VI.10 Assessing Rangeland Grasshopper Populations

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Introduction

Land managers need accurate and comprehensive methods for assessment of rangeland grasshopper populations to make appropriate management decisions and to support research. Some of the needed information at known locations includes grasshopper density, developmental stage, and species composition.

One option is to count and identify every grasshopper in an area. This procedure is called a census. Obviously, a complete census of grasshoppers in a State, a county or even a small ranch is impossible. Therefore, managers must have methods to sample a limited number of the grasshoppers in order to estimate the status of entire grasshopper populations over large and often remote geographic areas where rangeland grasshoppers occur. The result of sampling large areas to estimate grasshopper populations is called a survey. In this chapter, we will explore techniques and issues related to sampling and surveying rangeland grasshoppers.

Overview of Types and Purposes of Surveys

Nymphal Survey.—This is an early season survey to identify areas with high densities of grasshoppers. The nymphal survey notes grasshopper density, species, and developmental stages at recorded sites on all rangeland areas where grasshoppers may be a problem in a State. Developmental stage data are useful for timing the adult survey later in the year (discussed later in this chapter). In years when resources and time are limited for the nymphal survey, areas associated with a greater risk of grasshopper outbreak (such as a potential treatment block) should receive a greater priority for survey. Priority can be determined using previous year adult survey maps, other historical data, and cooperator reports, including requests from and discussions with local people. Other considerations include current conditions, weather (drought or above normal precipitation), cattle prices, range conditions, economics (benefit–cost), species composition, and politics.

Nonoutbreak Years/Areas.—In general, survey sites should be 5 miles (7.65 km) apart on accessible routes. Another alternative is to use sentinel sites (fixed locations) that have been proven as predictive indicator locations. All areas will have uniform priority.

Outbreak Years/Areas.—Deploy survey sites first to high-priority areas as discussed above. Within a potential treatment block (highest priority), survey sites may be a quarter to a half mile (0.4–0.8 km) apart (an area probably less than the entire infestation). These data can be used to establish density estimates for management decisions for the block, including use in the Hopper Decision Support System (Hopper). Grasshopper populations that lie outside but near the potential treatment block are of secondary priority. These areas may not be sampled, but you can collect data in them later during the adult survey.

Proposed Treatment Areas.—A proposed treatment area is one where grasshopper densities exceed the economic threshold (ET, determined by Hopper) for a given treatment, or where land owners or managers have indicated a desire for their lands to be treated (escrow accounts established, letters of request on file, and cooperative agreements in place). For management purposes, a single average grasshopper density is needed for the proposed treatment block. You can combine estimated grasshopper densities over all sample stops within the proposed treatment block to obtain this single average grasshopper density. This average density is useful for the decision-support process, which may include economic analysis with Hopper.

Delimiting Survey.—The purpose of a delimiting survey is to determine the perimeter of the area infested with economically important densities of grasshoppers. (The economic density can be estimated using Hopper.) Often, delimiting surveys are a continuation of the nymphal survey, and they also may be used in the adult survey to collect additional data for forecasting. These data also should be sufficient to support a single density estimate for a proposed treatment area for use in Hopper (to determine the ET). Surveyors can record key grasshopper species composition and developmental stages during the delimiting survey. Survey sites may be one-quarter to one-half mile apart. Concentrate sampling effort in the transition between high-density areas and lower density areas to delineate the perimeter of a treatment block.

Adult Survey.—This is a midseason forecasting survey timed to evaluate *economic species* (5 to 10 in each State) in prime reproductive stage (fifth instar through early adult stage) to predict hazard for the following season. Record grasshopper density, species composition, and developmental stages at survey sites. Determine priorities for survey areas to sample by using nymphal survey maps and other historical data and cooperator concerns (requests from and discussions with local people). In general, survey sites should be 5 miles apart on accessible routes. Sample areas containing grasshopper densities of the greatest concern should be sampled with more survey sites (delimit high-density areas) to provide more information for hazard prediction.

Common Data Set Survey.—These data are used to provide regional- and national-level hazard maps. A data base can be developed (and saved) for improving existing models for predicting hazard. For example, while trained surveyors frequently refer to differences in vegetation and grasshopper dynamics throughout the 17 Western United States, so far surveyors have collected little data to confirm these impressions. In an effort to describe just how different outbreak dynamics can be throughout the West, it is necessary to collect data on both density and grasshopper species composition. These data will be used to develop a better understanding of grasshopper dynamics in different ecoregions (biologically similar areas) throughout the West and provide a mix of strategic planning maps that will be valuable at regional and national scales.

These data are collected as part of the normal adult survey. In general, sample sites are at least 5 miles apart on accessible routes with uniform priority. For States that survey more than 1,000 sites, 10 percent of the sites are used for the common data set. All other States should provide data for about 100 sites.

General Guidelines for Surveying Large Areas

Each year, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA, APHIS) conducts the preceding surveys of grasshopper populations throughout the rangelands of the Western United States. The surveys are managed within each State to meet local, State, and Federal needs for the information. Planning begins each fall for the surveys to be conducted the next summer. The survey manager determines the areas that need to be surveyed, when to begin and end each survey, survey site intervals, method of determining population, and logistics of completing the survey.

