Management of Forest Pests

Insect populations interacting with humans

- Chronic Outbreaks
- EcDam
- Periodic Outbreaks
- Latent Outbreaks

Time

Insect Numbers
• The question is: What’s the economic damage level?

• As an insect population grows it reaches a point where it begins to cause enough damage to justify control measures.

Calculation of the Economic Damage Level

\[ EcD = \frac{C \times N}{V \times I} \]

• C is the unit cost of controlling a pest, e.g. $20/acre.

• N is the number of pests injuring the commodity unit, e.g. 800 tip weevils/acre.

• V is the unit value of the commodity, e.g. $500/acre.

• I is the percentage of the commodity unit damaged, e.g. 10% loss.

\[ EcD = \frac{20 \times 800}{500 \times 0.1} = 320/\text{pests per acre} \]
In agriculture: Control of the Lygus bug

In farming you practice pest control via the 3-S approach.

Squat
Squint &
Spray
Other than intensive plantation forestry, we cannot practice the 3-S system because forestry deals with four dimensions:

1. Height  
2. Width  
3. Length  
4. Time – 100yr rotations are still common.

In forestry if pests consume more than the allowable annual cut – they are at the EcD level.

![Diagram showing forest growth and allowable annual cut](image)
1. GrStock = Yrs*Vol. → (100)(200) → 10,000 cu.units

2. Allowable cut = GrSt R/2 → 10,000 cu.units/50 → 200 cu.units

So, if a pest removes >200 cu.units per acre it’s reached the level of causing economic damage!

In a general sense, then, insects can directly affect timber production.
Insect control in agriculture is big business: a 10 billion dollar business.


In agriculture and intensive forestry (trees grown on short rotation like crops) applied pest control is routine.

What Does “Control” Mean?

Simple: How many insects do you have to kill to stop an outbreak? Dah!

\[ Mq = \frac{(\text{Fecundity})(\text{Sex Ratio}) - 1}{(\text{Fecundity})(\text{Sex Ratio})} \]

- Fecund. = Avg. Nos. Eggs Laid/Female
- Sex Ratio = \( \frac{\text{No. Females}}{\text{No. Females} + \text{No. Males}} \)
Example of the Mq

The western spruce budworm:
- Each ♀ lays about 170 eggs.
- You collect 1000 pupae and rear them to adults & 500 are females and 500 males

\[
Mq = \frac{(170)(0.5) - 1}{(170)(0.5)} = 0.988 \quad \text{Must die.}
\]

\[(170 \text{ eggs}) \times (0.988) = 168\]

So! 170

\[
\begin{array}{c}
-168 \\ 2
\end{array}
\]

One is a male & the other is a female.
By killing 99.8% of the population:

By killing 98.8% here, Pop. will level off.

There is Direct Control

“Operations aimed directly at the pest in question for purposes of immediate suppression!”
Direct Control Tactics

1. Mechanical – chipping infested material, peeling of infested bark, sprinkler system on log decks;

2. Chemical methods – application of insecticides to reduce insect populations below the level of economic damage;

3. Physical methods – application of sterile males to reduce the reproducing population below the level of economic damage.

Mechanical control circa. 1920.
Chemical Control

Bark Beetle Spray

Spruce Budworm Spray

Chemical Control

Seed Orchard, Texas

Recently-planted pine seedlings
It was hoped that the weightlessness of Skylab might induce some intracellular redistribution of material within the embryo or alter the permeability of cell membranes to cause an early end to diapause. Research performed in biological experiments on the Biosat 2 satellite in 1967 had demonstrated the feasibility of such approaches. Thus, the purpose of the experiment was to prematurely terminate the diapause of gypsy moth eggs by exposure to zero gravity.

“Taking the gypsy moth to outer space and....”

There is Indirect Control

“Operations designed to modify environmental factors to secure the ultimate limitation of insect numbers.”

Three common methods:

1. Biological control
2. Silvicultural control
3. Legal control
Permanent Biological Control: Typically Applied To an Introduced Pest!

