Moving from Fisheries Economics to Ocean Economics
Expanding bioeconomic fisheries models

Claire W. Armstrong, et al.

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Moving from Fisheries Economics to Ocean Economics
Expanding bioeconomic fisheries models

Claire W. Armstrong and MANY more!
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AARES, Canberra, 2016
Video picture from Sørmannsneset, Norway, 220 m depth (16. mai 1998), showing the crushed remains of Lophelia cold water coral spread over the area, due to trawling.

30-50% of CWC habitats in Norwegian waters have been destroyed or impacted (Fosså et al. 2002, *Hydrobiologia*)
Aims

- Broader bioeconomic model than purely fisheries
- Ecosystem based – include habitat
- Ecosystem services – include non-use values of habitat

=> Combine valuation and bioeconomic modelling for more holistic model of marine ecosystem service
Model of endogenous habitat change

- Fishery-habitat interaction; growth and cost
- Two gear types – habitat destructive and non-destructive
- Non-renewable habitat
\[ \Pi = \int_{0}^{\infty} e^{-\delta t} \left[ (p - c_1(X, H))h_1 + (p - c_2(X, H))h_2 \right] dt \]

\[ \frac{dX}{dt} = F(X) - h_1 - h_2 \]

a) Habitat is preferred

\[ \frac{dX}{dt} = F(X, H) - h_1 - h_2 \]

b) Habitat is essential

\[ \frac{dH}{dt} = -\alpha h_1 \]

Nonrenewable habitat

\[ X \] is the biomass of fish stock
\[ H \] is the habitat
\[ F \] is the stock growth
\[ h_i \] is harvest (i harvesters; 1 and 2)
\[ c_i \] is unit cost of harvest
\[ p \] is unit price of harvest
\[ \alpha \] is the coefficient of habitat destruction perpetrated by harvest type 1
\[ \delta \] is the discount rate

Kahui et al (forthcoming Land Economics), based on Swallow in JEEM (1990)
Steady state analysis – preferred model
Steady state analysis – preferred and essential models
So far CWC as habitat provider…

But what other services might cold water corals supply?
Components of TEV associated with CWC

**TOTAL ECONOMIC VALUE (TEV)**

**USE VALUES**
- Direct Use
  - Consumables
  - Jewellery
- Indirect Use
  - Functional Values
  - Habitat/Carbon sequestration

**NON-USE VALUES**
- Bequest
  - Benefit for future generations
- Existence
  - Cultural Aesthetic

**Option**
- Future direct or indirect values
  - Bioprospecting
  - Tourism
Existence values
Existence values
How manage fisheries when taking into account these values?
Adding non-fishery values $V(H)$:

$$\Pi = \int_{0}^{\infty} e^{-\delta t} \left[ (p - c_1(X, H))h_1 + (p - c_2(X, H))h_2 + V(H) \right] dt$$

$$\frac{dX}{dt} = F(X) - h_1 - h_2$$

Habitat is preferred

$$\frac{dH}{dt} = -\alpha h_1$$

Nonrenewable habitat

But what functional form does $V(H)$ have, if it exists?

- $F(X,H)$ is the stock growth
- $X$ is the biomass of fish stock
- $H$ is the habitat
- $h_i$ is harvest (i harvesters; 1 and 2)
- $c_i$ is unit cost of harvest
- $p$ is unit price of harvest
- $\alpha$ is the coefficient of habitat destruction perpetrated by harvest type 1
- $\delta$ is the discount rate
- $V(H)$ is the non-use value function
“I don’t know why I don’t care about the bottom of the ocean, but I don’t.”
Discrete Choice Experiment - workshops
Bottom trawling may have damaged 30-50% of CWC in Norway.

