Introduction to bat monitoring

Version 1.0

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Contents

Department of Conservation
Te Papa Atawhai

Deciding which method to use

This section of the bat module should be read before selecting an inventory or monitoring method. It contains comparative tables and decision trees for selecting the most appropriate method for your objectives.

Use the 'Comparative tables' and 'Decision trees' together to guide you to the most suitable and cost-effective method to use to answer specific inventory and monitoring questions. Not all methods are suitable for both bat species, and not all methods are appropriate for both inventory and monitoring.

Therefore, the comparative tables are organised as follows:

- Methods for inventory of long-tailed bats
- Methods for monitoring long-tailed bats
- Methods for inventory of lesser short-tailed bats
- Methods for monitoring lesser short-tailed bats

The tables are further arranged by methods that count bats away from roosts, at roost sites, or both. There are 14 methods: four methods for use away from roost sites, eight at roost sites, and two that can be used in both situations.

We encourage you to familiarise yourself with the full range of methods and challenges before setting out to count bats, and make informed decisions based on the most recent information in the Inventory and Monitoring Toolbox. New research, technologies and analytical techniques may well lead to improved methods and greater certainty around population estimates and trends.

Methods for inventory and monitoring of bats away from their roost sites

Finding roost sites and trying to obtain counts of bats at their roosts can be difficult, time consuming and expensive. Consequently, bat researchers frequently count bats away from their roost sites.

There are numerous techniques that can be used to inventory or monitor bats while they forage, or commute between foraging areas and roost sites. Not all are in common use in New Zealand. Bat detectors are used widely overseas to detect and count the ultrasonic calls of bats (e.g. Helmer et al. 1987; Walsh et al. 1993; Boonman 1996; Walsh & Harris 1996). They are probably the most common tool used for bat surveys in New Zealand (O'Donnell 2000a,b); for more details see 'Background to bat detectors' in the 'DOC best practice manual of conservation techniques for bats' (docdm-131465). The following are some of the common methods that can be used in New Zealand for inventory and monitoring of bats away from their roost sites:

- Bats: counting away from roosts—bat detectors on line transects (docdm-590701)
- Bats: counting away from roosts—automatic bat detectors (docdm-590733)
- Bats: counting away from roosts—visual counts (docdm-590754)

- Bats: trapping away from roosts—inventory and species identification (docdm-590776)
- Bats: casual reports (docdm-142161)
- Radio-tracking to monitor short-term survival (information on this method is included in 'Bats: trapping at roosts—estimating survival and productivity'—docdm-590867)

Once you have been guided to one or more methods, read the method specifications carefully to ensure each method meets your study objectives.

Methods for inventory and monitoring of bats at their roost sites

Inventory and monitoring methods for roosting bats can be grouped into two broad categories: (1) those used to find roost sites and determine whether they are currently occupied by bats (i.e. inventory of roost sites in an area, casual records, searching for sign); and (2) those used to estimate the number of bats using the roosts. Methods used to estimate the number of bats using roosts can be split into those applied outside of the roost (which generally attempt to minimise or avoid disturbance to the bats) and those applied inside the roost (which usually entail a degree of disturbance) (Thomas & LaVal 1988). Generally, the most accurate counts will be achieved by using a combination of techniques, e.g. a count of bats exiting the roost at dusk followed by a count of any bats remaining inside.

Many of the methods used for counting bats have been developed for bats roosting in sites such as caves and buildings (e.g. Kunz 2003; Kunz & Reynolds 2003; McCracken 2003). Species occupying these roost types are often more site-faithful than those occupying trees, and they may occupy the same roost site for several weeks at a time. However, long-tailed bats and lesser short-tailed bats primarily roost in relatively small and often inaccessible hollows in trees. They regularly change roost sites, utilising a large pool of roosts. These behaviours make it particularly challenging to find a method to accurately count all bats exiting a roost and those remaining inside. Therefore, several of the methods most commonly used for inventories and monitoring of bats elsewhere have limited applicability to New Zealand species.

Some of the most common methods for surveying roost sites in an area and for inventory and monitoring the number of bats using roosts include:

- Bats: exit counts at roosts—cameras and recorders (docdm-590789)
- Bats: exit counts at roosts—simple visual counts (docdm-590804)
- Bats: trapping at roosts—estimating population size (docdm-590819)
- Bats: trapping at roosts—estimating survival and productivity (docdm-590867)
- Bats: roost occupancy and indices of bat activity—infrared beam counters (docdm-131260)
- Bats: roost occupancy and indices of bat activity—field sign (docdm-590882)
- Bats: roost occupancy and indices of bat activity—automatic bat detectors (docdm-590899)
- Bats: counting inside roosts (docdm-590915)
- Bats: casual reports (docdm-142161)

- Radio-tracking to monitor short-term survival (information on this method is included in 'Bats: trapping at roosts—estimating survival and productivity'—docdm-590867)

The methods listed above vary in their technological complexity and subsequently in their relative resource costs and amount of effort required to undertake the count. It is important to consider that, in addition to the costs of the actual counting method, there are costs associated with locating roosts. During summer months, maternity colonies of bats change roost site regularly which means radio-tracking is almost always necessary to find roost trees. Catching bats, attaching radio-tags and then following bats to their roost sites require considerable time, skill, and resources. Refer to the relevant sections in the 'DOC best practice manual of conservation techniques for bats' (docdm-131465) for more details.

Use the 'Comparative tables' and 'Decision trees' together to guide you to the most suitable and cost-effective method to use to answer specific inventory or monitoring questions. Once you have been guided to one or more methods, read the method specifications carefully to ensure each method meets your study objectives.

Applying the decision-making process: an example

We recommend you refer to 'Decision tree 2' because it describes an overall structured process to guide the planning and design of a monitoring programme.

This section provides an example of a planning process used to address a common management question applicable to bats. The example used is: *What are the potential impacts of a 1080 poison operation on a population of lesser short-tailed bats?* The decision trees 2a, 2b and 2c illustrate the need for monitoring programmes to be adaptive in response to the type of question being asked, the resources available and the level of precision that is acceptable.

Poisoning operations using toxic baits are of particular concern for lesser short-tailed bat populations because their feeding habits make them vulnerable to toxins in two ways; either from direct consumption of toxic baits because this species commonly feeds on the ground, or from secondary poisoning after consumption of arthropods that feed on baits (Lloyd & McQueen 2000; Sherley et al. 2000). Although feeding trials with lesser short-tailed bats showed that they did not consume carrot or grained-based baits that are commonly used with 1080 and second-generation anticoagulant poisons (Lloyd 1994; McCartney 1994), there is still concern about potential impacts because of limited field trials (Sedgeley & Anderson 2000; Lloyd & McQueen 2002).

In Decision tree 2a, the first question is: *What is the lesser short-tailed bat population size before and after a poison operation?* Obviously, managers would be looking for no declines of lesser short-tailed bats during the operation, and potentially an increase in numbers once mammal pest numbers were reduced. In this scenario, it would not be possible to obtain an accurate census of the population because of the difficulties in monitoring all bat roosts simultaneously (see 'Specific problems with counting bats'). Thus, in Decision tree 2b, the question has been redefined: *Does a population index (apparent survival of radio-tagged bats) change after the poison operation?* In this situation there has been a trade-off between achievability and precision—the manager is willing to accept a less precise answer with a more achievable question. The trade-off is that it is possible to get good data on the fate of individual tagged bats, but the sample size will be small. Hence, the ability to extrapolate the results to the total population is limited because the behaviour of the radio-tagged bats may not be typical of the population. Decision tree 2c offers an alternative response to the same issue—where, because of limited resources, the manager would not be able to obtain the necessary results to answer the question.

