Section 12: Genetic control and area-wide management

- Three basic approaches to genetic control:
  - autocidal or genetic modification;
  - use of chemosterilants; and
  - sterile insect technique (SIT) [also known as the sterile insect release method (SIRM) or sterile male technique (SMT)].
- Only SIT is used regularly as a genetic technique, though genetic modification is becoming increasingly possible with advances in methods of genetic engineering.
- Area-wide management, often employing SIT, is increasingly viewed as desirable.

Sterile insect technique (SIT)

- Basic concept involves release of sterilized laboratory-reared insects that will mate with fertile insects in the field, thereby neutralizing their reproductive potential.
- Usually male insects are sterilized and released.
- Sterility is accomplished through irradiation or chemosterilization.
- It is important that the insects released will cause no damage; thus, there is reluctance to release insects that might feed and cause injury (e.g. adult beetles, female mosquitoes) whereas insects that do not cause injury are safe for release (e.g., moths, adult fruit flies, male mosquitoes).

Conditions for effective SIT

- An effective and reasonably economic method of mass rearing of the target insect.
- The released insect must disperse rapidly (or be capable of being dispersed rapidly) through the wild population.
- Sterilization must not affect sexual competitiveness.
- Females preferably mate only once.
- It must be possible to overwhelm the native population with sterile insects (ratio of sterile to fertile fertile males of at least 10:1, preferably higher).

Model for sterile insect technique (SIT)

Gener-ation	No. virgin females in area	No.sterile males released per gener-ation	Ratio sterile to fertile males	% females mated to sterile males	Pop. of fertile females
F_1	1,000,000	2,000,000	2:1	66.7	333,333
F_2	333,333	2,000,000	6:1	85.7	47,619
F_3	47,619	2,000,000	42:1	97.7	1,107
F_4	1,107	2,000,000	1807:1	99.9	Less than 1

How SIT works

- When more sterile males are available than fertile males, the likelihood of mating with a sterile insect is high, suppressing the reproductive output of the fertile population.
- In generation 1, 2/3 of the males are sterile, so 2/3 of the matings should result in reproductive failure.
- As the population of fertile males decreases, the ratio of sterile to fertile increases, depressing the population even faster.
- Once attaining a low level of fertile insects, it is easy to maintain the population at low levels with continued releases. In some cases, the pests are eliminated (eradicated), so no further releases are made.

Eradication

- Pest eradication is a wonderful concept, but hard to implement.
- Works best when the aforementioned requisites are met PLUS the likelihood of reintroduction is low. If reintroduction is likely to occur, continued releases of steriles can be made; this is occurring with medfly in California and Florida due to history of reintroduction.
- If fertile population is high initially, it may need to be brought down to lower levels with insecticides prior to beginning the SIT program; this often meets with resistance because urban areas are treated.

Some SIT eradication success stories

- New world screwworm fly - southern USA, Mexico, into Central America, Libya
- Mediterranean fruit fly (medfly) - North, Central, South America and Egypt
- Melon fly - Okinawa, southern Japan
- Tsetse fly - Zanzibar

New world screwworm fly

Screwworm eradication from North America

- The following graphic shows the progress of eradication of screwworm, starting with the southeastern USA in the 1950s. After eliminating screwworm from the USA in the 1960s, it became apparent that the Mexico-USA border was too porous, and re-introduction would continue. Thus, the program was extended to Mexico (1980s), then Central America, and now to the narrow (and easy to maintain) isthmus of Panama.

Problems with SIT

- Must provide reliable sterilization
- Must have reliable supply of sterile insects
- Costs of production
- Regional cooperation
- Released insects must be competitive with wild insects for mating
  - Lab rearing quality control issues
  - Sterilization quality control issues
- Sterile insects should not inflict direct damage
- Re-invasion of sterility zone

Other genetic approaches

- Chromosomal translocation - disruption of chromosomes by radiation produces individuals with lower fitness, and matings of treated with untreated individuals produce only 50% of the normal level of offspring.
- Hybrid sterility - different populations of the same species sometimes will mate but not produce offspring.
- Competitive displacement - a serious problem could possibly be replaced by an introduced, but less troublesome species.

Other genetic approaches

- Cytoplasmic incompatibility - as in the case of hybrid sterility, geographic races sometimes cannot produce fertile offspring, but in this case it is due to nongenetic components such as the presence of Wolbachia rickettsial symbionts.
- Chemosterilization - chemicals with mutagenic capacity are sprayed, or insects are lured into proximity of the chemicals with baits.
- NOTE: though these approaches have potential, none are used due to technical difficulties or environmental/health concerns.

Questions on sterility

- Describe the process of sterile insect techniques (SIT).
- Is SIT necessary for eradication? What limits eradication?
- Can you name examples of successful SIT?
- What are other genetic approaches to insect management?

Area-wide management

Definitions of area-wide management:

- E.F. Knipling - systematic reduction of pest abundance to predetermined levels through use of uniformly applied pest suppression measures over large geographical areas clearly defined by biologically-based criteria.
- D.A. Lindquist - long-term planned campaign against a pest population in a relatively large predefined area with the objective of reducing pest to non-economic status.

