Dynamic Pool models

- Yield-per-recruit
  - Beverton-Holt
  - Ricker
- SSB-per-recruit
- eggs-per-recruit
- Section 7.7 in text

Dynamic pool models

Primary difference from surplus production models:

- Dynamic pool models account for variable growth, mortality, and reproductive potential by age
- Currently used to examine reproduction and recruitment potential

Dynamic pool models

How they work:

- Consider explicitly how growth and mortality affect stock biomass and reproductive potential
- First, stock biomass is separated into age-specific components,
- The model then calculates effects of growth and mortality on each age-specific component,
- Last, all age-specific component effects are summed
Yield-per-recruit models

- Examine trade-off between capturing many small fish early in their life vs. less larger fish later in life
- If F is set too high, many fish will be harvested before they have had a chance to grow to large body sizes
- This is termed ‘growth overfishing’

Yield-per-recruit models

- If F is set too low, large fish will be captured but total yield will be low due to low numbers of fish harvested

Thus, age at harvest must be traded-off against harvest rate because growth and mortality vary with age differently

Fig. 7.11
Yield-per-recruit models

- Yield assumed to depend on growth, age at first capture and fishing mortality
- Effects of recruitment added later

Yield-per-recruit models

- Consider the biomass of a stock \( (N \times \text{average wgt}) \) present at any time,
- The yield from that stock at a given time is the biomass \( (B) \times \) the instantaneous fishing mortality rate \( (F) \)

So we have:

\[
Y_t = F_t N_t W_t
\]
Yield-per-recruit models

\[ Y_t = F_t N_t W_t \]

Over the course of a time period,

\[ Y = \sum_{t_c}^{t_{max}} F_t N_t W_t \]

Where \( t_c \) and \( t_{max} \) are ages at first capture and maximum age respectively.

Yield-per-Recruit Calculations

<table>
<thead>
<tr>
<th>Age</th>
<th>Wgt</th>
<th>N alive</th>
<th>Biomass (kg)</th>
<th>Catch (n)</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6</td>
<td>100</td>
<td>60</td>
<td>41</td>
<td>25</td>
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<tr>
<td>2</td>
<td>0.9</td>
<td>45</td>
<td>40</td>
<td>19</td>
<td>17</td>
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<tr>
<td>3</td>
<td>2.1</td>
<td>20</td>
<td>42</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>4.1</td>
<td>9</td>
<td>37</td>
<td>4</td>
<td>15</td>
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<tr>
<td>5</td>
<td>6.3</td>
<td>4</td>
<td>26</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>8.4</td>
<td>2</td>
<td>15</td>
<td>1</td>
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<tr>
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<td>1</td>
<td>8</td>
<td>0.3</td>
<td>3</td>
</tr>
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<td>8</td>
<td>11.2</td>
<td>0.4</td>
<td>4</td>
<td>0.2</td>
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<tr>
<td>9</td>
<td>12.6</td>
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<td>2</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>13.5</td>
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<td>1</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td></td>
<td>237</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sum/R</td>
<td></td>
<td>2.37</td>
<td>0.98</td>
<td></td>
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</tbody>
</table>

With \( F = 0.6 \) and \( M = 0.2 \)

Yield-per-Recruit Calculations

<table>
<thead>
<tr>
<th>F</th>
<th>Y/R</th>
<th>B/R</th>
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</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0</td>
<td>21.46</td>
</tr>
<tr>
<td>0.1</td>
<td>1.12</td>
<td>12.94</td>
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<td>1.36</td>
<td>8.27</td>
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<td>1.32</td>
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<td>0.4</td>
<td>1.2</td>
<td>4.00</td>
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<tr>
<td>0.5</td>
<td>1.08</td>
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<tr>
<td>0.6</td>
<td>0.98</td>
<td>2.37</td>
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<tr>
<td>0.7</td>
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<tr>
<td>0.8</td>
<td>0.83</td>
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<td>0.9</td>
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<tr>
<td>1.0</td>
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<td>1.26</td>
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</tbody>
</table>
Yield-per-recruit models

Advantages:
- Both F and M are explicit in the model
- Increased biological realism
- Avoid having to address year-to-year variation in recruitment
- Can see effects of F and Age of Entry on age and size in the catch
### Yield-per-recruit models

#### Limitations/Assumptions:
- Constant recruitment is assumed
- This assumes age-structure remains stable
- Ignore any temporal variation in F and M
- Stable environment
- No density-dependence in growth and mortality

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### Yield-per-recruit models

- Yield-per-Recruit is good for determining if ‘growth overfishing’ is occurring
- But, since the models assume constant recruitment, they can’t detect ‘recruitment overfishing’
  
  This is when the fish population is fished so hard that an adequate number of recruits is not produced

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### Yield-per-recruit models

- In order to deal with the potential for ‘recruitment overfishing’:
  
  - We need to incorporate stock-recruitment relationships
  
  - Remember, our replacement line (SSB per R) is a function of F
    - High F = low SSB per R
    - Low F = high SSB per R
Reproductive Potential models

- Examine changes in other life parameters from effects of fishing mortality rate

- Yield may be fine, but stock could be overfished in terms of its ability to replenish itself

- These models examine effects of fishing on reproductive potential of remaining stock
Reproductive Potential models

Spawning Stock Biomass per Recruit (SSB/R)

• Examine stock biomass remaining after fishing and estimate fraction mature
• Sum contribution to SSB at each age
• Max SSB/R occurs at $F = 0$ (virgin population) and SSB/R evaluated in terms of fraction of Max
• SSB/R at each $F$ results in replacement line with slope of $R/SSB$

Reproductive Potential models

Eggs per Recruit (EPR)

• Examine stock biomass remaining at each age, percent maturity, and fecundity
• Sum lifetime egg production at each age
• Max EPR occurs at $F = 0$ (virgin population) and EPR evaluated in terms of fraction of Max
• Often used to evaluate variable age-0 survival by altering the seed number of age-1 recruits
• Does increased age-0 survival offset higher $F$?