Why is it important to inventory or monitor bats?

The maintenance of habitat and populations of threatened and uncommon species is a high priority for conservation managers worldwide.

The bat species known to occur in New Zealand are all endemic. They are the:

- Long-tailed bat (*Chalinolobus tuberculatus*)
- Lesser short-tailed bat (*Mystacina tuberculata*)
- Greater short-tailed bat (*Mystacina robusta*)

Bats are protected by the Wildlife Act 1953. Long-tailed bats and lesser short-tailed bats are listed as 'vulnerable' by International Union for Conservation of Nature (IUCN) criteria. Greater short-tailed bats are generally considered to be extinct because there has been no confirmed sighting since 1967 (Daniel 1990; Lloyd 2005a). There are eight forms of New Zealand bats currently recognised by the DOC Bat Recovery Group, and all are considered 'acutely threatened' by DOC threat classification criteria (Table 1) (Winnington 1999; Lloyd 2003a,b; Hitchmough et al. 2007). Bats have become less widespread and have declined in number since humans arrived in New Zealand. They were once widespread, but recent work indicates they are now rare or absent at many sites where formerly they were common. There are few areas where they occur in large numbers, and their numbers may still be declining (Lloyd 2005a; O'Donnell 2005). None of the New Zealand taxa can be considered secure on the mainland. All face a high risk of extinction in the medium term if conservation management is not successful at reversing their declines (Molloy 1995; Hitchmough et al. 2007).

Table 1. Conservation status of New Zealand bats.

Taxon recognised by Hitchmough (2002)	Conservation Management Unit* recognised by Bat Recovery Group, 2004† current	Scientific name	Revised DOC conservation status‡
1. long-tailed bat (North Island)	1. long-tailed bat (North Island)	*Chalinolobus tuberculatus*	nationally vulnerable
2. long-tailed bat (South Island)	2. long-tailed bat (South Island)	*Chalinolobus tuberculatus*	nationally endangered
3. greater short-tailed bat	3. greater short-tailed bat	*Mystacina robusta*	data deficient
4. northern lesser short-tailed bat	4. northern lesser short-tailed bat	*Mystacina tuberculata aupourica*	nationally endangered
5. central lesser short-tailed bat	5. eastern lesser short-tailed bat 6. north-western lesser short-tailed bat	*Mystacina t. rhyacobia* *Mystacina t. rhyacobia*	range restricted range restricted
6. southern lesser short-tailed bat	7. southern North Island lesser short-tailed bat 8. South Island lesser short-tailed bat	*Mystacina t. tuberculata* *Mystacina t. tuberculata*	nationally critical nationally endangered

* Conservation Management Units are defined as population units that are of interest to conservation managers. These may be populations or subpopulations that are worthy of protection because they are distinctive in some way or one of a number of subpopulations vital to maintaining long-term viability of a taxon. They may be distinctive genetically, behaviourally, morphologically, or geographically.

† Based on a revision endorsed by the Bat Recovery Group.

‡ Hitchmough et al. 2007; based on a revision endorsed by the Bat Recovery Group (olddm-496393).

Determining where bat populations are located and whether populations are increasing, decreasing or stable is fundamental to assessing their conservation needs. Results from inventory and monitoring programmes can be used by conservation managers to make decisions about the size and conservation status of a population and whether active management is required. Monitoring is also vital to determine the effectiveness of conservation management. This may involve monitoring the condition of the bat population or monitoring the changing condition of the threat (e.g. changes to habitat, introduced predators).

For more explanations and definitions of the terms inventory and monitoring see ‘A guideline to monitoring populations’ (docdm-870579).

Deciding where and when to inventory or monitor bats

This section suggests priority areas for targeting survey and monitoring work. Knowledge of the distribution and abundance of bat populations in New Zealand remains incomplete.

Inventories are still required in many regions, particularly remote forest areas. They might lead to identification of important populations and, in places, active management. This section also outlines how environmental and seasonal variables influence bat activity and recommends conditions that are optimum for inventory and monitoring.

Deciding where to inventory bat populations

Many of the surveys undertaken over the last 10 years have identified sites where bats were rare or absent, but some have also identified new populations. For example, lesser short-tailed bats were more common in several places in the central North Island than thought previously, e.g. > 6000 *M. tuberculatus rhyacobia* were discovered in the forests of Mt Ruapehu (Lloyd 2001). However, there are still large tracts of New Zealand that remain unsurveyed and some bat taxa are still poorly understood. For example, we know very little about the distribution and status of North Island long-tailed bats.

Sites that could be targeted for survey include:

- Areas where historic records indicate that important bat populations were once present.
- Areas where no previous work on bats has been undertaken, e.g. areas of Southland, the West Coast, North-west Nelson, eastern North Island and Northland.
- Sites such as mainland islands, Operation Ark sites, and kiwi zones where management of threats (e.g. through predator control) is occurring for other reasons. Inventory at these sites would be worthwhile because, if bats are found to be present, the likely benefits of the management to the bat population can be monitored in the future.

The DOC bat database contains many bat sightings and is a useful source of information to find out where bat work has already been carried out. Each DOC conservancy should have a separate Microsoft Excel spreadsheet for this purpose. Access rights are held by the conservancy bat contact (see 'Bat Recovery Group contacts'—docdm-132033). For examples of spreadsheets containing data, see the 'Canterbury Conservancy bat database' (docdm-213179) and the 'West Coast Conservancy bat database' (docdm-249920).

Deciding where to monitor bat populations

Managing bat populations so their numbers recover has only just begun in New Zealand, and we still do not know how effective techniques are at reversing declines. Therefore, monitoring is required, especially so the benefits of conservation management can be assessed and reported on, and so management can be adapted and improved if it is not resulting in an increase in bat numbers. Management operations that are worth monitoring include any pest control operation in areas that still support important bat populations.

The DOC Bat Recovery Group recommended 24 priority sites for management and monitoring of New Zealand bats (Table 2). The major criteria for inclusion were whether a site supported a particularly dense or significant population (both core populations at the heart of existing ranges and outliers at the edge of their range), and whether bats were present in existing sites where management for biodiversity conservation was occurring. These populations were selected because their characteristics encapsulate the distinctive genetic, behavioural, and morphological variety of the taxa (Parsons et al. 1997; Winnington 1999; O'Donnell 2005; Lloyd 2003a,b). 'Decision tree 3' provides a simple pathway for assessing whether monitoring should be undertaken at a site.

When to count bats away from roost sites

Bat activity is greatly influenced by environmental conditions. To improve chances of encountering bats, surveys should only be undertaken on fine, relatively warm nights (e.g. when dusk temperature is ≥ 7°C) and preferably between October and March, the months when bats are most active. Winter surveys should generally be avoided, although lesser short-tailed bats can remain active to some extent all year round.

When to count bats at roosts

Direct counts of bats emerging from roosts (roost exit counts) can be undertaken in spring, summer and autumn, when bats are active. Counts are most often undertaken during summer months because bats emerge from roosts regularly and exit the roost over a relatively short period. Bat numbers at roost sites are usually most stable early in the breeding season when the females come together to give birth (maternity colonies), and before the young fledge (in New Zealand this is November to early January). Maternity colonies usually begin to disperse in late summer and autumn.

Counts are more problematic during winter. Many bat species require different types of roosts seasonally and may hibernate at sites not used during summer. Roosting behaviour of tree-roosting long-tailed bats has not been studied in winter. We do not know whether these bats roost communally, but we assume they hibernate for at least some of the time and emerge from roost sites far less frequently than at other times of the year. Lesser short-tailed bats do roost communally for at least some of the time during winter and continue to use trees, but their roost emergence behaviour is variable. Sometimes lesser short-tailed bats hibernate and do not emerge from a roost for several days during winter, while at other times they may be active, moving in and out of a roost throughout the night (Lloyd 2005b; Sedgeley 2001).

