Section 5: Sampling and monitoring arthropods

- To be able to estimate insect abundance is important in decision making relative to pest management.
- Approach to sampling varies with goals:
  - Approximate, quick and simple, versus accurate, time-consuming, complex.
  - Cost (available time) may determine approach selected.

Methods of sampling

- Absolute methods - estimate density from precise area; used to compare densities based on area.
- Relative methods - estimate density without strict regard to area sampled; used to compare among efforts based on effort.
- Population index - measures product or effect of a population.

Examples of absolute methods

- Visual examination
- Quadrate sampling
- Suction sampling
- Enclosure devices
- Extraction
- Emergence
- Aerial nets

Visual examination is often an effective, if time consuming, way to sample arthropods. For insects that are likely to take flight, an aspirator (shown here) is a handy way to capture and hold them for examination.

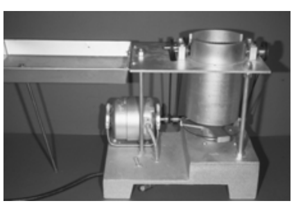
Visual inspection is commonly used for detecting household and structural pests, and important where the insects that might be encountered are unknown, cryptic, or variable.

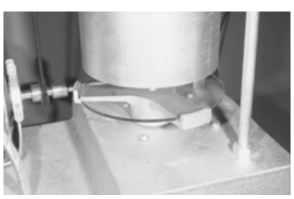
Cryptic pests, such as termites, are difficult to detect visually. Dogs and electronic detector are sometimes used to find invisible tunneling like that which occurred in this wall baseboard, followed by visual confirmation.

Quadrate sampling delineates an exact area of sampling, though the area need not really be 4-sided.

An aphid sampler (left) samples a known volume of air by suction, while the enclosure (right) samples a known area of ground.

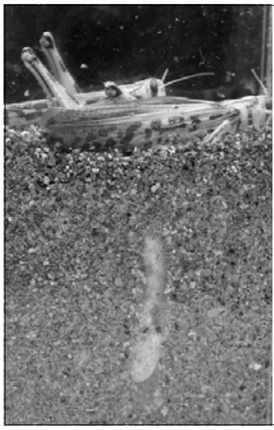
A mite brushing machine brushes items from the surface of leaves, propelling them downward onto a thin film of oil that coats a glass plate (shown below). Thus, it is possible to determine the number of mites per leaf.





Live traps (above) are used to capture small animals such as rodents, which then can be examined for both tick or flea vectors. By sampling blood (below) the disease incidence in the animal population can be determined. It is the combination of animal population, disease incidence and insect vector population that determines the threat to humans.

Emergence traps often are used to capture insects that live below-ground or under water. Usually such traps take advantage of the insects tendency to move to light, and have a capturing or killing mechanism at the top of the trap.



Some insects occupy cryptic habitats, which makes sampling difficult. In the case of grasshopper egg pods, for example, which are deposited beneath the surface of the soil (left, see grasshopper depositing eggs) you can dig up defined volumes of soil, sift through the soil for egg pods, and obtain an estimate of potential population size. This is a great deal of work, however, and usually it is easier to watch for their hatch to begin population assessment.

How would you know when to begin counting newly hatched grasshoppers? Do all species hatch simultaneously?

Examples of relative methods

- Sweep net
- Vacuum trap
- Timed counts
- Traps
  - Visual
  - Chemical
  - Interception

A pheromone-baited trap like this captures moths when they fly and crawl upwards and are captured in the container on top.

Sweeping with a net is a very common and inexpensive method of sampling. Flight traps (right) cost substantially more, and are limited to flying insects.

Various vacuum samplers are used, and are often called "D-vacs" after the original model. They are efficient, but costly and noisy to operate.

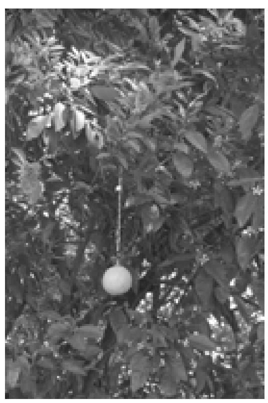
Here a vacuum sampler is used to vacuum the contents of a box placed over shrubs. This effectively converts its operation from a relative to an absolute sampling procedure.

Dippers are commonly used to sample for mosquito larvae in water, whether it is a very artificial breeding area such as an automobile scrapyard (above), or a more natural water source (below).

Traps are widely used for insect sampling and monitoring. Light traps (shown here) were more popular before the advent of pheromones. They have the advantage, and disadvantage, of being fairly non-selective. They can be operated off battery or household current. Here the battery is being re-charged by a solar panel.

