14

Area-based surveys

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14.1 Introduction: what are area-based surveys?

Area-based surveys are frequently used to estimate the relative abundance, density, or diversity of amphibians. While the methodological details of area-based surveys can vary considerably, the basic principles behind these surveys are usually the same. Small, defined units, referred to as plots, quadrats, or transects, are selected randomly from larger areas of interest. These small units are then sampled for amphibians, and the data collected are used to make inferences about the relative abundance or diversity of amphibians in the larger areas.

Area-based surveys can be employed in a variety of situations. For example, one might want to compare amphibians in primary forest to amphibians in secondary forest or pasture. Or, one might want to analyze changes in amphibian communities over time (i.e. monitoring) or across an environmental gradient like elevation or distance from a disturbance. Area-based surveys are also used in experimental studies, for instance when habitats are modified and amphibians are compared between treatment and control areas. Finally, area-based studies are commonly used to study the basic habitat relationships and community ecology of amphibians (e.g. Toft 1980; Hairston 1987).

14.1.2 Why use area-based surveys?

Area-based surveys are useful primarily because they are rigorous and repeatable and because they can be replicated to put confidence intervals on estimates of abundance or diversity. Although haphazard surveys (i.e. walking around a large area and looking for amphibians) can yield count data and species lists, data from haphazard surveys are limited in their utility. One problem with haphazard surveys is that there is no way to repeat them consistently. If, years later, one wants to re-survey the same site or compare the site to some other area, there

is simply no way to collect comparable data. Second, haphazard surveys result in single estimates with no information on variation. As a result, any measure of abundance or diversity will lack confidence intervals and hypothesis testing will often be impossible.

Time-constrained surveys, in which a set amount of time is spent searching for amphibians, are one step more rigorous than haphazard surveys. However, when carried out in very large areas, time-constrained surveys lead to many of the same problems concerning rigor and repeatability as do haphazard surveys. Controlling the time period involved in a survey is important, but this can be done within the context of area-based surveys.

In this chapter, we first outline the different kinds of area-based surveys and illustrate their use in the amphibian research literature. We then discuss when each of the different kinds of area-based surveys is preferable. Finally, we consider the major methodological issues involved in designing area-based surveys. In the interest of brevity, we focus on uses of area-based surveys in amphibian conservation and management rather than basic population or community ecology. Most of these uses involve the collection of count data (which are assumed to reflect relative abundance; see Chapters 24 and 25) or else the estimation of true density. Throughout this chapter, we use the term abundance to indicate relative abundance or counts and density to signify an estimate of true density. Our recommendations concerning area-based sampling are based in part on a survey of approximately 100 studies that used area-based sampling to collect data on amphibian abundance or diversity (see Table 14.1). They are also based

Table 14.1 *Summary of a literature review of 89 studies that used area-based sampling. Studies are divided by whether the primary sampling units were plots/quadrats, transects, transects nested within plots, or quadrats nested within plots or transects. Summary data show the percentage of studies of each type that were: (1) terrestrial, aquatic, or both; (2) tropical or temperate; (3) single-species or multi-species studies, (4) targeting frogs, salamanders, caecilians, or multiple groups; and (5) conducted during daytime, at night, or both.*

Approach	N	Terrestrial/ aquatic/both	Tropical/ temperate	Single/ multiple species	Frogs/salamanders/ caecilians/multiple	Day/night/ both
Plots/quadrats	33	53/37/10	34/66	34/66	39/26/8/26	55/28/17
Transects	29	34/45/21	34/66	52/48	55/14/0/31	35/56/9
Nested transects	15	67/7/26	27/73	33/67	40/47/0/13	38/50/12
Nested quadrats	12	92/0/8	42/58	50/50	42/8/50/0	29/0/71

on our own experience using plots and transects to sample terrestrial salamanders, stream salamanders, and neotropical frogs.

14.2 Kinds of area-based survey

There are two basic types of area-based survey: plot or quadrat surveys and transect surveys. The terms plot and quadrat are often used interchangeably and refer to rectangular or square sampling units. Plots and quadrats can span a wide range of sizes, from 0.5 m^2 stream-bed quadrats to forest plots of several hectares. Our literature review found that when plots were used as a primary sampling unit, their median dimensions were 25 m (range 4–400 m) by 20 m (range 2–240 m). The great variation in plot size in the literature highlights the need to adapt plot designs specifically to the species and habitat of interest.

Transects are long, narrow plots, designed to be searched by one investigator in a single pass. Our review found that the median length of amphibian transects was 100 m (range 7–2000 m) with a median width of 2 m (range 1–8 m). The most common transect lengths were 50 m and 100 m and the most common widths were 1 and 2 m. Transects are often sampled visually, but frogs can also be sampled by listening for calls (see Chapter 16).

In addition to these basic designs, researchers often use nested designs in which one type of sampling unit is contained within another (e.g. transects or quadrats nested within large plots). In these designs, researchers randomly select plot locations within the areas of interest, and then randomly choose quadrat or transect locations within the plots. These nested quadrats or transects are used to make inferences about the abundance or diversity of amphibians within the plots, and the plots are used to make inferences about amphibians in the larger areas.

14.3 Specific examples of area-based surveys

Beyond the general classification of plots, quadrats, and transects, there are many specific uses for area-based surveys. In this section, we give several examples chosen to reflect the diversity of area-based surveys and some of their more common uses.

14.3.1 Leaf-litter plots

Anurans are abundant in the leaf-litter of tropical forests and can contribute substantially to amphibian diversity in these habitats. Taxa frequently encountered in the leaf litter include terrestrial genera such as *Eleutherodactylus* in the

Neotropics, *Arthroleptis* in Africa, and *Philautus* in South Asia. The leaf-litter amphibian fauna may also include Bufonids, Ranids, Leptodactylids, and other amphibians that breed in aquatic habitat but spend most of their adult lives on the forest floor.

Small plots have been frequently used to sample leaf-litter amphibians in tropical forests (Inger 1980; Vonesh 2001; Rocha *et al.* 2001). To carry out leaf-litter surveys, researchers mark off the boundaries of a plot and carefully sift through the leaf litter for amphibians until they have covered the entire plot. Searching leaf litter in this manner is time-consuming, so plots are typically small: usually 1–64 m^2. Rocha *et al.* (2001) argued from a direct comparison of methods in Atlantic rainforest that small plots (i.e. 2 m^2) surveyed very carefully were likely to be superior to larger plots (i.e. 64 m^2) surveyed more superficially. Leaf-litter quadrats are typically searched during the day for reasons of convenience, though Rocha *et al.* (2000) found that both counts and species richness were actually higher at night.

Because leaf-litter surveys disturb the habitat, researchers usually search each plot only once. However, litter plots can be highly replicated within any area of interest. Vonesh (2001), for example, searched a total of 150 25 m^2 quadrats in Kibale National Park, Uganda, 50 each in undisturbed forest, selectively logged forest, and pine plantation. Conducting a few trial surveys will give a good idea of how large a plot can be effectively surveyed, how many plots can be searched, and how abundant amphibians are likely to be in any given sample. Habitat data can also be an important component of leaf-litter surveys: variables measured commonly include leaf-litter mass or depth (often correlated with amphibian abundance: Allmon 1991; Vonesh 2001), herb cover, canopy cover, and soil moisture, temperature, and pH.

14.3.2 Natural-cover surveys for terrestrial salamanders

Terrestrial salamanders are regularly found underneath natural-cover objects (e.g. rocks and logs) on the forest floor. Natural-cover surveys for terrestrial salamanders can be carried out using plots or transects, though these are typically much larger than leaf-litter plots, encompassing 100–2000 m^2. In natural-cover surveys, one turns over all accessible rocks and logs and searches for salamanders underneath them. Although natural-cover surveys sample only a fraction of salamander population, the resulting counts have been shown to be highly correlated with density estimates from more extensive mark–recapture (Smith and Petranka 2000). However, salamanders move back and forth between cover objects, the leaf litter, and underground retreats, so proper timing of these surveys is critical. Generally, the best time for natural-cover surveys is when the soil underneath cover objects is wetter than the surrounding leaf litter. Cover-object surveys, like leaf-litter surveys, can disturb the microhabitats of interest, and Smith and Petranka (2000) recommend re-sampling plots once annually. Habitat data collected during cover surveys usually include herb cover, canopy cover, soil moisture, and soil temperature, as well as data on the number, type, and decay classes of cover objects searched. Salamander counts can be divided by the number of cover objects on a plot to correct for differences in search effort (e.g. Marsh and Beckman 2004); however, whether or not this yields more accurate estimates of relative abundance has not been tested.

