10 Mammals

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Introduction

Census methods for mammals depend critically on the size of the species and its natural history. If species are diurnal, common and highly visible, the census problem is relatively simple. If species are nocturnal, rare and difficult to detect, the census problems are most difficult. As in all ecological census work, you need to decide the purpose of the study and the level of precision you require. Higher precision bears costs in time and money, and methods that lead to higher precision might not be practical for some species within a finite budget.

A sequence of decisions to facilitate the choice of methods for a mammal census is outlined in Figure 10.1 (Table 10.1). Just because many studies of a particular species or group of species have used a particular method does not mean that you must use this method for your study. Many studies have not used the best methods in the past, and there is no reason to continue using sub-optimal techniques that waste time and money.

Total counts

The simplest way to determine how many individuals of a particular species of mammal live in an area is to count all of them. This census method we might consider the Holy Grail of mammal-census methods, yet it can hardly ever be achieved. Total counts can be done on large mammals in restricted areas (Bookhout 1994), but one should always be sceptical of the accuracy of total counts, since in most cases to date there is a negative bias – estimated numbers are less than actual numbers. Grey whales have been counted since 1975 as they migrate south along the coast of central California and, while one might think that a party of observers could count all the whales moving close to shore, in fact they recorded only 79% of the whales (Rugh *et al*. 1990). The message is clear: if you think you can do a total count, check your assumption by double-counting with two independent sets of observers.

Method

If numbers are small, you can count isolated blocks of individuals, but if they are larger you will need to photograph the groups and count from the photos. This method can be used with

Ecological Census Techniques: A Handbook, ed. William J. Sutherland.

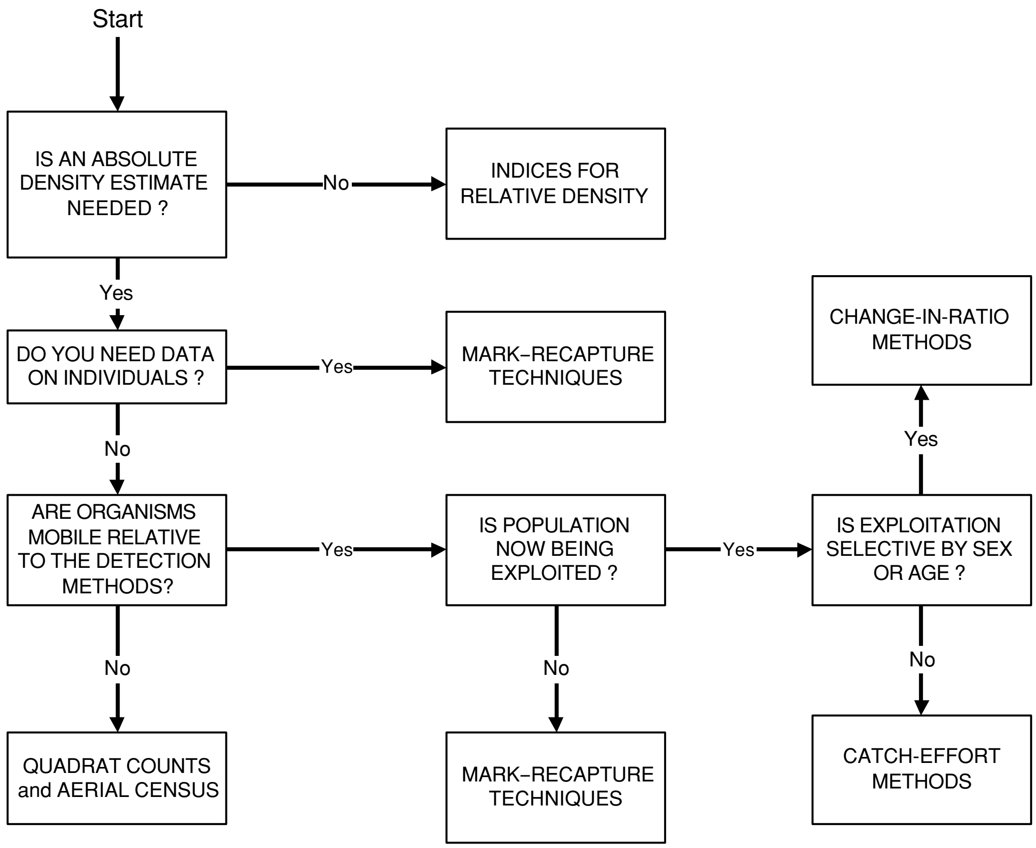

Figure 10.1 A decision tree for census techniques for mammals. It is important as a first step to have clear objectives for your census, and then to pick the best methods to achieve these objectives. Within each box of methods there are many alternative procedures (see Chapter 2, page 00). (Modified after Caughley (1977).)

helicopter or airplane counts of large mammals like elephants, reindeer and red deer, if visibility is excellent. Helicopters, although expensive, are particularly useful since they can hover until the count has been completed.

Biases

Few total counts have escaped the negative bias of undercounting what is actually there. There is unfortunately not a consistent undercounting bias that can be used for corrections of the raw counts. Observers differ dramatically in their ability to see even large mammals, so care must be taken to use the same observers whenever possible. Trees and shrubs hide some individuals, whereas others are spooked by the helicopter or airplane and may be counted twice.

Table 10.1. *A summary of methods suitable for various groups*

	Carnivores	Sea mammals	Primates	Ungulates	Bats	Rodents	Rabbits, hares and pikas	Insectivores and elephant shrews	Endentates	Page
Nesting or resting structures			+			+				00
Bat roosts and nurseries					*					00
Line transects	?	+	+	*	?	?	+		+	00
Aerial surveys	?	*		*						00
Individual recognition	?	+	+	+						00
Counting calls	+	?	+		+					00
Trapping	?			?	?	*	+	*		00
Counting dung	+			*	?	+	*		?	00
Feeding signs for herbivores	+		?	?	?	+	?		?	00
Counting footprints and runways	+			+		?	?	?	?	00
Hair tubes and hair catchers	?					*		+		00
Counting seal colonies										00

* Method usually applicable, + method often applicable, ? method sometimes applicable. The page number for each method is given.

Nesting or resting structures

Tree squirrels build drays in trees and beavers build lodges in lakes and streams. Any mammal that builds a visible structure can be censused by counting these structures using standard line-transect or quadrat methods (Chapter 2). Burrowing rodents, such as ground squirrels, leave obvious signs of digging in many habitats, so counting burrows can be used as a census method for these species.

Method

Searches for tree nests, burrows, or other structures built by mammals must be systematic and cover the area of interest, either in its entirety or with a set of random samples. You must know the habitat used by the species you are surveying, and you must determine whether the structures are being used. Animal signs would include digging, fresh droppings and possibly scent. Sites may have to be revisited to determine occupancy. If you wish to obtain an estimate of the absolute density, you will need to count the number of individuals occupying a sample of nesting or resting sites.

Advantages and disadvantages

Few mammal species make obvious nesting or resting sites, but many rodents dig burrows. For species that inhabit these structures, it is not always easy to determine whether a site is active or not without a great deal of observation. Burrow counts are poor estimates of rodent abundance unless one knows that the burrow is active (Van Horne *et al*. 1997). Boonstra *et al*. (1992) developed a tracking method to locate rodents in active burrows. For some species in colder environments infrared imaging can be used to detect active burrows from their heat production (Boonstra *et al*. 1994). For arctic ground squirrels that live in burrows Hubbs *et al*. (2000) developed a powder-tracking tile method that gives results closely correlated with absolute density.

Biases

Occupied burrows or nests may contain more than one individual, or in some cases one individual may inhabit several burrow or nest sites, so some knowledge of natural history may help prevent biases in converting counts into absolute density. The major bias to avoid is that of counting both occupied and unoccupied burrows or nests.

Bat roosts and nurseries

Bats are among the most difficult mammals to census because of their mobility. Both the large fruit bats or flying foxes (Megachiroptera) and the much smaller Microchiropteran bats roost by day and are active at night. Most of the census methods for bats are applied to these roost sites.