- Slow growing; 4-25mm/year
- 2445 km² protected
- Not allowed to damage on purpose
### DISCRETE CHOICE EXPERIMENT

<table>
<thead>
<tr>
<th></th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3 (no change)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size of protected areas</strong></td>
<td>5.000 km²</td>
<td>10.000 km²</td>
<td>2.445 km²</td>
</tr>
<tr>
<td><strong>Attractive for industry</strong></td>
<td>Attractive for oil/gas</td>
<td>Attractive for fisheries</td>
<td>To some degree for both</td>
</tr>
<tr>
<td><strong>Importance as habitat for fish</strong></td>
<td>Not important</td>
<td>Important</td>
<td>To some degree</td>
</tr>
<tr>
<td><strong>Cost per household per year to protect more cold water coral areas</strong></td>
<td>100 kr/year</td>
<td>1000 kr/year</td>
<td>0</td>
</tr>
</tbody>
</table>

I prefer

22 municipalities * 20 participants * 12 choice cards = 4800 choices

- average willingness to pay to protect more cold water coral
- preferences for what factors should be emphasised
Marginal willingness to pay (WTP) in EUR per household using the Mixed logit model.

***, ** and * indicate estimates significant at 1%, 5% and 10% levels, respectively.

<table>
<thead>
<tr>
<th></th>
<th>Marginal WTP (EUR)</th>
<th>s.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size small (5000 km²)</td>
<td>35.0046***</td>
<td>8.7921</td>
</tr>
<tr>
<td>Size large (10 000 km²)</td>
<td>51.5938***</td>
<td>9.6956</td>
</tr>
<tr>
<td>Oil/gas</td>
<td>10.6724</td>
<td>6.2237</td>
</tr>
<tr>
<td>Fishing</td>
<td>19.4476*</td>
<td>7.2791</td>
</tr>
<tr>
<td>Habitat</td>
<td>163.5352***</td>
<td>10.3174</td>
</tr>
</tbody>
</table>

Max logLikelihood = -3424, AIC/n =1.4961, pseudo R² = 0.3255,
n (observations) = 4683

Aanesen et al Ecol Econ (2014)
People willing to pay, but...

Size matters

Don’t care

Really care
\[ PVNB = \int_0^\infty e^{-\delta t} \left[ (p - c_1(X, H))h_1 + (p - c_2(X, H))h_2 + V(H) \right] dt \]

\[ \frac{dX}{dt} = F(X) - h_1 - h_2 \quad \text{a) Habitat is preferred} \]

\[ \frac{dH}{dt} = -\alpha h_1 \quad \text{Nonrenewable habitat} \]

\[ V(H) = b \log H + \gamma \quad \text{Non use value} \]

\[ F(X, H) \] is the stock growth
\[ X \] is the biomass of fish stock
\[ H \] is the habitat
\[ h_i \] is harvest (i harvesters; 1 and 2)
\[ c_i \] is unit cost of harvest
\[ p \] is unit price of harvest
\[ \alpha \] is the coefficient of habitat destruction perpetrated by harvest type 1
\[ \delta \] is the discount rate
\[ V(H) \] is the non-use value function
\[ b \] and \[ \gamma \] are constants

Hammond and Brown (1974) and Rondeau in JEEM (2001)
Steady state analysis – Preferred model for CWC and North East Arctic cod fishery data
Steady state analysis – Preferred model for CWC and North East Arctic cod fishery data and non-use values
$H^*(X)$ Preferred

$H^*(X)$ w/non-use values

$X^*(H)$ Preferred

$X^*$

$0$

$H^*$
Including 1.3% of the EU population
This raises some issues:
We have to a large degree solved (or at least understand) «the tragedy of the commons» in fisheries.

1. But what about «the tragedy of common habitats»?
2. How are we incorporating the broader ecosystem services in our fisheries management?
3. Are we including the broader public values or just stakeholder values?
4. Do we have governance systems that enable a more holistic management?
Thanks to:

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- The Research Council of Norway
‘Challenging new frontiers in the global seafood sector – a Northern Enlightenment’

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