The ability to resample salamanders more frequently without degrading cover objects is one big advantage for artificial cover objects (ACOs; see Chapter 13) over natural-cover surveys. However, counts from grids of ACOs may be only weakly correlated with counts from natural-cover surveys (Hyde and Simons 2001), and ACOs may under-represent smaller size classes of salamanders (Marsh and Goicochea 2003). Thus, natural-cover surveys are recommended over ACOs for relative abundance and diversity estimation until ACOs have been more thoroughly validated.

14.3.3 Nocturnal transects

Nocturnal transects have regularly been used to survey forest frogs in tropical habitats. At night, frogs may crawl up onto vegetation where they can be seen at or below eye level. Terrestrial-breeding frogs are commonly found with nocturnal transects. Additionally, researchers have reported low counts but a remarkably high richness of aquatic-breeding species (e.g. Pearman 1997).

Researchers typically set up transects by flagging vegetation in a straight line of 30–100 m. These transects are walked slowly, searching with a flashlight or headlamp for frogs. The width of transects is usually no more than 1–2 m to each side, as beyond this distance too many frogs are likely to be missed (Funk *et al.* 2003). Some frogs along transects may be found by localizing their calls, so in a sense these transects may be considered a form of aural survey (Chapter 16). However, female frogs of most species do not call, and many additional males will be seen that are not heard calling. Thus, counts from nocturnal transects will usually be higher than counts from aural surveys.

Nocturnal transects often involve only moderate disturbance to the vegetation, and in these cases surveys can be repeated multiple times and used in conjunction with mark–recapture density estimation (Funk *et al.* 2003). However, in habitats with dense understory vegetation, habitat degradation could lead to reduced counts in subsequent surveys. The optimal conditions for carrying out nocturnal transects can also vary widely among species and habitats

Temperature and moisture are often positively associated with frog calling activity (Townsend and Stewart 1994; Duellman 1995), although very heavy rains can actually reduce activity. Practicing transects in a variety of weather conditions can allow one to determine the best times for carrying out nocturnal transects. Habitat data measured in conjunction with nocturnal transects often include herb cover, canopy cover, tree stems, and tree diameter at breast height.

14.3.4 Quadrats for stream amphibians

Amphibians with adult or larval stages that live in streams may be sampled underneath rocks in the stream bed or at the edge of the stream. Several researchers have used quadrat surveys to sample amphibians, particularly larvae and small adults, in rocky stream beds (Barr and Babbitt 2002). Quadrats of 0.25–4 m^2 are randomly selected within a channel unit (pool, run, or riffle) and then all rocks are carefully removed to uncover the amphibians present. Quadrat surveys of a stream bed are in several respects analogous to leaf-litter surveys for tropical frogs: they are time-consuming so quadrats are typically small, they are moderately destructive so each quadrat is only searched once, and many quadrats can be surveyed in the course of a study. Habitat data collected during these kinds of surveys usually includes information on the size and number of rocks turned, as well as stream characteristics such as water temperature, pH, and flow rate.

14.3.5 Soil quadrats for caecilians

Several recent studies suggest that excavating soil quadrats may be a useful method for sampling caecilians. Measey *et al.* (2003) counted caecilians in the Western Ghats of India with 1 m^2 quadrats that were nested within 100 m^2 plots. They used a bladed hoe to dig out the soil to a depth of 0.3 m and sift through it for caecilians. This technique was surprisingly effective: they detected from zero to 12 caecilians per quadrat, with a mean density of 0.51–0.63/m^2. The one downside of the technique was that some of the caecilians (≈13%) showed signs of injury from the sampling procedure, although using a forked digging tool in place of a bladed hoe could possibly reduce injury rates (G.J. Measey, personal communication). Measey (2006) further suggested that because most caecilians were found near the surface, sampling could be made more efficient by first searching a larger plot (e.g. 25 m^2) to only a shallow depth and then searching one or more quadrats within each plot to a greater depth. It bears mentioning that not all caecilians are ecologically equivalent and some species may be more likely than others to be detected in soil quadrats. Gower *et al.* (2004), for example, found that timed digs in Tanzania resulted in high counts of one caecilian species, whereas a second species was detected almost exclusively on the surface during rainy nights