Use caution when counting bats at hibernation roosts (hibernacula). Frequent disturbance is likely to awaken bats more often than under natural conditions and may cause excessive energy losses and reduce their over-winter survival (Thomas 1995).

Table 2. Recommended priority sites for management of bat populations and main management techniques to be applied at each.

Taxon	Site	Conservancy	Secure	Management area identified	Statutory advocacy	Non-statutory advice	Pest control	Protection of roosts	Protection of foraging sites	Restoration of foraging and roost sites
1. Northern short-tailed bat	Little Barrier	Auckland	Yes	Done	—	—	Island invasion contingency plan	—	—	—
	Mainland	Northland	No	Needed	✓	✓	✓	✓	✓	✓
2. Eastern short-tailed bat	Urewera Whirinaki	ECHB and BOP	Yes (maybe in MI)	Needed	✓	✓	?	?	—	—
3. North western short-tailed bat	Ōhakune	Tongariro /Taupō	No	Done	—	—	✓	✓	—	—
	Pureora	Waikato	No	Needed	✓	—	✓	✓	✓	—
4. Southern North Island short-tailed bat	Tararua	Wellington	No	Done	—	✓	✓	✓	—	Establish second population
5. South Island short-tailed bat	Ōpārara	West Coast	No	Needed	—	✓	✓	✓	—	—
	Eglinton	Southland	No	Done	—	—	✓	✓	✓	—
	Codfish	Southland	Yes	Done	—	✓	Island Invasion contingency plan	—	—	—
6. Greater short-tailed bat	Tī tī Islands	Southland	No	Needed	—	✓	✓?	✓	✓	✓

Taxon	Site	Conservancy	Secure	Management area identified	Statutory advocacy	Non-statutory advice	Pest control	Protection of roosts	Protection of foraging sites	Restoration of foraging and roost sites
7. South Island long-tailed bat	Geraldine	Canterbury	No	Done	✓	✓	✓	✓	✓	✓
	Eglinton	Southland	No	Done	✓	✓	✓	✓	✓	—
	Dart	Otago	No	Done	✓	✓	✓	✓	✓	—
	Maruia	West Coast	No	Needed	✓	✓	✓	✓	✓	—
	Landsborough	West Coast	No	Done	—	—	✓	✓	—	—
	Catlins	Otago	No	Needed	✓	✓	✓	✓	✓	—
	Waikaia	Southland	No	Needed	✓	✓	✓	✓	✓	—
	Stewart Is	Southland	No	Needed	✓	✓	✓?	✓?	✓?	✓?
8. North Island long-tailed bat	Whareorino	Waikato	No	Needed	✓	✓	✓	✓	✓	—
	Ruakuri	Waikato	No	Needed	✓	✓	✓	✓	✓	✓?
	Puketitiri	ECHB	No	Done?	✓	✓	✓	✓	✓	✓?
	Ōhakune	T/T	No	Needed	—	✓	✓	—	—	—
	Whanganui	Wanganui	?	Needed	?	?	?	?	?	?
	Whangārei	Northland	?	Needed	?	?	?	?	?	?

Specific problems with counting bats

Developing techniques for inventory of bats and monitoring trends in bat populations is particularly challenging. Bats are highly cryptic and nocturnal so it is difficult to count them directly, except sometimes at roost sites. Both long-tailed bats and lesser short-tailed bats are rare. They are also patchily distributed and highly mobile. They roost in trees that are difficult to locate, occupy roosts for relatively short periods, and the entire population is seldom present at any given roost. Although the aim of inventory and monitoring is to get complete counts, this is virtually impossible to achieve for New Zealand bats. Counts that can be achieved are usually from a subset of the population (an incomplete count), or are an indirect index of activity.

There are three types of complete count for bats: (1) a true census of an entire population where all individuals are counted; (2) a true census of an entire study area; (3) a complete count of bats using particular roosts. All three rely on the same three methods, but their achievability is very questionable. In reality, these counts will not be possible, and the investigator will have to rely on making inferences about population size from incomplete (partial) counts of the populations or from indirect indices of activity.

Difficulties with finding and counting bats away from roost sites

Finding roost sites and trying to obtain counts of bats at their roosts is difficult, time consuming and expensive, and counts can often be misleading (see 'Difficulties with counting bats at their roost sites'). Consequently, bat researchers frequently count bats as the bats fly around their foraging grounds or as they commute between foraging grounds and roost sites. Bats are usually surveyed indirectly by using bat detectors to count their ultrasonic calls; for more details see 'Background to bat detectors' in the 'DOC best practice manual of conservation techniques for bats' (docdm-131465). Recording the number of bat calls can only provide an index of activity because the number of bat calls does not necessarily correlate with the number of individual bats encountered. Therefore, relative abundance can only be estimated coarsely (e.g. you may be able to conclude that bats are common, uncommon or rare).

Counts undertaken away from roost sites are valuable for inventory purposes such as determining presence/absence, confirming species, distribution surveys, and for indexing levels of bat activity (e.g. among different habitat types). The value of index counts of bats away from roosts for monitoring purposes, particularly long-term monitoring, is still being assessed (e.g. O'Donnell & Langton 2003). However, index counts are likely to be of lesser value for monitoring purposes (than for inventory) because environmental conditions have a large influence on bat activity levels (O'Donnell 2000c) and it is not usually possible to standardise all aspects of surveys. It is necessary to use in-depth statistical modelling procedures to distinguish between variation in counts resulting from variability in environmental or sampling conditions, and the actual variation in bat activity levels between surveys.

Difficulties with counting bats at their roost sites

Many bat species are gregarious, and at different times of the year roost in colonies. In both New Zealand bat species, breeding females come together at roost sites (maternity roosts) in summer to give birth and raise their young, and, in winter, they may congregate to roost at favoured hibernation sites. Therefore, counts of bats at roost sites offer the greatest potential for obtaining estimates of colony and population size (Kunz 2003). Radio-tracking is almost always necessary to find roost trees.

The number of bats using roost sites, particularly those using tree roosts, often fluctuates on a daily, seasonal or annual basis (see Fig. 1 for an example of daily variability). Bats using a roost may be a small part of a larger colony, or may constitute the entire colony. Therefore, each visit to a roost can only provide a snapshot of a colony at that time (Stebbings et al. 2005). Regular long-term monitoring during summer months of the number of bats using a roost may provide a useful *indication* of the status of bats within that particular site. Monitoring will be more informative when accompanied by an ongoing survey to look for new roost sites and identify roosts that are occupied simultaneously. A reduction in numbers of bats counted at a roost could mean there are fewer bats present in the area, but it is more likely to mean that members of a colony are roosting elsewhere.

