Causes of performance differences between scallop culture in Peru and Chile: a bio-economical modelling approach

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Master Thesis
Master in Marine and Lacustrine Science and Management
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Causes of performance differences between scallop culture in Peru and Chile: a bio-economical modelling approach
• $T_{\text{summer}} = 22^\circ\text{C}$

• $T_{\text{summer}} = 19^\circ\text{C}$

Peru: Taylor et al., 2008
Chile: Wolfgang Stotz, 2000
• Scallop density = phase-depending

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Materials & Methods

• Use R
  → Create dynamic model
  → Easy implementation of other functions

• Scallop-function
  – Initial seed size → 30 mm vs. 10 mm
  – Starting stock → 2.88 million vs. 15 million
The Model

- Ecological Element
- Economic Element
- Decision Element
The Model

• Growth $\rightarrow$ Von Bertalanffy

\[
\frac{dL}{dt} = K \cdot (L_\infty - L(t))
\]

Ecological Element

Economic Element

Decision Element

N = 2.88 million
Seed = 30 mm
The Model

- Growth $\rightarrow$ Von Bertalanffy
  \[ \frac{dL}{dt} = K \times (L_\infty - L(t)) \]
- Stock population $\rightarrow$ Mortality
  \[ \frac{dN}{dt} = -Z \times N(t) \]

N = 2.88 million
Seed = 30 mm
The Model

- Growth $\rightarrow$ Von Bertalanffy
  \[
  \frac{dL}{dt} = K \times (L_\infty - L(t))
  \]

- Stock population $\rightarrow$ Mortality
  \[
  \frac{dN}{dt} = -Z \times N(t)
  \]

- Biomass
  \[
  B(t) = \text{Weight}(t) \times N(t)
  \]
The Model

- **Ecological Element**
  - Total Initial Cost (TIC)
    - buying seed
    - seedling

- **Economic Element**
  - Operation Expenses (OE)
    - guard
    - maintenance
    - boat
    - harvest cost & material cost → depend on n° of scallops

- **Decision Element**
  - Total Operation Cost (TOC)
    - $T_{OC_{Peru}} = \text{Cost} (t = H) + \Delta HC$
    - $T_{OC_{Chile}} = \text{Cost} (t = H) + \Delta CM$

=> PROFIT = Total Sales - TOC
The Model

<table>
<thead>
<tr>
<th>Size scallops</th>
<th>Stocking density</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20 mm</td>
<td>30 %</td>
</tr>
<tr>
<td>20 – 30 mm</td>
<td>50 %</td>
</tr>
<tr>
<td>30 – 40 mm</td>
<td>65 %</td>
</tr>
<tr>
<td>&gt; 40 mm</td>
<td>80 %</td>
</tr>
</tbody>
</table>

- **Total Initial Cost (TIC)**
  - purchase of seed
  - seedling

- **Operation Expenses (OE)**
  - guard
  - maintenance
  - boat
  - harvest cost & material cost

- **Total Operation Cost (TOC)**

- **Profit** = Total Sales - TOC

- **Model Size scallops Stocking density**
  - Stocking density < 20 mm: 30%
  - Stocking density 20 – 30 mm: 50%
  - Stocking density 30 – 40 mm: 65%
  - Stocking density > 40 mm: 80%
The Model

- **Ecological Element**
  - Total Initial Cost (TIC)
    - buying seed
    - seedling

- **Economic Element**
  - Operation Expenses (OE)
    - guard
    - maintenance
    - boat
    - harvest cost & material cost
      \( \rightarrow \) depend on n° of scallops

- **Decision Element**
  - Total Operation Cost (TOC)
    \( TOC_{\text{Peru}} = Cost(t = H) + dHC \)
    \( TOC_{\text{Chile}} = Cost(t = H) + dCM \)

\[ \Rightarrow \text{PROFIT} = \text{Total Sales} - \text{TOC} \]
The Model

- Harvest time → Profit

Ecological Element

Economic Element

Decision Element
The Model

- **Ecological Element**
- **Economic Element**
- **Decision Element**

**Net Present Value**

\[
NPV(i, N) = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}
\]

- Harvest time $\rightarrow$ Profit
The Model

- Harvest time → Profit
- Net Present Value
  \[ NPV(i, N) = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} \]
- Internal Rate of Return
Comparison

**Peru**
- N = 2.88 million
- Seed = 30 mm
- Size = 84 mm
- Stock = 2 million
- Profit = 300,000 US$
- Wait 2 years:
  - Yearly profit = 16,300 US$

**Chile**
- N = 2.88 million
- Seed = 30 mm

Graphs showing the total profit per year vs. the moment of harvest in years.
Comparison

<table>
<thead>
<tr>
<th>Country</th>
<th>Seed (mm)</th>
<th>Total Profit (N million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peru</td>
<td>30</td>
<td>2.88</td>
</tr>
<tr>
<td>Chile</td>
<td>10</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Profit after 1 year:
- Peru: 300,000 US$
- Chile: 72,000 US$
Comparison

- N = 15 million
- Size = 10 mm

Results

Peru vs. Chile (2)

Profit after 1 year:
- 66% of stock
- 80 mm
- 1,200,000 US$
Discussion & Conclusion

• Low investment cost in Peru
  → low threshold

• Employment vs. Carrying Capacity
Future Modelling

• Nutrient availability
• Growth data from Chile

• Multiple cohorts in one year
  » Peru: 2 cohorts
  » Chile: 6 cohorts

  » NPV & IRR comparison
  » 30 fishermen work in 1 lote