14.4 Modifications

The previous examples highlight some of the basic uses of plot and transect surveys. However, several modifications to these approaches have also been proposed. We cover two in detail: distance sampling (a modification of transect surveys) and adaptive cluster sampling (a modification of quadrat surveys).

14.4.1 Distance sampling

In bird surveys, distance sampling is widely used to estimate both density and detection rates (Gregory *et al.* 2004). The general idea of distance sampling is to make counts along a transect, but also keep track of the distance between the center of the transect and each animal found. Any decrease in counts with distance from the center of the transect is ascribed to changes in detectability. By modeling the way that detectability decreases with distance, one can estimate density from transect counts (for example with the program DISTANCE; Thomas *et al.* 2006). Unfortunately, distance sampling has been judged only moderately effective for amphibians (Fogarty and Vilella 2001; Funk *et al.* 2003), except when estimating burrow abundance of the fossorial salamander *Phaeognathus hubrichti* (Dodd 1990). This may be in part because many amphibians typically go undetected even at the center of the transect, leading to imprecise density estimates. Still, distance sampling does allow one to test whether detectability differs among habitats when mark–recapture is not feasible.

14.4.2 Adaptive cluster sampling

Amphibians are often highly aggregated in space with many individuals in some areas but few to none in other areas. This can be frustrating because it means that many randomly located sites may contain no amphibians. Adaptive cluster sampling can help focus sampling efforts in areas where animals are actually being found, but do so in a repeatable way (Thompson and Seber 1996). In adaptive cluster sampling, one starts by searching a randomly chosen quadrat within the area of interest. If this plot satisfies some pre-determined criterion (e.g. more than one amphibian found) then one begins to search adjacent plots. This process continues until a network of plots has been searched and is surrounded by so-called edge plots that fail to meet the criteria. Noon *et al.* (2006) used adaptive cluster sampling to search leaf-litter plots in the Western Ghats but found that the technique was actually less efficient than simple random sampling for detecting individual species. They postulated that the technique might have worked better if amphibians had been more abundant and more highly aggregated; however, more research is needed before adaptive cluster sampling can be recommended as a first-line approach to sampling.

14.5 Design issues: choice of sampling unit

There are two basic issues in the design of area-based studies: the size and shape of the sampling units and the number of these units to sample. In terms of size, small plots or quadrats are generally effective in situations where amphibians are small and fairly abundant and sampling a small area will tend to lead to nonzero counts. They are also useful when habitat heterogeneity is high because they can be highly replicated across the study area. In contrast, larger plots will generally be more effective when amphibians are less abundant, but are visible enough that larger areas can be efficiently searched. Plot surveys have been commonly used for searching low vegetation for frogs and searching coarse woody debris for salamanders (Woolbright 1991; Bailey *et al.* 2004). In both of these cases, small, randomly chosen quadrats might well contain no amphibians, and some would not even contain appropriate vegetation or woody debris for sampling.

With respect to the shape of the sampling units, linear transects sometimes offer advantages over rectangular plots. For one, transects are narrow and thus allow the researcher to do all sampling in a single pass. Because plots are fairly wide, it can be difficult for a single investigator to keep track of which areas have already been searched, particularly during nocturnal surveys. Second, transects cut across a good length of habitat, which may help to average out patchiness in the environment. For example, when we conducted transect searches to determine the effects of forest roads on salamanders, we found a highly significant relationship between distance from roads and salamander counts (Marsh and Beckman 2004). However, when we later surveyed 8 m × 8 m plots in similar habitats we found no significant relationship. In these plot surveys, the patterns in counts were almost identical, but the standard deviation in salamander counts was more than twice as high because of patchiness in salamander distributions.

