over a nest within a colony, ensuring that the trap does not fall onto an adjacent nest when triggered. For large species, such as the Southern black-backed gull, drop traps or walk-in traps placed over the nest can be used. An example of a walk-in trap can be found on the Gull Research website (http://www.talk.gull-research.org/viewtopic.php?t=865).

Please note that the banding of adult red-billed gulls, black-billed gulls, and white-fronted terns is *not* recommended as the disturbance to such high density colonies is too high. Also, it is vitally important to have a purpose for banding to answer original research questions, and the result must be written up in a timely manner to avoid overuse of banding or disturbance. A considerable amount of resighting is required to attain a meaningful result, and if resighting cannot be thoroughly followed through banding must *not* be done.

Banding chicks

Chicks should be banded as late as possible before they fledge. For densely nesting species, such as red-billed gulls, black-billed gulls, and white-fronted terns, it is quickest and most efficient to herd all chicks into an enclosure. The weather needs to be fairly calm, dry, and not too hot or too cold. If birds are nesting on an island, ensure observers are walking upstream to prevent pushing the chicks into the current downstream (chicks should be prevented from going into the water as wet chicks should not be handled). Herding is done by having several people walking in a line and slowly herding all the chicks into an enclosure approximately 5 meters in diameter made out of chicken wire (or other suitable material). The sides of the enclosure need to be movable – opened to let the chicks walk in, and then closed immediately to form a circular shape (shapes with corners should not be used as it can lead to piling up of chicks with some birds trapped in the corners and others piling on top). The entire structure needs to be very stable (the sides should not be able to tip over), and linens may need to be placed over the top of the enclosure on a hot day to provide shade. The chicks are then banded one at a time (having several qualified banders available helps to speed up the process), and placed into another enclosure of approximately 5 meters in diameter. Only once all chicks have been banded are they released at the same time for safety.

For low density nesting species, such as black-fronted terns and Southern black-backed gulls, chicks are generally visible before fledging because of their size or due to behaviours such as congregating near water. Chicks are chased and caught using a small, long-handled butterfly net and then banded in the same manner as adults. If possible, all chicks of a clutch should be caught at once and then banded to avoid a long banding process and splitting up siblings. The number of chicks banded will depend on the number of successful pairs breeding in an area and the amount of time and resources that are available.

Resighting

Data on adult survival and recruitment should be collected as often as possible and in as many areas as possible. Take note of the species and colour combination/inscription on the band. A GPS point should be taken at the locations where banded birds are seen. Send resighting information to the Banding Office. Raising awareness about the presence of banded birds to the public may also help in more birds being spotted in and outside of the breeding season.

3.1.3. Data collection

There are several types of data collected for survival. This includes information for the nest site where birds will be caught (Fig. 6), banding information (Fig. 7), and resighting data of banded birds (Fig. 8). The nest information shown here is simply used as a reference to the location and circumstances under which an adult and/or chick(s) were banded, but can be expanded if monitoring of the nest is being conducted (see the section on Breeding Success). Similarly, the Department of Conservation has guidelines for banding records and resighting information, but any licensed bander should be familiar with these procedures (see the Department of Conservation bird banding website for more information, https://www.doc.govt.nz/our-work/bird-banding/). Snapshots of Banding Office requirements for both banding and resighting are given below (Figures 9, 10).

	A	B	C	D	E	F	G	H	I
1	SPECIES	SITE	SEASON	NEST #	FOUND BY	NZTM E	NZTM N	DATE FOUND/CHECKED	
2	Wrybill	Tasman River	2017/18	1	Jane Smith	1369506	5140877	16-Oct-17	
3	Wrybill	Tasman River	2017/18	2	Jane Smith	1371030	5139546	16-Oct-17	
4	Wrybill	Tasman River	2017/18	3	Jane Smith	1370463	5138782	16-Oct-17	
5	Wrybill	Tasman River	2017/18	4	Jane Smith	1371411	5135314	18-Oct-17	
6	Wrybill	Tasman River	2017/18	5	Jane Smith	1370644	5134602	19-Oct-17	
7									
8									

Figure 6. Image showing data collection template for nest site where birds will be caught.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1					Colour bands											
2	Species	Season banded	Date banded	Month	Bird left leg (top to bottom)	Bird right leg (top to bottom)	Colour band type	Metal band	Age	Sex	Location banded	NZTM Easting	NZTM Northing	Bander	Comments	Nest #
3	Wrybill	2015-16	9-Oct-15	10	yellow, orange	orange, red	3.5mm wrap	C-12345	Adult	F	Tasman River	1370000	5134000	Jane Smith	metal on left tibia	X10
4	Wrybill	2015-16	20-Oct-15	10	yellow, orange	orange, black	3.5mm wrap	C-12346	Adult	F	Tasman River	1370001	5134001	Jane Smith	metal on left tibia	X11
5	Wrybill	2015-16	20-Oct-15	10	yellow, orange	orange, yellow	3.5mm wrap	C-12347	Adult	F	Tasman River	1370002	5134002	Jane Smith	metal on left tibia	X12
6	Wrybill	2015-16	20-Oct-15	10	yellow, orange	orange, green	3.5mm wrap	C-12348	Adult	F	Tasman River	1370003	5134003	Jane Smith	metal on left tibia	X13
7	Wrybill	2015-16	10-Nov-15	11	orange, black	red, orange	3.5mm wrap	C-12349	Adult	M	Tasman River	1370004	5134004	Jane Smith	metal on right tibia	X14
8																

Figure 7. Image showing data collection template for banding of birds.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1						COLOUR BANDS								
2	SPECIES	SEASON RE-SIGHTED	DATE RE-SIGHTED	METAL BAND	COLOUR BAND (YES/NO)	BIRD LEFT LEG (top to bottom)	BIRD RIGHT LEG (top to bottom)	LOCATION RE-SIGHTED	NZTM E	NZTM N	OBSERVER	NEST #	COMMENTS	
3	Wrybill	2016/17	7-Nov-16	unknown	Yes	yellow, orange	orange, red	Tasman River	1372350	5134963	Jane Smith	N/A	Not breeding, seen feeding	
4	Wrybill	2016/17	8-Nov-16	unknown	Yes	yellow, orange	orange, yellow	Tasman River	1372351	5134964	Jane Smith	N/A	Not breeding, seen feeding	
5	Wrybill	2016/17	9-Nov-16	unknown	Yes	yellow, orange	orange, green	Tasman River	1372352	5134965	Jane Smith	N/A	Not breeding, seen feeding	
6	Wrybill	2016/17	10-Nov-16	unknown	Yes	orange, black	red, orange	Tasman River	1372353	5134966	Jane Smith	N/A	Not breeding, seen feeding	
7	Wrybill	2016/17	11-Nov-16	unknown	Yes	orange, black	black, red	Tasman River	1372354	5134967	Jane Smith	N/A	Not breeding, seen feeding	
8														

Figure 8. Image showing data collection template for resighting of banded birds.