Area To Be Surveyed.—The criteria for deciding what areas to survey vary from State to State. Historical and recent information on the outbreaks of grasshopper and control activities provide the best guide to the areas that need to be surveyed. Priority is given to areas that have frequent outbreaks that tend to persist over several years. These are the areas where control is most likely to be requested.

Nymphal survey concentrates on areas that had high grasshopper densities the preceding fall and on areas that cooperators indicate may need treatment during the current season. Information from the nymphal survey is useful for making management decisions during the current season. Adult grasshopper surveys cover the general area where grasshoppers occur because information from these surveys is targeted for predicting future trends and recording historical information.

Survey managers consider many other factors when determining what areas within a State to survey. The amount of rangeland versus cropland is important in some States. Likewise, the amount of rangeland versus forested or mountainous areas is important. In recent years, Conservation Reserve Program (CRP) land is included as part of the surveyed area in some States.

The survey in Nevada targets areas where large parcels of the rangeland have burned, removing much of the sagebrush. Much of the rangeland in southwestern Wyoming is not surveyed because historical records show that, even if an outbreak occurs, it is usually short lived and grasshopper populations collapse on their own. Other States may concentrate surveys on rangeland that is sufficiently productive so that the costs of treatment can be recovered and leave out areas of low forage productivity.

Survey Timing.—The objectives of each survey are considered while planning the surveys. Weather strongly influences when each species of grasshopper will hatch. Nymphal surveys are timed to occur after the majority of the potential pest species hatch but must be completed in a timely manner, allowing management decisions to be made for effective management and forage protection. Adult surveys are timed to include the period when most individuals of the potential pest species are nearing reproductive maturity but before the seasonal population decline. This timing gives results that yield the best indication of the reproductive potential of the grasshopper populations.

Survey Site Interval.—The standard interval between survey sites used in APHIS grasshopper surveys is 5 miles, but each State office adjusts this distance to meet its own needs. When habitat or populations are homogeneous (similar) over large expanses the distance between sites can be lengthened beyond 5 miles without detriment to survey quality. If the rangeland is interrupted by crops, forest, river, or other features or the habitat or grasshopper population are localized, then shorter survey site intervals may become necessary. Often the availability of roads dictates the interval between sites.

Method of Estimating Grasshopper Density.—The 18-ft^2 sample method used by many APHIS offices in the Western United States is a simple and quick way of determining the density of grasshoppers on rangelands. (A few States use a less reliable method correlating the number of grasshoppers caught in a sweep net to a population density.) At each survey site, choose a sample area typical of the rangeland to be surveyed. Next, look ahead and determine the approximate route you will walk (fig. VI.10–1). Pick a spot on the ground about 10 paces in front of you. Choose the spot before you determine if any grasshoppers are actually present there.

Visualize a sample area surrounding the spot that is equal to 1 ft^2 on the ground. You can use landmarks such as a stick, pebble, tuft of grass, or flower to help keep your eye focused on the sample area chosen. Once the area is set in your mind, walk slowly toward the area and determine the number of grasshoppers that are in the area by counting the grasshoppers as they flush out of the visualized sample area.

Do not count individuals that hop into the sample area while counting. When you reach the spot, probe the area with the handle of your insect net or other suitable object to make sure all individuals have flushed and been

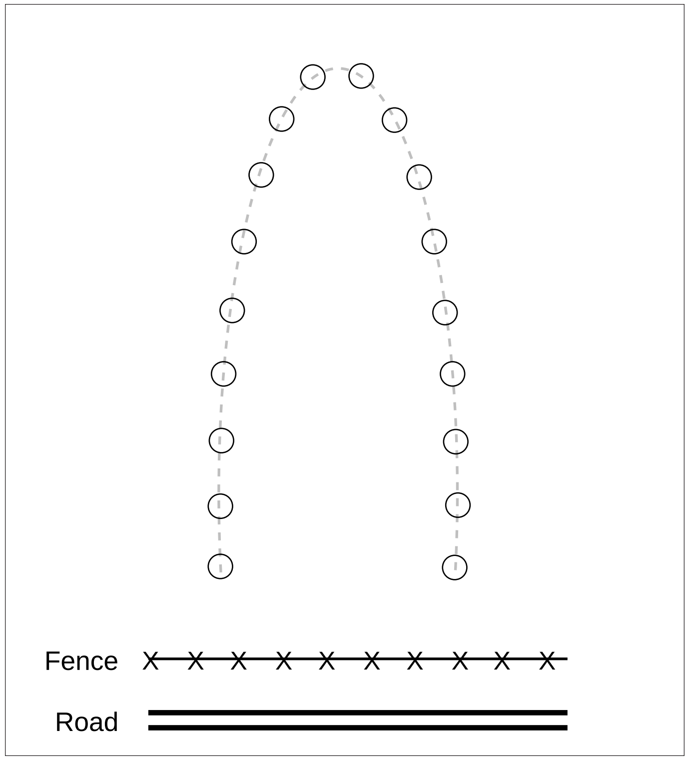

Figure VI.10–1—Configuration of the 18 1-ft^2 sample areas counted during a grasshopper surver on rangeland.

Figure VI.10–2—Using a prod can help flush grasshoppers out of the 0.1-m^2 counting rings. (APHIS photo.)

counted (fig. VI.10–2). Record the number counted and repeat the count at a total of 18 sample areas. The total number of grasshoppers counted in the 18 1-ft^2 sample areas, divided by 2, gives you the number of grasshoppers per square yard.

Logistics of Completing a Survey

After determining the area to be surveyed, survey timing, survey site interval, and the method to determine grasshopper density, you can decide the logistics for completing the survey. A combination of the size of the area to be surveyed and the site interval determines the total number of sites to be visited. For example, if the area to be surveyed is 30 million acres and the site interval is 5 miles, you will need approximately 1,875 survey sites. Plan 10 percent more survey sites for a delimiting survey where needed. For this example, the total number of survey sites is now 2,062.

Next, calculate the time it takes to sample each survey site. Include the time to actually complete the count at a survey site, plus time to record the data, travel between sites, travel to the area, contact cooperators and landowners, time lost to bad weather, and vehicle servicing and repair. This time ranges from 45 minutes to an hour and 15 minutes per site in the States surveyed by APHIS. For example, if you allot 1.1 hours for each site, to complete a survey of 2,062 sites takes 2,268 hours. If the time window to complete the survey is 6 weeks (240 work hours), 10 surveyors are needed to complete the survey. Other examples are outlined in table VI.10–1.

Issues Related to Sampling Error

Sample Accuracy, Precision, and Bias.—There are two broad criteria for evaluating sampling procedures: accuracy and precision. Both are important, and both must be present in some degree of balance.

To illustrate accuracy, imagine a person shooting a rifle at a target. If all hits are in the bull's-eye, these hits are accurate. If, however, the sights are not properly aligned, the hits will be outside of the bull's-eye. In statistical language, these hits are inaccurate, and the degree to which they miss the bull's-eye is called bias. Specifically, bias is the distance from where hits should fall to where they do fall. In terms of grasshopper sampling, accurate counts are those that include all grasshoppers that are within the correctly envisioned area. If the sampler consistently counts fewer or more grasshoppers than what are there, and/or if the sampler is envisioning an area that is smaller or larger than it should be, then the counts will be biased.

Notice that accuracy requires hits to fall in the bull's-eye, but is not concerned with size of the bull's-eye. In order to hit a very small bull's-eye consistently, surveyors need very high precision. In terms of grasshopper sampling, low precision might allow one to accurately estimate an infestation at 10–50 grasshoppers/yd^2, but high precision could accurately fine-tune the estimate to 28–32/yd^2.

Table VI.10–1—Example of logistics for completing a grasshopper survey over a large area

Survey type	Thousand acres surveyed	Stop interval (miles)	Acres represented per stop	+ 10% No. of stops	Hours to for delimiting	Hours for each stop	complete survey	Survey window	Surveyors needed
Adult	30,000	5	16,000	1,875	2,062	1.1	2,268	6 wk	10
Adult	10,000	3	5,760	1,736	1,909	1.0	1,909	5 wk	10
Nymphal	5,000	5	16,000	313	344	1.1	278	3 wk	3
Nymphal	25,000	10	64,000	390	430	1.2	516	2 wk	7
Delimiting	25	0.5	160	156	N/A	0.5	78	3 d	4
Delimiting	100	2	2,560	39	N/A	0.75	30	2 d	2

Land managers realistically can desire both accuracy and a certain minimum level of precision. Accuracy of grasshopper sampling can be affected by a number of factors will be discussed here. As far as we know, however, there is only one way to increase precision (estimate density within a narrower range), and that will be the subject of the next two paragraphs.

Rangeland grasshoppers generally appear to be distributed at random, with predictable probabilities of occurrence within samples taken at reasonably homogeneous sites. In mathematical terms, grasshoppers follow a “Poisson” distribution (a probability function which offers a description of a number of possible outcomes), which is not typical of most insects. Therefore, grasshopper sampling requires some atypical rules.

For all practical purposes, surveyors can increase sampling precision only by accurately counting more grasshoppers. This can be accomplished only by taking more samples in an accurate manner because an individual sample area cannot be increased without an accompanying loss in accuracy. In 1981 Onsager published a simple relationship between the counts and precision. In general, rapid gains in precision are made by continuing to examine samples until at least 40–60 total grasshoppers have been counted. On the other hand, there is little to be gained in precision by sampling after 150–200 grasshoppers have been counted.