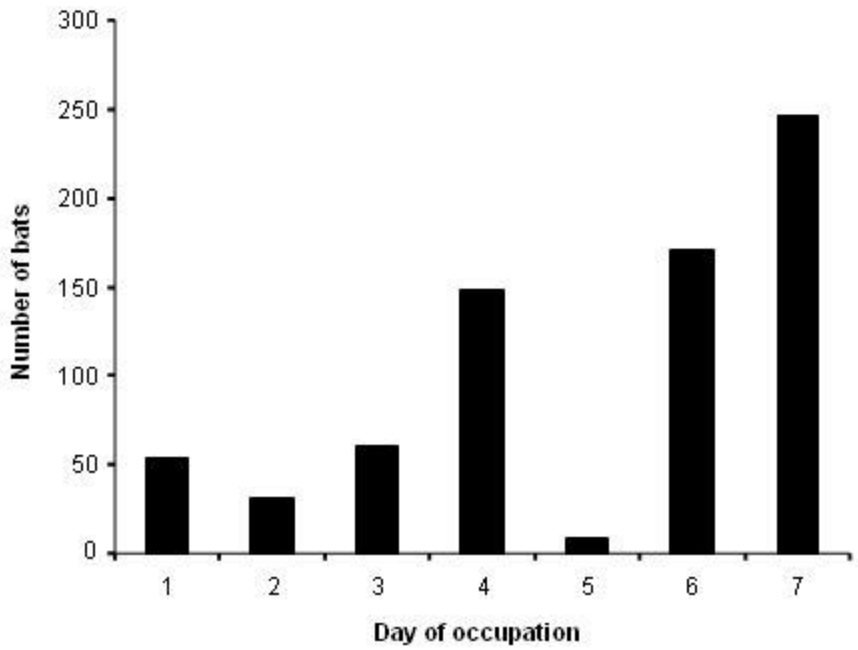


Figure 1. Example of daily variability in the number of lesser short-tailed bats exiting a roost on Codfish Island, July 1996.

How accurate are counts at individual roosts?

It is only possible to make a complete count of bats at an individual roost if all bats using the roost can be accounted for. The most accurate counts of bats using a roost will generally be achieved by combining methods for counting bats exiting a roost at dusk with counts of bats remaining inside the roost (e.g. O'Donnell 2002). A complete count of bats flying out from a roost is only possible if all the roost exits are accounted for and all of the exiting bats are visible. To achieve a complete count of bats inside a roost, the interior needs to be accessible and all roosting bats need to be visible. It is seldom possible to see bats roosting inside tree cavities and it is easy to overlook single bats or small groups of bats roosting in obscure crevices inside caves or buildings. Most roost counts simply give a reasonably accurate assessment of the number of bats exiting a particular roost site on a particular night.

Can roost counts be used for estimating population size?

A complete census of a population using counts at roost sites is only possible if all roosts or colonies have been located, all major roosts are geographically discrete with no inter-site movements, all individuals are highly visible, and the roost is either fully occupied during the daytime, or fully vacated at night (Thomas & LaVal 1988; Thompson et al. 1998; O'Shea & Bogan 2003). Roosting behaviours of long-tailed bats and lesser short-tailed bats are such that it is probably impossible to meet the conditions listed above ('How accurate are counts at individual roosts?'). Following are examples of roosting behaviours that make roost counts particularly challenging:

- Roost sites of long-tailed bats and lesser short-tailed bats can be widely distributed in the landscape and the pool of roosts used by a colony can be large—in the case of the long-tailed bat, roosts may number in the hundreds. These factors make it very difficult to locate all roosts in an area (O'Donnell & Sedgeley 1999; Lloyd 2005a; O'Donnell 2005; O'Donnell & Sedgeley 2006). Catching bats, attaching radio-tags and then following bats to their roost sites require considerable time, skill, and resources. Refer to the relevant sections in the 'DOC best practice manual of conservation techniques for bats' (docdm-131465) for more details.
- A proportion of colony members will always be roosting alone. Radio-tagged bats have been recorded roosting alone 30%–90% of the time (depending on sex and age). It would be impossible to locate all solitary roosts.
- During summer months, maternity colonies of long-tailed bats change roost sites almost every day (O'Donnell & Sedgeley 1999) and those of lesser short-tailed bats every 1–58 days (Sedgeley 2003; Lloyd 2005b).
- Entire colonies seldom roost together in the same tree; rather, they are spread among several sub-colonies on any one day (O'Donnell 2000d; O'Donnell & Sedgeley 2006).
- Banding studies have shown that composition of individual long-tailed bat roosting groups changes daily (O'Donnell 2000d; O'Donnell & Sedgeley 2006).
- Long-tailed bat populations are often made up of several distinct colonies that rarely mix at roost sites (O'Donnell 2000d).

Despite these major difficulties, various studies have attempted to estimate population size (or population density) in a specified area by summing roost counts (e.g. Gaisler et al. 1979; Speakman et al. 1991). A similar approach was used to obtain population estimates for lesser short-tailed bats in Rangataua Forest in New Zealand, where several attempts were made to locate as many roosts as possible and conduct exit counts simultaneously (Specht 2002). That method required tremendous effort and resources, including numerous radio-transmitters attached to bats to locate roosts, radio-tracking by plane and on foot to locate roosts, and several sets of video recorders and cameras to count bats as they exited the roosts. Although this effort let the researchers obtain minimum population estimates, it is unlikely that all roosts occupied were found and counted every night. For more details, see case study A in the Toolbox method 'Bats: roost occupancy and indices of bat activity—infrared beam counters s' (docdm-131260).

Nowhere has it been demonstrated that there is a consistent correlation between numbers of long-tailed bats or lesser short-tailed bats emerging from a roost and actual population size. For example, counts of lesser short-tailed bats from individual roosts in the Eglinton Valley, Fiordland, seemed to underestimate total population size by 50% to 90% (and possibly more). For more details see table 1 in the Toolbox method 'Bats: trapping at roosts—estimating population size' (docdm-590819).

Recently, lesser-short-tailed bats have been tagged using Passive Integrated Transponder tags (PIT tags); also known as microchips. Automatic tag readers positioned at the roost hole have successfully recorded the number of bats with tags as they exited the roost. If this information (number of bats with tags emerging at dusk) is used in conjunction with a simultaneous video count at the same roost (total number of bats emerging), a coarse, one-off population estimate can be calculated (e.g. Lincoln-Petersen Index). See the Toolbox method 'Bats: trapping at roosts—estimating population size' (docdm-590819) for more details.

Can counts at roost sites be used for estimating population trends?

The assumption underlying use of roost counts for population monitoring is that trends observed at roosts reflect trends across the population. For example, most studies focus on maternity colonies, but monitoring maternity roosts clearly gives little information on the male portion of the population or the portion of the population that roosts solitarily. Studies in the UK (Walsh et al. 2001) and in the Eglinton Valley in New Zealand (Pryde et al. 2005) have shown (particularly if raw data are analysed) that changes in average roost counts may not reflect changes in population size. See case studies A and B in the Toolbox method 'Bats: exit counts at roosts—simple visual counts' (docdm-590804).

Recent and ongoing research is investigating the potential of using mark-recapture methods to monitor trends in numbers of long-tailed bat populations and whether there are any relationships between roost counts and population trends (e.g. Pryde et al. 2005). Also see the Toolbox method 'Bats: trapping at roosts—estimating population size' (docdm-590819) for more details.

New research technologies and analytical techniques may lead to improved methods and greater certainty around population estimates and trends.