These templates can be copied, or directly downloaded as an Excel file (SurvivalDataTemplate.xlsx) from www.braid.org.nz. Descriptions of headings are also shown in a separate worksheet in the Excel files.

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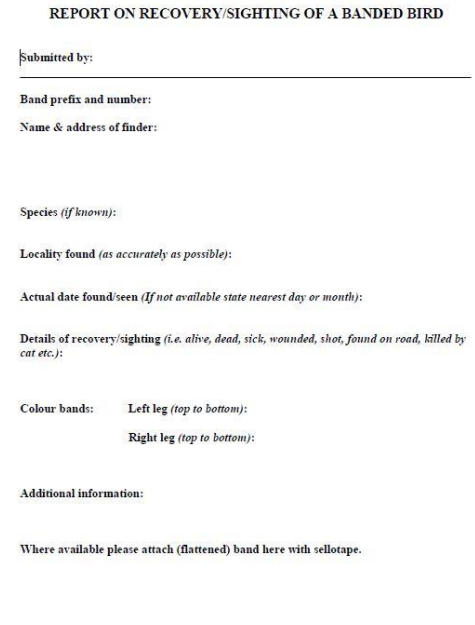
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Description of columns ->	PRIMARY MARK: can be band or transponder (prefix "PIT") Even if this is removed or illegible, this remains the unique identifier for this animal Bands issued, and bands lost/destroyed/used for training are also entered here		This is a crucial code that gives info on what happens to a band/mark. Only one code per line.	autofills, do not enter Use this to CHECK whether you have used the correct NZNBBS_code	3-digit code of species (except for NZNBBS_Codes 0, L, T)	autofills, do not enter (unless species code = XXX) Use this to CHECK whether you have entered the correct species code		This MUST be in date format. If you do not know the date, enter today's date, and enter U under date accuracy	How accurate is the date?	What types of marks does the bird now have? Provide codes as per Lookup - can have more than one code listed.	Prefix and number of band or transponder in ADDITION to (or as replacement of) PRIMARY MARK		Describe the type of co band used (butt-band, wraparound, flag, alpha numeric), and whether was glued or soldered	
2	Example description	Band_prefix	Band_number	NZNBBS_Code	Lookup_Code	Species_Code	Scientific_name	Common_name	Date	Date_Accurac	Mark	Added_mark_prefi	Added_mark_numbe	Colour_band_type	Glue_sr_oth
3	Bands issued but not yet	CX	1001	0	STOCK ISSUED				15 April 2018	D					
4	used = Stock take	CX	1002	0	STOCK ISSUED				15 April 2018	D					
5	Use date that Stock take is	CX	1003	0	STOCK ISSUED				15 April 2018	D					
6	submitted to Banding Office	CX	1004	0	STOCK ISSUED				15 April 2018	D					
7	Band used for training - will not be used on a bird	K	15357	L	LOST band / destroyed / used for training.				15 March 2015	W					
8	Bands returned to Banding Office	E	191599	R	Returned band to Banding Office				17 April 2018	D					
9		B	115251	R	Returned band to Banding Office				17 April 2018	D					
10	Bird banded with metal band only	Y	17523	1	First marking	445	*Limosa lapponica*	Eastern Bar-tailed Godwit	20 October 1999	D	0				
11	Same bird, engraved flag added	Y	17523	3	Add/change mark	445	*Limosa lapponica*	Eastern Bar-tailed Godwit	26 January 2000	D	0, 3			Engraved flag	
12	Same bird, recaptured	Y	17523	2b	Recaptured (but not re-marked)	445	*Limosa lapponica*	Eastern Bar-tailed Godwit	9 March 2010	D	0, 3				
13	Same bird, resighted	Y	17523	2a	Resighted without being caught	445	*Limosa lapponica*	Eastern Bar-tailed Godwit	28 April 2012	W	0, 3				
14	Same bird, dead	Y	17523	x	DEAD: Recovery	445	*Limosa lapponica*	Eastern Bar-tailed Godwit	28 April 2012	D	0, 3				
	Bird banded elsewhere, recaptured in New Zealand. Use NZNBBS_Code "Z" to	072	88262	Z	Foreign Scheme band/mark	445	*Limosa lapponica*	Eastern Bar-tailed Godwit	25 February 2003	D	0, 2				

EXAMPLES

Figure 9. Snapshot of banding template from the DOC Banding Office. See www.doc.govt.nz for details.



REPORT ON RECOVERY/SIGHTING OF A BANDED BIRD

Submitted by:

Band prefix and number:

Name & address of finder:

Species ***(if known)*****:**

Locality found ***(as accurately as possible)*****:**

Actual date found/seen ***(If not available state nearest day or month)*****:**

Details of recovery/sighting ***(i.e. alive, dead, sick, wounded, shot, found on road, killed by cat etc.)*****:**

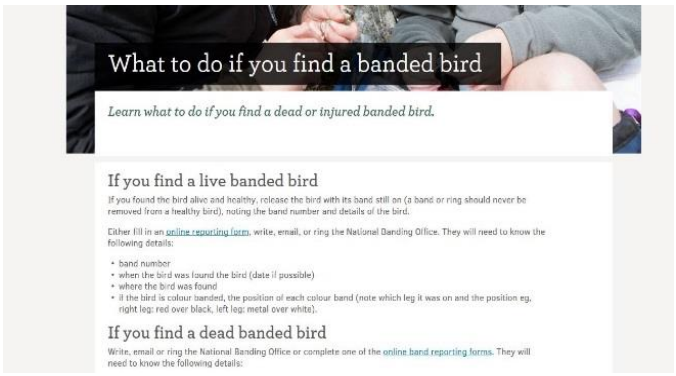
Colour bands: **Left leg** ***(top to bottom)*****:**

Right leg ***(top to bottom)*****:**

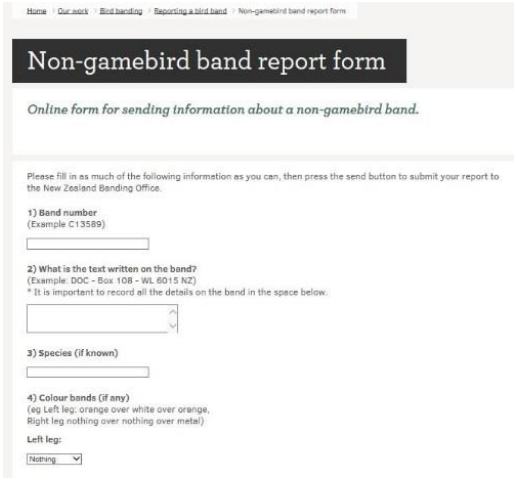
Additional information:

Where available please attach (flattened) band here with sellotape.

a)



b)



c)

Figure 10. Snapshots of DOC resighting templates. a) Form to be filled in and mailed, b) instructions of what to do and what information to write down, and c) a non-gamebird example of an online form. See www.doc.govt.nz for further details.

3.1.4. Analyses

It is advised that external guidance on analyses is asked for in regards to analyses and whether or not the banding project in consideration is worth doing given time and resources.