Sticky adhesive, combined with color-based (below) or odor based attraction (right), can be used for sampling

A fruit model makes a good visual trap, such as this grapefruit model. When covered with adhesive, it allows estimation of adult numbers.



Urban pest control companies often use sticky traps to sample for insect pests in commercial establishments and schools. They are not visually attractive (some would describe them as disgusting), so they must be placed in out-of-the-way places, such as store rooms.

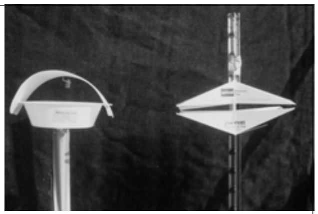
Insects stuck in adhesive are messy, and can be difficult to remove and identify. Also, such traps may not be selective.

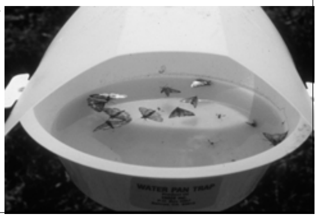
The bucket trap (left) and wing trap (below) introduce selectivity by using pheromones as lures.

Pheromone traps are popular because they provide specificity, are commercially available, and can be used under a variety of circumstances

Though pheromone traps usually rely on adhesive for insect retention, this is not always optimal. Bucket traps, water-pan traps, and other designs sometimes are more effective than sticky traps.

Shown here is a comparison of sticky wing and water pan traps for European corn borer monitoring: water is more effective in this case.





There are an infinite number of trap designs, and a rich literature surrounding their development and use. It is important to investigate the literature prior to sampling. Here is an example of an unusual method: a black, swinging, sticky-covered ball for deer flies.

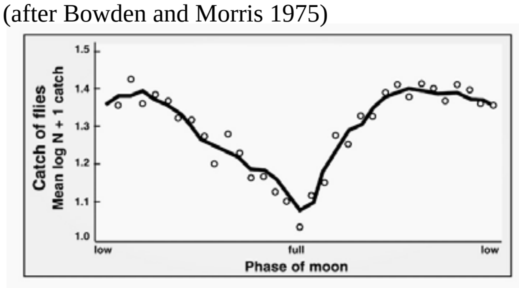
This is a food-based trap, called a McPhail trap. This, or a variation of this design, is widely used for tephritid fruit flies, and can be used for yellowjackets as well. A liquid bait (often protein hydrolyzate) is placed inside. The insects fly in from below, through the circular opening in the bottom. Once inside, they have difficulty escaping, and usually drown.

Mosquito traps are quite varied, but often involve the use of dry ice as a source of carbon dioxide, and a small fan to blow the mosquitoes into a receptacle.

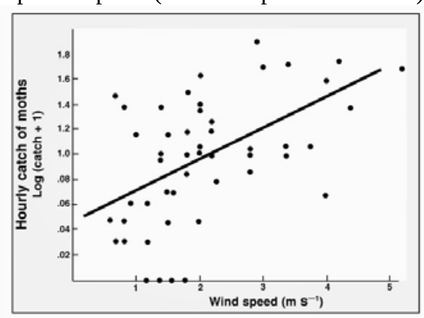
This flight trap, called a malaise trap, is an example of an interception trap. There is no active element to the trap, they flying insects insects are intercepted, crawl upwards, and are captured in a jar. The other common interception technique is a transparent pane of plastic or glass which interrupts flight. Insects are captured on adhesive or fall into a reservoir or receptacle.

Termite-sniffing dogs have become popular for detection of these hidden pests.

Sampling with traps of any design is not without its problems. Here you see the effect of the phase of the moon on capture of flies by a light trap. The light trap does not compete well with a full moon. (after Bowden and Morris 1975)

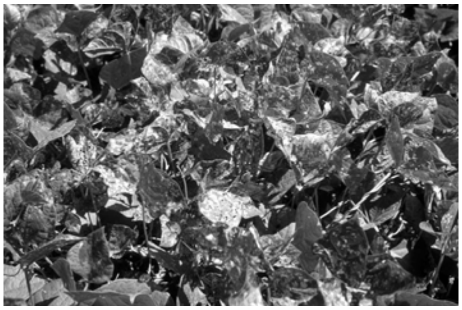


Similarly, wind amplifies pheromone trap captures, as shown by the positive relationship of wind speed and Spodoptera capture (after Campion et al. 1974).