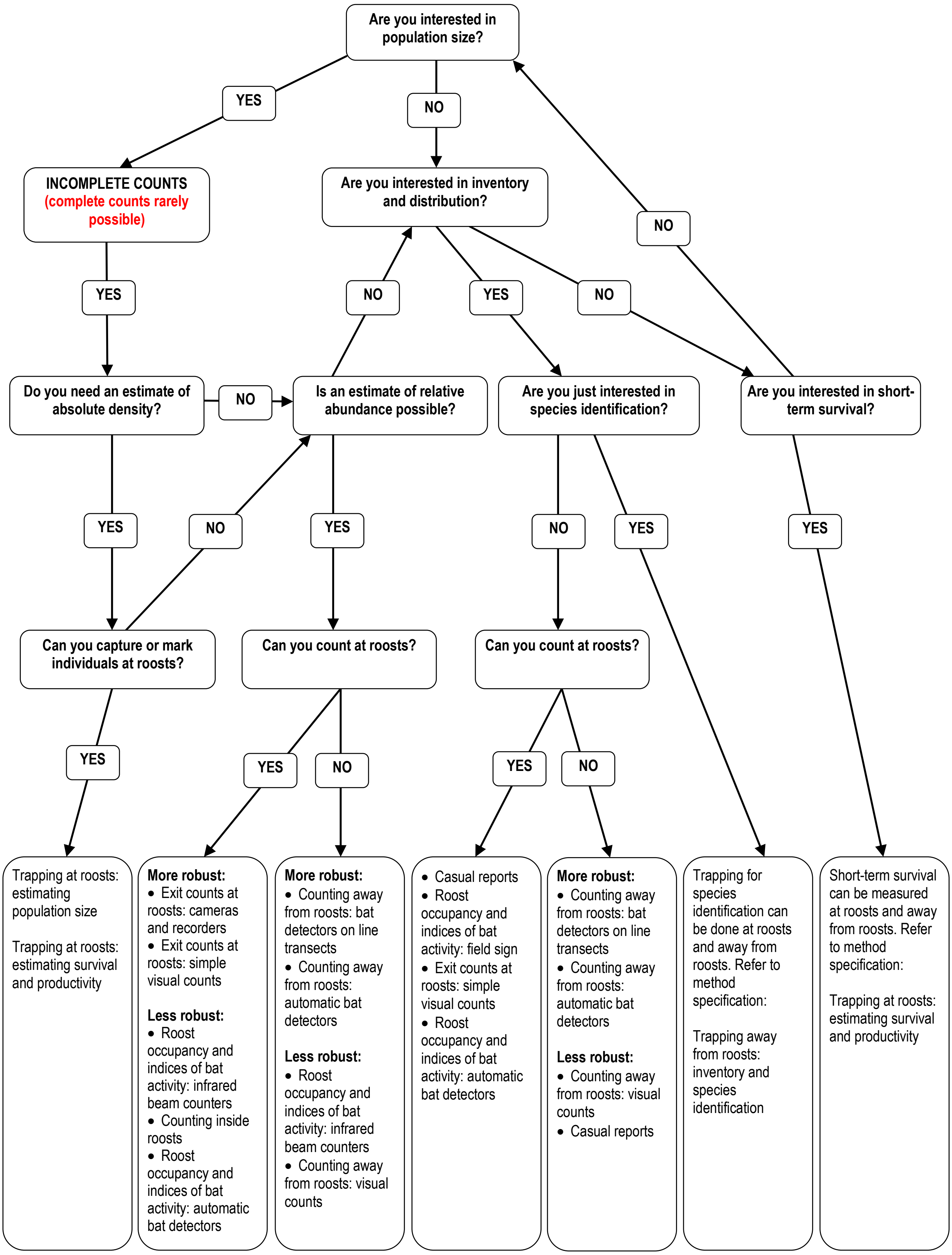
Decision trees

Use the 'Comparative tables' together with these decision trees to guide you to the most suitable and cost-effective method to use to answer specific inventory and monitoring questions.

Once you have been guided to a method(s), read the method specifications carefully to ensure it meets your study objectives.

'Decision tree 1' asks prompting questions about what the objectives of your inventory or monitoring study are, and guides you towards the most suitable methodologies.

Decision tree 1. Bat methods decision tree.

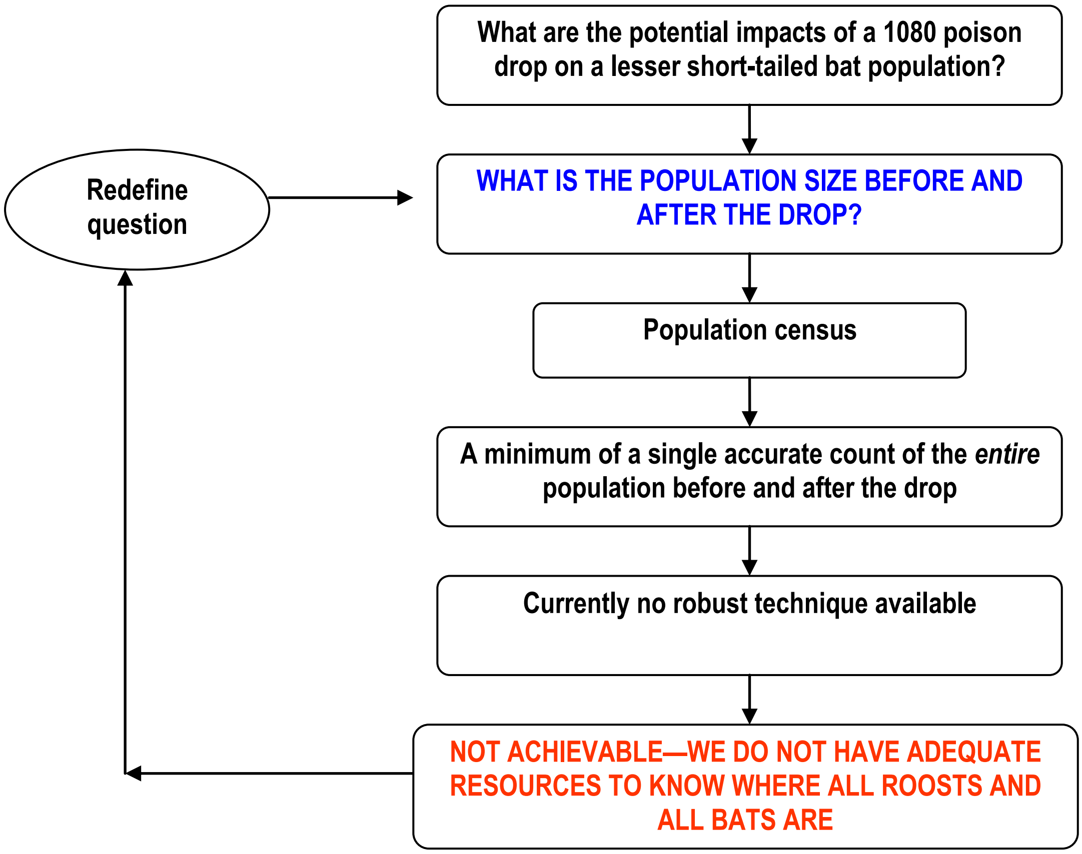


Decision tree 2

This section provides an example of a planning process used to address a common management question applicable to bats. The example used is: What are the potential impacts of a 1080 poison operation on a population of lesser short-tailed bats? Decision trees 2a, 2b and 2c illustrate the need for monitoring programmes to be adaptive in response to the type of question being asked, the resources available and the level of precision that is acceptable.