Estimated (Visualized) Versus Delineated Samples.— For all but the most experienced persons, samples that are mechanically delineated (by wire frames or hoops) should yield greater accuracy and consistency between different individuals than visualized or estimated samples (fig. VI.10–3). Delineated samples are inconvenient in that templates should be placed about a day before they are examined (necessitating two trips to each survey site) and they require investment in bulky, single-purpose equipment. However, during the training process or when high accuracy is very important, the extra effort associated with delineated samples is worthwhile.

Sample Area Size.—Experiments have shown that examination of sample areas as large as 1.08 ft^2 (0.1 m^2) tends to detect only about 90 percent of the true density estimated by less subjective but more labor-intensive methods of sampling. Successively larger sample areas

Figure VI.10–3—One of the most valuable tools in field surveys is the 0.1-m^2 counting ring. Counting the number of grasshoppers in a series of rings provides an accurate count of grasshoppers per square meter or square yard. (USDA photo.)

detect successively lower percentages of the true density, so the 1-ft^2 sample area is about as large as even a well-experienced sampler should attempt to examine. Experiments found that persons with moderate experience were able to count grasshoppers accurately in 0.06-ft^2 (0.05-m^2) rings, even when densities exceeded 125/yd^2. That area is approximately the size of a 9-inch pizza pan (about 1/20 of a square yard) or an 8 1/2- × 8 1/2-inch square (about 1/18 of a square yard).

Bias in Selecting a Site.—Sample sites must be representative of the general area. Atypical vegetation or topography could influence grasshopper density and species composition. For example, surveyors should avoid sites near roads, cattle trails, ditchbanks, fencelines, or any features not representative of the general habitat in the area.

Bias in Selecting a Visualized Sample Area.—Even a slight bias may seriously affect the outcome of the survey. If a sampler counted only 1 more grasshopper per sample than was actually present, the density estimate would be increased by 9 grasshoppers/yd^2 (assuming that

9 samples/yd^2 are taken at each survey site). Subconsciously, a sampler may choose movement by a grasshopper to be the center or edge of the area that will be visually delimited and counted. To demonstrate the potential for bias, one need only consistently use the last grasshopper movement as the edge of the visualized area and not include that grasshopper in the count. Such counts are obviously low estimations of actual densities. To prevent inaccuracy, exercise great care to select a point, patch of vegetation, pebble, or small topographic feature from which to base the boundaries of the visualized sample area. These boundaries must be established before the counting begins.

Sample Area Shape.—Most experienced samplers agree that the best sample area shape is the one they were taught to use. Some prefer squares while others prefer circles, and both can defend their viewpoint. Advantages of squares are that standard areas are easily visualized, and a variety of standard templates are easily found or constructed. For example, the suggested 8 1/2- × 8 1/2-inch square template can be made from a standard sheet of writing paper. However, a visualized square entails keeping mental track of four 90-degree corners that are equidistant from each other and connected by straight lines.

The advantage of circles is that a sampler can concentrate on one central point plus a constant omnidirectional radius without shifting focus. However, a circular standard area is not easy to visualize without studying a standard template, and round templates usually are not available in a variety of convenient dimensions. For example, a 0.5-ft^2 circular template would require a diameter of 9.57 inches.

Effects of Weather.—Variations in daily weather conditions probably contribute more to sampling error than any other single factor like size or shape of typical samples, visualized versus delineated sample areas, or total area sampled. Cool temperatures reduce grasshopper mobility, and lack of mobility can make smaller grasshoppers inconspicuous and larger ones relatively easier to spot before they flush. Cool weather most often occurs during the nymphal stages, when their small size makes grasshoppers most difficult to see. Under such conditions, additional prodding with a stick or pole is required to provoke movement and ensure that all grasshoppers in the sample area are counted.

Under extreme conditions, the sampler will have to stoop and brush the ground with a hand to ensure a more accurate count. Warm temperatures are generally the best condition for conducting surveys because of the increased activity of grasshoppers and ease with which they are seen. However, because of this increase in activity, the sampler must begin concentrating on the sample area from a greater distance. Higher temperatures are usually associated with sunny conditions, which can cause the sampler's own shadow to become a factor. The sampler must approach the sample so the shadow will not flush grasshoppers prematurely.

Cloudy conditions reduce general visibility and can make some inconspicuous grasshopper species even more difficult to detect. Rain or mist may reduce the activity of grasshoppers even more than cool temperatures. In addition, rain or mist causes grasshoppers to hide and may prevent movement even when prodded. When counts are conducted in the rain, even with extra care, they are generally lower than the actual density of grasshoppers. Therefore, grasshopper surveys should not be conducted under these conditions.

Wind can be particularly troublesome when it is strong enough to provide a lot of background movement within the plant canopy, to alter the normal trajectory of grasshoppers that hop in the vicinity of the sample, or to whisk away grasshoppers that take flight. Under these conditions, probing with a stick to flush grasshoppers may also dislodge seeds or other dry pieces of vegetation, which blow in the same direction as most disturbed grasshoppers. When this happens, some seeds (those that appear to be grasshoppers) will need to be followed and probed again to determine if they were grasshoppers.

