# An Ecological-Economic Model of Genetic Interaction between Farmed and Wild Salmon

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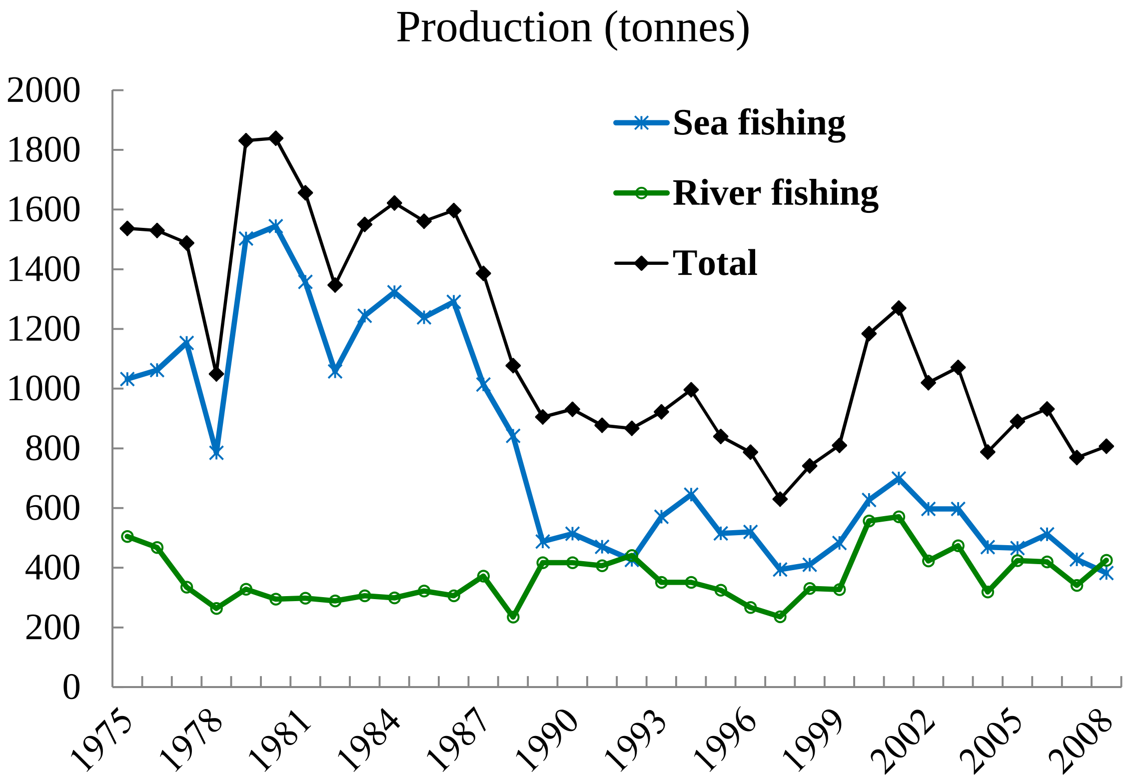
# Outline of the talk

- Problem of interest;
- Research objective;
- Methodology;
- Results;
- Discussion and conclusion;
- Future research.