The most useful calculations conducted with survival data will involve mark-recapture analyses. However, these are complex assessments and will require the interested party to have advanced statistical knowledge or to seek external assistance (Lettink & Armstrong 2003; Pryde 2003). Consequently, the methods are not outlined in this document.

3.1.5. Report summary and storage

The most efficient format for a report summary is shown in Figure 11, with the emphasis placed on year and location banded compared to year and location an individual was resighted. This allows an instant overview of movements and potential age. Storage of data will be most useful with the Department of Conservation Banding Office as they have a national database of all banded birds which also includes sightings.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			METAL BAND		COLOUR BANDS		BANDING LOCATION				RESIGHT LOCATION			
2	SPECIES	DATE BANDED	BIRD LEFT LEG	BIRD RIGHT LEG	BIRD LEFT LEG (top to bottom)	BIRD RIGHT LEG (top to bottom)	NZTM E	NZTM N	AGE	DATE RE-SIGHTED	NZTM E	NZTM N	COMMENTS	
3	Wrybill	9-Oct-12	N/A	C-12345	yellow, orange	orange, red	1370000	5134000	Adult	7-Nov-16	1372350	5134963	Not breeding, seen feeding	
4	Wrybill	20-Oct-12	N/A	C-12346	yellow, orange	orange, yellow	1370001	5134001	Adult	8-Nov-16	1372351	5134964	Not breeding, seen feeding	
5	Wrybill	20-Oct-12	N/A	C-12347	yellow, orange	orange, green	1370002	5134002	Adult	9-Nov-16	1372352	5134965	Not breeding, seen feeding	
6	Wrybill	20-Oct-12	N/A	C-12348	orange, black	red, orange	1370003	5134003	Adult	10-Nov-16	1372353	5134966	Not breeding, seen feeding	
7	Wrybill	10-Nov-12	N/A	C-12349	orange, black	black, red	1370004	5134004	Adult	11-Nov-16	1372354	5134967	Not breeding, seen feeding	
8														

Figure 11. Image showing a hypothetical example for use as a summary of resighted banded birds.

4. Breeding Success

Monitoring of nests provides important information in regards to breeding success and can therefore be used to determine habitat quality, understand population dynamics, and assess the effects of conservation management. It can provide insight into the number of pairs a particular habitat can sustain, such as a section of river. If the habitat changes, for example, this will be noticeable in the change of the number of breeding pairs utilizing that section. It is also important to establish a baseline for the reproductive success of a species. Some species may naturally have higher productivity than others, perhaps due to life history traits or the stability of the habitats they rely on. Monitoring nests before and after conservation management can indicate the success of management. For example, predator control should improve productivity, and this should therefore be reflected in the monitoring.

Nest monitoring can pinpoint the most problematic stage of breeding. For example, if hatching success is low, the incubation stage needs to be addressed. On the other hand, if hatching success is high but fledging success is low, chick rearing is problematic. This knowledge can focus and improve management. Additionally, using a tool to determine the cause of nest failure can reveal more detail into particular problem areas than if the causes are not verified. For example, knowing that mammalian predators are responsible for low hatching success can guide management plans.

Methods for nest monitoring are outlined below according to the nesting habit of species, solitary or colonial. There are also two large sections, one focuses on breeding success only without identifying the cause of nest fate (2.2.1) while the other focuses on breeding success with identifying the cause of nest fate (2.2.2). There have been several methods used for predator detection, such as interpreting signs at nest, bite marks, direct observations, hair traps, foot imprints, and mtDNA (Sanders & Maloney 2002; Steffens et al. 2012). The drawbacks of these methods included time, expense, and incorrect or uncertain identification of predators. With an improvement in technology and a reduction in costs of remote cameras, the use of videos has become the best and most frequently used means of predator identification for a variety of species (Mischler 2016; Mischler & Bell 2016, Bell 2017).

4.1. Unknown cause of nest fate

4.1.1. Methods for solitary nesters

E.G. Banded dotterel, black stilt, black-fronted dotterel, Caspian tern, pied stilt, South Island pied oystercatcher, spur-winged plover, wrybill.

Locating nests

For how to locate nests, please see section 3.1.1: Methods for solitary nesters.

Up to 30 nests of each species in question should be monitored, if possible, as long as the number of nests is statistically robust. For river sections that may support large numbers of breeding pairs and 30 nests are found for one species in question in one section, it may be beneficial to find additional nests in another section of river. For example, if 30 nests are found at the top end of a river, it may be useful to find additional nests in the middle section and near the river mouth as nesting conditions and breeding success could vary. If time and resources are not available to monitor such a large number of nests, perhaps aim to monitor 10 nests each at the top end, middle, and river mouth sections.

Monitoring nests to hatching

Nests should be monitored every 3-5 days until hatching or failing. If a nest is found where birds are still laying (full clutch size not reached; Table 6), check nests until the clutch size no longer changes. If/when a full clutch is present, there are three scenarios for checking nests: 1) when walking towards the nest

using a GPS point, look for the cairn from a distance of 100-200 meters and watch to see if a bird runs off the nest as you approach it slowly. If you see the bird leave the nest, there is no need to approach as it is clear the bird is still incubating and the nest is still active; 2) if one or both birds are in the area of the nest but the behaviour does not clearly indicate whether or not a nest is still present, approach the nest and determine the contents. Pairs that have lost a nest usually remain in the territory for a few days after egg loss but act less agitated than when a nest is active. If eggs are missing or broken, the nest has failed. If eggs are still present but are cold and have material stuck to the underside, check the nest 1-2 days later to determine a final outcome; 3) if there are no birds near the nest, check the nest as described in scenario 2, and return 1-2 days later for a final outcome.

Please note that these three scenarios will vary depending on the intensity of which monitoring is being carried out. If monitoring intensity is high (i.e. interested in individual egg loss), then nests need to be approached every time to check the number of eggs. However, this also needs to be balanced with disturbance and risk of attracting predators to nests by leaving a scent. The expected degree of egg loss on overall productivity also needs to be considered. For example, whether the major cause of failure for a particular species is due to complete loss of a nest or due to the loss of individual eggs needs to be questioned. For black-fronted terns, failure is due to complete loss, not individual eggs.

Pairs may or may not re-lay after a failed attempt, and they may or may not re-lay in the same territory. The only way to determine whether or not it is the same pair nesting in a given territory is if at least one bird of the pair is banded. If no birds are banded, the nest should be treated as a new one.

When a nest is found, calculate the approximate date of hatching using Table 6. Check nests every day at 2-3 days before hatching to ensure chicks are seen before they leave the nest. Table 7 outlines terms and definitions used for breeding success calculations.

Table 6. List of solitary breeders with clutch sizes, incubation period, and fledging period to use for monitoring (Marchant & Higgins (1993), Higgins & Davies (1996)).

Species	Eggs laid	Incubation period (days)	Fledging period (days)
Banded dotterel	3	25	35
Black stilt	4	25	35
Black-fronted dotterel	2-3	24	30
Caspian tern	2	24	35
Pied stilt	4	25	30
South Island pied oystercatcher	1-3	25	30
Spur-winged plover	3-4	32	45
Wrybill	2	30	35

Table 7. Definitions of terms used for various breeding success calculations.