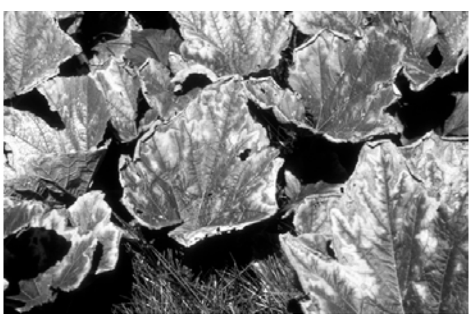
Examples of population indexes

- Defoliation
- Frass
- Tents, nests, or webs
- Emergence holes
- Tunnels
- Sounds
- Biting counts

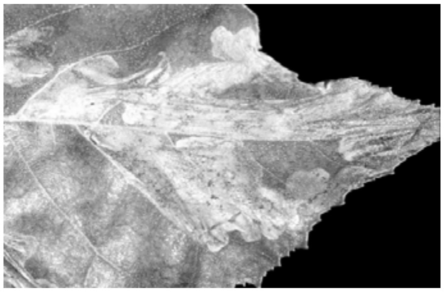


The level of insect feeding (damage) on foliage, as shown on these bean plants, is a good index of insect (Mexican bean beetle) abundance.

The number of peppers that drop to the ground (in this case in the irrigation furrow) is a good index of pepper weevil activity.

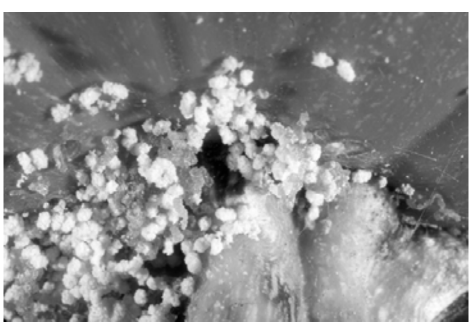


The amount of hopperburn, caused by the toxic feeding secretions of leafhoppers, is an index of their abundance.



Though the leaf miners (in this case, birch leafminer) may be difficult to see, the mines (tunnels) they form are easy to see, and long-lasting.

A drop cloth is a good means to collect insect fecal material (frass) produced by tree-feeding insects.



Sometimes frass or emergence holes are the best way to assess the occurrence of boring insects. Shown is pickleworm frass extruded from a pumpkin.

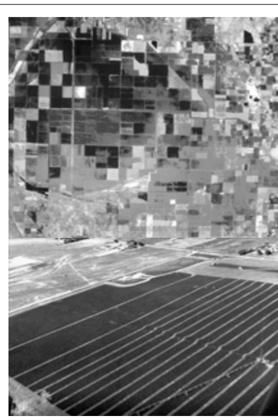
Cicada abundance can be assessed by the presence of shed cuticles but also by their level of calling.

Freshly molted cicada (above) and shed nymphal cuticle (below)

Tents caused by fall webworms, tent caterpillars, ugly-nest caterpillar, and other nest-building insects are a good index of their abundance.

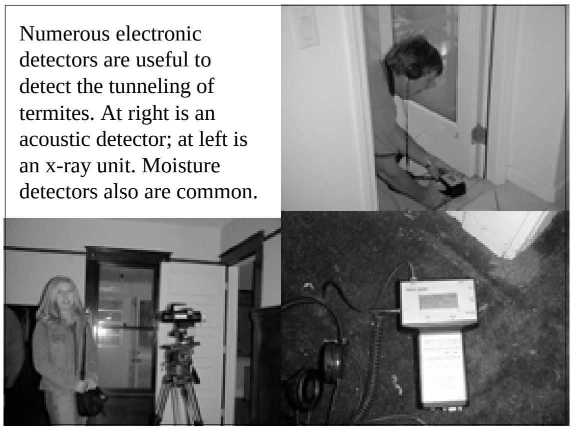
Fall webworm nests

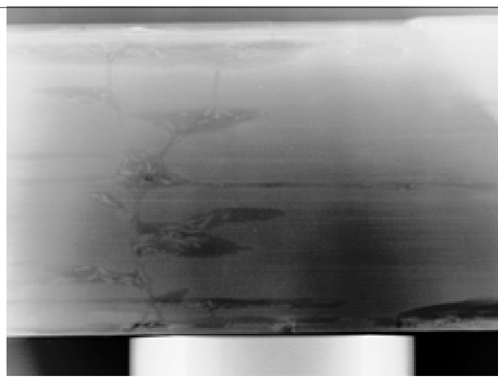
Remote sensing, whether using satellite (above) or aircraft (below) imagery, depends on the response of vegetation to insect infestation. Both visible and nonvisible portions of reflected light wavelengths can be used in assessing plant cover and vigor.



