MANAGING NORTHERN BALTIC SALMON FISHERIES UNDER SOCIAL-ECOLOGICAL COMPLEXITY
CONTENTS

Introduction to the conflict between sequential salmon fisheries

Description of the bioeconomic model

Ecological and economic implications of ignoring behavioral complexity of anglers
THE MIGRATION ROUTES AND FISHERIES OF RIVER TORNIJOKI SALMON STOCK
COMMERCIAL SALMON FISHERY IN DECLINE

Finnish marine commercial salmon catch

Source: Natural Resources Institute Finland, Fishery total
SALMON ANGLING GAINS POPULARITY

Salmon catch taken by anglers at River Tornionjoki (kilograms)

- Sweden
- Finland

Source: Natural Resources Institute Finland
SALMON SPAWNING RUN

Number of salmon

Date

Natural Resources Institute Finland
www.luke.fi/nousulohet
How the optimal management of the commercial fishery depends on the recreational fishery?

What are the implications of ignoring angling and the behavioral complexity of angling?
THE BIOECONOMIC MODEL

Direct effect: Commercial effort decreases the fish available for anglers

Indirect effect: Angling effort decreases the number of spawners

Salmon age-structured population dynamics

Discounted net present value of salmon coastal fishery

Anglers update number of trips and their type: Effort and catch oriented anglers

Satisfaction per angling trip

Stay home or go fishing

Need the money.

Enjoy the nature!

More is more!
MODEL SPECIFICATIONS

Age-structured population model
• Leslie matrix model with 10 age-classes
• Beverton-Holt stock-recruitment relationship

Optimized commercial trap-net fishery
• Commercial fishermen are profit maximizers
• Dynamic optimization is used to define the commercial effort through time

Recreational fishery
• Type-specific utilities based on valuation studies
• Anglers decide whether to stay home or go fishing based on the satisfaction of previous angling trip
• Socialization defines the frequency of angler types through time
ATTRIBUTES OF

1. EFFORT ORIENTED ANGLERS
   - Enjoy the nature
   - Strong preference for solitude

2. CATCH ORIENTED ANGLERS
   - Prefer to catch something
   - Slight preference for solitude
SCENARIOS

1. No recreational fishing
   A hypothetical scenario to see what is the optimal level of commercial effort when there is no angling

2. Static recreational fishing
   A scenario that mimics the current ICES salmon assessment model, where recreational fishing is described by a constant mortality

3. Endogenous recreational fishing with angler behavioral complexity
   Recreational fishing effort is endogenously changing. Anglers change the frequency of angling trips, dependent on how satisfying each trip is.
OPTIMAL COMMERCIAL TRAP NET EFFORT

- No angling
- Static angling
- Endogenous angling
COMMERCIAL FISHERY: CATCH PER UNIT OF EFFORT

Catch per unit of effort

- No angling
- Static angling
- Endogenous angling

CPUE vs Time

- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1.0

Time

- 0
- 20
- 40
- 60
- 80
- 100
ENDOGENOUS ANGLING: HARVEST

![Graph showing the comparison between Coastal trap net fishery, Effort oriented harvest, and Catch oriented harvest over time.](image)

- **Coastal trap net fishery**
- **Effort oriented harvest**
- **Catch oriented harvest**

**Table:**

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<tr>
<td>100</td>
<td>8x10^4</td>
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</table>
ENDOGENOUS ANGLING: NUMBER OF ANGLERS

The diagram illustrates the number of anglers over time, with two types of angling: effort-oriented and catch-oriented. The effort-oriented angling shows a decrease in the number of anglers over time, while the catch-oriented angling shows an increase. The graph is labeled with the date 20/07/2016 and includes the authors' names: Maija Holma, Andries Richter, and Atso Romakkaniemi.
ECONOMIC VALUE OF THE FISHERY

Net Benefits of the Recreational fishery  Discounted NPV of the commercial fishery

No angling  Static angling  Endogenous angling
NUMBER OF SALMON SMOLTS

Period

No angling
MSY
Static angling
Endogenous angling

Number of salmon smolts

Period
SALMON SPAWNING STOCK SIZE

Spawning stock size

Stock size in numbers

Period

Static angling
No angling
Endogenous angling

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Atso Romakkaniemi
CONCLUSIONS

• Summed economic value is greatest under endogenous angling scenario

• Surprisingly, the highest commercial effort is realized in the Case 3 under complex angler behavior.