Term	Definition
Nest failure (cause of)	- Divided into categories to use as causes of nest failure, such as predation, desertion, flooding, died during incubation, damaged in nest, and failed cause unknown - Used to determine hatching success and nest success
Hatching success	The probability of ≥ 1 eggs in a nest surviving until they hatch

Nest success	- The probability that an egg will successfully survive, hatch and fledge - Includes any contents of the nest, and ignores partial losses through the failure of some but not all eggs to survive and hatch
Egg failure (cause of)	- Divided into categories to use as causes of individual egg failure, such as predation, desertion, flooding, died during incubation, died during hatching, damaged in nest, failed cause unknown - Used to determine egg success, and contributes to calculations for hatching success and fledging success
Egg success	The probability of an egg hatching in a nest if it survives
Fledging success	The probability of a chick fledging once it hatches

Cause of overall nest failure is classified into one of the following:

- Predation - Eggs are classified as preyed upon if they disappear before the earliest possible hatch date. If there is any doubt whether or not eggs have been predated, classify the nest failure as unknown because it is difficult to tell subsequent scavenging from predation.
- Desertion (fertile eggs) - eggs are cold and clammy with grit stuck to the underside and no sign of the pair. Any eggs that failed to hatch one week after the remaining clutch has hatched, and any complete clutches that are deserted, are opened to determine whether they have died during incubation (i.e. embryo present).
- Flooding - water has moved through nest bowl (evidenced by flood debris or flow records), and eggs are missing or lying outside the bowl or parents have deserted.
- Died during incubation (infertile) - any eggs that failed to hatch one week after the last chick has hatched, and any complete clutches that are deserted, are opened to determine whether they are infertile (i.e. no evidence of an embryo).
- Damaged in nest – eggs remain in nest bowl but have a crack or dent sufficient to cause failure, or eggs may have been pushed out of nest bowl without any signs suggesting predation, and there is no record or evidence of flooding.
- Failed, cause unknown - not enough checks to be able to categorise outcome, e.g. adults and eggs disappear but nest may have hatched or failed, and does not fall into any of the above categories.

Cause of individual egg failure is classified into one of the following (definitions are the same as above for nest failure):

- Predation
- Desertion (fertile)
- Flooding
- Died during incubation (infertile, addled)
- Died during hatching – egg is star cracked or contains a visible hole from which fully-developed chick was attempting to emerge, chick remains inside or mostly inside the egg.
- Damaged in nest
- Failed, cause unknown

Monitoring nests to fledging

Monitoring chicks to fledging can be difficult and time consuming. For banded dotterels, for example, chicks and parents may move up to 500 meters away from the nest, chicks are highly cryptic, and can hide well among vegetation. Generally, chicks should be checked at least once a week if time allows. It is enough to confirm that chicks are alive based on the presence of chick behaviour by the parents, and it is not necessary to locate each chick of a clutch during each visit. For the first couple of weeks after hatching, chicks remain close to their parents and in the vicinity of the nest bowl (within ~ 200 meter

radius of the nest). As the chicks grow older the family may move further away from the original nest. If a family cannot be located, the area around the nest should be searched in ever widening circles for a sign of at least one adult/parent displaying chick behaviour. If the missing chicks are very young (< 2 weeks) and not near the nest area, they are likely to have died and the parents left the area. These searches need to be repeated as often as necessary to confirm the outcome. If chicks and families disappear long before the expected fledging date (Table 6), the chicks are assumed to have failed.

Adult behaviour when chicks are nearby often include a broken wing display, agitated calling with nervously running and/or flying around, and sometimes dive-bombing. If chicks are present, adults will persist with this behaviour until the observer leaves the area. If chicks have recently died, adults may still carry out a bit of this behaviour but do not persist for very long. Once chicks are nearly ready to fledge, they tend to be easier to find as they are large and may spend time along the water's edge and out in open areas. Keep an eye out for, and maintain a count of, flying chicks in the general vicinity of where families were known to spend time as fledglings may remain in the area even after they are able to fly. Listening for chick begging calls is also a great way to locate chicks. Failures at the chick stage should be recorded (weekly), but the cause of failure can usually not be determined.

Modified Mayfield method

When conducting nest monitoring, it has long been determined that nest losses in early incubation are under-represented, consequently the observed nest success is higher than the true nest success. Mayfield (1975) stated that 1) mortality is a function of time, and 2) survival is the converse of mortality. To counteract any potential positive bias, the number of days over which a sample of nests is monitored needs to be kept track of. This allows for the estimation of daily survival of a sample of nests by using exposure days.

- Exposure days is 'the cumulative number of days that the nests in the sample were monitored' (Dinsmore et al. 2002)
- Nest-day is the unit for measuring exposure. It is representative of one nest monitored for one day. If two nests are observed for 6 days (for example), the exposure is 12 nest days. This is equivalent to 3 nests for 4 days, or one nest for 12 days
- Mortality rates (probability) = total number of losses/total number of exposure days
- Survival rates (probability) = 1-[(total number of losses)/(total number of exposure days)]

If a large sample is available and high precision is desired, it is possible to calculate a survival rate for each day, followed by computing the probability of survival for a specific number of days (n). This can then also be split up between incubation and chick rearing periods.

For example, as taken from Mayfield (1975):

- Incubation period: 35 nests lost during 878 nest days (this is a sample).
    - Mortality = 35/878 = 0.040 per nest day
    - Survival = 1-0.040 = 0.960 per nest day
    - If incubation is over a 14 day period, then the probability of nest survival for the entire sample is 0.960^14 = 0.56.
- Chick rearing period: 22 nests lost during 735 nest days (sample)
    - Mortality = 22/735 = 0.030 per nest day
    - Survival = 1-0.030 = 0.970 per nest day
    - If chick rearing is over a 9 day period, then the probability of nest survival for the entire sample is 0.970^9 = 0.76.
- Probability of survival of nest from incubation to fledging is 0.56x0.76 = 0.43.

- Hatching rate = number of young/number of eggs present just before hatching.
    - If, for example, this is 0.73, then 27% of eggs present at hatching do not hatch.
- If there are no significant losses of eggs or young without losing the entire nest, multiply incubation, hatching, and chick rearing probabilities to calculate the probability that an egg will survive = 0.56x0.73x0.76 = 0.31.
- If eggs and/or chicks disappear from nests without losing the entire nest, then a smaller unit of exposure (instead of nest day) needs to be used, i.e. egg-day and/or nestling-day. The concept is the same as described above. For a continuation of the example, see Mayfield (1975), readily available for download from Google Scholar.
- Since nests are not generally checked on a daily basis, use the midpoint between checks for calculation of exposure days if a nest has failed.

As an alternative, it is also possible to use the program MARK to estimate nest survival by creating models supported by Akaike's Information Criterion (AIC). See Dinsmore et al. (2002) for further details.

4.1.2. Methods for colonial nesters

E.G. Black-billed gull, black-fronted tern, red-billed gull, Southern black-backed gull, white-fronted tern.