Method

Bats may be counted at the roost site or as they emerge from the site (O'Shea *et al*. 2003). A National Bat Monitoring Programme in the UK (http://www.bats.org.uk/nbmp/) has been working for 10 years to standardise monitoring of British bat populations. Three principal methods have been applied: observations at summer maternity roost sites and at winter hibernation sites, together with summer field surveys using bat detectors. Standardised monitoring protocols have been developed to collect UK-wide baseline data for each of the target species. To cross-validate, a double-sampling approach has been applied, whereby each species is monitored by two of the three principal methods:

(1) Maternity colony monitoring. Volunteers stand outside roost sites (generally houses) at sunset and count numbers of bats emerging. Two counts are made in June. Some weather and site details such as habitats surrounding the site are recorded. This survey is appropriate for volunteers with little or no previous experience – including householders.
(2) Field survey monitoring. Volunteers are allocated a randomly selected grid reference along a stretch of waterway or of a 1-km^2 area. They select a route to walk along the waterway or around the square, which includes stopping points spaced out appropriately. The route is walked once during the day to record the habitats present. Two evening surveys walking the route with a bat detector and powerful torch are made in July/August. Bats are recorded while the observer is in transit and while he or she is standing still at the stopping points. This method requires training in the use of a bat detector.
(3) Hibernation-site monitoring. Counts are made of all species encountered at a range of sites selected by surveyors – typically caves, mines and cellars. Two survey visits are made, one in January and one in February each year. Hibernating bats are identified and counted without disturbance. A torch with a deep-red filter will help prevent disturbance in caves or buildings. Photos can be taken and counted later to minimise disruption to colonies.

    Warren and Witter (2002) showed that their monitoring programme in Wales could detect a 5% population change over a 5-year period of monitoring. O'Donnell (2002) suggested that 10 years might be a more conservative figure, given the high variability in night-to-night counts for some species roosting in caves.

A variety of ultrasonic bat detectors has been used over the past 30 years to identify free-flying bats (O'Farrell *et al*. 1999). Analyses of recorded echo-location calls with older machines were often slow and typically restricted to few calls, but modern computing power has allowed species identification from calls in real time. Use of the Anabat II detector (http://www.titley.com.au/tanabat.htm) and its associated analysis system allows an immediate examination, via a lap-top computer, of the time–frequency structure of calls as they are detected. These calls can be stored on the computer for later examination. Many bats can be identified as to species by qualitatively using certain structural characteristics of calls, primarily approximate maximum and minimum frequencies. All bat calls are not equally useful for identification. To identify calls precisely, it is important to use a continuous sequence of calls from an individual in normal flight rather than single isolated calls. Counts of free-flying bats with bat detectors are subject to high variability, so with every monitoring programmme it is necessary to reduce this variation by counting sufficient replicates.

Advantages and disadvantages

Counts of bats are essential for determining population trends, especially for species of conservation interest, but there are problems with some monitoring methods both for the bats and for the humans counting them. In warm humid climates, bats in caves may transmit histoplasmosis, a serious fungal disease of the lungs. This fungus grows in soil and material contaminated with bat or bird droppings, and spores become airborne when contaminated soil is disturbed. Breathing the spores causes infection. Caves can be physically dangerous to inexperienced people. In a very few cases rabies appears to have been contracted by visiting bat roosts (Constantine 1988), although most cases of rabies come directly from bites by rabid bats.

Biases

There are no completely censused bat populations from which we can validate the counting methods used to index bat populations. Consequently we have at present no way of determining whether there are systematic biases in the existing counts. Typically, even if one roosting site can be counted precisely, we do not know all the roosting sites of a species. Some species use caves and houses only occasionally, which adds variation to counts made at roosting sites. Larger roosts may be easier to find than smaller roosts, and we do not know whether population trends from small and large roosts are congruent.

Line transects

If a species is relatively large and conspicuous, one of the best methods for estimating abundance is the line transect. This method is described in Chapter 3 and in much more detail in Buckland *et al*. (1993); see http://www.ruwpa.st-and.ac.uk/distance/. Line transects can be walked, driven, swum, or flown, and they have become more popular during the past decade.

Method

The essential feature of line transects is that one walks along a straight path and records the individuals seen and their perpendicular distance from the transect line (Figure 10.2). Some individuals to the side of the path being walked escape detection by the observer, and the critical assumption is that all animals on the path is seen. The data gathered on perpendicular distances are used to construct a detection function for distances off the transect line. It is assumed that the detection function has some smooth shape, but a variety of shapes is possible (Krebs 1999,

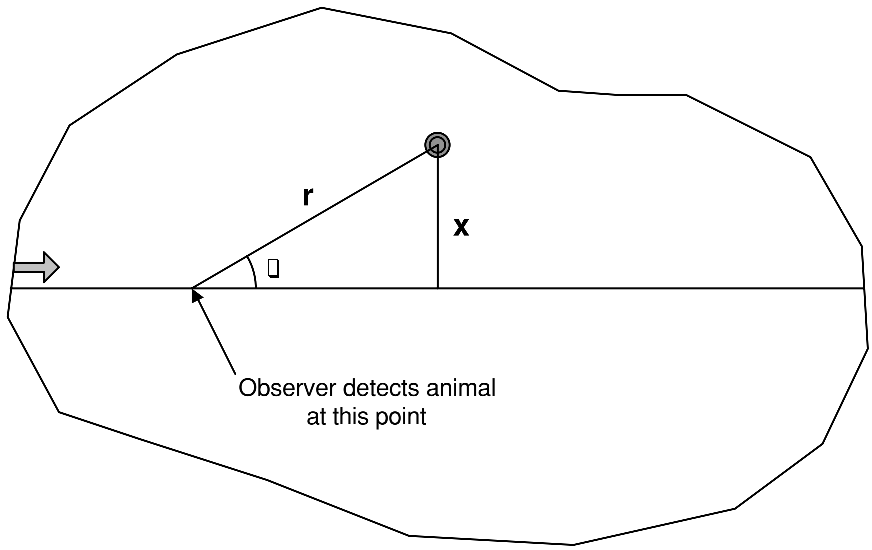

Figure 10.2 An illustration of the basic measurements that can be taken for each individual sighted along a line transect in the direction indicated by the arrow. The key measurement is the perpendicular distance (x_i). If the sighting distance (r_i) is easier to record in the field, the sighting angle (θ) must also be measured. The perpendicular distance $x = r \sin \theta$. Note that not all individuals need to be seen for this method to work.

p. 161). Line transects are best used for visible mammals in open habitats. The sample size should be at least 40 sightings, and better results are obtained from 60–80 sightings.

Advantages and disadvantages

Roads and tracks are often used as the path of the line transect, and there is a general problem of non-random sampling of the study area if convenience sampling is used instead of random sampling. Individuals must be located before they move or the detection function will be biased. If too many animals are observed, there may be problems with recording perpendicular distances accurately. Observers vary greatly in their ability to see animals, particularly if the habitat is less open. Perpendicular distances should be measured accurately rather than just estimated. If the species being studied is rare, it might be difficult to obtain the recommended sample size of 40 sightings. If habitats are interspersed, it might not be possible to get habitat-specific estimates of abundance.

Line transects can be used to estimate the abundance of indices of mammal activity, such as dung piles and burrows. A line transect may be converted to a rectangular sampling quadrat of fixed size if the observer can be certain of sighting all individuals within the fixed strip. This approach is not recommended for most mammals because detectability is not usually 100% and, in constraining sightings to a fixed strip width, data are lost for sightings more distant from the path of the line transect.

Biases

The most important biases arise from non-random sampling from roads or other paths of convenient travel. Perpendicular distances may be underestimated if they are not measured accurately. It is critical that all individuals on the centreline of the path are detected. For sea mammals such as whales or dolphins that surface only momentarily, it may be difficult to determine the sighting distance.

Aerial surveys

Large mammals that are readily seen from the air can be censused most effectively from aerial surveys that utilise light aircraft or helicopters. The most common method involves flying strip transects and counting all the individuals within the strip. An alternative approach is to use the line-transect methodology discussed above to estimate abundance (Burnham & Anderson 1984).

Method

The details of the methods of aerial surveys are covered in Norton-Griffiths (1978) and Krebs (1999). The aircraft used must allow the observers unlimited downward vision, and there must be precise control of the aircraft's altitude to permit a strip of defined width to be counted. Streamers on the wing struts of the aircraft can be used to delineate the width of the strip to be counted.

Advantages and disadvantages

There is no other method for covering very large areas rapidly for mammals that are relatively sparse on the ground or that range over very large spatial areas. Much experience in doing aerial counts has been accumulated, and the statistical analysis is well defined. The major disadvantage is the cost of aircraft usage, together with a very slight danger of aircraft accidents while surveying in remote regions. Aerial surveys can be difficult to use in areas with high relief, although helicopters can be useful in these situations if blocks defined by topography are counted instead of strips.

Large groups of animals can be photographed if they cannot be counted quickly. There is great variation among observers in their ability to count from aircraft, and this must be standardised as much as possible. Observers grow tired after a few hours of counting, and counting becomes less precise the faster one has to count.