Ichneumonid parasitoid

Ichneumonid egg

Ichneumonid pupae punching through caterpillar exoskeleton

Permanent Biocontrol: (1) pest introduced from Europe, (2) principal parasitoid introduced a few yrs. later, & (3) typical host-parasitoid curve occurs which is about 90° out of phase -- density dependent relationship!
Permanent Biological Control

Benefits:
- Self perpetuating
- Selective in action
- Doesn't create more problems than it solves

Problems:
- Not so useful against direct pests
- Takes several yrs. to establish
- Must be used over large area
- Some degree of damage must be tolerated

Temporary Biological Control

Has the same objectives as direct control -- “get them now, all of them!”
Examples of temporary biological control would be: (1) the rearing and release of parasitoids or (2) pathological biological control (use of viruses, bacteria, or nematodes).

Steps in rearing egg parasitoids

1. Wheat moths
   - Wheat
   - Wheat moth eggs
2. Storage container for wheat moth eggs
Bottle full of the egg parasitoid *Trichograma* sp.  

(4) Bottle full of *Trichograma* taken to dark room  

(5) Little wasps attracted to light  

Wheat moth eggs glued to cardboard  

*Trichograma* parasitizing wheat moth eggs  

Cardboard with wheat moth eggs
(7) Cardboards with parasitized eggs are cut into small rectangles and placed in refrigerator.

(8) Temperature of refrigerator and time parasitized eggs are kept in frig controls the emergence time of adult wasps – the egg parasitoids.

Cardboards with thousands of wheat moth eggs parasitized by *Trichograma*
Rearing the *Trichograma* sp.

The egg parasite, *Trichograma* sp.

- Ovipositor
- Wheatmoth egg
Pathological Biological Control

Pest
Pathogen
Environment

- Viruses
- Bacteria (*Bacillus thuringiensis*)
- Fungi
- Nematodes
- Protozoa

In 1911 Prof. Dr. Berliner, an entomologist, who lived in the city of Thuringia, isolated the bacteria from dead flour moths and named it:

*Ich namen dis bacteria, Bacillus thuringiensis Berliner*
**Bacillus thuringiensis**

1. Bt is one of the rod-like bacteria that propels itself by use of flagella & Bt produce spores -- one of the sporiferous bacteria.

2. Among the spores produced is a **resistant spore type** that has a thick wall.

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**The 1929 control project using Bt spores and crystals that were dusted over trees infested with the gypsy moth**
Bt Spraying

1952 Ford trimotor

1960 Bt spray deposition study

2005 Bt spray in Yakima

Nothing to do with this course, but…

I remember that Ford trimotor well in 1952.
Bt has several toxins: chemicals deadly to the Lepidoptera

The crystals found in the resistant spore contain a toxin called endotoxin delta.

This endotoxin delta, by itself, kills caterpillars and larvae of mosquitoes, blackflies, and midges and its absolutely, positively, non-toxic to any vertebrate.

To understand the mode of action of Bt let’s review insect digestion
The Bt crystals dissolve under high pH: pH has to be high!

Ugh!
Midgut becomes totally impermeable & nutrients can't penetrate into the body cavity. Guess what happens?
Bt Toxins Continued, mode of action

(1) The endotoxin delta (found in the proteinaceous crystal) hinders the permeability of the midgut. The insect stops feeding and the blood is contaminated and insect dies from septicemia.

(2) Many lepidopterans can’t dissolve the crystal (pH too acidic). In many of these caterpillars, toxic proteins enter blood when vegetative spores are digested. Septicemia also occurs and the insects die within 24 - 36 hrs.

Conclusions:

The efficiency of Bacillus thuringiensis depends on:

• Quality of proteins that make up the crystals

• Ability of caterpillars to dissolve the crystals, i.e. those with high pH in the midgut

• The ability of toxic products from vegetative spores to cause septicemia
**LD<sub>50</sub> = 5000ml/kg**

(84kg)(5000) = 420,000mg

You’d have to eat over 1.25 lbs. of pure B<sub>t</sub>

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**Fungi kill**

Spores of several fungi are used to control pests, e.g. *Beauvaria bassiana.*
Fungal spores are disseminated

Land on insect cuticle and exude a corrosive compound that allows the exploratory hyphae to penetrate

The point is: the spores do not geminate in gut of the insect

Problems:

• RH of atmos. around 90%
• The insects die slowly

Use of *B. bassiana* in Viet Nam.
Another example of temporary biological control would be the use of entomophagous viruses.

(1) Viral diseases are caused by the nucleic acid contained in virus particles called virions.

(2) Virions can be rod shaped, filamentous, spheres or complex in shape.

(3) The virions in insect viruses are encased in proteinaceous coats that are polyhedron in shape or granular or more complex.