In itself, wind can become a major distraction to the concentration of the sampler. Wind moves clothing, equipment, and other items near the site and/or the sampler. If collections of grasshoppers are required in addition to the count, the consistent operation of a sweep net sometimes may become almost impossible. Wind generally is accompanied by other adverse conditions and tends to further aggravate less-than-ideal conditions already present. Walking at an angle to the wind is helpful, but going slower, concentrating harder, and spending more time at each sample are requirements for achieving accurate counts under windy conditions.

When weather conditions become increasingly unfavorable, it is critical that a sampler apply an increasing level of concentration if survey data are to have meaning. Nevertheless, in spite of the highest degree of concentration, if foul-weather sampling should yield high densities near some pivotal action threshold, it would be wise to verify some of the results later during favorable weather.

Effects of Habitat.—The nature of the vegetative canopy can affect sampling results. A short, sparse, and uniform canopy is easiest to sample accurately. A classic example would be crested wheatgrass that has been mowed or subjected to moderate grazing pressure. As vegetation becomes taller, the vertical dimension increases the volume you must examine simultaneously for grasshoppers. When vegetation becomes more dense, as when the sampler goes from bunchgrass to sod, it becomes easier to overlook smaller nymphs or species.

Where vegetation is strongly clumped, it becomes more difficult to apply representative sampling intensity to occupied and unoccupied portions. Habitats dominated by tall, thick, well-spaced clumps of shrubs are the most difficult to sample. Sample areas with dense vegetation require thorough probing with a stick, even under the best weather conditions.

Other Insects.—You may confuse other insects with grasshoppers as the other insects move from a sample area when the sampler approaches, probes, or brushes the area by hand. Most often, these insects are leafhoppers. During nymphal surveys, leafhoppers can be about the same size as very young grasshoppers. At low densities, you can follow these small insects and flush them again to determine if they are grasshoppers. Grasshoppers and other insects that move ahead of the sampler may land and flush new grasshoppers from a sample area before they can be counted. Be aware of this possibility, especially during the adult survey.

Disturbance of Sample Area.—Sample areas undisturbed for 24 hours before survey can produce accurate counts. Disturbance of sample areas just prior to or during counting can reduce the density estimate significantly. Cattle grazing or moving through the site are the most frequent source of direct disturbance. Vehicles driven by the sampler or others through or near the site also can affect the count. Nearby farming activity, such as harvesting or irrigation, may cause local movement of grasshoppers, and that can affect the counts. If densities at sites near these activities yield results that are of concern, additional counts at a later date may be required.

Dense Grasshopper Populations.—When finding grasshoppers at densities of 1 per square foot or fewer, counting is relatively easy. In denser populations where you flush several grasshoppers from each sample area, take greater care. When this happens, the sampler should take a mental picture of the action in the sample area to estimate the number of grasshoppers.

Concentration of the Sampler.—Concentration plays the central role in dealing with all factors that affect survey and can become critical at the end of a long day for a tired sampler. Many of the factors that complicate surveying are uncontrollable, but you can practice and improve concentration. A sampler may take several actions to maintain good concentration. A sampler continually using visualized sample areas can recalibrate by frequently referring to a physical template the size of the visualized area to be counted.

Removal of as many distractions as possible during the actual counting can help greatly. Wearing a billed hat or cap not only shades the eyes from the sun but can help focus the attention toward the ground and reduce distraction. The use of a long probing stick helps flush grasshoppers from the sample area. By simply slowing down while approaching and counting sample areas, you can reduce or eliminate many problems.

Training New Scouts

In the past, it was common practice for an experienced sampler to line up a class of novices, have everyone count grasshoppers in a certain number of visualized sample areas, compare results, and repeat the process until counts by the novices approximated those by the expert. There are three major disadvantages to this system. First, the expert may have unknown biases that are then passed on to the trainees. Second, a trainee cannot verify or recalibrate density estimates in the absence of an expert. Third, the system cannot be used for self-instruction.

A novice must learn to overcome two major tendencies that contribute to sampling error. The first is a tendency to overestimate size of the sample area. The second is a tendency to count all grasshoppers that are moving in the general vicinity of the sample area, even though there is uncertainty whether the movement originated inside or outside of the sample area. Both of these negative tendencies can be minimized by starting trainees out with delineated samples (all sample areas marked with wire rings or squares). When the trainees show proficiency with that setup, they can advance to using visualized sample areas and then carry one standard template along for periodic confirmation or recalibration of proper sample area size. To obtain accurate counts, sample areas should be small enough to be totally comprehended without shifting the focus of attention (preferably about 0.5 ft^2 each, but not over about 1 ft^2; see Issues Related to Sampling Error, Sample Area Size in this chapter).

The Importance of Species Composition and Developmental Stage

Information on species composition and average stage of development is necessary to take maximum advantage of biological relationships that are considered in Hopper (see VI.2). Useful information may include proportions and developmental stage of grasshopper infestations made up of known pest species, grass feeders, mixed feeders, forb feeders, or bait feeders. Environmental assessments of proposed management activities also may require such documentation.