Biases

Most observers in aerial censuses tend to undercount, and this negative bias typically ranges from zero when there are few animals to a very high fraction when many animals have to be counted quickly (Marsh & Sinclair 1989). Additional biases with aerial surveys can occur when strict control of the aircraft's altitude is not maintained, so that the actual strip width becomes too wide or too narrow. Observer training can reduce the differences among individuals in the ability to detect animals, but even trained observers differ dramatically in their counts (LeResche & Rausch 1974).

Individual recognition

Many large mammals have individual markings that lend themselves to being visually recognised. Killer whales exhibit individual colour variation and in addition they can be distinguished from one another by the shape and size of their dorsal fins. Wild dogs in Africa have coat-colour variation, so individuals can be identified from photographs. The use of individual recognition marks makes it possible to use all the methods of mark–recapture (Chapter 3) on populations of mammals that are never captured in traps or subjected to a tagging or marking procedure. These types of non-invasive studies are clearly desirable for species of high conservation interest.

Method

A catalogue of photographs of individuals must be maintained for the population of interest, and, if the public is involved, a mechanism for obtaining and copying photos taken by amateur observers is needed. The use of digital cameras with data and time stamps can now make the electronic collection of such photos possible. As in all population studies, good record keeping is critical to the success of these projects. Typically the species chosen are long-lived, and there is relatively little turnover from year to year.

Advantages and disadvantages

One advantage of this method is that it can make use of untrained observers to increase sample sizes. Photos must be of high quality, and a well-defined screening process must be defined in order to eliminate photos that are too poor to allow certain identification. Because this method can be very time-consuming, it can rarely be done solely by paid observers, so amateur input can be essential to successful sampling.

With these methods it is important to define the population being sampled and to cover the area occupied by the population. Most individuals in the population must be identified to provide the most precise population estimates. By providing spatial locations of the photographs, it is also possible to map the movements of individuals when there is good coverage of the areas occupied.

Biases

Care must be taken to ensure that individuals with similar markings are not confused in the counts. For humpback whales, Blackmer *et al*. (2000) showed that colouration patterns on the flukes changed with age, and that dorsal-fin shape was a more stable characteristic for individual recognition. If a total count is to be achieved, a high level of sampling effort must be expended. If mark–recapture methods are to be used on these data, all the assumptions of the particular method must be evaluated (Chapter 3). In particular, some individuals may be more easily located than others, so equal detectability cannot be assumed in a mark–recapture model.

Counting calls

Bats make ultrasonic calls that can be recorded by a bat detector. Lions roar, and seals and sea lions can be heard roaring even in dense fog. Whale and seal calls can be recorded underwater with a hydrophone. The idea is to count calls or bursts of calls for a standard unit of time, and to use these counts as an index of population size.

Method

In these cases it is not possible to recognise individuals from their calls, but species can be distinguished. Stirling *et al*. (1983) showed that it was possible to record and distinguish calls of ringed seals, bearded seals and walruses under the ice in the Canadian arctic. Bat detectors can catalogue species calls automatically.

Advantages and disadvantages

The major disadvantage of all index methods is that they must be calibrated relative to absolute abundance before they can be used reliably. Anderson (2003) has argued strongly against the use of indices like call counts to estimate relative abundance for wildlife species. The problem is that for many species like bats there might not be any other feasible method to use, and you then have to decide whether a poor data set is better than no data set.

Biases

There are many sources of variation in calling rates, ranging from seasonal effects associated with breeding (Cleator *et al*. 1989) to diurnal effects caused by weather factors. If bat detectors are used, there is a problem of standardising different machines, and the key is to develop a standard protocol to control as many of these sources of variation as possible.