A further use of transects is when one wants to test the effects of an environmental gradient such as elevation or distance from habitat disturbance. Transects can be oriented parallel to the gradient to allow for a continuous analysis of the effects of the gradient on amphibian abundance (e.g. Lehtinen *et al.* 2003). One can also set up transects perpendicular to the gradient of interest (e.g. Marsh and Pearman 1997); however, this approach has the disadvantage of restricting analysis to a few specific points along the gradient. Sampling perpendicular to the gradient may be reasonable when there are particular points of interest in the gradient (Jaeger and Inger 1994), but should probably be avoided when the gradient and its effects on amphibians are poorly understood.

Although transects may present some advantages over plots, there are also some situations where plots are likely to be superior. First, when the area to be sampled is small and round or rectangular, plots are far more practical than very short transects. Also, plots may be useful when many observers are available for sampling. Observers can cover a rectangular plot in parallel, making these more convenient to sample than several distinct transects. Finally, plots should generally be selected when one is sampling amphibians in conjunction with mark–recapture analysis. Even if amphibians move only a few meters between captures, they will tend to wander off of transects and small quadrats, leading to low detection rates and difficulty with estimating population parameters (Schaub *et al.* 2004).

14.5.1 Design issues: how many replicates?

After deciding between plots and transects the next question is usually "how many?" Strictly speaking, the number of replicates needed depends on the magnitude of differences in amphibian abundances one is hoping to detect and on how much background variation exists between survey dates, sites, and observers. For example, to compare amphibians between two habitats in which the standard deviation in counts is equal to 25% of the mean, one would need about nine replicates per habitat to detect a 50% difference in counts between habitats (at 90% power) and almost 50 replicates to detect a 20% difference.

In theory, larger plots or transects will tend to average out some habitat variation, so one would tend to need fewer plots than small quadrats. Typical levels of replication in the literature are five to 30 for large forest plots, 10–50 for transects, and 20–100 for small quadrats. To estimate how many replicates are needed, one can do a few practice plots to calculate variance. From these estimates, the R library *pwr* (R Development Core Team 2005) has a number of modules for doing power analysis and the downloadable program Monitor.exe (Gibbs *et al.* 1998) can perform power calculations for detecting changes over time.

In some cases, time may be limiting and the more realistic answer to the question of "how many plots?" is simply "as many as you can." Thus, an alternative approach is to do a few practice sites and estimate the time needed for one replicate. Then consider how much total time can be committed to the project. Dividing the latter by the former yields an estimate of how many replicates can be surveyed.

14.5.2 Reducing variation among replicates

More variation among replicates means surveying more sites, so anything that reduces variation will usually be helpful. Standardization of sampling methods is one critical aspect of reducing variation. For area-based surveys, standardization can include things like always searching plots for the same amount of time, always searching the same microhabitats within a plot, and always using the same surveyors for each plot.

These suggestions are valid for all animals, but for amphibians there are additional considerations. Because amphibian activity is highly dependent on weather conditions, amphibian counts can vary by orders of magnitude from day to day or even from hour to hour. There are two main approaches to dealing with this kind of variation. The first is to restrict surveys to periods of time when amphibians are most likely to be observed. This requires flexibility with scheduling surveys but can dramatically reduce the amount of survey effort needed. It also requires some initial surveys to get a sense of amphibian activity patterns. The second approach is to carry out surveys in a variety of conditions, but to collect data on weather-related variables that may be associated with activity levels (e.g. rainfall within the past week, rainfall at the time of the survey, temperature, humidity). These variables can then be included as covariates in any analysis of amphibian counts, thereby controlling some of the background variation.

In conjunction with either of these two approaches, surveys can be paired or grouped in a way that ensures that background variation will not confound a hypothesis being tested. For example, in a comparison of forest to pasture, each forest plot could be paired with a pasture plot so that one of each (or two or three of each) is surveyed on the same date. The pairing of these surveys ensures that any day-to-day variation affects both habitats equally. Additionally, by using survey date as a random effect in the statistical analysis, one can remove most of this variation from the variable of interest.

