Relationship between age, size and reproduction in populations of American ginseng across a range of harvest pressures

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Overview

- Evolutionary implications of harvest
- Case studies from animal and plant species
- Evidence for selective harvest in American ginseng

Study details

- Methods
- Results
- Conclusions
Wild harvested species

All images from www.wikimedia.org
Harvest often targets specific phenotypes
Harvest can lead to evolutionary change in natural populations

Assuming portion of variation is genetically determined
CASE STUDY: declines in horn and body size linked to trophy hunting in bighorn rams, *Ovis canadensis*

CASE STUDY: Size selective harvest in fisheries can result in life history change

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Selection response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake whitefish, <em>Coregonus clupeaformis</em></td>
<td>Smaller body size; slower growth</td>
</tr>
<tr>
<td>Atlantic salmon, <em>Salmo salar</em></td>
<td>Smaller size at maturity</td>
</tr>
<tr>
<td>Pink salmon, <em>Oncorhynchus gorbuscha</em></td>
<td>Smaller size at maturity</td>
</tr>
<tr>
<td>Chinook salmon, <em>O. tshawytscha</em></td>
<td>Smaller size at maturity</td>
</tr>
<tr>
<td>European grayling, <em>Thymallus thymallus</em></td>
<td>Earlier age at maturity</td>
</tr>
<tr>
<td>Atlantic cod, <em>Gadus morhua</em></td>
<td>Earlier age at maturity</td>
</tr>
<tr>
<td>Orange roughy, <em>Hoplostethus atlanticus</em></td>
<td>Increased fecundity</td>
</tr>
<tr>
<td>European plaice, <em>Pleuronectes platessa</em></td>
<td>Earlier age at maturity</td>
</tr>
</tbody>
</table>

CASE STUDY: Decline in height of the harvested snow lotus, Saussurea laniceps

Similar declines observed in ginseng from herbarium specimens

Harvest of ginseng is size selective

1. Harvest often restricted to plants with 3 or more leaves
2. Harvesters are likely motivated to leave behind juvenile plants
   a) Larger plants yield more valuable roots
   b) Traditional conservation ethics
3. Larger plants are more apparent

Is variation in size genetically determined?

- Germplasm bank planted by Bob Beyfuss
- Plants collected from wild populations in eight states
- Differences in leaf area and sympodium height persisted
Research Question

Do life-history traits vary among populations with different harvest pressures?
### How to assess harvest pressure?

<table>
<thead>
<tr>
<th>Method</th>
<th>Potential Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask harvesters</td>
<td>...potential for bias</td>
</tr>
<tr>
<td>Monitor population</td>
<td>...harvest infrequent</td>
</tr>
<tr>
<td>Legal status of location</td>
<td>...poaching common</td>
</tr>
<tr>
<td>Stage-structure impacts</td>
<td></td>
</tr>
</tbody>
</table>

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Experimental harvest


HARVEST INDEX

\[ \text{HARVEST INDEX} = \frac{\text{Seedlings} + \text{Juveniles}}{N} \]
Study populations

[Map showing study populations in IN, WV, PA, NY, MD, VA, and potentially other states indicated by stars.]
Data collection

- 2004-2006
- Size
  - Sympodium (stem) height
  - Leaf area
- Reproductive data
  - Flowering (Y/N)
  - Seed production (Y/N)
  - Number of seeds
- Age
- Frequency of deer browse
Aging plants using stem scars

Camera lucida drawings from www.fws.gov
Data analysis

- Regression with model effects:
  - Age
  - Harvest Index
  - Age X Harvest Index
- Correlation between deer browse and Harvest Index
- Statistical software: SAS JMP v. 6.0

## Results

<table>
<thead>
<tr>
<th>Population</th>
<th>Location</th>
<th>N</th>
<th>Harvest Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC</td>
<td>Vermillion Co, IN</td>
<td>173</td>
<td>0.4122</td>
</tr>
<tr>
<td>EP</td>
<td>Lancaster Co, PA</td>
<td>99</td>
<td>0.4173</td>
</tr>
<tr>
<td>EB</td>
<td>Preston Co, WV</td>
<td>46</td>
<td>0.5057</td>
</tr>
<tr>
<td>HP</td>
<td>Albany Co, NY</td>
<td>280</td>
<td>0.5286</td>
</tr>
<tr>
<td>CC</td>
<td>Garrett Co, MD</td>
<td>154</td>
<td>0.6538</td>
</tr>
<tr>
<td>LK</td>
<td>Franklin Co, PA</td>
<td>349</td>
<td>0.6879</td>
</tr>
<tr>
<td>GB</td>
<td>Greenbrier Co, WV</td>
<td>123</td>
<td>0.7213</td>
</tr>
<tr>
<td>TP</td>
<td>Albany Co, NY</td>
<td>62</td>
<td>0.7235</td>
</tr>
<tr>
<td>TR</td>
<td>Parke Co, IN</td>
<td>133</td>
<td>0.7802</td>
</tr>
<tr>
<td>PO</td>
<td>Bedford Co, VA</td>
<td>300</td>
<td>0.7829</td>
</tr>
<tr>
<td>AD</td>
<td>Mercer Co, WV</td>
<td>75</td>
<td>0.8486</td>
</tr>
<tr>
<td>RD</td>
<td>Pulaski Co, VA</td>
<td>129</td>
<td>0.9583</td>
</tr>
</tbody>
</table>