Trapping

Small mammals are readily live-trapped in box traps, which is the most common method for assessing the abundances of many mammal species. Many trap designs can be found, but three types of live traps are most commonly used. The Longworth live trap consist of two parts, a tunnel (the trapping mechanism) and a nest box for food and bedding (see http://www.alanaecology.com/). Longworth traps are very expensive but have the advantage of being able to be locked in the open position so that they can be prebaited. They can also be ordered with an optional shrew hole to permit small shrews to escape (most shrews die within a few hours in a live trap). Sherman live traps are lightweight aluminium traps that are all one piece. Four sizes and folding and rigid styles are available. They have the advantage of being light in weight and the folding types of traps are easy to store and carry in the field. They have the disadvantage of being difficult to clean and, because it is difficult to use bedding and food in them, they may cause more inadvertent trap mortality, particularly among young animals. The thin aluminium of the folding traps can be easily chewed through by some rodents. Sherman traps are relatively inexpensive and available from H. B. Sherman Traps, Inc., 3731 Peddie Drive, Tallahassee, Florida 32303 (http://www.shermantraps.com/). Wire-mesh traps are typically used for larger species of small mammals, such as squirrels, and they are manufactured in a variety of sizes and with one door or two doors for entry. The two largest manufacturers are Havahart (http://www.havahart.com/) and the Tomahawk Live Trap Company (http://www.tomahawklivetrap.com/) but other local suppliers produce a variety of wire-trap designs.

In addition to simple box traps, small mammals can also be captured in pitfall traps dug into the ground. These must be deep enough for the species involved and have smooth sides so that animals cannot climb out. They should be covered with a board, to prevent rain from flooding them, and should have drainage holes in the bottom as well.

There are several designs of multiple-catch traps for rodents, but they are mainly used for pest-control purposes rather than population studies. Multiple-catch traps do not work with all small mammals, and may lead to individuals fighting and killing one another in the confined space of the trap.

Method

A variety of trapping designs has been suggested. Typically a trapping grid is surveyed in a checkerboard configuration, and, depending on the species, traps are placed at the checkerboard intersections, which are often 15–30 m apart. The size of the trapping grid must be adjusted to the size of the home range of the species being studied (Bondrup-Nielsen 1983). The typical trapping grid is 10 by 10 but in most studies a larger configuration would be better, particularly for density estimation. Anderson *et al*. (1983) recommend a trapping-web design instead of a checkerboard grid for estimating density more precisely, and the authors of a recent intensive evaluation of trapping grids versus webs prefer the web design for density estimation (Parmenter *et al*. 2003).

To protect small mammals from cold and rain, boards are often used to cover live traps. Food is usually provided to lure animals into the traps, but also to sustain them once they have been caught. Peanut butter mixed with oats is often used as a bait, but the best bait will depend on the species under study, and some experimentation may be needed.

Traps have usually been visited twice a day in early morning and evening, but accumulating evidence suggests that four checks a day would be better, to reduce the stress of capture. For some species overnight trapping should not be used. If night trapping is required, night checks should be carried out if possible, or traps should be set as late as possible and checked as early as possible in the morning. Pitfall traps should be visited as often as possible, and, since they are multiple-catch traps, animals can injure one another by fighting.

Population size is usually estimated by mark–recapture methods (Chapter 2), and a variation of line-transect methods can be applied to trapping-web data. To estimate population density for a trapping grid, one needs to know the effective trapping area of the grid as well as the estimated population size, since some individuals that live at the edge of the trapping area get caught in the edge traps. A boundary strip is usually added to checkerboard grids with a strip width of one-half the average movement of the individuals captured within the grid (Stenseth and Hansson 1979), but this is only an approximate method.

Advantages and disadvantages

The major disadvantage of live-trapping is that it requires a great deal of sustained work in order to achieve good population estimates. A high fraction (>50%) of individuals in a population must be marked in order to achieve estimates with narrow confidence bands (Pollock *et al*. 1990). With small rodents that have life spans of the order of months, frequent live trapping (every 2–3 weeks) is essential to obtain a good description of demographic events. The best estimators of population size, like the programs CAPTURE and MARK, demand multiple trapping sessions (typically five or more) and this demand conflicts with the requirement not to disturb the individuals being studied by confining them in traps too often. The advantage of live-trapping studies is that one obtains data on reproductive status, weight and movements of individuals at the same time as one gets density estimates.

Care must be taken in handling small mammals because of diseases that can be transmitted to humans (Begon 2003). The list is long – from plague to hantavirus, leptospirosis, cowpox, rabies and a host of viral and bacterial diseases not yet described. On the positive side, many ecologists have handled thousands of small mammals and been bitten numerous times, with no apparent damage to their health. Caution is essential, however, particularly with regard to tropical species that have been little studied for transmissible diseases.