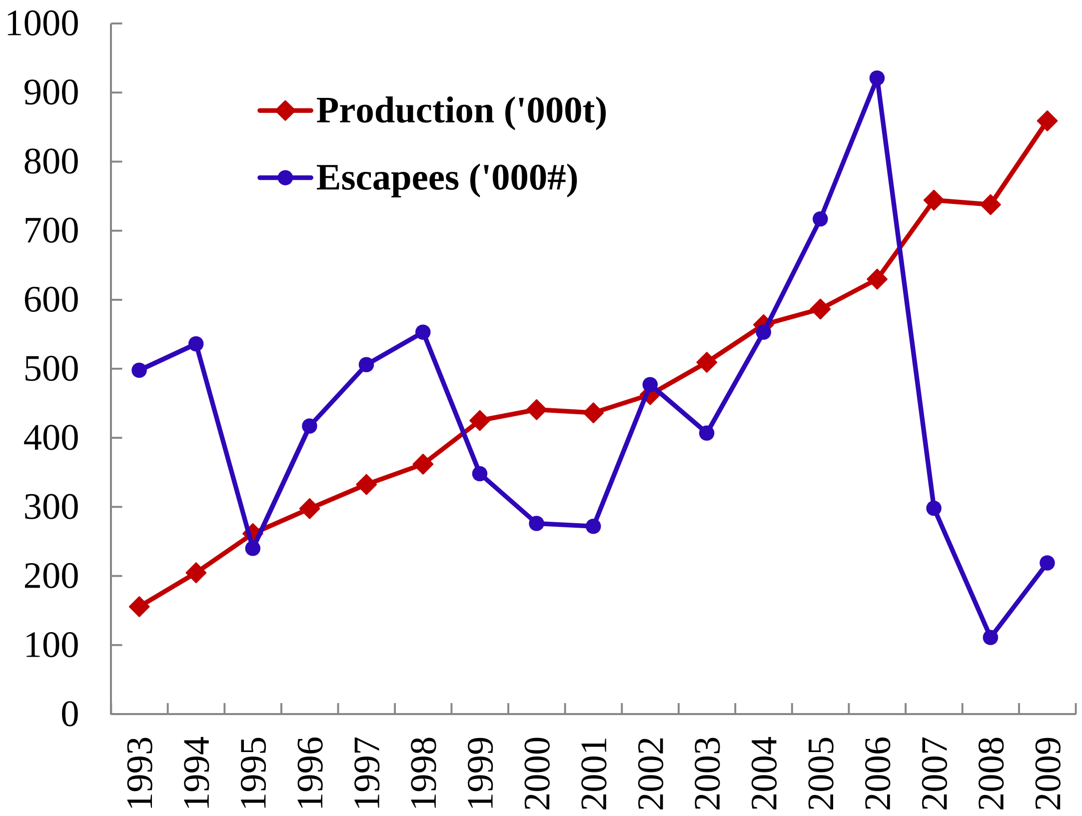
# Problem of Interest

- Famed escapees has become one of the biggest challenges;
- Potentially thread wild salmon stocks and fisheries;
  - **Biological/Ecological effects**;
    - ***Crossbreeding;***
    - Disease spreading;
  - **Economic effects**;
    - Market Values;
    - Non market values;

# Atlantic Salmon in Norway



# Salmon Farming in Norway



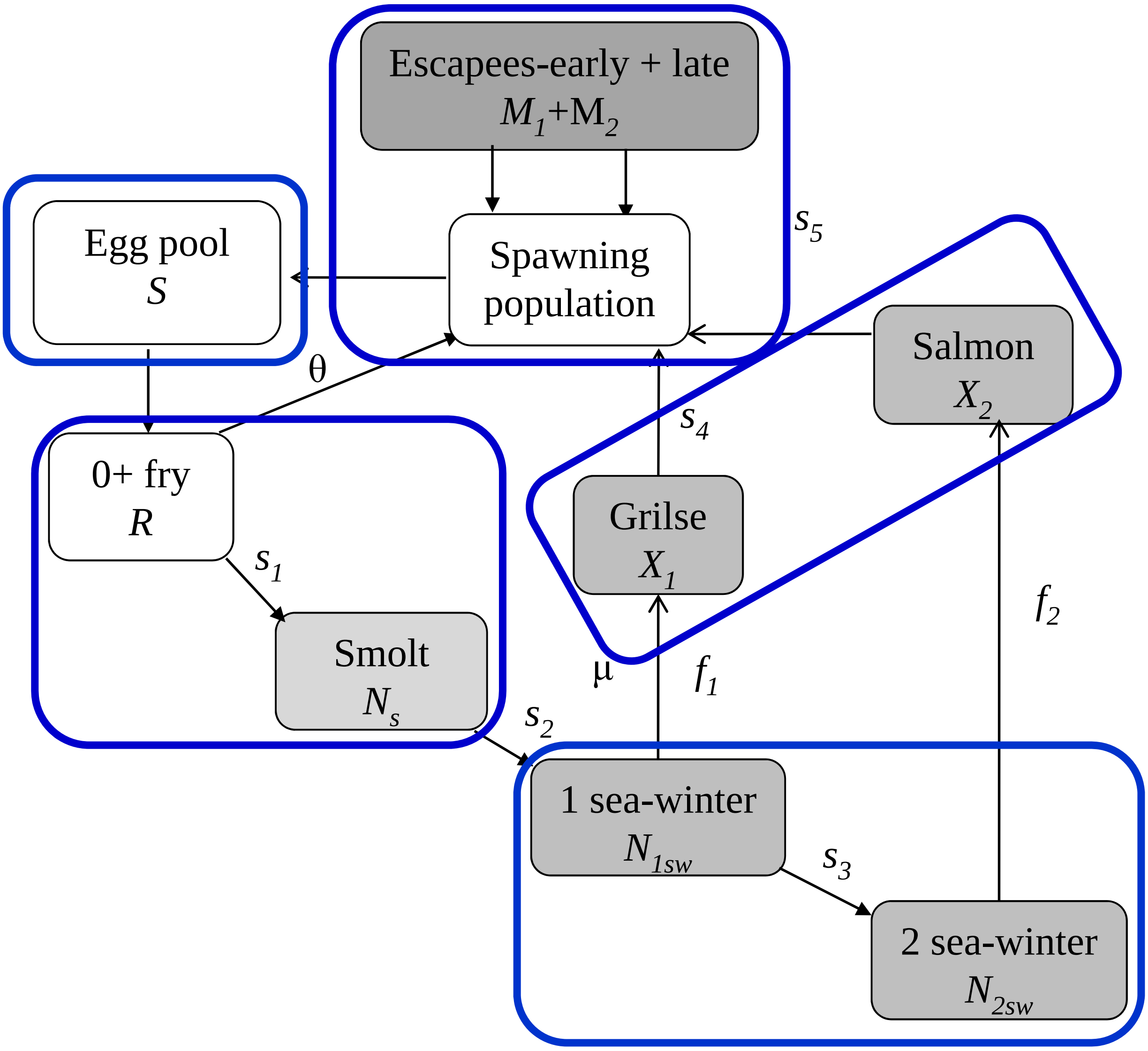
# Research Objective

- To examine economic impacts of genetic interaction between wild and farmed escapees;

- To develop a bioeconomic model to incorporate
  - genetic effects through life-history traits; and
  - market and non-market values of fishing and wild stock;

# Research Method - Biological

## Age- and stage-structured salmon dynamic model:



# Research Method - Economic

**Only market values included - harvests;**

$$\Pi = \sum_{t=1}^{T} \rho^{t} \pi_{t} = \sum_{t=1}^{T} \rho^{t} \left( \boxed{p^{s} H_{t}^{s}} + \boxed{b_{t} H_{t}^{r}} \right)$$