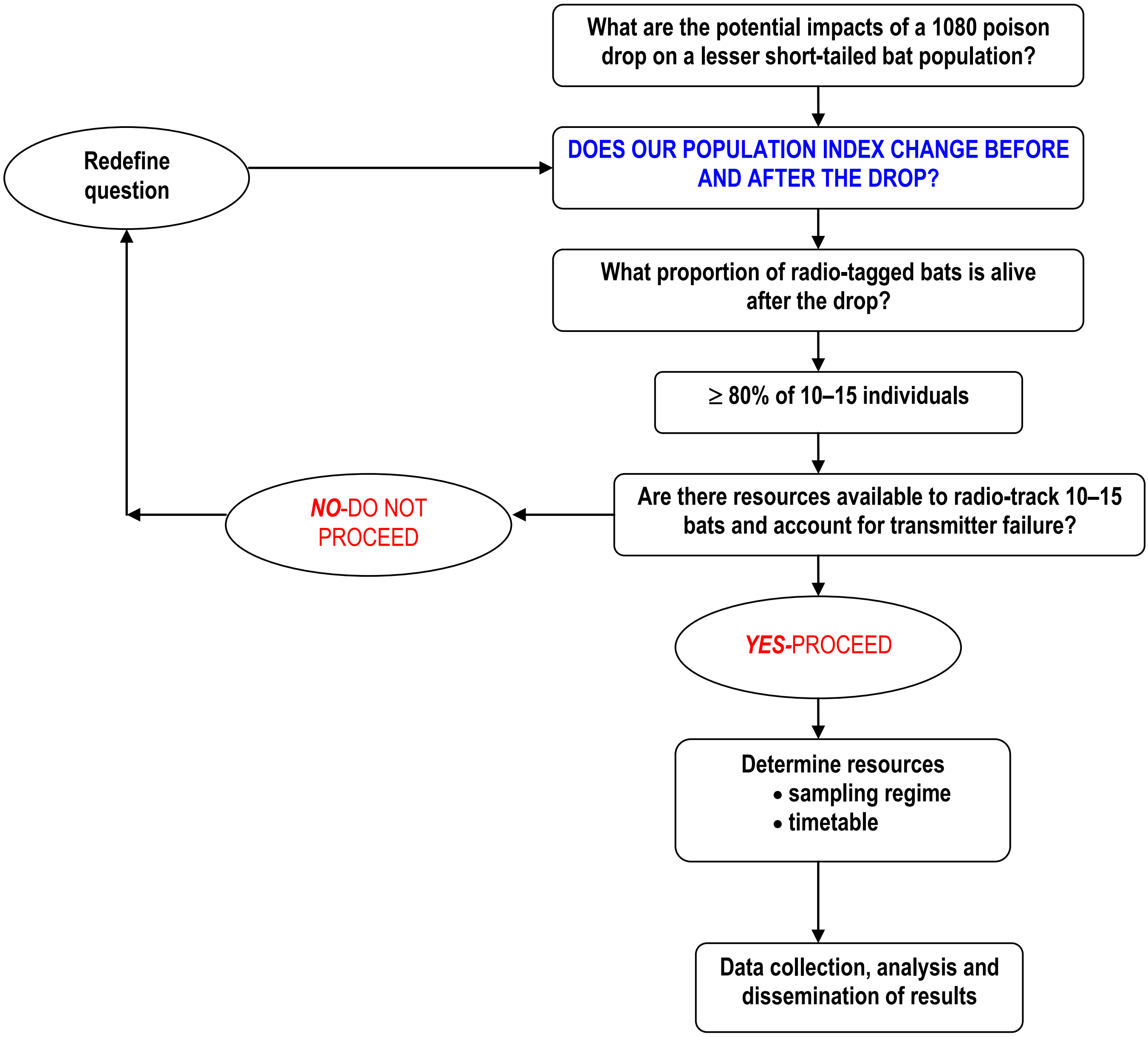
Decision tree 2a. Example of process for determining method of management monitoring.

Question: What is the lesser short-tailed bat population size before and after the drop?



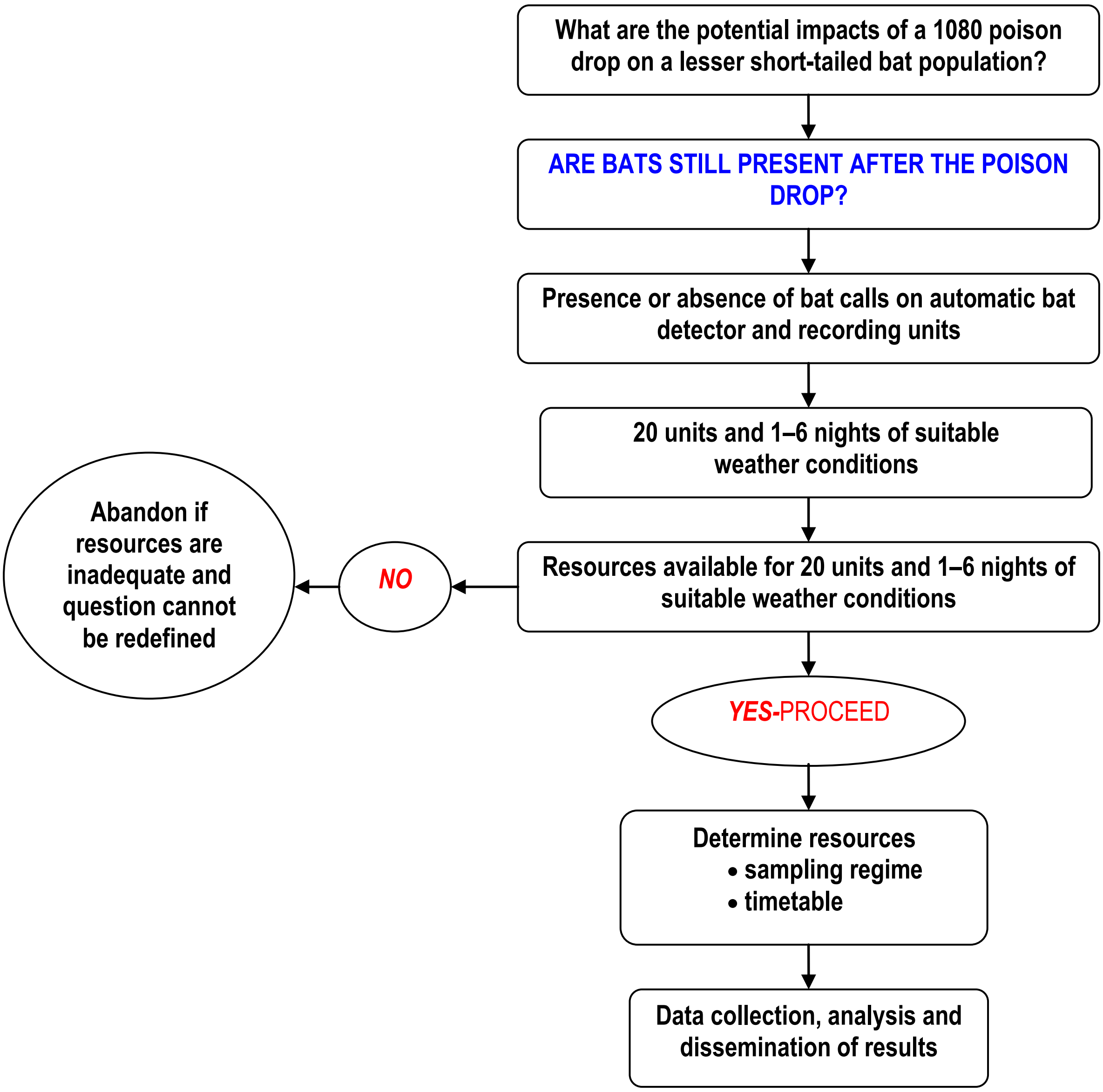
Decision tree 2b. Example of process for determining method of management monitoring.

Question: Does our population index change before and after the drop?