14.5.3 How many times to survey each replicate?

The number of times each replicate should be surveyed will depend on how destructive a method is to the microhabitats where amphibians are found. If a sampling method tends to degrade the habitats of interest, repeat surveys will result in lower counts and the appearance of population declines where none would otherwise exist. In these cases (e.g. leaf-litter plots) one can sample a different, randomly chosen set of quadrats in each survey period. This will tend to increase sampling error (since different plots will be surveyed each time) but will eliminate any bias associated with habitat degradation from surveys.

However, even when there is little disturbance associated with sampling, one is still faced with a trade-off between the number of times each site can be surveyed and the total number of sites that can be covered. If amphibian abundance is highly variable within an area, but there is not much variation from one survey to the next, more replicate plots that are surveyed less frequently is likely to be optimal (e.g. Smith and Petranka 2000). The exception to this is when using repeat surveys with mark–recapture to estimate detection rates (see Chapter 24).

14.6 An example of study design

Suppose one wanted to compare counts of a single amphibian species in forest habitat to counts in pasture. Assuming that only one forest area is available for sampling and that it is entirely surrounded by pasture, one would have at least four choices for area-based surveys: large plots, small quadrats, transects, or some nested design. If a total of 1000 m^2 could be surveyed in each of the two habitats, one could sample five 20 m × 10 m plots, 10 50 m × 2 m transects, or 40 5 m × 5 m quadrats (Figure 14.1a–c). Alternatively, one could use a nested design

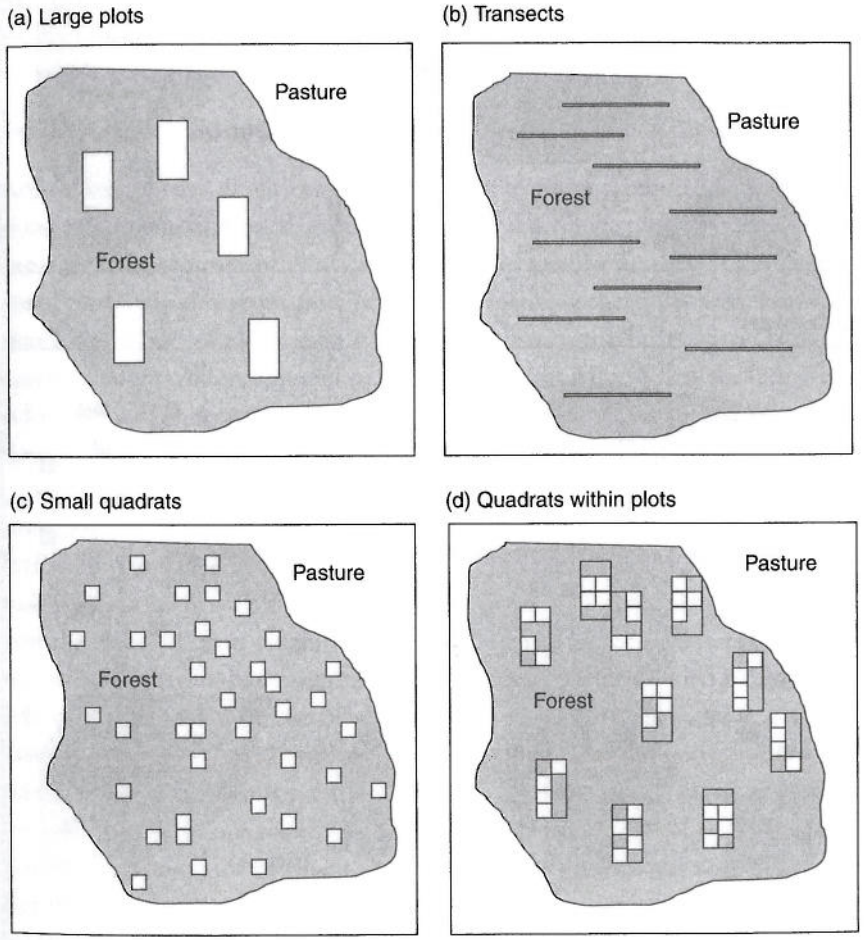

Fig. 14.1 Four possible designs for area-based sampling to compare a single forest area to surrounding pasture. Equal numbers of samples would be randomly located within pasture but these are not shown. (a) Five plots of 200 m^2. (b) Ten transects of 50 m × 2 m. (c) Forty 5 m × 5 m quadrats. (d) Four 5 m × 5 m quadrats nested within each of ten 200 m^2 plots.