Sea fishing
Commercial

River fishing
Recreational

$p^{s}$ Prices for 1SW and 2SW salmon from sea harvest;

$b_{t}$ Prices for salmon from river harvest;

# Research Method - Economic

**Market and non-market values included – Social Welfare;**

$$W_t = \boxed{\alpha[U(H_t)]} + \boxed{(1-\alpha)[V(X_t^w)]}$$

⇑ Utility from harvesting

⇑ Utility from wild salmon stock

| | |
|---|---|
| $\alpha$ | Relative weight |
| $H_t$ | Total harvest in weight (kg) |
| $X_t^w$ | Wild salmon stock |

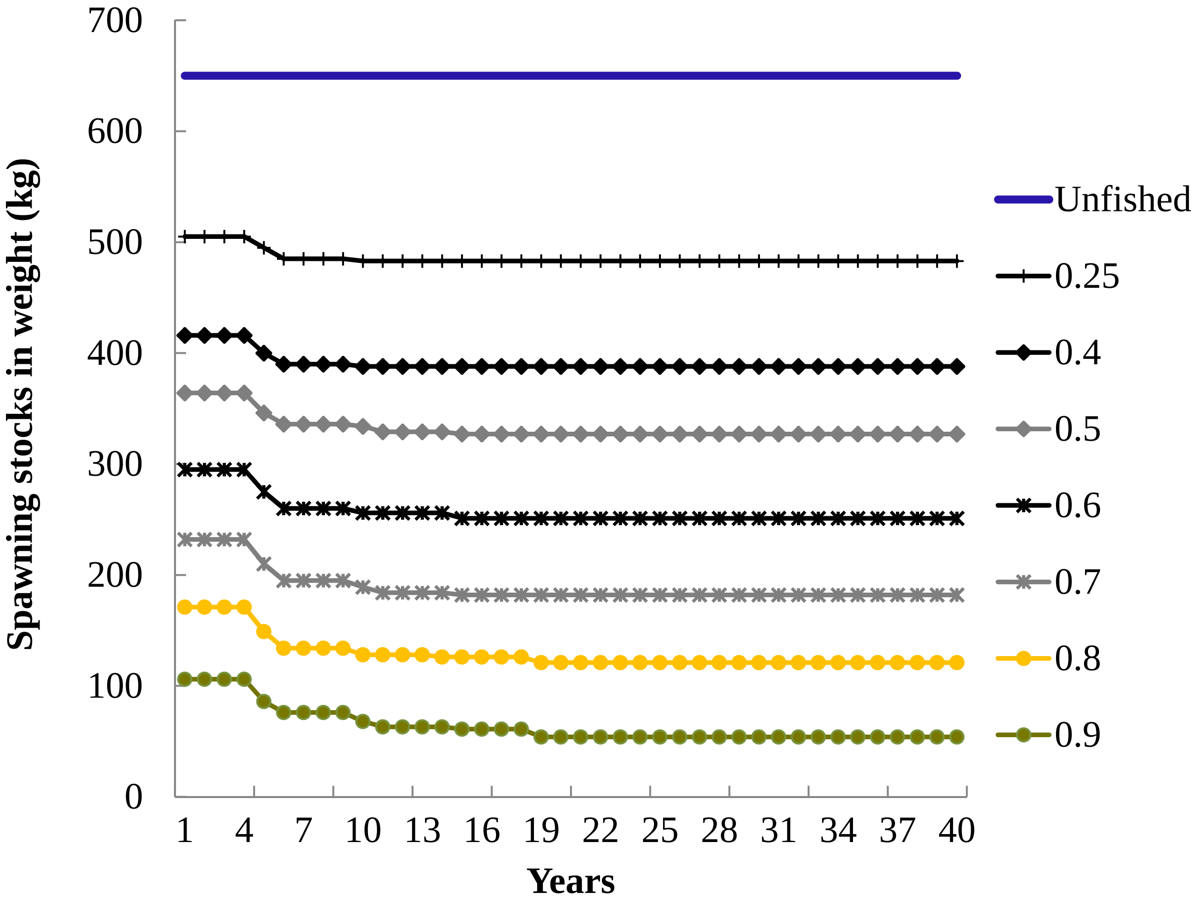
# Research Method

## Simulation runs:

- An example river;
- Unfished population as the starting point;
- Three scenarios for escapees:
  - **I:** without escapees;
  - **II**: with escapees – 20% of total spawning population;
  - **III**: with escapees – 50 as a fixed number;
- Harvest:
  - Sea: River fishing = 50:50;
  - Sea fishing: 1SW:2SW=40:60
  - River fishing: 1SW:2SW=60:40
- 10 generations;

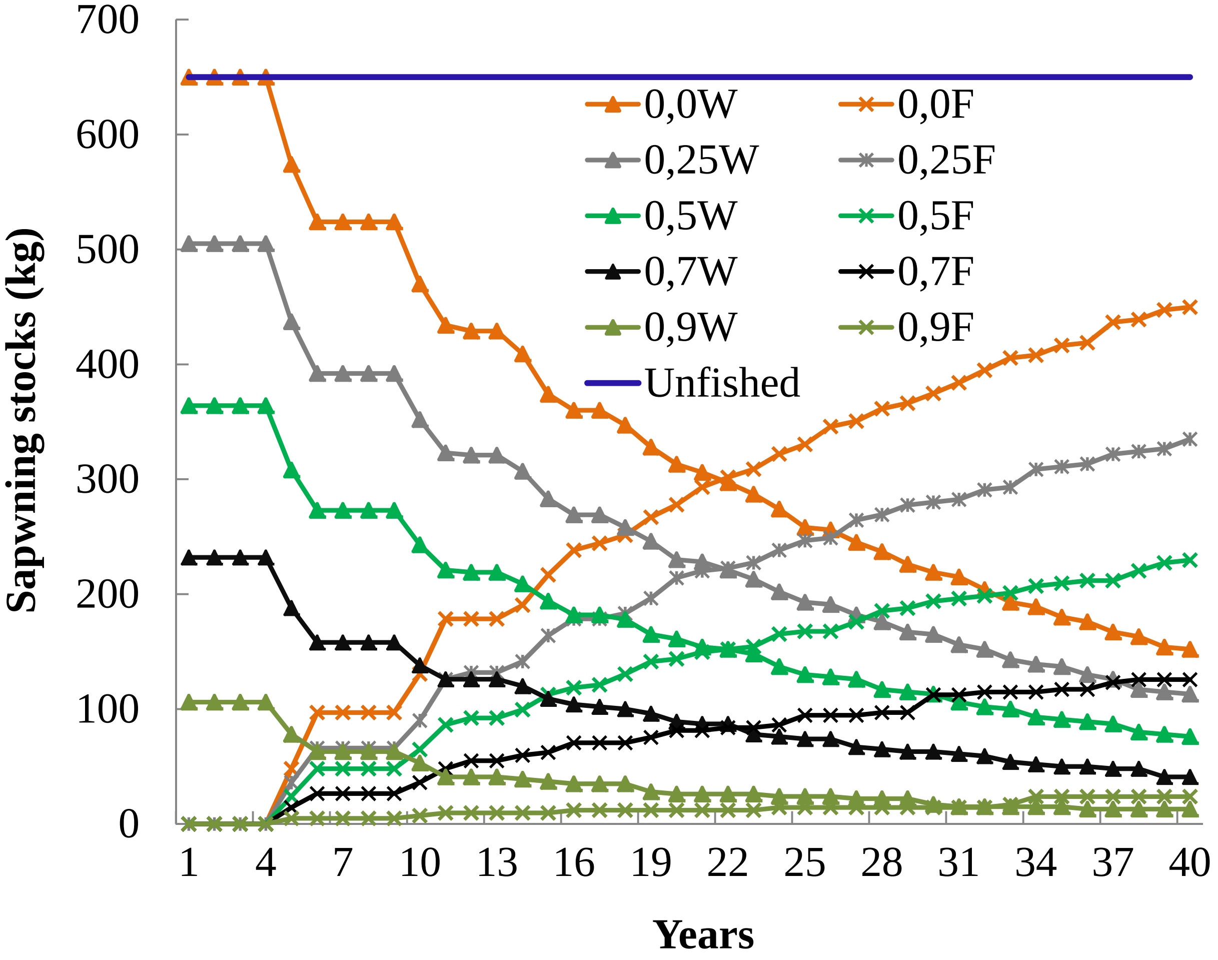
# Results – Ecological effects

**Spawning population** (kg) **– Scenario I** (no escapees):



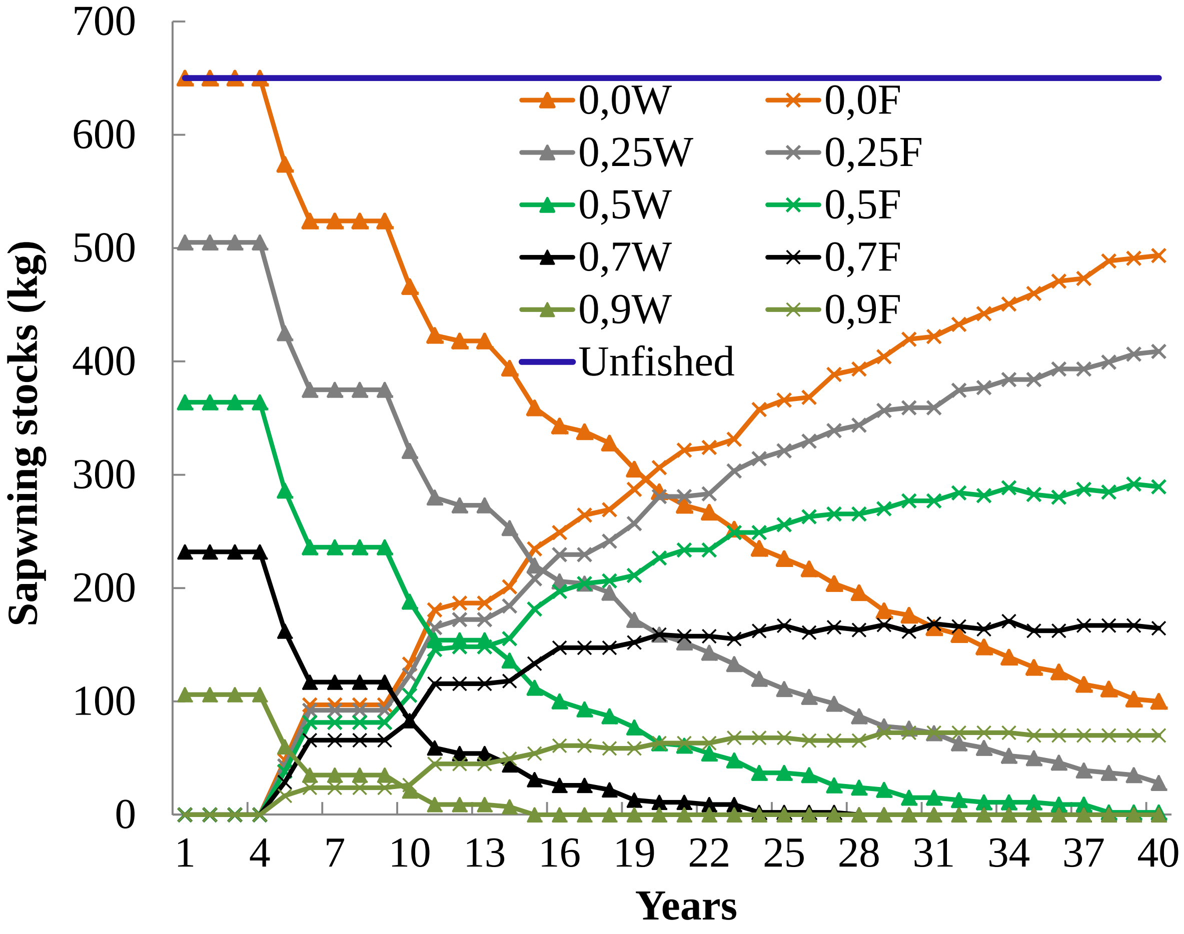
# Results – Ecological effects

## Spawning population (kg) – Scenario II (20%):



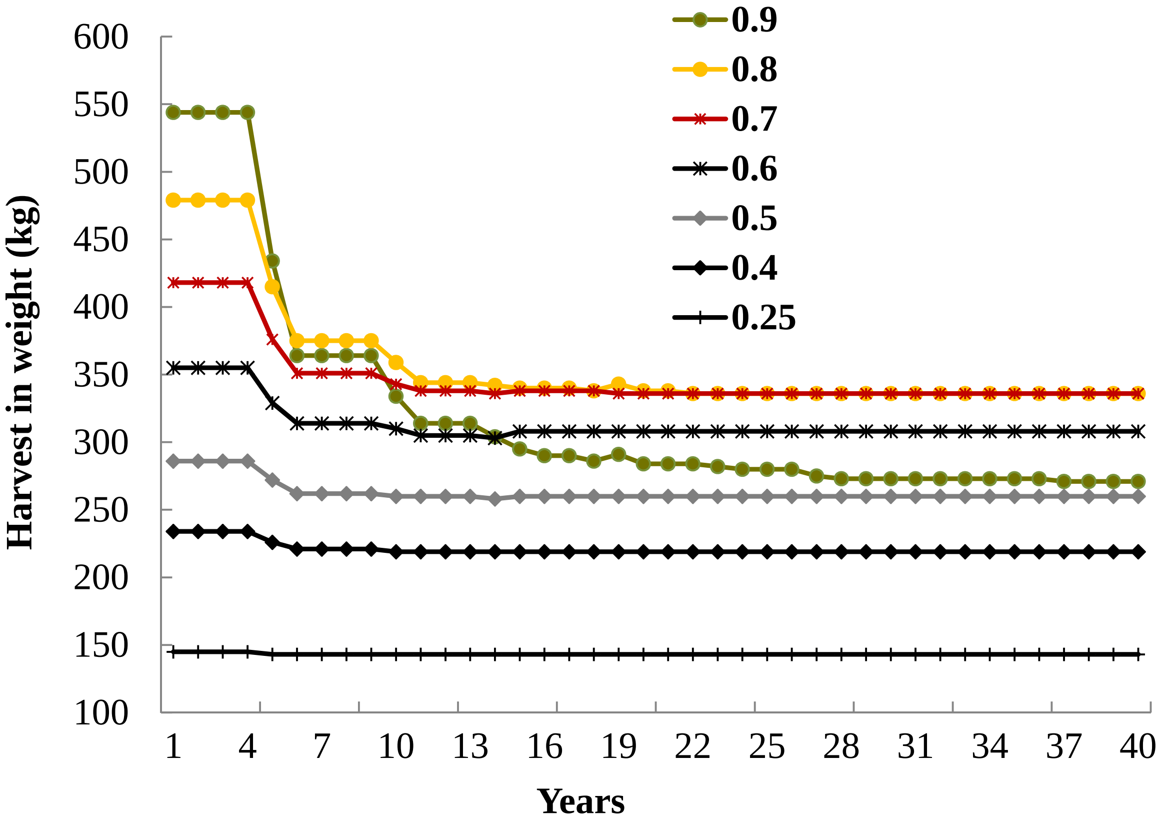
# Results – Ecological effects

## Spawning population (kg) – Scenario III (50):



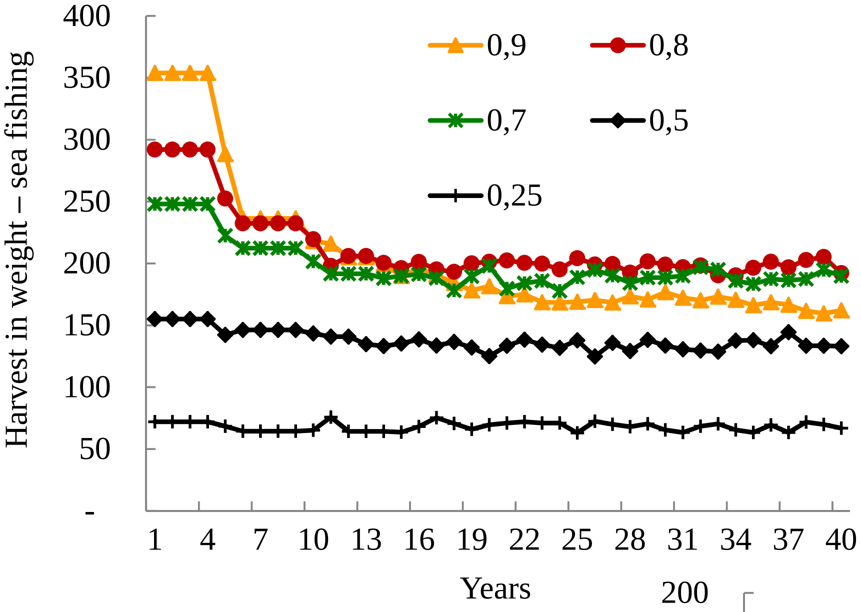
# Results – Ecological Effects

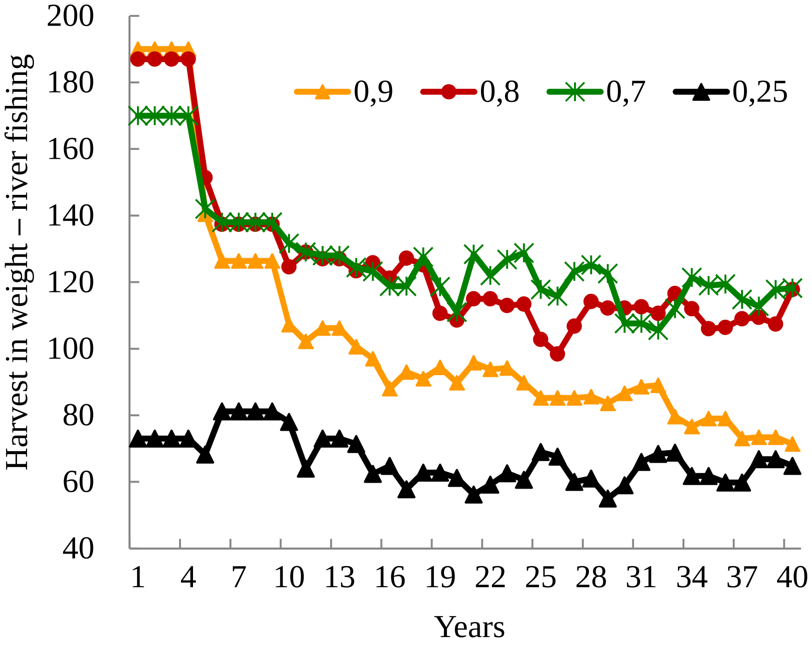
**Harvest** (kg) **– Scenario I** (without escapees):



# Results – Ecological Effects

## Harvest (kg) – Scenario II (20%):





# Results – Ecological Effects

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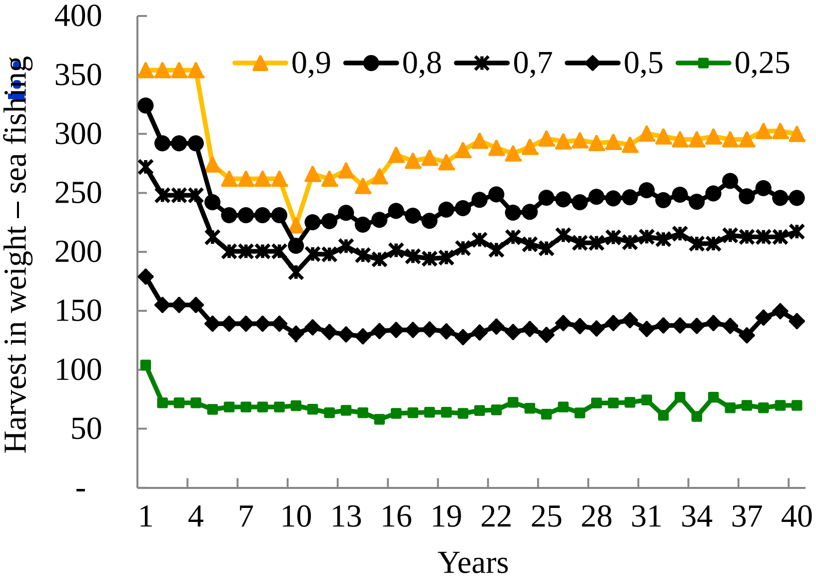
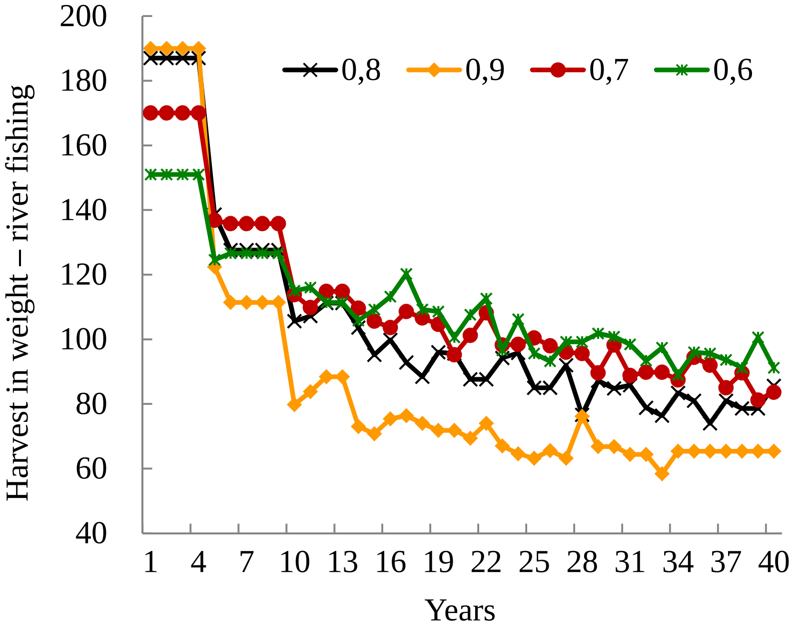
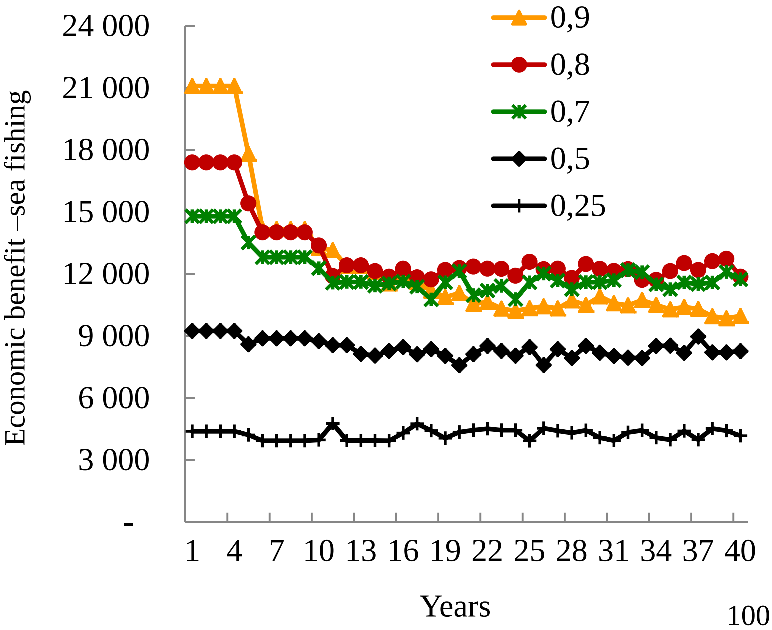
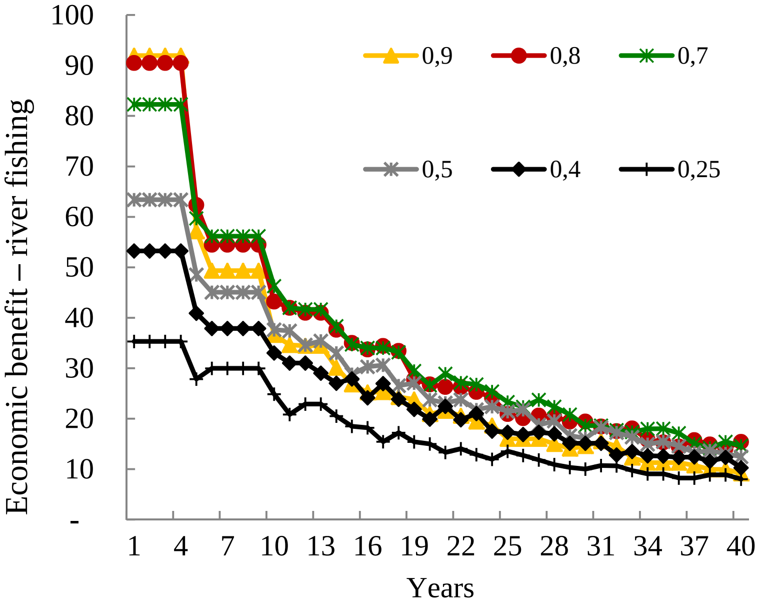




# Results – Economic Effects

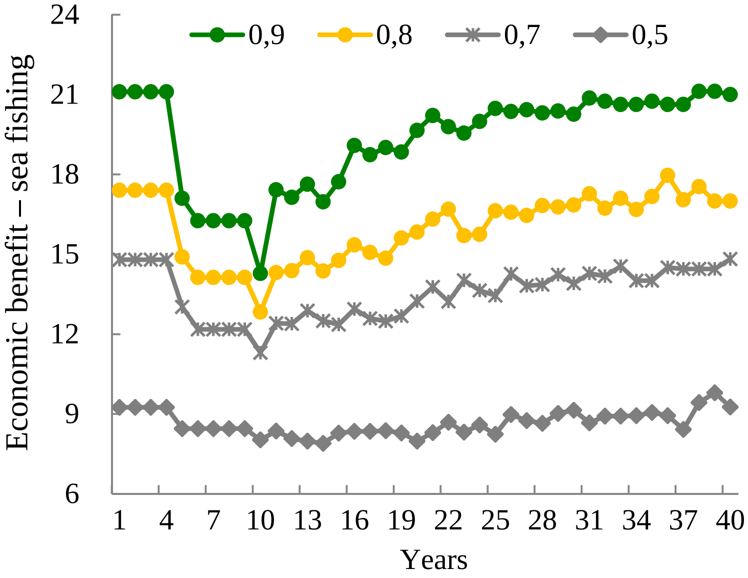
## Market values ('000 NOK) – Scenario II (20%):

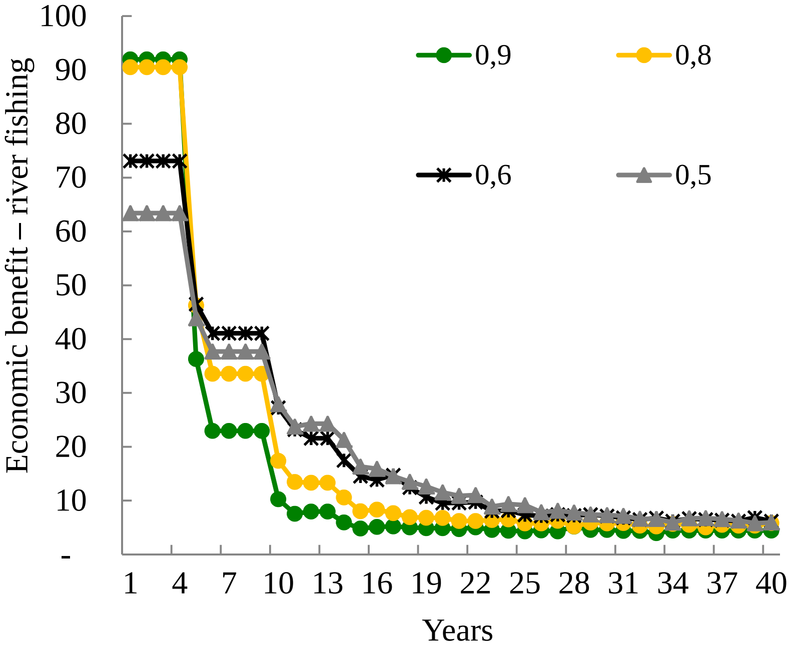




# Results – Economic Effects

## Market values ('000NOK) – Scenario III (50):





# Results – Economic Benefit

## **Market Value:** Undiscounted economic benefit ('000 NOK):

| Fishing mortality | 0,25 | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 | 0,9 |
|---|---|---|---|---|---|---|---|
| ***Scenario I - without escapees*** | | | | | | | |
| Sea fishing | 174 | 287 | 334 | 426 | 487 | **527** | 507 |
| River fishing | 1390 | 1961 | 2380 | 2615 | **2770** | 2656 | 2129 |
| Total benefit | 1564 | 2248 | 2714 | 3041 | **3257** | 3183 | 3636 |
| ***Scenario II – with escapees (20%)*** | | | | | | | |
| Sea fishing | 170 | 276 | 337 | 418 | 483 | **520** | 499 |
| River fishing | 714 | 1007 | 1183 | 1344 | 1421 | **1421** | 1227 |
| Total benefit | 884 | 1283 | 1520 | 1762 | 1904 | **1941** | 1726 |
| ***Scenario III – with escapees(50)*** | | | | | | | |
| Sea fishing | 171 | 280 | 346 | 445 | 541 | 639 | **773** |
| River fishing | 551 | 734 | 807 | **834** | 815 | 770 | 655 |
| Total benefit | 722 | 1010 | 1153 | 1279 | 1356 | 1409 | **1428** |

# Results – Social welfare

## Economic effects – social welfare:

| Weight α<br>Fishing mortality | **0.0** | **0.5** | **1.0** | **0.0** | **0.5** | **1.0** | **0.0** | **0.5** | **1.0** |
|---|---|---|---|---|---|---|---|---|---|
| | Scenario I (no escapees) | | | Scenario II (20%) | | | Scenario III (50) | | |
| 0.00 | **112.52** | 56.26 | 0.00 | 99.95 | 49.98 | 0.00 | 97.58 | 48.79 | 0.00 |
| 0.25 | 107.45 | 96.85 | 86.24 | 94.91 | 90.05 | 85.19 | 86.62 | 85.56 | 84.50 |
| 0.4 | 103.70 | 98.73 | 93.76 | 91.12 | 91.85 | 92.59 | 76.85 | 84.48 | 92.11 |
| 0.5 | 100.86 | 98.83 | 96.79 | 88.40 | 92.04 | 95.68 | 68.22 | 81.67 | 95.12 |
| 0.6 | 96.41 | 98.12 | 99.83 | 83.96 | 91.32 | 98.68 | 53.72 | 75.49 | 98.16 |
| 0.7 | 91.04 | 96.31 | 101.58 | 78.66 | 89.54 | **100.42** | 40.72 | 70.41 | 100.10 |
| 0.8 | 84.37 | 93.21 | 102.05 | 71.96 | 86.49 | 100.01 | 31.04 | 66.30 | 101.56 |
| 0.9 | 71.84 | 85.86 | 99.88 | 59.50 | 79.27 | 99.03 | 21.09 | 61.99 | **102.89** |

NB: α represeting weight on harvest:
α = 0 no weight on harvest;
α = 1 full weight on harvest

# Conclusion Remarks

- The stock and harvest of wild salmon suffer substantial decline; even disappear;
- The stock and harvest of farmed fish increase, eventually become dominant;
- Total harvest and economic benefit reduce slowly with a lower escapee rate, but maybe increase with a higher escapee rate;
- Further losses in social welfare are observed when stock value taken into account;
- Modest fishing mortality preferred if harvest and stock values are equally weighted.

# Implications

- Changes in economic values may overlook the severe ecological impacts of farmed escapees on native stocks;
- Non-market value of native species should be taken into account when assessing economic values;
- Appropriate management strategies should be developed and implemented to reduce the escapees .

# Future research

## Future research:

- Assessing non-market values;
- Exploring different management strategies – selective harvesting;

# Acknowledgement

- The project is funded by the Norwegian Research Council through Norwegian Environmental Research Program;