• This is a result of strong competition between the commercial and recreational fishery.

• When the utility of staying at home is low, it is possible that the fish stock crashes as the number of effort oriented anglers increase


THANK YOU
SALMON POPULATION MODEL

Data provided by ICES Baltic Salmon and Trout Assessment Working Group (WGBAST 2016).

\[ S_{i,t+1} = S_{i,t} A_t \]
\[ i \in \{1, \ldots, 10\} \]
ENDOGENOUS ANGLING: RECREATIONAL HARVEST PER TRIP

![Graph showing biomass and time for catch-oriented and effort-oriented anglers.]

- **Catch oriented anglers**
- **Effort oriented anglers**
Dynamic optimization of the commercia fishing effort

\[ H_{i,t}^v = (1 - e^{-q_i E_{v,t}}) h r_i s_{i,t} \]

\[ \pi_{v,t} = \sum_{i=1}^{10} p_i H_{i,t}^v g - c E_{v,t} \]

\[ NPV_{v} = \max_{E_{v,t}} \sum_{t=1}^{50} \pi_{v,t} / (1 + r)^{t-1} \]
There are $a$ types of anglers: effort (denoted by $f$) and catch oriented (denoted by $c$).

Effort per angler ($e_{a,t}$) is the number of fishing days ($n_{a,t}$) multiplied by fishing motivation ($\varepsilon_{a,t}$):

$$e_{a,t} = \varepsilon_{a,t} n_{a,t}$$

Total type-specific effort depends on the number of anglers ($N_{a,t}$) and the effort of single angler ($e_{a,t}$):

$$E_{a,t} = e_{a,t} N_{a,t}$$
ANGLER DECISION MAKING

Total recreational effort:

\[ E_{tot,t} = E_{c,t} + E_{f,t} \]

Total recreational harvest in number of fish, summed over all salmon age-classes:

\[ H_{i,t}^{R, tot} = h_r s_{i,t} e^{-q_i E_{r,t}} (1 - e^{-q R_i E_{tot,t}}) \]
Type-specific recreational harvest:

\[ H_{i,a,t} = H_{i,t}^{R,\text{tot}} \left( \frac{E_{a,t}}{E_{\text{tot},t}} \right) \]
Utility of catch oriented anglers depends on the number of fish caught per trip

$$U^c_t = \frac{\mu H^c_t - \theta H^c_t^2}{e_{c,t}}$$

Utility of effort oriented anglers depends on the weight ($W$)

$$U^f_t = \frac{\mu W^f_{i,t} + \theta W^f_{i,t}^2}{e_{f,t}}$$
ANGLER DECISION MAKING

• Number of angling trips at t+1 ($e_{a,t+1}$) depends on last year’s benefits from angling ($U_{a,t}$) and the average utility obtained from leisure ($\bar{U}_{a,t}$).

• Average utility obtained from leisure is the result of angling and the exogenous utility from staying home and doing an alternative activity $\bar{U}$.

• Free days per year is given by $\bar{e}$

$$e_{a,t+1} = e_{a,t} \frac{U_{a,t}}{\bar{U}_{a,t}}$$

• Discrete version of replicator equation (Sigmund 1986)

$$\bar{U}_{a,t} = \frac{e_{a,t} U_{a,t} + (\bar{e} - e_{a,t})\bar{U}}{\bar{e}}$$
EVOLUTION OF ANGLER BEHAVIOR

- Total number of anglers is $N_T = N_{f,t} + N_{c,t}$

- Adopting angling as a new hobby: $\tau N_t$ stop and $\tau N_t$ start angling

- Socialization determines the angler type according to the prevalence of each angler type

\[
\frac{e_{f,t} N_{f,t}}{e_{c,t} N_{c,t} + e_{f,t} N_{f,t}} \quad \frac{e_{c,t} N_{c,t}}{e_{c,t} N_{c,t} + e_{c,t} N_{c,t}}
\]
EVOLUTION OF ANGLER BEHAVIOR

- The difference equations of the angler types:

\[
N_{f,t+1} = (1 - \theta)N_{f,t} + \theta N_T \frac{e_{f,t}N_{f,t}}{e_{c,t}N_{c,t} + e_{f,t}N_{f,t}}
\]

\[
N_{c,t+1} = (1 - \theta)N_{c,t} + \theta N_T \frac{e_{c,t}N_{c,t}}{e_{c,t}N_{c,t} + e_{c,t}N_{c,t}}
\]