Locating nests

For how to locate nests, please see section: 3.1.2 Methods for colonial nesters.

For black-fronted tern and Southern black-backed gulls, up to 30 nests of each species in question should be monitored, if possible, as long as the number of nests is statistically robust. For river sections that may support large numbers of breeding pairs and 30 nests are found for one species in question in one section, it may be beneficial to find additional nests in another section of river. For example, if 30 nests are found at the top end of a river, it may be useful to find additional nests in the middle section and near the river mouth as nesting conditions and breeding success could vary. If time and resources are not available to monitor such a large number of nests, perhaps aim to monitor 10 nests each at the top end, middle, and river mouth sections.

Please note that for black-billed gulls, red-billed gulls, and white-fronted terns, monitoring of specific nests is very difficult due to the high densities of colonies. Not only is it challenging to keep track of particular nests, but the level of disturbance caused is also very high. Detailed monitoring of these species is *not* recommended. For these species, the best measure of breeding success is a nest count at mid-incubation or at time of hatching, and a count of chicks as close to fledging as possible. Ropes can be laid throughout the colony in straight parallel lines to divide it into sections (approximately 2 meters wide). Each section is walked by an observer, counting all nests (differentiating between empty and nests with eggs/chicks) between the two ropes. Once a section has been counted, ropes can be moved to create adjacent sections. This should only be done by skilled and experienced observers as the procedure needs to be carried out quickly to minimize disturbance. Chicks can be counted by taking a photograph from as high a vantage point as possible, or with a drone. Limitations are under-estimating the number of chicks due to challenges of seeing each individual in crèches or as a result of camouflage.

Monitoring nests to hatching

Nests should be monitored every 3-5 days until hatching or failing. If a nest is found where birds are still laying (full clutch size not reached; Table 8), check nests until the clutch size no longer changes. If/when a full clutch is present, there are two scenarios for checking nests: 1) nests can be checked by walking systematically through the colony site, using GPS locations or cairns, and examining contents while walking, or 2) nests are observed from a high vantage point with binoculars or a telescope, where the birds can be seen on their nests. If birds are sitting where nest had previously been found, it is assumed the bird is still on eggs. Any new nests that are noticed at this time need to be checked and mapped. Birds incubating lone nests separated from the rest of the colony can often also be seen from a distance, so that the nest does not need to be approached.

Please note that these two scenarios will vary depending on the intensity of which monitoring is being carried out. If monitoring intensity is high (i.e. interested in individual egg loss), then nests need to be approached every time to check the number of eggs. However, this also needs to be balanced with disturbance and risk of attracting predators to nests by leaving a scent. The expected degree of egg loss on overall productivity also needs to be considered. For example, whether the major cause of failure for a particular species is due to complete loss of a nest or due to the loss of individual eggs needs to be questioned. For black-fronted terns, failure is due to complete loss, not individual eggs. As mentioned above, this is *not* recommended for black-billed gulls, red-billed gulls, and white-fronted terns.

When a nest is found, calculate the approximate date of hatching using Table 8. Check nests every day at 2-3 days before hatching to ensure chicks are seen before they leave the nest.

Table 8. List of colonial breeders with clutch sizes, incubation period, and fledging period to use for monitoring.

Species	Eggs laid	Incubation period (days)	Fledging period (days)
Black-billed gull	2-3	22	30
Black-fronted tern	2-3	23	30
Red-billed gull	1-3	23	35
Southern black-backed gull	2-3	25	53
White-fronted tern	1-2	26	32

Definitions and classification of nest and egg failure are the same as outlined above for solitary nesters (Table 7 and below).

Monitoring nests to fledging

Monitoring chicks to fledging can be difficult. If colonies are small, chicks may cover large areas similar to what is done by solitary nesters. If colonies are large, chicks may form a crèche. For species such as the black-fronted tern, the nest will be surrounded by faeces for approximately the first week if chicks are present. Adult behaviour when chicks are nearby often include agitated calling with nervously running and/or flying around, and dive-bombing. If chicks are present, adults will persist with this behaviour until the observer leaves the area. If chicks have recently died, adults may still carry out a bit of this behaviour but do not persist for very long. Once chicks are nearly ready to fledge, they tend to be easier to find as they are large and may spend time along the water's edge and out in open areas. Keep an eye out for, and maintain a count of, flying chicks in the general vicinity of the colony as fledglings may remain in the area even after they are able to fly. Listening for chick begging calls is also a great way to locate chicks. Failures at the chick stage should be recorded, but the cause of failure can usually not be determined.

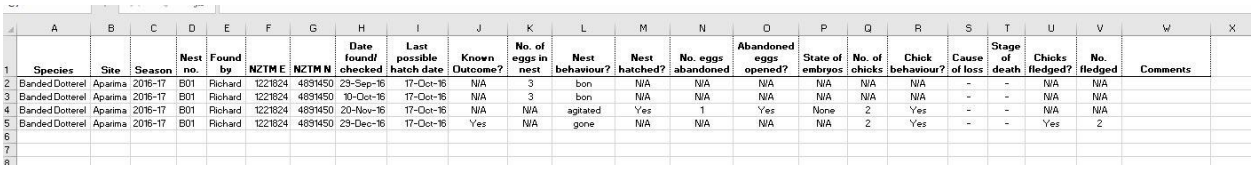
There are several possibilities for monitoring chicks of colonial breeders: 1) band chicks within 3 days of hatching, and then attempt to relocate them (read band numbers) once every week by systematically walking through the colony, or by sitting ~50 meters away and waiting for an adult to fly in with food. This would also include counting and removing bands of dead chicks (can be difficult to find), 2) banding chicks two weeks after hatching, followed by weekly attempts to relocate them. This would reduce the number of young chicks banded that have a high chance of dying, 3) do weekly counts of the number of chicks seen/found, without banding, or 4) do a final chick count as close to the time of fledging as possible. As discussed above for mark/recapture studies, banding should only be done if followed through with a lengthy project, and any handling of chicks requires the appropriate permits, etc.

Modified Mayfield method

Please see above in the Solitary nesters section (page 29) for details.

4.1.3. Data Collection

There is a lot of information collected for breeding success. Figure 12 outlines how data should be collected. As much detail as possible should be gathered as this will help to clarify any uncertainties and potential inconsistencies associated with failures, particularly for calculating fledging success.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Species	Site	Season	Nest no.	Found by	NZTM E	NZTM N	Date found/ checked	Last possible hatch date	Known Outcome?	No. of eggs in nest	Nest behaviour?	Nest hatched?	No. eggs abandoned	Abandoned eggs opened?	State of embryos	No. of chicks	Chick behaviour?	Cause of loss	Stage of death	Chicks fledged?	No. fledged	Comments	
2	Banded Dotterel	Aparima	2016-17	B01	Richard	1221824	4891450	29-Sep-16	17-Oct-16	N/A	3	bon	N/A	N/A	N/A	N/A	N/A	N/A	-	-	N/A	N/A		
3	Banded Dotterel	Aparima	2016-17	B01	Richard	1221824	4891450	10-Oct-16	17-Oct-16	N/A	3	bon	N/A	N/A	N/A	N/A	N/A	N/A	-	-	N/A	N/A		
4	Banded Dotterel	Aparima	2016-17	B01	Richard	1221824	4891450	20-Nov-16	17-Oct-16	N/A	N/A	agitated	Yes	1	Yes	None	2	Yes	-	-	N/A	N/A		
5	Banded Dotterel	Aparima	2016-17	B01	Richard	1221824	4891450	29-Dec-16	17-Oct-16	Yes	N/A	gone	N/A	N/A	N/A	N/A	2	Yes	-	-	Yes	2		
6																								
7																								
8																								

Figure 12. Image showing the data collection template that should be used for breeding success studies, completed with hypothetical data.

