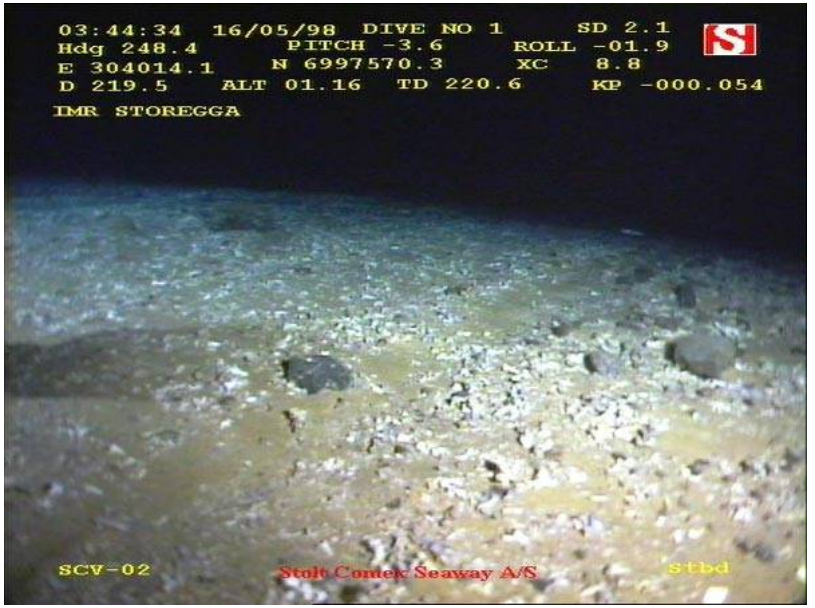
Habitat-fisheries interactions and destructive fishing

Eirik Mikkelsen, Norut Northern Research Institute
Claire Armstrong, UiT-The Arctic University of Norway



Photos:
IMR Norway

norut
NORTHERN RESEARCH INSTITUTE

UNIVERSITY OF TROMSØ

UiT / THE ARCTIC UNIVERSITY OF NORWAY

- **Fisheries depend on** the state of **habitats**
  - Botsford et al 1997 Science, Lindholm et al 2001 CB, Seitz et al 2014 IJMS…
- Some **fishing** practises **harm habitat**
  - Rodwell et al 2003 CJFAS, Jørgensen et al 2015 IJMS, Auster 1998 CB, Kaiser et al 2002 F&F…
- Some HFI bioeconomy studies /reviews..
  - Knowler 2002 JoBE, Barbier 200 EE, Foley et al 2012 IJoE, Kahui et al 2016 LE

Types of habitat-fisheries interactions

- **Biophysical**
  - Growth rate of fish stock
  - Carrying capacity
- **Bioeconomic**
  - Unit costs of fishing / catchability of fish stock
  - Price of fish

(Based on Foley et al 2012 IJoE)

Basic model

- **Gordon-Schaefer** biomass-based fisheries economic model **with growth depending on habitat** (biophysical model)
- **Fishing is habitat-destructive - or not**
- Fisheries manager maximises profits by setting effort
- We consider **steady state** fishing effort, harvest, fish stock, habitat stock, profits

Questions

1. How does the habitat-interaction *basically* influence the fishery?
2. What if destructive fishing gear is *inadvertently* introduced?
3. How *should* destructive fishing gear be managed?
4. Criteria for real cost-efficiency improvements with destructive fishing gear and habitat-interactions?
5. Cost of ignorance / value of knowledge about habitat-interactions and destructivity of fishing?

Basic model

- Fish stock:
  - $\dot{x} = rx\left(1 - \frac{x}{K}\right) + \beta xy - q_i E_i x$
- Habitat stock:
  - $\dot{y} = gy\left(1 - \frac{y}{R}\right) - \gamma E_2 y$
- Profits:
  - $\pi = px(q_i E_i) - c_i E_i$

i=1,2
i=2 → Destructive fishing

Habitat-fisheries interaction

Habitat-destruction of fishing effort of «fleet 2»

i.e. a **Biophysical** interaction, affecting fish stock growth
NOT Bioeconomic affecting unit costs, catchability or price)

How does the habitat-interaction *basically* influence the fishery?

- The fish stock's **effective** intrinsic growth rate **and** carrying capacity are adjusted
- «Effective r» → $r(1+\frac{\beta y}{r})$
- «Effective K» → $K(1+\frac{\beta y}{r})$

B = interaction parameter
y= habitat stock

- **Higher** effort, harvest, fish stock, profits **compared to «standard model»** even for a non-destructive fishing fleet

What if a destructive fishing fleet is *inadvertently* introduced?