Biases

Individuals are not all equally catchable, no matter what type of trap is being used, so methods of population estimation that assume equal catchability must be treated carefully. To avoid bias, authors of many small-mammal studies have attempted to catch a large fraction (>80%) of the individuals in the population, thus reducing the margin for errors of estimation. However, it is important to remember that traps are selective – juvenile animals are rarely captured and breeding males that move over large areas are often captured all the time. The resulting population estimates should be noted as referring to the trappable population, not the entire population. In extreme cases some subordinate individuals may never be caught in traps, and would be invisible in the analysis of trapping data.

Estimation programs such as CAPTURE and MARK have methods for estimating population size in the presence of varying probabilities of capture, and these should be used to alleviate the major problem of individual variation in trappability.

Counting dung

If the species of interest has characteristic dung, it may be easier to find and count dung than to try to capture the animals themselves. Dung can be used simply as an index of the presence or absence of a species, but attempts to use the amount of dung as an index of population abundance have also been made.

Method

Dung can be counted with quadrats (circular, rectangular, square) or by line-transect methods. Some species deposit dung in piles and a clear operational definition of a sampling unit of dung must be made before counts can be undertaken. If quadrats are to be used in sampling, effort can be minimised by determining the optimal quadrat size and shape for the particular species (Krebs 1999, p. 105).

There is a major problem with dung counts in determining the age of dung. In some studies only fresh dung is to be counted, and, since the appearance of dung will change depending on temperature and moisture conditions, it is essential to define carefully what is to be counted. The best method for avoiding this problem is to re-count the same quadrats and clear them of all dung each time they are counted. The counting interval must depend on the rate of decay of dung. In tropical areas with dung beetles, this could be a matter of hours and consequently these methods could not be used. In polar regions dung may last for tens of years.

Attempts to estimate absolute abundance from dung rely on known rates of production of faecal pellets. Since rates will typically vary with diet, values from zoo animals are often unreliable estimates of this parameter. An alternative approach is to calibrate dung counts with live-trapping estimates of population size on the same area, and thus derive an empirical relationship between dung counts and population size (Krebs *et al*. 2001).

Advantages and disadvantages

Life produces dung, and consequently the presence of a species in an area can be as certained by dung counts. In habitats where dung persists this method can be used very effectively to index population abundance with a minimum of effort. As techniques for identification of individuals from DNA in dung are developed, fresh dung can also potentially become a way of estimating population size by mark–recapture of dung from specific individuals (Eggert *et al*. 2003).

If a long-term study is needed, it is important to have permanent quadrats that are cleared at each sampling so that the issue of dung age does not arise. If no independent estimate of population abundance is available, all of the cautions about using indices need to be considered carefully.

For some species of larger mammals the type of dung produced varies between the growing and non-growing seasons, and this can be used to advantage to index seasonal habitat use.

Biases

The main problem in sampling dung is that it is typically not randomly distributed in the landscape, and that it can decompose at quite different rates in various micro-habitats.

Feeding signs for herbivores

If a herbivorous species leaves characteristic marks on their food plants, these feeding marks or scars can be used both to determine presence and absence and to index the relative abundance of a population.

Method

Counting feeding signs depends on detailed knowledge of the natural history of the species and the food plants it utilises. Since diets of most mammals change seasonally, there may be one season in which the feeding signs are most easily counted.

Voles in grasslands cut tillers of grasses and leave these fresh cuttings in their runways. A census of these clippings was used over 80 years ago to index vole numbers in Britain (Chitty 1996). Ungulate browsing surveys can both index population sizes and measure the pressure these herbivores are exerting on their food plants. In all these cases standard methods of quadrat sampling can be used to estimate feeding marks.

Advantages and disadvantages

Like dung counts, the measurement of feeding signs is easily done during the day and does not depend on capturing or seeing animals. For species that have very broad diets and large seasonal shifts in diet, this method will not usually be the best way to index abundance. The main problem is to validate independently whether the particular feeding sign that you are measuring is a good index of abundance.

Biases

If similar species have similar diets, it might not be possible to separate species in the analysis of relative abundance. If diets vary markedly from year to year depending on the availability of alternative foods, what works well in one year may give a biased representation of abundance in other years.

Counting footprints and runways

Tracks of species in soft ground or snow are an excellent way of determining presence and absence. If standard methods are employed, these counts can be used as an index of relative abundance.

In Finland, Korpimäki *et al*. (2002) used snow tracking to index stoat and weasel abundance 1–2 days after fresh snows. O'Donoghue *et al*. (1997) used snow-track transects to index population changes in coyotes and lynx in northern Canada. Sand tracking stations have been used to index dingo populations in Australia (Allen *et al*. 1996).