Clarification of headings are as follows:

- Last possible hatch date – calculated using Table 6 (solitary nesters) and Table 8 (colonial nesters). This date can be used to determine when to increase the frequency of checks (around hatching) or to help reduce uncertainties associated with the disappearance of eggs.
- Known outcome? – at the end of the season, could the success or failure of the nest be determined?
- Nest behaviour? – the activity/behaviour of any adults near the nest to help decide whether or not a nest is still active (if checking from a distance). For example, 'bon' means 'bird on nest', 'ban' means 'bird at nest', no birds present, bird is agitated, etc.
- State of embryos – the state of any abandoned eggs once opened. For example, infertile (no embryo), died during incubation (embryo), or died during hatching.
- Chick behaviour? – the activity/behaviour of any adults near the nest once eggs have hatched to help decide whether or not chicks are still present (without finding them). For example, parents seen in nest area and agitated, parents dive-bombing, parents displaying broken wing, etc.
- Cause of loss – use categories described above for eggs (predation, desertion (fertile), flooding, died during incubation (infertile), died during hatching, damaged in nest, failed with cause unknown). This can be very difficult to determine for chicks. It is generally unknown unless a dead chick is found or an event is witnessed.
- Stage of death – this is either at egg stage or chick stage.

In the future, it may be most efficient to use technology (i.e. ipads, phone apps, etc) to record data in the field. The information collected as shown in Fig. 12 would remain the same. It would simply serve as an alternative method for various parties to collect the same information.

This template can be copied, or directly downloaded as an Excel file from www.braid.org.nz. Descriptions of headings are also shown in a separate worksheet in the Excel file.

4.1.4. Analyses

Summary tables are shown in Tables 9, 10, and 11. There are several analyses to be carried out for breeding success, and these are shown in Table 9 and 11. Some of the values calculated for hatching success (Table 9) are required again for use in calculating fledging success and nest success (Table 11). To calculate hatching and egg success, fill out the blanks as shown in Table 9. This will provide values of:

- No. of nests with known outcome (A), where known outcome refers to whether or not a nest has hatched (i.e. what happened to the nest in terms of predation, etc),
- No. of nests that hatched ≥1 egg (B),
- No. of eggs laid (of the nests in A) where fate is known (C),
- No. of eggs (of the eggs in C) that died during incubation/infertile (D),
- Total No. of eggs that hatched (E).
- The values of A-D can then be used to calculate hatching (F) and egg success (G).

$$\text{Hatching success (F)} = \frac{\text{No. of nests that hatched} \geq 1 \text{ egg (B)}}{\text{No. of nests with known outcome (A)}}$$

$$\text{Egg success (G)} = \frac{\text{(No. of eggs laid where fate is known (C) – No. of eggs died during incubation/infertile (D))}}{\text{No. of eggs laid where fate is known (C)}}$$

Nests without a known outcome are not included in analyses.

For fledging and breeding success, fill out the blanks as shown in Table 11. This will provide values of:

- Total No. of females that attempted to breed (excluding those for which outcome is unknown) (H)
- No. of chicks fledged given as a range of min-max (I). The range of min-max is an important one as it provides the most representative estimate possible for a value that is difficult to obtain due to the nature of chick behaviour. The minimum value of the range is the actual confirmed number of fledglings (seen flying, using banded chicks, etc). The maximum value of the range is determined as a realistic estimate of fledglings without having been able to confirm. The range should be reported to allow users of the values to visualize uncertainties; however, the minimum value should be used as the representative one because it is the most conservative.

To calculate the range, consider the following example. Eight nests with two eggs each were monitored, amounting to a total of 16 eggs. Of the 16 eggs, six were depredated, resulting in 10 chicks. Of these 10 chicks, 4 were confirmed to have fledged, and the observer was highly certain that another two chicks had fledged but could not confirm this. As a result, the range (No. of chicks fledged (I)) would be 4-6. As mentioned above, nests without a known outcome are not included in analyses.

The values of H and I from Table 11 combined with E-G from Table 9 can then be used to calculate fledging (J) and breeding success, along with hatching success per female and fledging success per female as a min-max range.

$$\text{Fledging success as min-max (J)} = \frac{\text{No. of chicks fledged as min-max (I)}}{\text{total No. of eggs that hatched (E)}}$$

Nest success as min-max = Hatching success (F) * Egg success (G) * Fledging success as min-max (J)

$$\text{Hatching success per female} = \frac{\text{total No. of eggs that hatched (E)}}{\text{total No. of females that attempted to breed (H)}}$$

$$\text{Fledging success per female as min-max} = \frac{\text{No. of chicks fledged as min-max (I)}}{\text{total No. of females that attempted to breed (H)}}$$

4.1.5. Report summary and storage

There are several suggested summary tables, as shown in Tables 9, 10, and 11. The emphasis is placed on calculations outlined above as well as including all years monitored as this provides an instant overview of productivity across a given time period.

Table 9. Table shown as a hypothetical example for use as a summary of hatching success across several years. (taken from Leseberg et al. 2005).

Wrybill	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Total no. of nests	17	10	19	26	28	26	51	43	36	40	58
No. of nests with known outcome (A)	16	10	19	26	28	26	33	38	32	34	51
No. of nests that hatched ≥ 1 egg (B)	16	10	17	22	24	19	21	26	23	22	37
No. of nests that failed	0	0	2	4	4	7	12	12	9	12	14
Total no. of eggs laid	33	19	38	52	52	51	62	73	61	66	95
Of the nests in (A):											
No. of eggs laid where fate known (C)	31	19	38	52	52	51	61	68	54	59	80
No. of eggs laid where fate unknown	0	0	0	0	0	0	1	5	7	7	15
Of the eggs in (C):											
No. of eggs – infertile or died during incubation (D)	1	1	0	6	1	3	5	2	0	2	6
No. of eggs that failed – other causes	1	0	6	4	10	11	21	24	18	22	20
Total no. of eggs that hatched (E)	29	18	32	42	41	37	35	42	36	37	54
Hatching success **(F) = B/A**	1	1	0.89	0.85	0.86	0.73	0.64	0.68	0.72	0.65	0.73
Egg success **(G) = (C-D)/C**	0.97	0.95	1	0.88	0.98	0.94	0.92	0.97	1	0.97	0.93