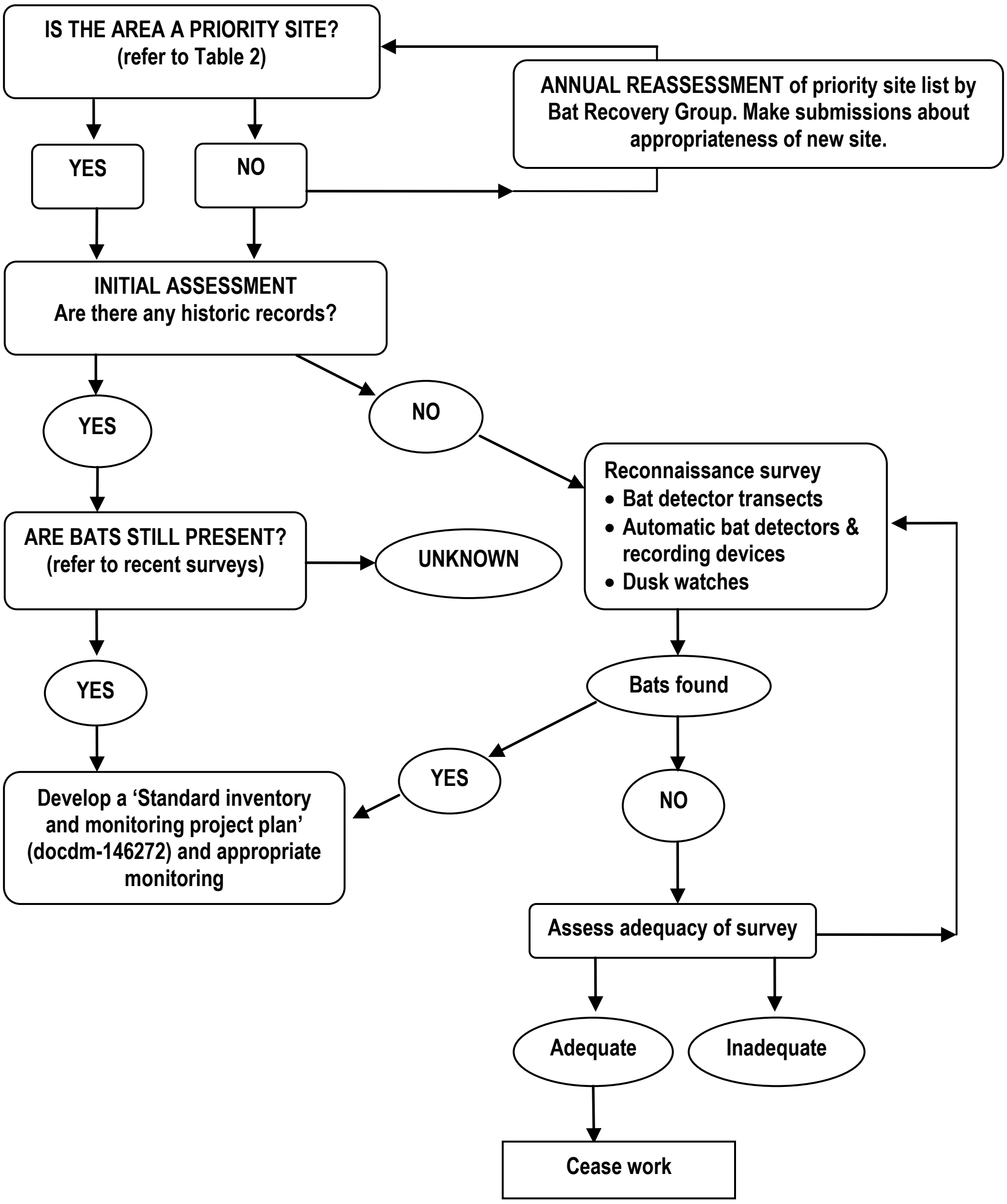


Decision tree 2c. Example of process for determining method of management monitoring.

Question: Are lesser short-tailed bats still present after the poison drop?



Decision tree 3. How to determine whether monitoring of bats is a priority for an area.



Comparative tables of methods

The comparative tables are organised as follows:

- Methods for inventory of long-tailed bats (Table 3)
- Methods for monitoring long-tailed bats (Table 4)
- Methods for inventory of lesser short-tailed bats (Table 5)
- Methods for monitoring lesser short-tailed bats (Table 6)

The tables are further arranged by methods that count bats away from roosts, at sites or both. There are 14 methods; four methods for use away from roost sites, eight at roost sites, and two that can be used in both situations.

Each method is scored for its relative precision in answering the specific inventory and monitoring objectives; ✓✓✓ = Good; ✓✓ = Medium; ✓ = Poor; × = Not recommended; — Not applicable. The relative costs or resources required (equipment costs, personnel costs, skills required) for each method are also assessed and ranked as Low, Medium or High. Once you have been guided to a method(s), read the method specifications carefully to ensure it meets your study objectives.

Table 3. Methods for **INVENTORY** of long-tailed bats. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; × Not Recommended; — Not applicable. **Resource costs:** L = Low; M = Medium; H = High.

	Inventory objectives					Resources		
Methods	1. Presence	2. Distribution	3. Habitat relationships	4. Relative abundance	5. Significance of site	Equipment costs	Personnel costs	Skills required
Away from roosts (foraging and commuting bats)								
Counting away from roosts—bat detectors on line transects	✓✓✓	✓✓✓	✓✓	✓	✓✓	M	H	L
Counting away from roosts—automatic bat detectors	✓✓✓	✓✓	✓✓✓	✓	✓✓	H	M	M\H
Counting bats away from roosts—visual counts	✓	✓	×	×	✓	L	L	M
Trapping away from roosts—inventory and species identification	✓✓✓	×	×	×	×	H	H	H
At roost sites[†]								
Exit counts at roosts—cameras and recorders	✓✓✓	—	—	✓	✓	H	H	H
Exit counts at roosts—simple visual counts	✓✓✓	—	—	✓	✓	M\H	H	M\H
Trapping at roosts—estimating population size	—	—	—	✓✓✓	✓✓✓	H	H	H
Roost occupancy and indices of bat activity—infrared beam counters	✓	—	—	✓	×	M	M	M\H
Roost occupancy and indices of bat activity—field sign (caves and buildings only—little visible sign at roost trees)	✓	✓	—	×	×	L	M	L
Roost occupancy and indices of bat activity—automatic bat detectors	✓	—	—	×	×	M	M	M\H

	Inventory objectives					**Resources**		
Methods	1. Presence	2. Distribution	3. Habitat relationships	4. Relative abundance	5. Significance of site	Equipment costs	Personnel costs	Skills required
Counting inside roosts (inside cave and building roosts—the inside of tree roosts are usually inaccessible)	✓✓	✓	×	✓	✓✓	L	L	M
Equally applicable at roosts and away from roosts								
Casual reports								

†A large proportion of the high cost of these techniques reflects the amount of equipment, effort and skills required to find bat roosts (e.g. catching, attaching radio-transmitters and following bats to their roost sites). The relative costs and skill levels required will be reduced if counting at known roosts.

Inventory is a one-off survey or assessment with no intention to re-measure. If inventory of a site is repeated in the future this can be considered monitoring.
Common inventory objectives:
1. Are bats present?
2. What is their range/distribution nationally or at a site?
3. What are the species-habitat relationships (based on a single survey)?
4. What is the relative abundance (single count)?
5. What is the wildlife value/significance of an area (SSWI, etc.) (based on a single survey)?

Table 4. Methods for **MONITORING** of long-tailed bats. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; × Not Recommended; — Not applicable. **Resource costs:** L = Low; M = Medium; H = High.