Determine species composition by collecting with a sweep net (fig. VI.10–4) and identifying at least 50 grasshoppers from what is judged to be representative habitat. Other chapters in section VI of the User Handbook provide help in identifying grasshoppers. Because issues about habitat representation are beyond the scope of this chapter, our concern is largely reduced to the question, “How many grasshoppers do we need to identify?” We can develop some intuitive guidelines through examination of binomial confidence limits (mathematical description of confidence associated with an estimate) if we can agree on some useful examples of proportions that we will regularly encounter.

Figure VI.10–4—Catching grasshoppers in a sweep net is the first step in determining which of many species are active in a given area. (APHIS photo.)

In our experience, three to six pest species usually dominate extensive outbreaks of grasshoppers. As troublesome infestations build up over a time scale of several seasons, sweep-net samples tend to recover an increasing total number of species. Nevertheless, the proportion of individuals in the samples that are known pest species also tends to increase. Let’s consider two normal examples. First, assume that 90 percent of the grasshoppers are pest species. Second, assume that 50 percent of these grasshoppers are bait feeders (bait treatment probably will not be effective under these conditions).

Figure VI.10–5 shows 95 percent confidence limits for composition of 50 percent and 90 percent based on sample sizes ranging from 50 to 800 total grasshoppers. Notice that the highest proportion obviously is the easiest one to estimate precisely. For example, if 90 percent of a sample of 50 grasshoppers (45 of them) from 1 sample site are pest individuals, figure VI.10–5 suggests that the true proportion likely is somewhere between 78 percent and 97 percent, a range of 19 percentage points. If half of them (25) are bait feeders, the figure suggests that the true proportion is somewhere between 36 percent and 64 percent, a range of 28 percentage points.

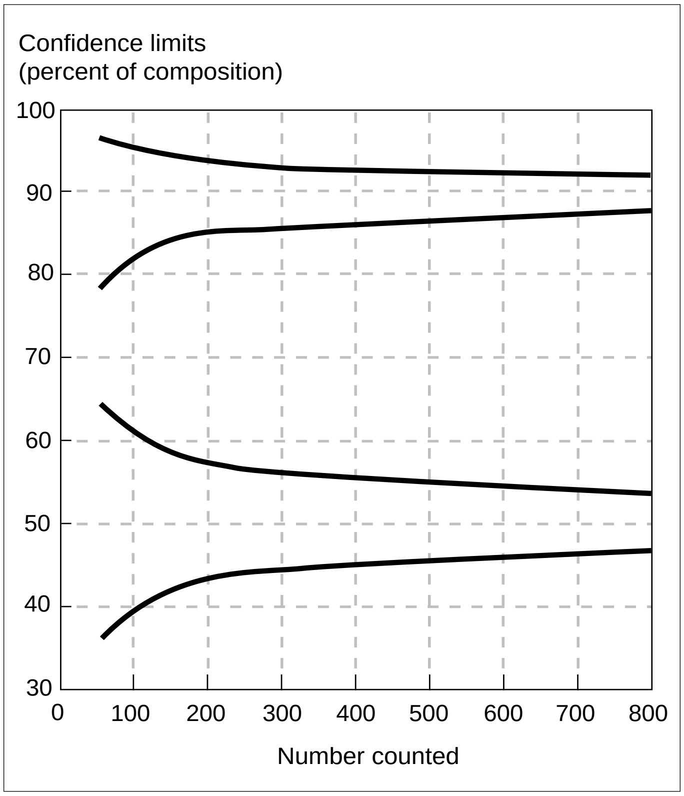

Figure VI.10–5—Confidence limits in relation to numbers of grasshoppers counted.

If those broad ranges do not inspire sufficient confidence to support a management decision, then we need to examine a larger sample or sample more sites. If our estimate of 90 percent pest species was from examination of 50 grasshoppers from each of 16 sites (720 out of 800), then the true composition is likely between 88 percent and 92 percent, a range of only 4 percentage points. Notice in figure VI.10–5 that our confidence intervals improve rapidly as sample size increases to about 200–300 grasshoppers. Notice also that minor improvements require major increases in effort when counts exceed about 400 grasshoppers.

Average stage of development usually is estimated as the summation of each observed instar number (adults are considered sixth instar for this purpose) divided by the number of individuals. Thus, for 20 fifth instars and 30 adults, the average stage is

$$\frac{(20 \times 5) + (30 \times 6)}{(20 + 30)} = \frac{100 + 180}{50} = 5.6.$$

During the nymphal survey, the stage of development is important for at least four major reasons. First, it is an indication of whether egg-hatch is completed. When very early instars predominate, it is possible that continued hatch will cause future increases in density. Second, knowing the stage of development helps to establish viable action windows. For example, if average life stage is 5.0, we know we have about 24 days until egg laying seriously begins to negate the opportunity for reducing next year’s population. Third, the developmental stage is used to estimate the amount of forage destruction that can be prevented by a treatment. For any given treatment, application early in the action window should be more economical than late in the action window. Fourth, ascertaining the developmental stage correctly makes it possible to time the adult survey accurately.