Area-wide objectives

- Reduce population AND eliminate any place of refuge that might allow re-establishment of high densities.
- Replace independent, localized, uncoordinated, conventional management that doesn't consider refugia with coordinated, regional suppression that may employ unconventional approaches and reduce cost and environmental impact.
- Often uses SIT.

Comparison of conventional and area-wide

	Conventional	Area-wide
Planning	Reactive, need-based	Planned, always implemented
Implementation	Individual, independent actions	Coordinated actions
Treatment area	Small area treated	Large area treated
Organiz. unit	Individual landholder	Geographical area or production unit
Economy	Less, no economy of scale	Greater, economy of scale
Technology	Conventional	Alternative tech. available
Benefits	Short-term	Long-term
Example	Typical farmer	Mosquito control district

Prerequisites for implementing area-wide management

- Target a key pest.
- Management technology is available.
- Biology/ecology of pest known.
- Strong stakeholder support (participation).
- Active R&D program, and educational outreach.
- Adequate funding.
- Legal authority.
- Governmental role?

Tsetse fly

Area-wide technology

- Area-wide management uses all technologies that are useful, not just SIT. Pheromone trapping, biological control, sterile insects, crop management, insect pathogens and insecticides all are used.
- Area-wide sometimes employs technology that might not be available to individuals, such as -
  - remote sensing
  - database management
  - mass rearing facilities (pest or beneficials)
  - insecticide resistance monitoring
  - management of refugia for genetic manipulation or resistance management

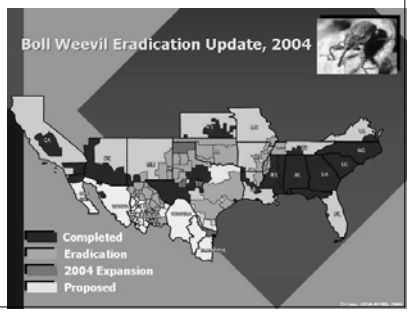
Area-wide management

- In planning for area-wide, there are:
  - Scientific considerations: biology, control technology
  - Sociological considerations: cost, environmental impact, public health, politics

Cattle ranchers in Mexico now are free of screwworm concerns

Boll weevils arrived in the United States from Mexico in 1892 and have caused an estimated $14 billion in yield losses and control costs to the U.S. cotton industry since then. In the cooperative boll weevil eradication program, the federal government supplies equipment, technical and administrative support and funds up to 30 percent of program costs. Growers pay at least 70 percent of program costs. The program has been successful in eradicating weevils from Virginia and the Carolinas, Georgia, Florida, south Alabama, California, and Arizona.

The boll weevil, *Anthonomus grandis* Boheman



Some examples of area-wide programs

- USA
  - Caribbean fruit fly - Florida
  - Pink bollworm - southwestern USA
  - Medfly - California, Florida
  - Codling moth -northwestern USA, Canada
- International
  - Onchocerciasis/blackfly - western Africa
  - Desert locust - northern and central Africa
  - Cassava mealybug - central Africa
  - Chagas disease/kissing bugs - South and Central America

Most Americans encounter area-wide insect management in the form of mosquito or grasshopper management programs. These can be large, expensive operations with numerous logistical challenges. Shown here is an insecticide-based grasshopper management program, which is organized by federal and state government, and financed by both government and ranchers.

Mosquito districts monitor mosquito populations and attempt to regulate water levels and larval populations, thereby eliminating the need for adult control, and the potential for nuisance biting and disease transmission. These are usually city or county-based operations.

CDC trap for adults (above) and mosquito larvae (left).

Under some conditions, mosquito populations evade the efforts of mosquito control districts - usually due to excessive rainfall - and then adulticiding programs are initiated. Insecticide can be applied from the air or ground to suppress adults and limit their disease transmission abilities. Adult control is difficult, however, and educational programs that advise people to avoid being out-of-doors at dusk and dawn (prime feeding times), and to use insect repellent liberally, are important ancillary activities.

Questions on area-wide management

- What is area-wide management? How does it differ from SIT? What are the prerequisites for successful area-wide management?
- How does area-wide management differ from conventional insect management?
- Can you name examples of successful area-wide management?

Questions from supplementary readings

- Reading 6, Area-wide pest management
  - Can you explain Knipling's model on the value of treating a population uniformly (e.g., 90% for each generation) versus a higher level of control periodically (e.g., 99% for one generation and then no control for several generations)?
  - What concerns is the public likely to voice when area-wide programs are proposed?
  - What techniques were used to eliminate the threats of malaria, yellow fever, onchocerciasis, and Chagas?

Questions from supplementary readings

- Reading 12, Medfly genetic sexing
  - What are the advantages of male-opnly releases of sterile insects?
  - What is the technology that allows male only release of medflies?
- Reading 12, Medfly recapture
  - Why are continuous releases made in California?
  - How does weather and host plants influence sterile medfly release programs in California.