	Monitoring objectives			Resources		
Methods	1. Surveillance	2. Status and Trend	3. Management	Equipment costs	Personnel costs	Skills required
Away from roosts (foraging and commuting bats)						
Counting away from roosts—bat detectors on line transects	✓✓✓	✓	✓	M	H	L
Counting away from roosts—automatic bat detectors	✓	✓	✓	H	M	M\H
Counting bats away from roosts—visual counts	×	×	×	—	—	—
Trapping away from roosts—inventory and species identification	×	×	×	—	—	—
At roost sites†						
Exit counts at roosts—cameras and recorders	—	✓	✓	H	H	H
Exit counts at roosts—simple visual counts	—	✓	✓	M\H	H	M\H
Trapping at roosts—estimating population size	—	✓✓✓	✓✓✓	H	H	H
Trapping at roosts—estimating survival and productivity	—	✓✓✓	✓✓✓	H	H	H
Roost occupancy and indices of bat activity—infrared beam counters	—	✓	✓	M	M	M\H
Roost occupancy and indices of bat activity—field sign (caves and buildings only—little visible sign at roost trees)	✓	✓	✓	L	M	H
Roost occupancy and indices of bat activity—automatic bat detectors	—	×	×	—	—	—
Counting inside roosts (inside cave and building roosts—the inside of tree roosts are usually inaccessible)	✓✓	✓✓	✓	L	M	M
Equally applicable at roosts and away from roosts						
Casual reports						
Radio-tracking to monitor short-term survival. Information on this method is included in 'Trapping at roosts—estimating survival and productivity'	—	×	✓✓✓	M	M	M

[†]A large proportion of the high cost of these techniques reflects the amount of equipment, effort and skills required to find bat roosts (e.g. catching, attaching radio-transmitters and following bats to their roost sites). The relative costs and skill levels required will be reduced if counting at known roosts.

Monitoring assesses change or trend over time and requires re-measurement of parameters at some pre-determined frequency.

Common monitoring objectives:

1. What species have moved into an area? Have range extensions occurred for a species of interest?
2. What is the population abundance or density of a species or community? Is this stable over time? What are the population trends? Does this relate to habitat use?
3. Do population estimates of density and abundance change as a result of management action? Over what time-scale does this occur? Has a species translocation succeeded? Has management been effective? Has species composition altered as a result of management? What are the visitor impacts?

Table 5. Methods for **INVENTORY** of lesser short-tailed bats. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; × Not Recommended; — Not applicable. **Resource costs:** L = Low; M = Medium; H = High.

	Inventory objectives					**Resources**		
Methods	1. Presence	2. Distribution	3. Habitat relationships	4. Relative abundance	5. Significance of site	Equipment costs	Personnel costs	Skills required
Away from roosts (foraging and commuting bats)								
Counting away from roosts—bat detectors on line transects	×	×	×	×	×	—	—	—
Counting away from roosts—automatic bat detectors	✓✓✓	✓✓	✓✓✓	✓	✓✓	H	M	M\H
Trapping away from roosts—inventory and species identification	✓✓✓	×	×	×	×	H	H	H
At roost sites†								
Exit counts at roosts—cameras and recorders	✓✓✓	—	—	✓	✓	H	H	H
Trapping at roosts—estimating population size	—	—	—	✓✓	✓✓	H	H	H
Roost occupancy and indices of bat activity—infrared beam counters	✓	—	—	✓	×	M	M	M\H
Roost occupancy and indices of bat activity—field sign (caves and buildings only—little visible sign at roost trees)	✓	×	—	✓	×	L	M	L
Roost occupancy and indices of bat activity—automatic bat detectors	✓	—	—	×	×	M	M	M\H
Counting inside roosts (inside cave and building roosts—the inside of tree roosts are usually inaccessible)	Not applicable to lesser short-tailed bats because they are not currently known to roost in buildings or caves, and it is usually impossible to count bats inside trees.							
Equally applicable at roosts								

	Inventory objectives					Resources		
Methods	1. Presence	2. Distribution	3. Habitat relationships	4. Relative abundance	5. Significance of site	Equipment costs	Personnel costs	Skills required
and away from roosts								
Casual reports								

†A large proportion of the high cost of these techniques reflects the amount of equipment, effort and skills required to find bat roosts (e.g. catching, attaching radio-transmitters and following bats to their roost sites). The relative costs and skill levels required will be reduced if counting at known roosts.

Inventory is a one-off survey or assessment with no intention to re-measure. If inventory of a site is repeated in the future this can be considered monitoring.
Common inventory objectives:
1. Are bats present?
2. What is their range/distribution nationally or at a site?
3. What are the species-habitat relationships (based on a single survey)?
4. What is the relative abundance (single count)?
5. What is the wildlife value/significance of an area (SSWI, etc.) (based on a single survey)?

Table 6. Methods for **MONITORING** of lesser short-tailed bats. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; × Not Recommended; — Not applicable. **Resource costs:** L = Low; M = Medium; H = High.

	Monitoring objectives			Resources		
Methods	1. Surveillance	2. Status and Trend	3. Management	Equipment costs	Personnel costs	Skills required
Away from roosts (foraging and commuting bats)						
Counting away from roosts—bat detectors on line transects	×	×	×	—	—	—
Counting away from roosts—automatic bat detectors	✓	✓	✓	H	M	M\H
Trapping away from roosts—inventory and species identification	×	×	×	—	—	—
At roost sites†						
Exit counts at roosts—cameras and recorders	—	✓✓	✓✓	H	H	H
Trapping at roosts—estimating population size	—	✓✓	✓✓	H	H	H
Trapping at roosts—estimating survival and productivity	Lesser short-tailed bats cannot be banded. Trials to test suitability of Passive Integrated Transponder (PIT) tags (microchips) for long-term marking began in 2006 and are ongoing.					
Roost occupancy and indices of bat activity—infrared beam counters	—	✓	✓	M	M	M\H
Roost occupancy and indices of bat activity—field sign (caves and buildings only—little visible sign at roost trees)	—	✓	✓	L	M	H
Roost occupancy and indices of bat activity—automatic bat detectors	—	×	×	—	—	—
Counting inside roosts (inside cave and building roosts—the inside of tree roosts are usually inaccessible)	Not applicable to lesser short-tailed bats because they are not known to roost in buildings or caves and it is usually impossible to count bats inside trees.					
Equally applicable at roosts and away from roosts						
Casual reports	[redacted]					
Radio-tracking to monitor short-term survival. Information on this method is included in 'Trapping at roosts—estimating survival and productivity'	—	×	✓✓✓	M	M	M

[†]A large proportion of the high cost of these techniques reflects the amount of equipment, effort and skills required to find bat roosts (e.g. catching, attaching radio-transmitters and following bats to their roost sites). The relative costs and skill levels required will be reduced if counting at known roosts.

Monitoring assesses change or trend over time and requires re-measurement of parameters at some pre-determined frequency.
Common monitoring objectives:
1. What species have moved into an area? Have range extensions occurred for a species of interest?
2. What is the population abundance or density of a species or community? Is this stable over time? What are the population trends? Does this relate to habitat use?
3. Do population estimates of density and abundance change as a result of management action? Over what time-scale does this occur? Has a species translocation succeeded? Has management been effective? Has species composition altered as a result of management? What are the visitor impacts?

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Appendix A

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

docdm-870579	A guideline to monitoring populations
docdm-132033	Bat Recovery Group contacts
olddm-496393	Bat Recovery Group minutes 03
docdm-142161	Bats: casual reports
docdm-590733	Bats: counting away from roosts—automatic bat detectors
docdm-590701	Bats: counting away from roosts—bat detectors on line transects
docdm-590754	Bats: counting away from roosts—visual counts
docdm-590915	Bats: counting inside roosts
docdm-590789	Bats: exit counts at roosts—cameras and recorders
docdm-590804	Bats: exit counts at roosts—simple visual counts
docdm-590899	Bats: roost occupancy and indices of bat activity—automatic bat detectors
docdm-590882	Bats: roost occupancy and indices of bat activity—field sign
docdm-131260	Bats: roost occupancy and indices of bat activity—infrared beam counters
docdm-590819	Bats: trapping at roosts—estimating population size
docdm-590867	Bats: trapping at roosts—estimating survival and productivity
docdm-590776	Bats: trapping away from roosts—inventory and species identification
docdm-213179	Canterbury Conservancy bat database
docdm-131465	DOC best practice manual of conservation techniques for bats
docdm-146272	Standard inventory and monitoring project plan
docdm-249920	West Coast Conservancy bat database