Crop Protection
PLSS 6344

Lecture 11: **I**ntegrated **P**est **M**anagement

"Sampling"

Overview

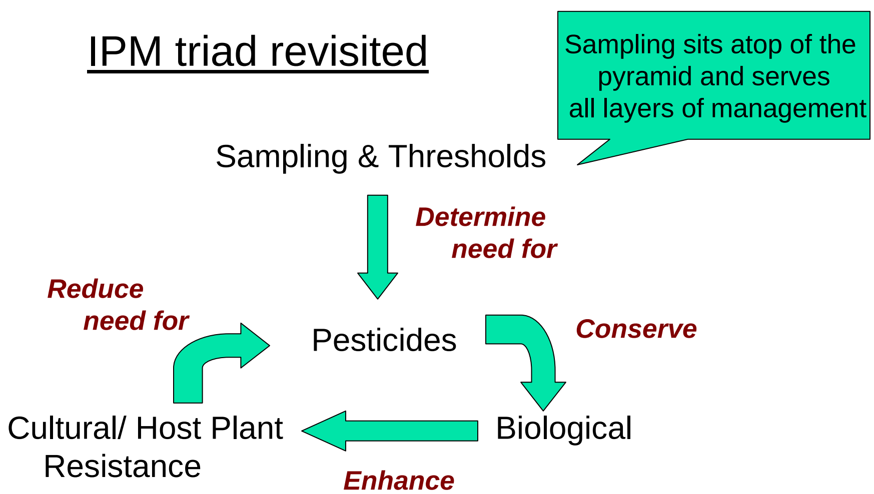
I. Introduction (Estimates vs. Exact #; Sampling Program)
II. Biological vs. Statistical Populations
III. Types of sampling programs
IV. Preliminary sampling Program
V. Sampling Design
VI. Sequential sampling

Lecture objectives

- Understand the concept of sampling and its importance in pest management
- Theoretical and practical aspects of sampling
- Students will learn how to initiate basic sampling plans for a given arthropod (insect) pest

Importance of Sampling in IPM

<u>IPM triad revisited</u>



I. Introduction

- Sampling = Collection of field observations to obtain a reliable estimate of the size of the arthropod population in a given area (e.g. # stalkborers in a corn field; boll weevil population in cotton field; # mosquitoes in a pond)
- Census vs. Sampling (Nearly impossible to count all inds. of an arthropod population in a given agroecosystem, sampling is thus **necessary**)
- 3 estimates of arthropod populations:
  - Absolute
  - Relative
  - Population Indices

I. Introduction

- Absolute vs. Relative Estimates
  - **Absolute** = all arthropods within the sample unit (difficult & intense. Often used in research but not in IPM systems)
    - **Extraction** (Vacuum sampler, sieving for non-mobile stages)
    - **Direct counting** (Vegetation removal for direct counting of thrips on onion, stemborers from cane splitting-easy w/large insects, but very difficult at higher density)
    - **Final absolute estimate** = (counts/ unit) × (Total sample units/acre)
  - **Characteristics of Absolute numbers**

  Want a best measure of density as possible
    - **Accuracy** - closeness of a measure to the true value
    - **Precision** - closeness of repeated measures to each other
    - **Bias** - degree of systematic error in estimating mean
    - **Fidelity** - accuracy with which population estimates over time reflect actual changes in population numbers

I. Introduction

- Absolute vs. Relative Estimates
  - **Relative** = No direct relation to the area, depends on technique--Use for comparison of pops.
    - **Sweep net** (E.g. # of leafhoppers per sweep)
    - **Trap** (yellow or blue sticky card - Pheromone traps, can be sex biased)
    - **Plant damage (Pop. Indices)** (Damage scoring or rating, disease presence)
  - **Characteristics of relative numbers**
    - Most often used in IPM
    - Cost efficient
    - Easy in most cases (but can be difficult in others)
    - Higher variance; may be difficult to interpret
    - Relative estimates can be converted into absolute estimates (regression analysis, experimentation etc..)