Method

Footprints can be assessed actively or passively. Active assessment typically use scents or baits to bring animals into the tracking plot, whereas passive assessment uses tracks made by animals in their daily travels. These indices measure activity as well as population abundance, and are best used on species for which activity levels are relatively constant at the times of year the counts are made. The method is to set out plots large enough to provide good tracks, to rake them clean and revisit them at fixed intervals. For snow tracking the intervals are usually set by fresh snowfalls. The important point is that old tracks are not confounded with new tracks.

A similar kind of approach can be used for small mammals that make runways in grassland or woodland habitats. The number of active runways intersecting a line transect of fixed length can be used as an index of abundance. Activity of runways can be determined by the presence of fresh scats or fresh plant clippings.

Advantages and disadvantages

The advantage of track counts is that they are a cheap way of determining the relative abundance of wide-ranging carnivores that live at low density. The disadvantage is that all these measures confound activity with abundance; so, if the index increases, it could be because of higher activity, higher abundance, or both. Territoriality in some carnivores may affect the use of trails, and the spatial design of the sampling programme for tracks must take into account the size of the home range of the species under study. Wilson and Delahay (2001) review these methods in more detail.

Biases

All indirect methods of census are best if they can be validated with a population of known size. This has been impossible with most of the cases in which track counts have been used, and consequently it is not possible to estimate bias. The best recommendation is to keep the design of the surveys constant with respect to environmental and seasonal conditions, and to train observers carefully in track identification.

Hair tubes and hair catchers

Method

Hair tubes are long tubes slightly larger in diameter than the species being studied, with sticky tape on the inside so that hairs are left on the tape as the animal passes through the tube (Lindenmayer *et al*. 1999). For larger mammals barbed wire or other sticky devices can be used to sample hair from individuals without needing to capture them (Mowat and Paetkau 2002).

Advantages and disadvantages

The critical assumption is that the hair can be identified as to species or species-groups (Harrison 2002). Keys to mammalian hair are available for many groups (Brunner and Coman 1974; Day 1966; Staines 1958; Wallis 1993), These keys are not necessarily complete, and we recommend that a reference collection be prepared for the species being studied. Keys may represent only hairs from the dorsal surface and colour patterns of species may vary geographically. In addition, there is variation in hair samples from different parts of the body of mammals. Some species cannot be distinguished from hair alone.

DNA can now be extracted from hair samples and thus hair sampling can be used as a mark–recapture method (Mowat and Paetkau 2002). Rigorous methods must be used to identify individuals with minimal typing errors (Paetkau 2003) but, once this has been achieved, these methods of using hair DNA hold great promise for answering population questions that could not be studied previously.

Biases

The major potential biases are in the identification of hair and, if DNA typing is used, in the precise identification of individuals.

Counting seal colonies

Seals and sea lions are a special case of mammals that must haul themselves out outo land to reproduce. Because adults come and go from land colonies, counts of adults present will always be undercounts unless some correction is applied. In some cases it is easier to count the pups since they do not go to sea for several weeks.

Method

Aerial counts can be made from high-quality photographs. Ground counts are more difficult without disturbing the colony, and many individuals are hidden in rock crevices and cannot be seen from a vantage point. If some individuals are marked or carry radio-tags, a correction for the proportion missed can be applied. Methods of mark–recapture can be applied to pups by marking them with fur clips or water-soluble paints.

Advantages and disadvantages

Counts can give information on breeding success as well as abundance.

Biases

Not all adults will come ashore and this part of the population may be missed totally. At any given instant some animals are at sea feeding, so a total count is not possible even with photographs. Some breeding colonies may be missed completely if they are in isolated regions. Recolonisation of islands occurs and one cannot assume that any particular island is a population isolate (Pyle *et al*. 2001; Wilson 2001).

Conclusions

Censusing mammals is an evolving art. The major pitfalls are now well identified, and the statistical methods for dealing with census data are well developed. For mark–recapture estimates, individuals vary in their probability of capture or detection. The higher the fraction of animals captured or marked, the more certain the estimates. For all indices of population abundance, the general warning is not to assume that there is a linear relationship between the index and absolute population size. For many species there is a growing literature of clever census methods that are highly specific and most useful as we try to study and conserve mammals around the world.

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