Infra-red imagery (above) and normal visual (below)

Numerous electronic detectors are useful to detect the tunneling of termites. At right is an acoustic detector; at left is an x-ray unit. Moisture detectors also are common.





This is what an X-ray image of termite tunneling looks like using a commercial termite sensor; there is no surface damage.

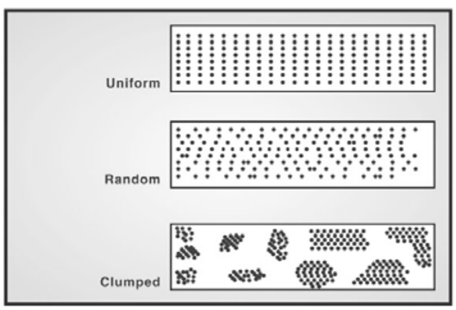
Development of a sampling plan

- Sampling “plan” (protocol) not the same as “method” (approach/technique)
- Should assess density of insects
- Should be independent of sampler
- Should be relevant to questions asked
- Should be practical

Components of a sampling plan

- Sample universe (area of concern)
- Timing (seasonality and developmental stage)
- Sample unit (actual area sampled)
- Spatial distribution (aggregated or clumped, random, uniform)
- Sample size (accurate vs. practical; calculated?)

Representative spatial distributions



Four common types of sampling plans

- Fixed sample size
- Sequential
- Variable-intensity
- Binomial

Fixed sample size

- Most common approach (e.g., "10") though optimal size can be calculated.
- Optimal sample size decreases with population density.
- Should be able to get by with fewer samples at high density.

Optimal sample size

- There are various means to calculate the optimal sample size if you elect to use a fixed sample. You want to be sure that you can be sure that you obtain an accurate assessment of the population.
- Calculation of optimal size is done too infrequently, probably because the results are unfavorable.
- One technique follows:

Calculating optimal sample size

- Within a homogeneous habitat, the number of samples needed to estimate the mean accurately, assuming a standard error of 5% of the mean, is calculated as follows:

$$n = s^2 / E\ x$$

Where n is the number of samples, s is the standard deviation, E is the predetermined standard error as a decimal of the mean (in this case 0.05), x is the mean.

Calculating optimal sample size

- Several calculations are required, including the mean, variance, and standard deviation.
- **Mean** (*x*): the numerical average of the counts (x) from each sample. This is calculated by summing the individual counts and dividing the summed counts by the number of counts.

- Example: 6 counts of leaf tissue reveal 17, 15, 10, 18, 25 and 20 insects per leaf, or 105/6, or a mean (*x*) of 17.5

More calculations

Variance: a measure of the variability among sample counts. This is calculated by subtracting the mean from each individual sample count, squaring the differences between these two values, summing the squared values, and then dividing the summed squared values by the number of samples taken minus 1.

Example:	x (count in each sample)	x-*x* (count-mean)	(x-*x*)^2 (differences squared)
	17	-.5	.25
	15	-2.5	6.25
	10	-7.5	56.25
	18	.5	.25
	25	7.5	56.25
	20	2.5	6.25
	105	0	125.50

$$\frac{\sum (x-x)^2}{n-1} = \frac{125.5}{5} = 25.1$$

More calculations

- **Standard deviation** (s)= a commonly used measure of variability among samples, and is calculated by determining the square root of the variance

  sq root of 25.1=5.01

- Note that the standard deviation decreases as the sample number increases, so variability decreases when you increase sample number. This is important when you are trying to determine if there is a difference between treatments or fields.

Recall that the optimal sample size is calculated as follows:

$$n = s^2 / E x$$

Where n is the number of samples, s is the standard deviation, E is the predetermined standard error as a decimal of the mean (in this case 0.05), x is the mean. So for our example:

$$n = \frac{5.01^2}{(0.05)(17.5)} = \frac{5.01^2}{0.87} = 33$$

Note that the optimal sample size increases as the standard deviation increases.
Also, if you desire greater confidence in your assessment (e.g., standard error of less than 5%) you can use a smaller predetermined standard error, which will require more sampling.

Remember that everything depends on your preliminary sampling where you determine mean values and variance among samples. Therefore, you should sample more thoroughly than you can imagine sampling on a routine basis.

Note that you will need to recalculate if mean and variance values change.

If in doubt, check the literature for acceptable sampling protocols, or consult a statistician.