- Manager sets effort unaware of this
- Destroy habitat → reduces fish stock (growth)
  - Steady state habitat: $R\left(1-\frac{\gamma r}{2gq_2}\left(1+\frac{\beta R}{r}-\frac{c_2}{pq_2K}\right)\right)$
  - Steady state fish stock is lower the stronger the interaction/ destructivity is.
- If unit cost ***c*** and catchability ***q*** same as non-destructive fleet:
- **Lower steady state fish stock, habitat stock, profits and harvest** than with non-destructive fleet

How *should* a destructive fishing fleet be managed?

- Set fishing effort considering habitat-interaction and destructivity:
  - $E_2 = \frac{r}{2q_2\left(1+\frac{R\beta\gamma}{q_2 g}\right)}\left(1+\frac{\beta R}{r}-\frac{c_2}{pq_2K}\right)$

«Reduction-factor»

Reduction should be larger with larger..
- Habitat size *R*
- Interaction term *β*
- Destructivity *γ*

..and with lower habitat intrinsic growth rate *g*

- For same *c* and *q* values as non-destructive fleet:
  - Steady state **habitat larger than when ignorant**, but not pristine
  - Steady state **fish stock same** as with **non-destructive fleet**
  - **Harvest and profits reduced** (by same factor as effort)

Criteria for real cost-efficiency improvements with destructive fishing gear and habitat-interactions?

- Classic / simple cost-efficiency measure:
  - $\frac{q_2}{c_2} > \frac{q_1}{c_1}$

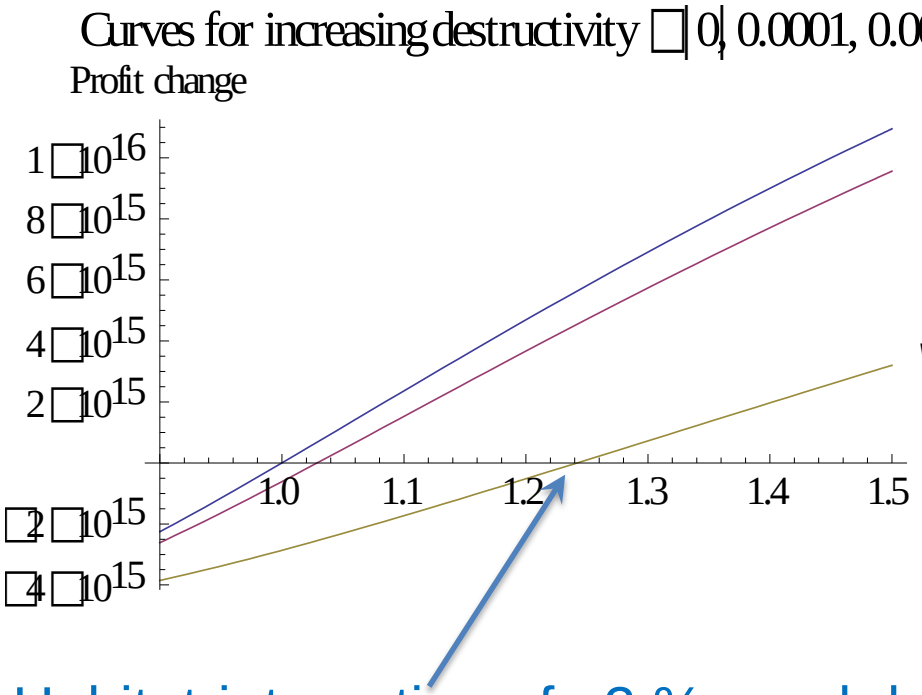
But this ignores habitat-interaction and destructivity!

- Profit-change with destructive fishing:
  - $\frac{rpK}{4\left(1+\frac{R\beta\gamma}{q_2 g}\right)}\left(1+\frac{\beta R}{r}-\frac{c_2}{pq_2K}\right)^2-\frac{rpK}{4}\left(1+\frac{\beta R}{r}-\frac{c_1}{pq_1K}\right)^2 > \mathbf{0}$
- Let:
  - $\frac{q_2}{c_2} = \frac{\alpha\, q_1}{\mu\, c_1}$
  - If $\alpha/\mu > 1$, increased cost-efficiency in oversimplified measure

Criteria for real cost-efficiency improvements with destructive fishing gear and habitat-interactions? (2)

- Criteria for cost-efficiency improvement:
  - $\frac{R\beta\gamma}{g} < \alpha q_1 \left[\frac{\left(1+\frac{\beta R}{r}-\frac{\mu c_1}{p\alpha q_1 K}\right)^2}{\left(1+\frac{\beta R}{r}-\frac{c_1}{p q_1 K}\right)^2} - 1 \right]$
  - Can't totally separate relevant parameters
  - Can use for numerical calculations
- But see that: **Less likely** fulfilled if **large habitat**, **strong interaction**, **strong destructivity**, **low habitat intrinsic growth rate**

Numerical illustration cost-improvement Cod in Barents Sea



γ=0

γ=0.0001

γ=0.001(0.1%)

Habitat:
β=0.02 (2%)
R=1
g=0.2

Varies catchability coeff. *q.*
Unit cost *c* constant.