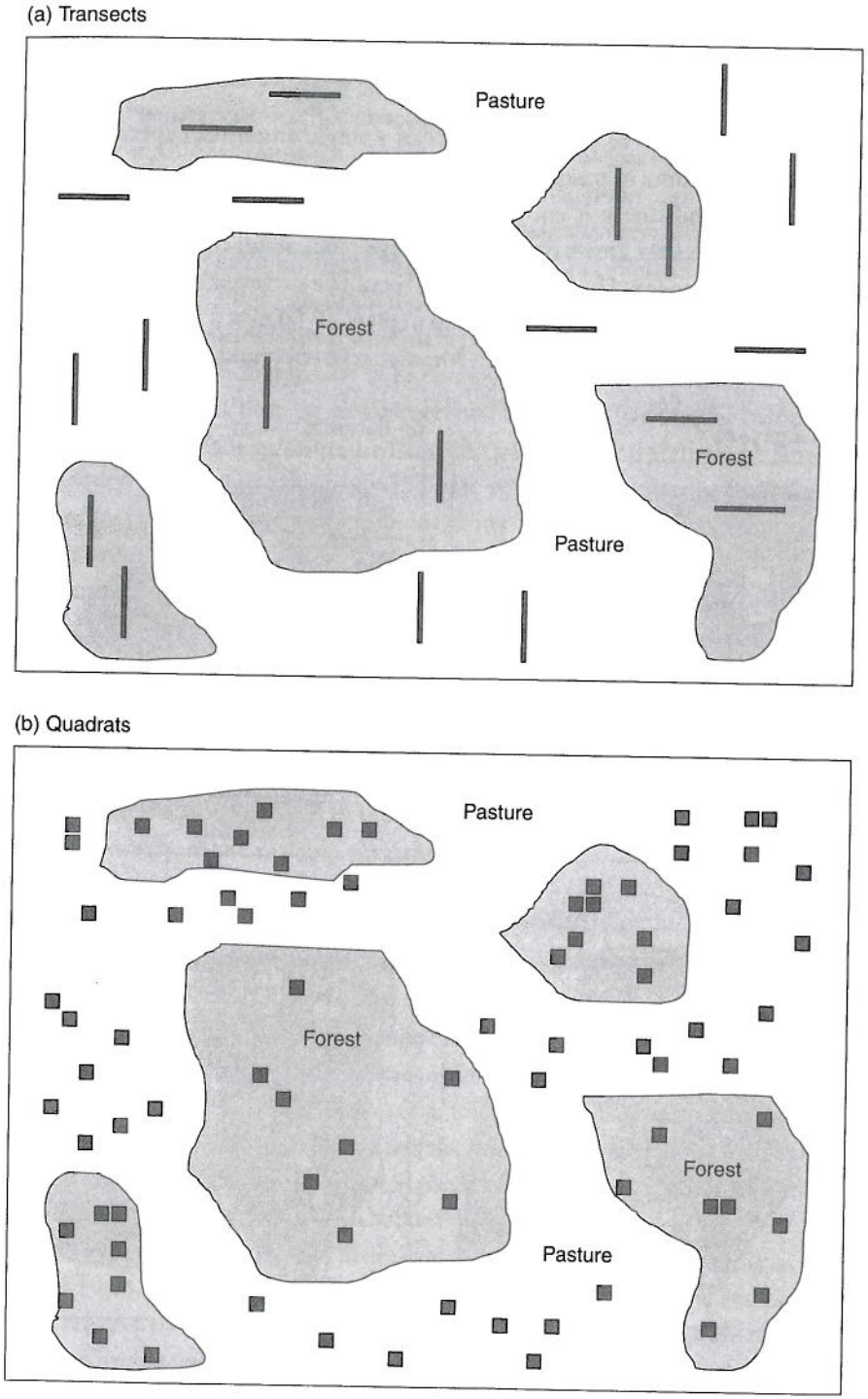

Fig. 14.2 Two possible designs for area-based sampling to compare five forest patches to surrounding pasture. (a) Two transects of 50 m × 2 m within each forest patch. (b) Eight 5 m × 5 m quadrats within each forest patch.

with 10 20 m × 10 m plots and four 5 m × 5 m quadrats chosen for sampling from within these (Figure 14.1d).