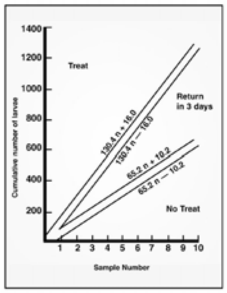
Sequential sampling

- Variable number of samples taken
- Sample until the population can be classified (e.g., no threat or control needed)
- More sampling at intermediate levels
- Efficient

More sequential sampling

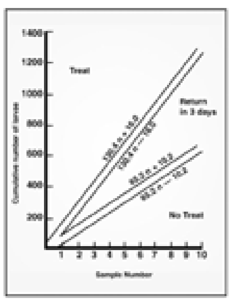
The chart at the right is a graphical display of the process of sequential sampling. In this case, we have elected to define 3 categories:

- a population requiring treatment
- a population not requiring treatment
- a population that is intermediate, and in need of close scrutiny, so if the population is determined to be intermediate, we will return and sample again in 3 days



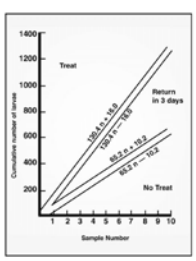
More sequential sampling

Along the bottom you see designation of sample number. As you continue to take samples you accumulate insect counts. So after taking 4 samples, if you have observed only 100 insects, you categorize the population as not requiring treatment. On the other hand, if you have observed 700 insects after 4 samples, you have a population requiring treatment.



More sequential sampling

- The location of the sets of parallel lines is determined mathematically, based on knowledge of the economic impact of the insects on the crop.
- If your counts fall between the parallel lines, you continue to sample.
- The width of the parallel lines is determined by your need for confidence in classifying the population accurately.



More sequential sampling

- In most cases, sequential sampling plans simply classify the population into 2 categories: needing treatment or not.
- More information on calculating sequential sampling plans, including how to calculate the dividing lines, can be found in most texts on sampling. For beginners, I generally recommend the following:
  - J.A. Onsager. 1976. The rationale of sequential sampling, with emphasis on its use in pest management. USDA Technical Bulletin 1526.

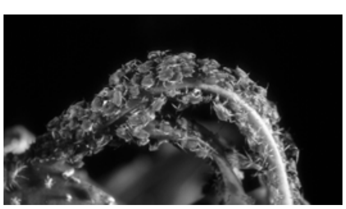
Variable intensity sampling

- Modification of sequential sampling
- Assures that sampling is broadly distributed over the sampling universe
- Spreads out sampling

Binomial sampling

- Records presence or absence; proportion infested or damaged
- Does not tabulate number of insects

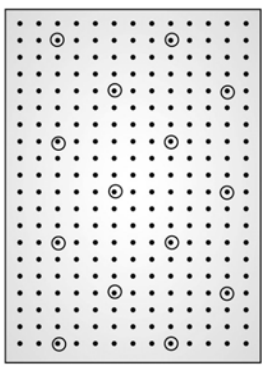
With insects such as these aphids, actual tabulation of insect numbers is a huge task. It may be better to approach such sampling on a presence-absence basis, simply recording whether or not plants (or portions of plants, such as individual leaves) are infested.



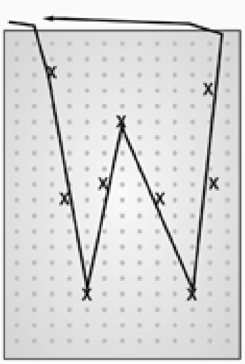
Allocation of sampling units

- How to allocate sampling effort from the sampling universe
  - Random sampling (unbiased, each unit has equal chance of being selected)
  - Stratified sampling (variation of random sampling based on knowledge of insect or distribution; assures collection)
  - Systematic sampling (predetermined pattern, e.g., “X, W or Z”-shaped transects are common)

Sampling of individual plants in this field (circled) is stratified, ensuring that both the margins and center are sampled. For species that enter from the edges, it may be most useful to concentrate sampling at the margins.



Sampling of this field (the path of the sampler is shown, as are the plants sampled) is systematic, and strives for a balance of good coverage and minimal effort. This is a common sampling plan.



Questions

- Can you describe the 3 basic methods of sampling, and provide examples of each?
- Can you describe the components of a sampling plan?
- Can you describe the types of sampling plans?
- How are sampling units allocated?

Questions from supplementary reading

- Reading 5, sampling
  - What is the difference between the sampling plan and sampling method?
  - How does the goal of a sampling plan affect the method selection process?
  - What is spatial dispersion?
  - What is the purpose of random sampling? How does it differ from stratified sampling? Systematic sampling?

View a Short Video on Sampling

View a Short Video on Scouting