I. Introduction

- Sampling Program
  - **Sampling technique** = method used to collect single sample
  - **Sampling Program** = How a sampling technique is used
    - Number of samples
    - Spatial and temporal patterns, etc…
  - **Sampling Design** = Processes of establishing a sampling program

II. Biological vs. Statistical

- **Biological population** = actual # of arthropod in a given area (E.g. # of SCB in a sugarcane field: this # can be up to 40,000/ha. Impossible to count so biological pop. is often unknown) **[Rightly said it is a known unknown!)**
- **Statistical population** = estimate of the biological population determined by sampling a proportion of the biological population (In the eg above, if SCB is counted on 10 plants sampled per field, statistical population = # larvae on those 10 plants)
  - Estimates from statistical pop. obtained from sampling, needs to be summarized
  - Descriptive statistics (most common to describe arthropod pop. characteristics)

II. Biological vs. Statistical

- **Descriptive statistics**

1. **Mean** = arithmetic average of the sample numbers

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \ldots\ldots + x_N}{N}$$

N = number of samples and $\bar{x}$ = mean

- E.g. If SCB counts in 10 sampling units (plants) were: 4, 0, 12, 9, 18, 21, 7, 11, 12, 15 what would be the mean?
- Average of "several means" of this type from subsets will give *m*, the best estimate of population size.

The mean is the most important characteristic of an arthropod population-central tendency-but does not tell all! Other statistics are needed.

II. Biological vs. Statistical

- **Descriptive statistics-Variation (numerical differences among samples)**

  2. **Range =** Largest value - smallest value (E.g. 21 - 0)
  3. **Variance** = spread of individual measurements of the statistical population
  4. **Standard Deviation (SD or s)** = Average of deviation of sample counts from the mean value - SD is the square root of variance
  5. **Standard Error** = Expected spread of the sample means is repeated samples of the same size are taken from the population. Magnitude decreases as # samples increased!

II. Biological vs. Statistical

- **Descriptive statistics-Variation**
  - Statistical programs on PC or Handheld calculators can perform most of these calculations

Sample Number (N_i)	Sample Count (X)	X^2
1	4	16
2	0	0
3	12	144
4	9	81
5	18	324
6	21	441
7	7	49
8	11	121
9	12	144
10	15	225
SUM	109	1545
Mean	*x* = 109/10 = **10.9**	

$$s = \sqrt{\frac{1}{N-1}(SUMX^2 - \frac{(SUMX)^2}{N})} = 6.30, V = s^2 = 37.7$$

$$SE = s/\sqrt{N} = 6.3/\sqrt{10} = 2.0$$

III. Types of Sampling

Two main types of sampling Programs

A. **Extensive**

- Conducted over broad area
- To predict damaging levels of pops.
- Area-wide surveys
- Pattern of pop. dynamics (flight of Monarch butterfly)
- Coarse estimate-few samples are usually taken, one stage sample, systematic pattern

III. Types of Sampling

Two main types of Sampling Programs

B. **Intensive**

- Analytical-used for research (frequent observation of species in a small area-GWSS egg parasitism in south TX)
- Used for life table, mortality, natality, migrations
- Often several stages sampled
- Requires higher precision level

IV. Preliminary Sampling Program

- **A. Used to start a program, estimate workable program (What – Where – When - How?)**

1. Try different techniques (Visual counts, mass trapping, damage estimate)

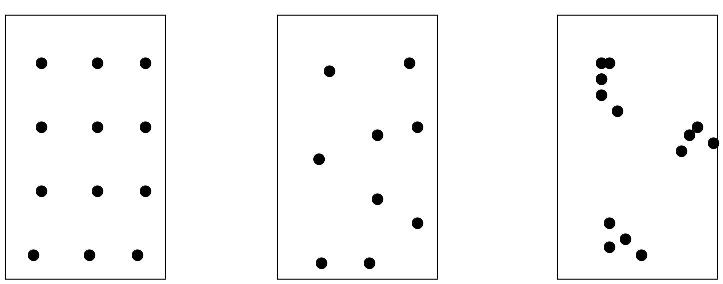
2. Knowledge of basic attributes of arthropod biology required
   - **What is it?** Proper and accurate identification is the first step
   - **What is the life history** (where does the insect pest feed on a plant, how many generations a year, where are the eggs deposited?)

3. Activity periods
   - **nocturnal vs. diurnal patterns; cool mornings vs host afternoons** (E.g., Lep. Moths; Alate aphids fly primarily during morning and late afternoon hours)

IV. Preliminary Sampling Program

- **Used to start a program, estimate workable program**

4. Dispersal pattern (spatial arrangement)
   - **three basic patterns: aggregated, random and regular**



Regular $\sigma^2 < \mu$ | Random $\sigma^2 = \mu$ | Clumped $\sigma^2 > \mu$

IV. Preliminary Sampling Program

- **Used to start a program, estimate workable program**

4. Dispersal pattern: Before making any statistical inference, test the relationship of arthropod distribution to known appropriate statistical distribution:
   - **Normal**= theoretical distribution wherein variation is random, mean and variance are independent
   - **Poisson series**= distribution of data with low mean (high proportion of 0)
   - **Bionomial** (Presence/Absence data)
   - **Negative bionomial** = variance is dependent upon the mean (clumped distribution)

Compute the mean and variance and compare them using established statistics

IV. Preliminary Sampling Program

- **Poisson: test of conformity**

Poisson probability: **P(n) =** $e^{-\bar{x}}(\frac{\bar{x}^n}{n!})$

- **Aggregation index** = variance to mean ratio ($I_D=s^2/\bar{x}$); this ratio is compared to 1 using chi-square test

I_D < 1≡ regular; I_D = 1 ≡random and I_D > 1 ≡ aggregated

- **Taylors' Power Law** = exponential function to describe the relationship between variance and mean

$$s^2 = a\bar{x}^b$$

Log-transformation gives: $\log(s^2) = \log(a) + b\log(\bar{x})$

b index of aggregation, b < 1 ≡ regular, b = 1 ≡ random, and b > 1 ≡ aggregated distribution

IV. Preliminary Sampling Program

Example: Data on EB on maize compared to Poisson distribution

Number of EB/cob	Observed frequency	Prob. Poisson	Expected freq.
0	1162	0.32	735.6
1	427	0.36	838.6
2	391	0.21	478
3	142	0.08	181.6
4	82	0.02	51.8
5	53	0.01	11.8
6	25	0.00	2.2
7	12	0.00	0.4
8	6	0.00	0.1

$$e^{-\bar{x}}\left(\frac{\bar{x}^n}{n!}\right)$$

N = 2300

Mean = 1.14; variance = 3.53

Chi-square = $\Sigma[((O_i-E_i)^2)/E_i]$= 1,919.6; P < 0.0001

Sétamou et al. 2000

IV. Preliminary Sampling Program

- **EB data analyzed with I_D**

I_D variance/mean = 3.53/1.14 = 3.10

chi-square = (n-1)× I_D = 59.02 > 1; n = 140

What is the Conclusion??

- **EB data analyzed TPL**

log(variance) = 1.26 + 1.47*log(mean)

b = 1.47 > 1, t = 24.64, df = 130

What is the Conclusion??

IV. Preliminary Sampling Program

- **A. Used to start a program, estimate workable program**
  5. Determine sampling universe (broad area from which sample should be drawn)
  6. Trial and error (experiment to find most acceptable procedures)

- **B. Objectives**
  - Reduce costs
  - Plan sampling program with low variances

V. Sampling Design

- **A. Elements of the Sampling Program** **(6 key elements)**
  1. Sampling techniques
  2. Number of samples (per unit habitat)
  3. Sampling Unit (size, selection, habitat)
  4. Pattern of sampling
  5. Timing of sampling
  6. Sampling Interval