In certain cases, it may be advisable to exclude particular species from the calculation of average stage of development. For example, in predicting the expected short-term response to a bait treatment, the developmental stage of grasshopper species that do not eat bait is irrelevant. Similarly, in estimating the economic benefits of a spray treatment, the developmental stage of nontarget species is not a consideration.

Future Considerations: The Potential for Sequential Sampling

Sometimes the number of grasshoppers per square foot is so low or so high that taking the full complement of required samples is a ridiculous waste of time. Under these circumstances, ranchers, university Cooperative Extension personnel, weed and pest district supervisors, and even USDA, APHIS grasshopper scouts could spend more of their sampling time on other tasks. Further, some scouts might intuitively leave a survey site before examining all samples when grasshopper densities are very low or extremely high. This is could be a perfectly valid thing to do for very busy people; in fact, it represents a crude form of something we call sequential sampling.

What is sequential sampling and how can it be used to sample grasshoppers? Well, it is the process of classifying grasshopper infestations into “high,” “low,” or “too close to call” categories, in sequence, from one sample to the next. Sequential sampling can save a lot of time by allowing you to stop sampling at a site when it has been determined, by a sequential sampling plan, that grasshopper densities are very low or extremely high. The technology for developing and using sequential sampling has been around for a long time, but is just now being proposed for use in grasshopper sampling.

Lower and upper grasshopper densities levels must be specified to use a sequential sampling plan. For example, we could specify grasshopper densities below which infestations are of no economic concern and above which economic concern may be justified. The computer program Hopper will allow you to calculate economic thresholds so that you can generate these upper and lower density levels.

Using sequential sampling, three possibilities exist after each sample: (1) density could be declared less than a lower level, say, 8/yd^2; (2) density could be declared greater than an upper level, say, 16/yd^2; or (3) no such decision may be concluded. When the first or second decision is made, sampling can stop because the infestation has been classified. When the third situation occurs, examination of another sample is mandated.

If a classification is not made within some arbitrary number of samples (say, within 18 samples), then sampling can stop and the grasshopper infestation is declared as being between the two levels. If this third decision occurs at most survey sites, use sequential sampling at a later date to determine whether the population has changed. Note that the total number of sample areas at 1 survey site can range from 1 to 18 in our example.

The advantages sequential sampling are several:

- It will save time when actual densities are either well above or well below the upper and lower levels.
- It reduces the number of samples at most survey sites.
- It allows the sampler to predetermine the proportions of decisions that will be correct. For example, a person could specify that at least 9 of 10 sites be correctly classified.
- It can be used to delimit the borders of grasshopper infested areas.

But sequential sampling also has some disadvantages:

- Density estimates will be less precise if sequential sampling is used and a classification is reached with a low number of samples.
- Some erroneous classifications cannot be avoided.
- A table must be consulted to know when to stop sampling.

How To Conduct a Sequential Sampling Effort.— Sequential sampling can be conducted by either counting all grasshoppers or by simply noting their presence or absence (presence–absence sequential sampling) in successive samples. Here, we offer an example of the presence–absence method.

In Wyoming, there is a need to develop a grasshopper sampling plan for use by ranchers, Cooperative Extension system personnel, and weed and pest district employees. The objective is to help these individuals rapidly decide if grasshopper densities are less than 8/yd^2 (no cause for concern), greater than 16/yd^2 (potential cause for concern), or in between (worth watching). These levels of grasshopper densities may be referred to as the lower and upper thresholds, respectively. Also, we can set these thresholds to any values that are appropriate for a specific situation.

In this example, we will use a visualized sample area defined by folding a sheet of 8 1/2- × 11-inch paper into an 8 1/2- × 8 1/2-inch square (0.5 ft^2). Once you have calibrated your eyes to the 8 1/2- × 8 1/2-inch square, take a copy of table VI.10–2 and examine the first sample at a survey site. If it contains no grasshoppers, write a zero in the “Running total” slot opposite sample number 1 (as shown in table VI.10–3, example A).

If there are no grasshoppers present in the second sample area, then add zero to the previous running total and enter zero in the “Running total” slot for “Sample area” number 2, as shown in table VI.10–3, example A. However, if at least one grasshopper is present in the second sample area, then add 1 to the previous running total and enter 1 in the “Running total” slot for “Sample area” number 2, as shown in table VI.10–3, example B. This new running total is then compared to the lower and upper stop values. Each time a sample area contains at least one grasshopper, add 1 to the running total. A minimum of four

Table VI.10–2—Presence–absence sequential sampling stop values for levels of 8 and 16 grasshoppers/yd^2, assuming samples areas are 0.5 ft^2 each. Note that other sample area sizes cannot be used with this table.