Any of these designs would permit a comparison of amphibian counts between the single forest patch and the surrounding pasture. However, because only one forest patch is sampled, inferences can only be made about that particular site. Thus, an even better design would use replicated forest patches rather than the single forest area, which would allow general inferences about amphibian counts in forest within this region. Assuming that five forest patches could be located, an area-based survey could employ a single 20 m × 10 m plot in each forest patch, two 50 m × 2 m transects, or eight 5 m × 5 m quadrats (Figure 14.2) Each of these could be paired with a parallel set-up in the surrounding pasture.

14.7 Assumptions of area-based surveys

Area-based surveys, as with any other research technique, require some assumptions to draw inferences from the data collected. First, plots or transects are assumed to be representative of the larger area of interest. In theory, a large sample of randomly chosen plots will closely approximate the larger area. However, smaller numbers of plots, even if randomly chosen, might be spatially aggregated or might under-represent particular microhabitats. When the larger area is known to vary, stratifying the area into different habitat types, and then randomly choosing plots within strata may be a better approach (Cochran 1977).

Second, area-based surveys generally yield count data with unknown detection rates. This is particularly true with more destructive techniques (e.g. leaf-litter plots, stream-bed quadrats) since one cannot use repeat surveys and mark–recapture to directly estimate detectability. Issues related to detectability and the interpretation of count data are covered in Chapters 24 and 25. Here, we simply point out that most uses of area-based surveys are aimed at comparing relative abundance or species richness among sites or time periods. Thus, the key assumption is not that all individuals are detected, but that detection rates are relatively constant among habitats or surveys. For instance, if vegetation differs between primary and secondary forest, counts from nocturnal transects in the two habitats may not be directly comparable since detection rates will likely depend on vegetation density. Furthermore, detectability is pretty much always an issue if one wants to compare abundances of different species. Distinct species tend to use different microhabitats, so area-based surveys will almost always detect some species at higher rates than others. Thus, characterizing amphibian communities usually requires multiple search techniques and some formal estimate of detectability.

Finally, with area-based surveys one generally assumes that amphibians do not move around much during the course of a survey. If amphibians are disturbed by the survey techniques and consistently escape the sampling area, these surveys will not be particularly effective.

14.8 Summary and recommendations

There is no single best approach for conducting area-based surveys. Which approach is optimal will depend on the site, the species, and the hypothesis being tested. That said, there are some general recommendations to keep in mind when conducting area-based surveys.

1) Before beginning a study, always practice the survey techniques. Testing out techniques is essential and usually leads to adjustments and improvements. Ultimately, trial surveys save time, because data will be of higher quality and there will be no need to repeat any surveys. Even two or three trial plots or transects can go a long way towards identifying potential problems and suggesting the necessary changes.
2) When in doubt, include more replicates. Almost nothing is as frustrating as coming up a few plots or transects short of an answer. When faced with a trade-off between the size of sampling units and the number of replicates, we believe that a greater number of smaller replicates will usually be optimal (the exception is when plots are so small that zero counts frequently result). Again, practicing plots of various sizes can help steer one to an appropriate-sized sampling unit.
3) Carefully consider the research question and how the survey design will answer that question. Going to the extreme of writing out a sample data set and attempting to analyze it can help identify errors or unstated assumptions in a sampling approach.
4) Know your amphibians. While this chapter has focused on the general concepts of area-based surveys, the details of a species' natural history will ultimately determine whether a particular sampling approach is successful. Understanding the basics of activity patterns and movement behavior are critical for effective sampling.

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