V. Sampling Design

- **A. Elements of the Sampling Program**

1. Sampling techniques
2. **Number of samples** (per unit habitat) : Compromise between accuracy and cost

Continuous: $N = [(t \times s)/(D \times \bar{x})]^2$

Bionomial: N =

N= number of samples required; t = Student's t-value;

s = standard deviation; $\bar{x}$ = mean; D = required level of precision

D = 10% or 0.10 for research

D = 25% or 0.25 in IPM

V. Sampling Design

- **A. Elements of the Sampling Program**

1. Sampling techniques
2. **Number of samples**

<u>Example:</u> EB # required for 25% precision level

mean= 1.14; variance = 3.53, *s* = 1.88

$$N = [(1.96 \times 1.88)/(0.25 \times 1.14)]^2 = 169$$

For 10%

$$N = [(1.96 \times 1.88)/(0.10 \times 1.14)] = 1045$$

V. Sampling Design

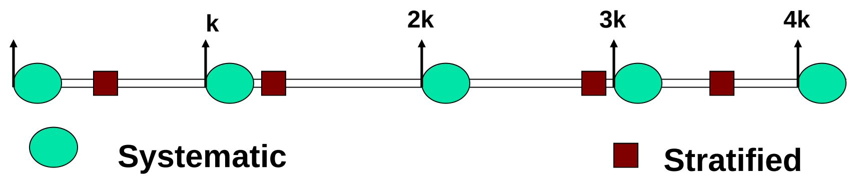
- **A. Elements of the Sampling Program**
  1. Sampling techniques
  2. Number of Samples
  3. **Sampling Unit** (land area, whole plant, plant parts, etc..
     a. Equal chance of selection
     b. Stability (same plant growth stage)
     c. Proportion of arthropods within each unit kept constant
     d. Can convert into unit area
     e. Balance between cost and accuracy
     f. Sampling unit easy to be determined in the field

V. Sampling Design

- **A. Elements of the Sampling Program**
  1. Sampling techniques
  2. Number of Samples
  3. Sampling Unit
  4. **Sampling Pattern**
     a. Depend on objectives of program
     b. Types of sampling patterns
        i. Unrestricted random (equal chance, not variance efficient)
        ii. Stratified random (subdivision into strata, more efficient and very common in IPM)
        iii. Systematic (equal distance sampling, analysis difficult)

V. Sampling Design

- **A. Elements of the Sampling Program**
  1. Sampling techniques
  2. Number of Samples
  3. Sampling Unit
  4. Sampling Pattern



V. Sampling Design

- **A. Elements of the Sampling Program**
  1. Sampling techniques
  2. Number of Samples
  3. Sampling Unit
  4. Sampling Pattern
  5. Timing
     - Consider Temperature effects (DD to predict arthropod occurrence)
     - For unknown spp., sample regularly until optimum time is detected
  6. Sampling Interval
     - Depend on generation time (short for fast developing pest *sp*.: 2-3 d for aphids; stemborers 1 to 2 weeks)
     - Consider the environment!

VI. Sequential Sampling

- **Reduce costs while maintaining precision**
- **Sampler make decision:**
  - Numbers too low stop sampling
  - Numbers very high and take treatment action
  - Numbers in between threshold, too close to call, recheck later
- **Method:**
  - Threshold lines predefined (lower and higher)
  - Compare successive sample tally to those limits

VI. Sequential Sampling

Sample no.	Don't treat	Tally 1	Tally 2	Tally 3	Treat
1	-	0	1	1	-
2	-	1	1	2	-
3	-	2	2	2	-
4	-	3	2	3	-
5	-	3	3	4	-
6	3	4	4	5	7
7	4	5	5	5	7
8	4	5	5	5	8
9	4	6	5	6	9
10	5	6	6	7	9
11	5	7	6	7	10
12	6	8	6	8	10
13	6	9		8	11
14	7	10		8	11
15	7	10		9	12
16	8	11		10	12
17	8	12		10	13
18	9	13		11	13
19	9			11	14
20	9			11	15
		Treat	Don't	Recheck	

Summary: Sampling Programs

- Sampling has been defined
- Biological pop. unknown, Statistical pop. used to make inference on Biological
- Factors to be considered in sampling, Sample size
- Different sampling patterns

" The sampling program is a mixture of art, science, and drudgery; art and science are in the sampling design"

R. F. Morris