Table 10. Table shown as a hypothetical example for use as a summary of suspected fate of (a) nests and (b) individual eggs across several years. (taken from Leseberg et al. 2005)

(a) **Banded dotterel**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**Total since 2016-17**
Total no. of nests that failed	1						1
Nest failure due to:							
Predation	0						0
Desertion (fertile eggs)	0						0
Flooding	0						0
Died during incubation (infertile)	1						1
Damaged in nest	0						0
Failed, cause unknown	0						0
(b) **Banded dotterel**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**Total since 2016-17**
Total no. of eggs that failed	3						3
Egg failure due to:							
Predation	0						0
Desertion (fertile eggs)	0						0
Flooding	0						0
Died during incubation (infertile)	3						3
Damaged in nest	0						0
Failed, unknown cause	0						0

Table 11. Table shown as a hypothetical example for use as a summary of overall productivity across several years. (taken from Leseberg et al. 2005)

Wrybill	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Total no. of ♀'s that attempted to breed[1] (H)	16	9	19	26	28	26	33	38	32	34	51
No. of nests - hatched ≥ 1 egg	16	10	17	22	24	19	21	26	23	22	37
No. of nests - fledged ≥ 1 chick	4	7	10	9	5	9	3	17	17	14	14
No. of nests - lost all chicks	8	1	1	6	14	9	5	9	6	5	13
No. of nests - unknown fledging outcome	4	2	6	7	9	1	13	0	0	3	10
No. of chicks fledged as min–max (I) [2]	4	10-12	10-17	14-19	6-16	13-17	4-23	18	25	20 - 25	20-35
Fledging success as min-max (J) =I/E	0.14	0.56-0.67	0.31-0.53	0.33-0.45	0.15-0.39	0.35-0.46	0.11-0.66	0.43	0.69	0.54 - 0.68	0.37-0.65
Breeding success as min-max (F x G x J)	0.13	0.53-0.64	0.27-0.47	0.25-0.35	0.12-0.33	0.24-0.32	0.06-0.38	0.28	0.5	0.34 - 0.43	0.25-0.43
Hatching success per female (E/H)	1.81	2	1.68	1.62	1.46	1.4	1.1	1.1	1.2	1.1	1.06
Fledging success per female as min-max (I/H)	0.25	1.11-1.33	0.53-0.89	0.54-0.73	0.21-0.57	0.5-0.65	0.003-0.2	0.47	0.78	0.59 - 0.74	0.39-0.63

[1] Excludes females that attempted to breed, where outcome was unknown

[2] Minimum is confirmed number of fledglings, maximum is a realistic estimate

4.2. Known Cause of Nest Fate

4.2.1. Methods for solitary nesters

E.g. Banded dotterel, black stilt, black-fronted dotterel, Caspian tern, pied stilt, South Island pied oystercatcher, spur-winged plover, wrybill.

Locating and monitoring nests

For how to locate nests, monitoring nests to hatching and monitoring nests to fledgling, please see section 3.1.1 Methods for solitary nesters and section 4.1.1 Methods for solitary nesters.

Modified Mayfield method

Please see above in section 4.1.1 solitary nesters section for details.

Determining cause of nest failure

Once nests are located, cameras will be placed at a sub-set of nests. The number of cameras is generally associated with the amount of funding that is available. The cost of the cameras, batteries, SD cards, and mini solar panels need to be considered, as well as materials to use as a stand. As a general rule, as many cameras as possible should be used to allow for the best coverage. Fewer cameras means a reduced chance of being able to identify the cause of predation, but a larger number of cameras means higher costs and time needed to check on the cameras as well process the pictures/videos recorded.

Cameras should only be placed at a nest once a full clutch has been laid to ensure that the pair is settled. Infra-red cameras, such as the Ltl Acorn 5210A trail cameras, should be used as they have shown to be reliable and effective and have a compatible mini solar panel. Ensure that the programming of the camera and the attachment of the camera and solar panel onto the stand are completed before approaching the nest to minimise the amount of time spent at the nest. The placement of the set-up at the nest should not take more than 5-10 minutes. Cameras and mini solar panels should be attached to a stand (cameras should be approximately 50 cm off the ground) and placed 2-3 meters from the nest, close enough to be able to trigger the video and identify predators but far enough away to ensure the bird will return to the nest. Be aware of vegetation around the nest that may move in the wind, thereby triggering the camera using battery power and storage space. Ensure the mini solar panel is facing north.

Cameras can be set to be motion triggered with the recording of a 10 second video and programmed to not record again for one minute. Using a 16 GB SD card, eight AA batteries, and a mini solar panel, these settings should allow 4-6 days of recording; however, temperature, sunshine hours, and activity at a nest will influence this time period, and it is therefore best to replace the SD card and check on the batteries every 2-4 days. Alternatively, cameras can be set to take three images, 10 seconds apart once triggered, then be not triggered for 1-minute stand-down period. Using this method, Acorn style cameras with solar panels will last for more than two weeks. Once eggs have hatched and chicks have left the nest, or the eggs have been depredated, the camera can be moved to another nest with eggs.

4.2.2. Methods for colonial nesters

E.g. Black-billed gull, black-fronted tern, red-billed gull, Southern black-backed gull, white-fronted tern.

Locating and monitoring nests

For how to locate nests and details on monitoring nests to hatching and monitoring nests to fledging please see section 3.1.2 Methods for colonial nesters.

Modified Mayfield method
Please see above in section 4.1.1 Solitary nesters section for details.

Determining cause of nest failure

For species with colonies of low density, such as the black-fronted tern and Southern black-backed gull, the same methods used for solitary nesters can be applied (see detailed methods outlined above). Once nests are located, cameras will be placed at a sub-set of nests. The number of cameras is generally associated with the amount of funding that is available. The cost of the cameras, batteries, SD cards, and mini solar panels need to be considered, as well as materials to use as a stand. As a general rule, as many cameras as possible should be used to allow for the best coverage. Fewer cameras means a reduced chance of being able to identify the cause of predation, but a larger number of cameras means higher costs and time needed to check on the cameras as well process the pictures/videos recorded.

For species with colonies of high density, such as the black-billed gull, red-billed gull, and white-fronted tern, methods are different from the low density colony nesters. For high density colonies, it is feasible to use a total of 4 cameras, two for daylight hours and two for night hours. For day-time monitoring, two cameras are set up on a separate tall wooden pole (with each camera approximately 1.5 - 2 meters above ground) facing into the colony at a distance close enough to capture all nests within each photo along with a buffer zone around the colony to ensure capturing footage of disturbances around the edge of the colony (~ 25-30 meters). Using two cameras ensures that at least one camera is working at all times in case of malfunctioning, and to allow for different angles into the colony. The cameras should run from dawn to dusk (~0600-2100), and set to take one picture every minute. Ensure the solar panel faces north, and cameras should be checked every 3-5 days to change the 16 GB SD card in each camera and to make sure the batteries are still functioning. Video clips are not feasible for high density colony nesting birds as there is too much activity at the colony which would continuously trigger the camera.

For night-time monitoring, two cameras are set up on a separate short wooden pole (cameras should be approximately 50 cm off the ground) and placed 1-3 meters from nests along the colony edge while facing into the colony. These should be placed as close as possible to the edge of the colony to capture as many nests as possible without causing disruption. The cameras must be in close proximity to the nests to enable the nests to be within reach of the infrared light of the camera. The cameras should run from dusk to dawn (~2100-0600), and follow the same set-up and checking procedures as the day-time cameras. Not all nests within a colony will be within reach of the cameras; however, if the cameras are placed at opposite sides of the colony, it is likely that at least one camera will capture footage of any predation events or disturbances.

As suggested by Sanders & Maloney (2002), an 'event' captured on video was defined as:

- Any activity that caused death of eggs, chicks, or adults (depredation, flooding, desertion, etc)
- Any species other than rabbits, hares, and passerines (but including magpies) approached the nest within 2 meters
- Any species other than rabbits, hares, and passerines (but including magpies) caused the incubating adult to leave the nest
- Any activity in bouts by the same species in the same night but spaced by over 30 mins was a separate event
- Start time of event was when the cause of event was first visible, and end time was when it was last visible
- A single event can have multiple deaths of eggs, chicks, and adults
- One nest can have multiple events.

Cameras can also be used to monitor breeding success in dense colonies, but methods for this are not outlined in the current document.

4.2.3. Data collection

Breeding success collection template is shown above in section 3.1.3 Data collection.

There are different ways of recording the data captured on video. Figure 13 outlines an example of how data should be collated. It is important to note when the cameras were put out and when they were retrieved in order to be able to calculate the number of days and nights monitored. Figure 14 shows a different way of collecting the information.

Unique number	Site	Season	Camera no.	Species	Nest no.	NZTM Easting	NZTM Northing	Date out	Date in	Date of detection	Time of detection	What detected?	Comments
AparimaNest4	Aparima	2016-17	2	Banded Dotterel	B01	1221824	4891450	05-Oct-16	19-Oct-16	15-Oct-16	15:05:25	Harrier	Ate eggs
AparimaNest49	Aparima	2016-17	10	South Island Pied Oystercatcher	P003	1221873	4891503	08-Nov-16	02-Dec-16	9-Nov-16	5:53:54	Hedgehog	Ate eggs

Figure. 13. Image showing the data collection template that should be used for nest camera monitoring, completed with hypothetical data. Data sorted according to detections without showing nest monitoring information.

Clarification of headings are as follows:

- Camera no. – this is a number specific to the camera, and may or may not be the same as the nest number
- Date out – the date the camera was put out at the nest
- Date in – the date the camera was retrieved from the nest

Nest Number	Species	Site	NZTM Easting	NZTM Northing	Filmed?	Fate	Cause of failure	Event filmed?	Comments	Date	4/09/2016	5/09/2016	6/09/2016	7/09/2016	8/09/2016	9/09/2016	10/09/2016
										Day	1	2	3	4	5	6	7
CS01	Banded dotterel	Cass	1399698	5138586	Yes	Hatched	Ferret	Yes	Three chicks hatched			3e	3e				3e
CS02	SIPO	Cass	1397860	5138267	Yes	Hatched		Yes	At least one chick hatched				1e	2e			2e
CS03	SIPO	Cass	1398340	5138804	Yes	Hatched	Hedgehog	Yes	Two chicks hatched				2e	2e			2e
CS04	Banded dotterel	Cass	1398968	5138157	Yes	Hatched	Hedgehog	Yes	Two chicks hatched								
CS05	Banded dotterel	Cass	1397873	5138412	Yes	Hatched		Yes	Three chicks hatched								

Figure 14. Image showing data collection template for nest camera monitoring. Data are sorted according to nest monitoring. Green shading indicates presence of camera (as suggested by N. McArthur, pers. comm.).

These templates can be copied, or directly downloaded as an Excel file from www.braid.org.nz. Descriptions of headings are also shown in a separate worksheet in the Excel file.

4.2.4. Analyses

Analyses for breeding success are outlined above in section 4.1.4 Analyses.

Whether video monitoring or time lapse of photos are used, the process of looking through all the videos and photos can be very tedious and time consuming. There are programs, such as any GIS program or ImageJ, that can be programmed to automatically detect differences in photographs. These programs use a series of base images to detect differences, such as the sudden presence of a predator in a time lapse segment. However, the programs generally require the input and use of arithmetic operations which are applied across a stack of aligned images, and determining the correct algorithm can be a challenging and time consuming task.

There are numerous analyses that can be conducted. Detailed accounts of length of time of lethal and non-lethal events, or detecting patterns of time of day/night when lethal events are likely to happen can be determined from the camera monitoring, as was done by Sanders & Maloney (2002). Mischler & Bell (2016) also calculated the number of day and night time hours monitored versus missed, as well as the amount of time aerial predators (such as harriers and black-backed gulls) spent at a mixed gull and tern colony. These values can readily be determined by closely examining the time of videos and images, and will therefore not be outlined in detail in this document. The more detailed the analyses, the more time consuming it is to look through the images/video footage. This is because each time stamp need to be closely inspected for calculations. As mentioned above, the key aim of using remote cameras is to be able to identify the cause of failure.

The Mayfield method can be applied here as well when combining breeding success with camera coverage.

4.2.5. Report summary and storage

The suggested report summary tables are shown in 3.1.5 Report summary and storage.

There are two suggested summary tables for the camera monitoring, as shown in Figures 15 and 16. The emphasis is placed on the identity of cause of nest failure. Clutches, chicks, and adults are listed individually (Fig. 15); however, chicks will be the most difficult to capture on video due to their mobility. It is also possible to add in multiple years of monitoring, where the 'Total' column would be used to represent each season. The information in Figure 16 needs to be calculated using the time stamps on each video. Since the cameras may malfunction, the days/nights where cameras were not working need to be subtracted from the total to provide an accurate representation of coverage. As with Figure 15, multiple years can be compared by using additional rows.

	A	B	C	D	E	F	G
1	**Cause of event**	**Clutches**	**Chicks**	**Adults**	**Total**	**Total %**	
2	Cat	20	0	1	21	35.0	
3	Ferret	11	0	0	11	18.3	
4	Hedgehog	17	0	0	17	28.3	
5	Stoat	2	0	0	2	3.3	
6	Harrier	5	0	0	5	8.3	
7	Black-backed gull	2	2	0	4	6.7	
8	**TOTAL**	57	2	1	60		
9							

Figure 15. Table shown as a hypothetical example for use as a summary of lethal causes of nest failure as determined from video monitoring.

	A	B	C	D	E	F
1	**Species**	**Season**	**Nests videoed**	**Days videoed**	**Nights videoed**	
2	Banded dotterel	2016/17	82	953	921	
3	Black-fronted tern	2016/17	23	582	612	
4	**TOTAL**		105	1535	1533	
5						

Figure 16. Table shown as a hypothetical example for use as a summary of nest failure coverage via video monitoring.

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