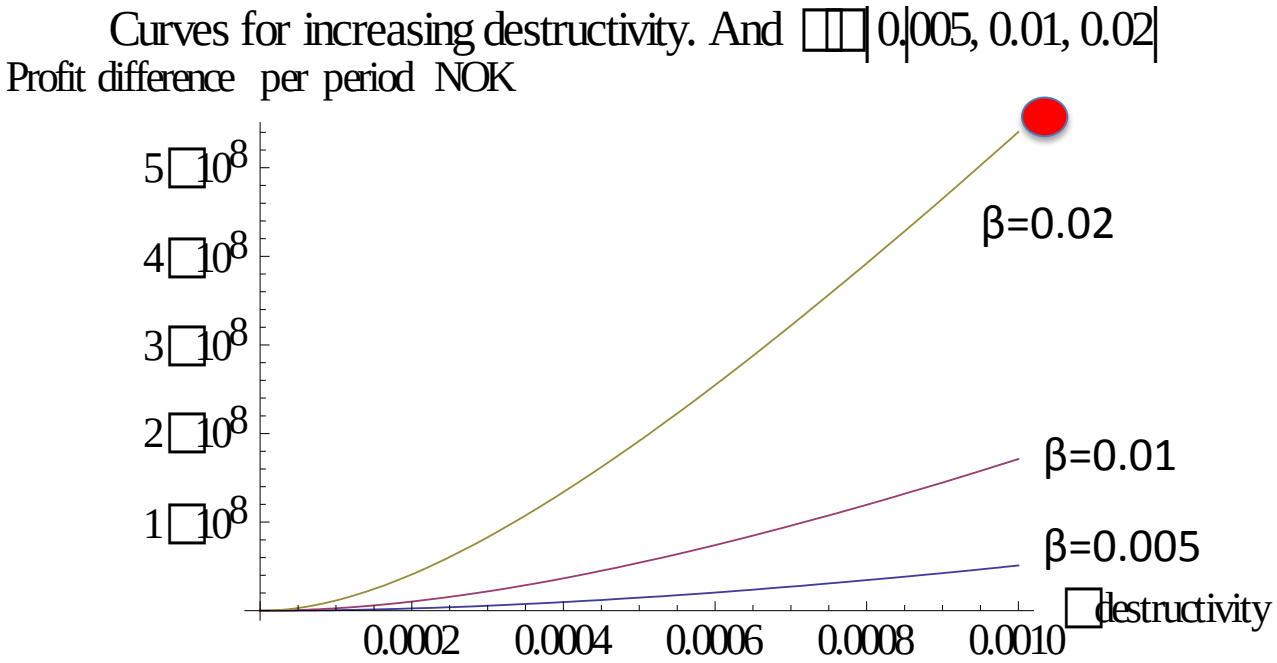
- Habitat-interaction of «2 %» and destructivity of «0.1 %» means crude cost-efficiency increase must be +25 % for actual efficiency increase

- **Data**: **Kahui et al 2016: *Land Economics.*** Bioeconomic Analysis of Habitat-fishery connections: Fishing on Cold-Water Coral Reefs. **+ guesstimates**

Cost of ignorance / value of knowledge about habitat-interactions and destructivity of fishing?

- …= Profit-difference optimally vs ignorantly managed destructive fishing fleet:
  - $\Delta\pi = \frac{1}{\left(1+\frac{\boldsymbol{R\beta\gamma}}{q_2\boldsymbol{g}}\right)}\left[\left(\frac{\boldsymbol{R\beta\gamma}}{q_2\boldsymbol{g}}\right)^2 \frac{rpK}{4}\left(1+\frac{\boldsymbol{\beta R}}{r}-\frac{c_2}{pq_2K}\right)^2\right]$ (per period)
- Increases with increasing destructivity *γ*, and with falling habitat growth rate *g*.
  - For interaction parameter *β* and habitat carrying capacity *R*, it depends…

Numerical illustration cost of ignorance Cod in Barents Sea



Habitat:
R=1
g=0.2

- = Annual loss of 540 Mill NOK ~ 63.5 Mill. US$
- NPV at 5% discount rate: 11.3 Bill NOK ~ 1.33 Bill US$
- **Data**: **Kahui et al 2016: *Land Economics.*** Bioeconomic Analysis of Habitat-fishery connections: Fishing on Cold-Water Coral Reefs. **+ guesstimates**

Summing up

- A Gordon-Schaefer type model with positive habitat-fisheries interaction
- Measure real cost-effefficiency differences of destructive vs non-destructive fishing
- Cost of ignorance / Value of knowledge
- Non-use/existence values of habitat not considered

Thank you!

Questions?

Eirik.mikkelsen@norut.no

www.norut.no

Financing from the Norwegian Research Council gratefully acknowledged!