Table 1: Study populations, their locations by county, mean population sizes over 2004-2006, and harvest indices.
Results

\[ r = 0.2348, \ p = 0.4871 \]
Results
Results

Table 2: Regression results for 2006

<table>
<thead>
<tr>
<th>N</th>
<th>Model Term</th>
<th>F ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>650</td>
<td>Age</td>
<td>908.905</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Harvest Index</td>
<td>6.756</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Age X Harvest Index</td>
<td>10.739</td>
<td>0.001</td>
</tr>
</tbody>
</table>

![Graph showing the relationship between predicted leaf area and age for different harvest indices.](image-url)
### Results

#### Table 3: Regression results for 2006

<table>
<thead>
<tr>
<th>N</th>
<th>Model Term</th>
<th>F ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>653</td>
<td>Age</td>
<td>300.699</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Harvest Index</td>
<td>0.262</td>
<td>0.609</td>
</tr>
<tr>
<td></td>
<td>Age X Harvest Index</td>
<td>12.046</td>
<td>0.001</td>
</tr>
</tbody>
</table>

![Graph showing predicted sympodium height vs age for different harvest indices]

**Harvest Index**
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9

**Predicted sympodium height (cm)**

**Age**
### Results

Table 4: Regression results describing the relationship between age and reproductive traits for plants in the 12 study populations.

<table>
<thead>
<tr>
<th>Year</th>
<th>Reproductive?</th>
<th>Produced Seeds?</th>
<th>Number of seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>( \chi^2 = 11.985, \ p=0.001 )</td>
<td>( \chi^2 = 2.510, \ p=0.113 )</td>
<td>( F=3.293, \ p=0.074 )</td>
</tr>
<tr>
<td>2005</td>
<td>( \chi^2 = 44.953, \ p&lt;0.0001 )</td>
<td>( \chi^2 = 13.630, \ p=0.0002 )</td>
<td>( F=2.383, \ p=0.125 )</td>
</tr>
<tr>
<td>2006</td>
<td>( \chi^2 = 50.293, \ p &lt;0.0001 )</td>
<td>( \chi^2 = 4.390, \ p=0.036 )</td>
<td>( F=1.780, \ p=0.185 )</td>
</tr>
</tbody>
</table>

Likelihood of inflorescence production consistently increased with age

Age did not consistently predict seed production
Table 5: Regression results describing the relationship between harvest index and reproductive traits for plants in the 12 study populations.

<table>
<thead>
<tr>
<th>Year</th>
<th>Reproductive?</th>
<th>Produced Seeds?</th>
<th>Number of seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>$\chi^2 = 3.259, p=0.071$</td>
<td>$\chi^2 = 4.740, p=0.029$</td>
<td>$F=2.714, p=0.104$</td>
</tr>
<tr>
<td>2005</td>
<td>$\chi^2 = 2.582, p=0.108$</td>
<td>$\chi^2 = 0.580, p=0.446$</td>
<td>$F=23.041, p&lt;0.0001$</td>
</tr>
<tr>
<td>2006</td>
<td>$\chi^2 = 0.078, p=0.780$</td>
<td>$\chi^2 = 22.630, p&lt;0.0001$</td>
<td>$F=23.594, p&lt;0.0001$</td>
</tr>
</tbody>
</table>

*Harvest index reduced likelihood of seed production in several study years*
Conclusions

- Populations with higher harvest indices had plants with smaller leaf areas and sympodium heights
  - Appears to be the product of slower growth
  - Consistent with the effects of size selective harvest
Conclusions

- Seed set and number of seeds was reduced in plants from populations with higher harvest indices
  - Not necessarily the product of size selective harvest
  - Allee effect
  - Similar density-dependent reductions in fecundity observed in fisheries

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