Three common types of insect viruses:

1. NPV (nuclear polyhedral viruses)
2. CPV (cytoplasmic polyhedral viruses)
3. Granulosis viruses
   - NPV replicate in nuclei of cells
   - CPV replicate in cytoplasm of midgut cells
   - Granulosis viruses have a single virion within their proteinaceous capsule
Virus polyhedrons on leaves & when insect ingests them the insects becomes infected
How about a bioengineered virus?

**NAME**
ACMNPy, AUTOGRAPH, CALIFORNICA NPy, VIEGTDEL -AaIT

ACMNPy - A genetically engineered baculovirus that contains a gene from the venom of the scorpion Antroctonus austailis

**TYPE:** ACMNPy is a genetically engineered bio-insecticide that is being used as a systemic insecticide.

**ORIGIN:** American Cyanamid, 1995.

**TOXICITY:** Non-toxic to warm blooded animals.

**FORMULATIONS:** Various.

**IMPORTANT PEST CONTROLLED:** Tobacco budworm and the cabbage looper.

**USES:** Experimentally being tested on cotton, tobacco and leafy vegetables.

**APPLICATION:** Used on an experimental basis only.

**ADDITIONAL INFORMATION:** Controls insects 80% faster than its naturally occurring counterpart, thereby avoiding crop damage from prolonged leading. Beneficial insects are not harmed.

**Autocidal Insect Control: Sterile Male Technique**
A Great Success in Control of the screw worm, *Cochliomyia hominivorax*

Screw worm maggot that feeds in wounds of cattle and other domestic animals in SW USA
This is how the sterile technique works

Autocidal Insect Control
(Criteria for Success)

1. Females should mate once

2. It must be possible to separate sexes in pupal stage

3. It must be possible to rear and sterilize large numbers of insects in a short time so as to be able to release millions & millions of males

4. Reared males must compete successfully with wild males.

5. There must be a practical release system
# Autocidal insect control successes

## Table 343

<table>
<thead>
<tr>
<th>Insect</th>
<th>Proposed Manner of Use</th>
<th>Status of Research and Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screwworm</td>
<td>For suppressing populations</td>
<td>In practical use</td>
</tr>
<tr>
<td>Mexican fruit fly</td>
<td>For regional basis</td>
<td>In practical use</td>
</tr>
<tr>
<td>Pink bollworm</td>
<td>For preventing establishment of incipient infestations</td>
<td>In practical use; additional improvements and pilot testing required</td>
</tr>
<tr>
<td>Oriental Mediterranean, and melon fly</td>
<td>To eliminate low level populations and maintain suppression of populations by cultural and chemical means</td>
<td>Effectiveness demonstrated in small island tests. Large pilot tests required</td>
</tr>
<tr>
<td>Codling moth</td>
<td>To maintain suppression after prior suppression of populations by cultural and chemical means</td>
<td>Effectiveness demonstrated in small orchard tests. Small pilot test under way</td>
</tr>
<tr>
<td>Bull weevil</td>
<td>To eliminate low level populations and maintain suppression by chemical, cultural, and other means</td>
<td>Pilot tests planned</td>
</tr>
<tr>
<td>Bollworm and budworm</td>
<td>For area suppression of low level populations</td>
<td>Pilot tests required</td>
</tr>
<tr>
<td>Cabbage looper</td>
<td>For area suppression of low level populations</td>
<td>Pilot tests required</td>
</tr>
<tr>
<td>Fall armyworm</td>
<td>For area suppression of low level populations</td>
<td>Pilot tests required</td>
</tr>
<tr>
<td>Tobacco hornworm</td>
<td>For area suppression after prior suppression by cultural means</td>
<td>Pilot test required</td>
</tr>
<tr>
<td>Clypeus moth</td>
<td>For preventing spread and to eliminate incipient infestations</td>
<td>Pilot test required</td>
</tr>
<tr>
<td>Mosquitoes (important vector species)</td>
<td>To maintain suppression after population suppression by sanitary and chemical means</td>
<td>One pilot test underway—others required</td>
</tr>
<tr>
<td>Tsetse flies</td>
<td>To eliminate low populations after prior suppression by chemicals and brush clearing</td>
<td>Pilot test planned</td>
</tr>
<tr>
<td>Horn fly</td>
<td>To eliminate low populations after animal spraying</td>
<td>Pilot test required</td>
</tr>
</tbody>
</table>