Sample number	Lower stop value	Running total	Upper stop value
1	—	_____	3
2	—	_____	3
3	—	_____	4
4	0	_____	4
5	0	_____	5
6	1	_____	5
7	1	_____	6
8	1	_____	6
9	2	_____	7
10	2	_____	7
11	3	_____	8
12	3	_____	8
13	4	_____	8
14	4	_____	9
15	5	_____	9
16	5	_____	10
17	6	_____	10
18	6	_____	11

samples is needed in this case to yield a running total that is potentially less than or equal to the lower stop value or is greater than or equal to the upper stop value. If either case is true, you can stop sampling and declare the infestation as being 8 or fewer per square yard or 16 or more per square yard, respectively. Thus, the sampling process repeats itself until one of the following occurs:

- The running total is equal to or less than the lower stop value (table VI.10–3, example A),
- The running total is equal to or greater than the upper stop value (table VI.10–3, example B), or
- A density classification has not been made after the 18 samples have been examined (table VI.10–3, example C).

Corresponding decisions about grasshopper infestations for this example may be found at the bottom of table VI.10–3.

As mentioned, you also can do sequential sampling by counting each grasshopper in each sample area. If this is done, the sampler must keep a running total of the number of grasshoppers counted, and the stop values used are different from those shown in table VI.10–2. This kind of sequential sampling would be useful in delimiting surveys where grasshopper density estimates are needed.

If sequential sampling is to be used throughout a State or region, then flexible methods for choosing realistic lower and upper thresholds must be developed.

Future Considerations: Electronics

Electronic mapping, using geographic information systems (GIS) (see VI.9) may be very useful for grasshopper survey. For example, maps produced using GIS are useful for historical perspectives, analyses of ecological correlates (such as topography, vegetation, and soil), planning surveys, and allocating limited resources. GIS also will allow maps to be updated daily during a survey. We can use these maps to focus the survey effort on the most important areas as the season unfolds.

Computer-interpolated maps of grasshopper densities can be combined with land-use maps, ecological buffer zone maps, and land ownership maps to produce final treatment area maps. GIS software also can calculate the size of any defined area on an electronic map. These maps can be printed on paper to be used in the field or for display at meetings.

Economical battery-powered, hand-held computers hold much promise for grasshopper surveys. Scouts recently have used these types of computers in the field to enter and store data. These data can be transmitted through normal telephone lines to a computer centrally located in each State. Sequential sampling protocols, described earlier in this chapter, could be programmed into these computers. The user would simply enter the number of grasshoppers in each sample area, and the computer could store and analyze the data and notify the user when to stop sampling.

Other types of electronic data-collection equipment being used at some sites store environmental data important for

Table VI.10–3—Three examples of using a presence–absence sequential sampling plan

Example A				Example B				Example C			
Sample area	Lower stop value	Running total	Upper stop value	Sample area	Lower stop value	Running total	Upper stop value	Sample area	Lower stop value	Running total	Upper stop value
1	—	0	3	1	—	0	3	1	—	0	3
2	—	0	3	2	—	1	3	2	—	0	3
3	—	0	4	3	—	2	4	3	—	0	4
4	0	0	4	4	0	3	4	4	0	1	4
5	0	[quit]	5	5	0	4	5	5	0	2	5
6	1		5	6	1	5	5	6	1	2	5
7	1		6	7	1	[quit]	6	7	1	2	6
8	1		6	8	1		6	8	1	3	6
9	2		7	9	2		7	9	2	4	7
10	2		7	10	2		7	10	2	4	7
11	3		8	11	3		8	11	3	4	8
12	3		8	12	3		8	12	3	5	8
13	4		8	13	4		8	13	4	5	8
14	4		9	14	4		9	14	4	6	9
15	5		9	15	5		9	15	5	6	9
16	5		10	16	5		10	16	5	7	10
17	6		10	17	6		10	17	6	7	10
18	6		11	18	6		11	18	6	8	11
Decision: Infestation is less than 8 grasshoppers/yd^2.				Decision: Infestation is greater than 16 grasshoppers/yd^2.				Decision: Infestation is between 8 and 16 grasshoppers/yd^2.			

grasshopper research and management. These devices automatically log information, such as temperature and precipitation, for weeks at a time without human intervention. Technology that allows a computer to read hand-written data directly from data sheets is also becoming available. A scout could use a standard pen and clipboard to record the data on a printed data sheet in the field. The data sheet could then be faxed directly to a waiting computer or delivered to a site with a page scanner and scanned into a computer. In both cases, software could read the image made from the data sheet, interpret the information, and automatically store it in a data base that corresponds to the specific data sheet. Paper data sheets would be inexpensive, familiar, and highly reliable for field data entry. Data still could be rapidly acquired and distributed for use in management decisions.

Another technology that is already showing usefulness for rangeland grasshopper management is Global Positioning System (GPS). With GPS, hand-held units receive information from navigational satellites and calculate the location coordinates of the unit. Surveyors can obtain latitude and longitude coordinates even for the most remote sites where there are no distinguishing landmarks. A computer can use these coordinates to map any data collected at the site. Also, the hand-held units help a person navigate back to a site.

High-quality survey data always will be the basis for sound management decisions. Most of these data will be collected by humans working under various conditions in the field. This chapter provides reference for current survey activities and a starting place for future innovations in survey technology.