BIOS 6150: Ecology
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• Week 12: Manipulating Abundance & Risk Assessment.

• Lecture summary:
  • Manipulating abundance - pests and harvesting:
  • Ecological risk assessment:
    • Assessing the risks of invasion and persistence of genetically engineered crops.
    • Crawley et al. (1993).
2. Reasons for manipulating abundance:

- **Pest and weed control:**
  - Economic injury level (EIL):
    - Figs. 15.1a & 16.2.
  - Economic action threshold:
    - Using chemical, biological & integrated methods

- **Harvesting, fishing, shooting and culling:**
  - Sustainable yields of harvested resources:
    - Table 16.6.
  - Maximum sustainable yield (MSY):
    - Fig. 15.7.
3. **MSY models of harvesting:**

- **Surplus yield models:**
  - Based on an n-shaped recruitment curve:
    - Fig. 5.8.
  - Product of logistic population limitation to a carrying capacity \( K \):
    - Fig. 16.12 (3rd ed.).
  - *Fixed-quota* harvesting.
  - *Fixed-effort* harvesting.
4. **Fixed-quota harvesting** (Fig. 15.7):

- Fragile equilibrium at MSY \((N_m \text{ at } h_m)\).
- 1 unstable equilibrium and 1 stable equilibrium at a lower *fixed-quota* harvest \((h_l)\).
5. **Fixed-effort** harvesting (Fig. 15.9):

- Safer than *fixed-quota* harvest. Stable equilibria:
  - \( H = qEN \)

  - where \( H \) = yield, \( N \) = harvested population size, \( E \) = harvesting effort, \( q \) = harvesting efficiency.
6. **Fixed-effort harvesting:**

- Multiple equilibria:
  - Variable recruitment leading to unstable equilibria Fig. 15.11
7. MSY models of harvesting:

• **Dynamic pool** models of harvesting:
  • **Surplus yield** models ignore population structure.
  • This is important because recruitment includes:
    • Adult survival & fecundity, juvenile growth & survival.
    • Harvesting usually most interested in mature age class.
  • Dynamic pool models *(Fig. 15.13)* estimate exploitable biomass and include:
    • 1. Recruitment rate
    • 2. Growth rate
    • 3. Natural mortality rate
    • 4. Fishing rate of exploited stock
8. Ecological Risk Assessment for the Use of Transgenic Plants:

- Three scales of perceived risk (unintended effects):
  
  1. **Gene**:
     - Potential for transfer of inserted DNA and consequences of expression in novel, hybrid or wild species.
  
  2. **Gene products**:
     - Adverse effects on non-target organisms.
  
  3. **Transgenic organism**:
     - Life history changes that can influence natural or managed habitats.
9. What are the primary risks?

- Invasion and Persistence into non-target locations:
  - These can include:
    - Non-target habitats.
    - Non-target crops.
  - Can pose a variety of problems:
    - Human health.
    - Conservation.
    - Biodiversity.
10. What are the processes by which plants invade and persist in non-target locations?

- These include:
  - Gene flow:
    - Primarily via pollen.
  - Resistance to natural enemy attack:
    - Predators.
    - Parasites.
    - Pathogens.
  - Superior competitors:
    - Intraspecific.
    - Interspecific.
11. Development of a risk assessment protocol for routine use:

- How do we assess invasion and persistence?
12. Demography of invasions:

• 3 phases:
  • 1. Colonization (Invasion):
    • Assumed to occur given routine agricultural use of large numbers of seeds.
  • 2. Establishment (Persistence):
    • Main focus!
  • 3. Spread (Hybridization):
    • Can be assessed from life history measurement.
13. Establishment:

- Three basic measures of population growth can be used in the absence of density-dependent constraints, these are:
  - 1. *Basic or net reproductive rate*, $R_0$
  - 2. *Finite rate of increase*, $\lambda$
  - 3. *Intrinsic rate of natural increase*, $r$
14. Finite rate of increase, $\lambda$, for the oilseed rape (canola) experiments:

- $\lambda_1 = (1 - d_1 - g) + g(1 - d_2)F$
  - $\lambda_1$ = proportion surviving + seeds produced by survivors.
  - where,
    - $d_1$ = proportion of seeds that die in one year
    - $g$ = proportion of seeds germinating in the first spring
    - $d_2$ = proportion of seeds that die over winter
    - $F$ = mean number of seeds produced per seed that germinates
  - A seed burial experiment estimated $d_1$ and seed sowing experiments estimated germination, plant survival and fecundity.
15. The oil seed rape (canola) example:

- From frequency distribution data:
  - Number of seeds produced per germinated seed ($F$) was 17.6 at one habitat in Berkshire.
  - Probability of seed germination ($g$) was 0.026.
  - Seed bank mortality was unknown.
- If all die in seed bank then finite rate of increase is:
  - $\lambda = gF = 0.026 \times 17.6 = 0.458$
  - Or, if the seed bank is completely viable then:
    - $\lambda = (1 - g) + gF = 0.974 + 0.026 \times 17.6 = 1.43$
- Because some seeds will die, $\lambda$ will lie between these extremes. Therefore data for the complete life cycle are needed to assess invasibility and persistence.
16. Results of Crawley et al. (1993):

- In the absence of interspecific competition, \( \lambda \) was very high:
  - 19.1, 15.7 and 11.5 for control, kanamycin- and glufosinate-tolerant genotypes.

- But \( \lambda \) was always <1 in the presence of competitors
  - Fig. 1.
Figure 15.1a: Population fluctuations and levels of equilibrium abundance and economic injury (EIL).
Figure 16.2 (3rd ed.): Economic injury level (EIL) defined as largest difference between crop value and cost of pest control with increasing pest density.
Table 16.6 (3rd ed.): Effects of harvesting on life history performance in blowflies.

Table 16.6 Effects produced in populations of the blowfly *Lucilia cuprina* by the destruction of different constant percentages of emerging adults. (After Nicholson, 1954b.)

<table>
<thead>
<tr>
<th>Exploitation rate of emerging adults (%)</th>
<th>Pupae produced per day <em>(a)</em></th>
<th>Adults emerged per day <em>(b)</em></th>
<th>Mean adult population <em>(c)</em></th>
<th>Mean birth rate (per individual per day) <em>(a / c)</em></th>
<th>Natural adult deaths per day <em>(d)</em></th>
<th>Adults destroyed per day <em>(e - b - d)</em></th>
<th>Accessions of adults per day <em>(e / c)</em></th>
<th>Mean adult life span (days) <em>(c / e)</em></th>
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<tr>
<td>0</td>
<td>624</td>
<td>573</td>
<td>2520</td>
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<td>712</td>
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<td>878</td>
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<tr>
<td>90</td>
<td>1361</td>
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<td>878</td>
<td>1.55</td>
<td>125</td>
<td>1134</td>
<td>126</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Figure 15.7: Maximum sustainable yield (MSY) at $N_m$ and equilibria generated by different fixed quota harvesting levels.

$u =$ unstable, $s =$ stable
Figure 5.8: Density-dependent effects on births and deaths and \( n \)-shaped recruitment.
Figure 16.12 (3rd ed.): Logistic population growth and highest harvest frequency at intermediate density with highest growth rate (c).
Figure 15.13: Dynamic pool flow model: