

# Ecosystem model of Icelandic waters using the Atlantis modelling framework

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**MareFrame**



# Atlantis

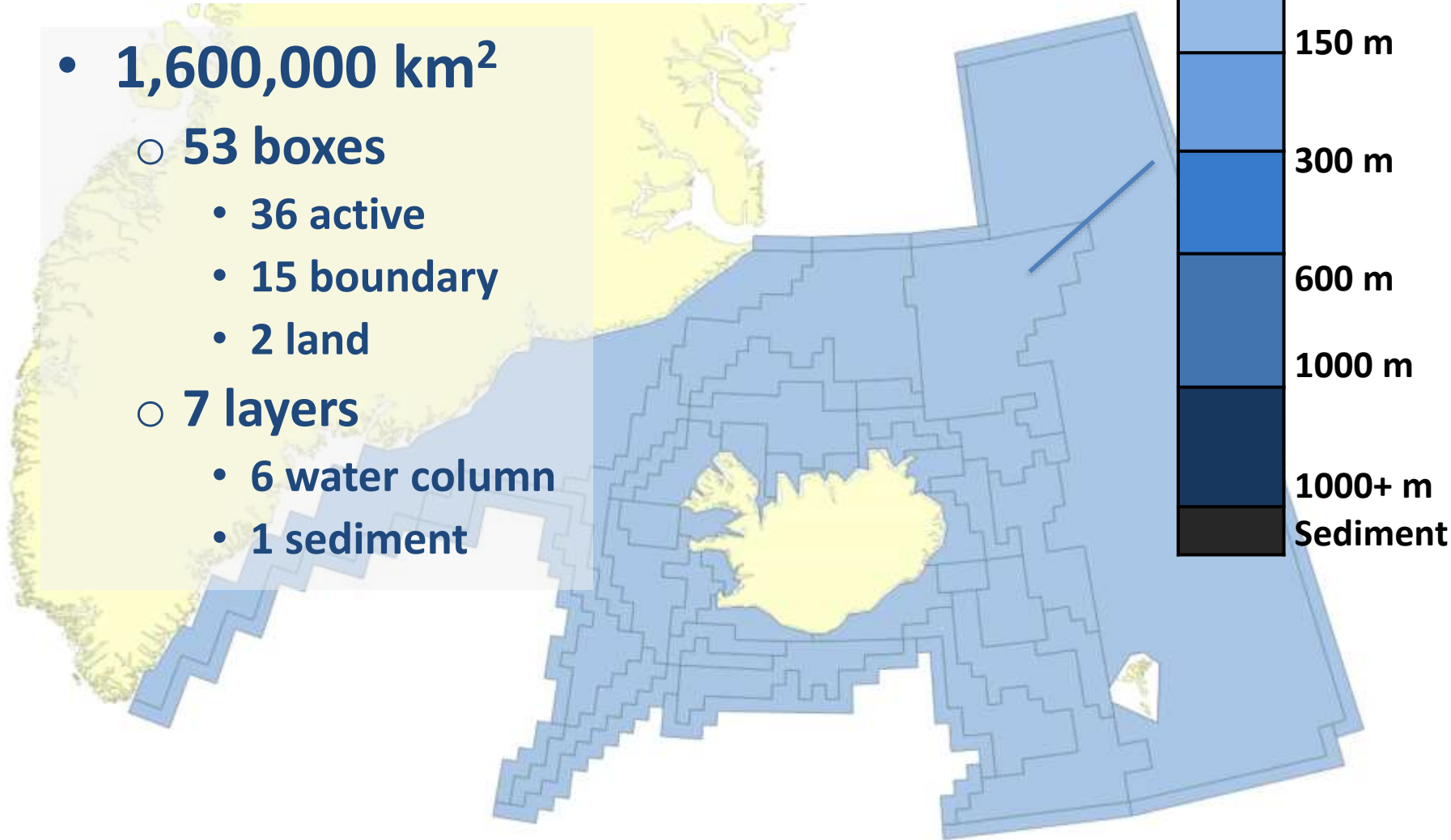
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- Simulates the entire ecosystem.
- Ecosystem model
- Fisheries model
- Sampling and assessment model
- Management model
- Socio-economic model

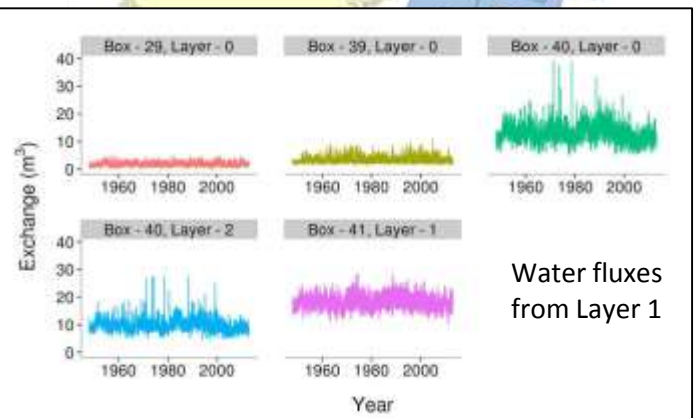
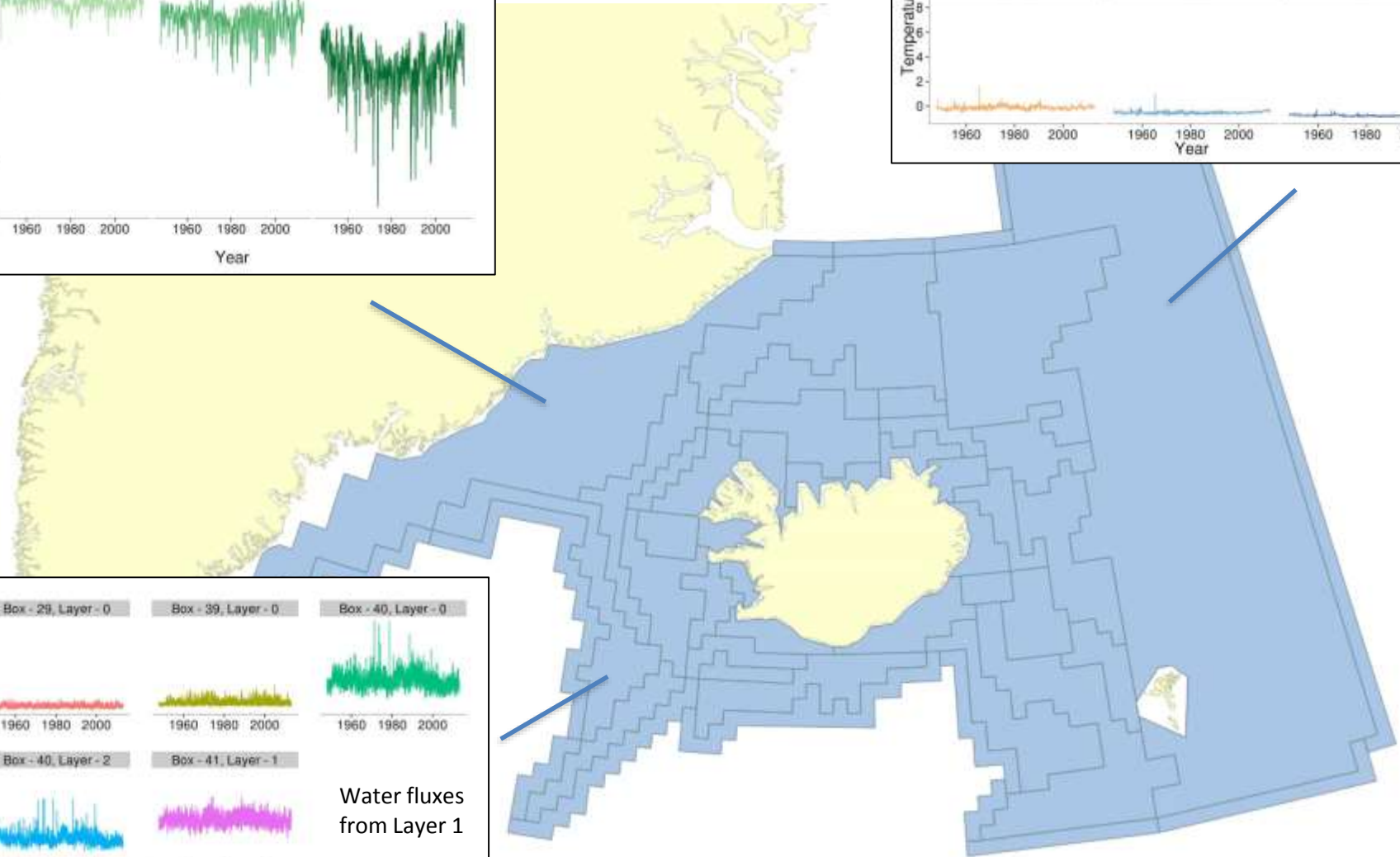
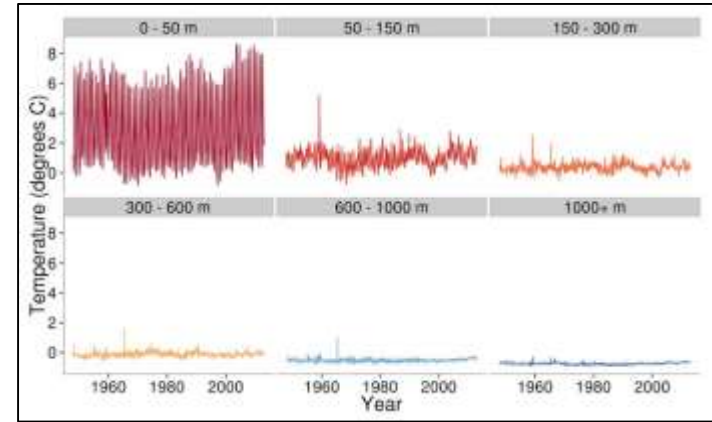
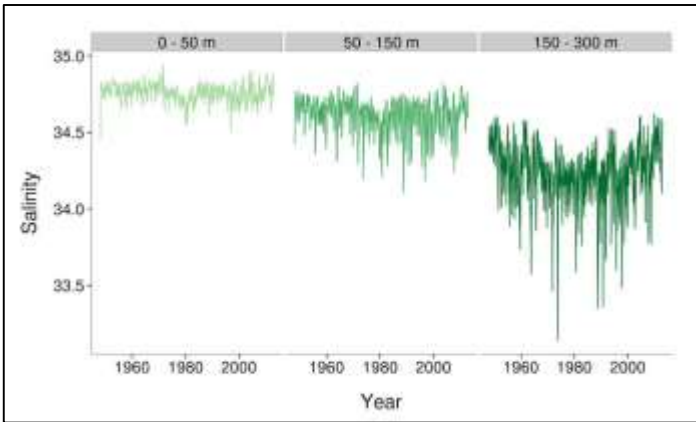


# The model area

- **1,600,000 km<sup>2</sup>**
  - **53 boxes**
    - 36 active
    - 15 boundary
    - 2 land
  - **7 layers**
    - 6 water column
    - 1 sediment



# The oceanography model



# The biology model

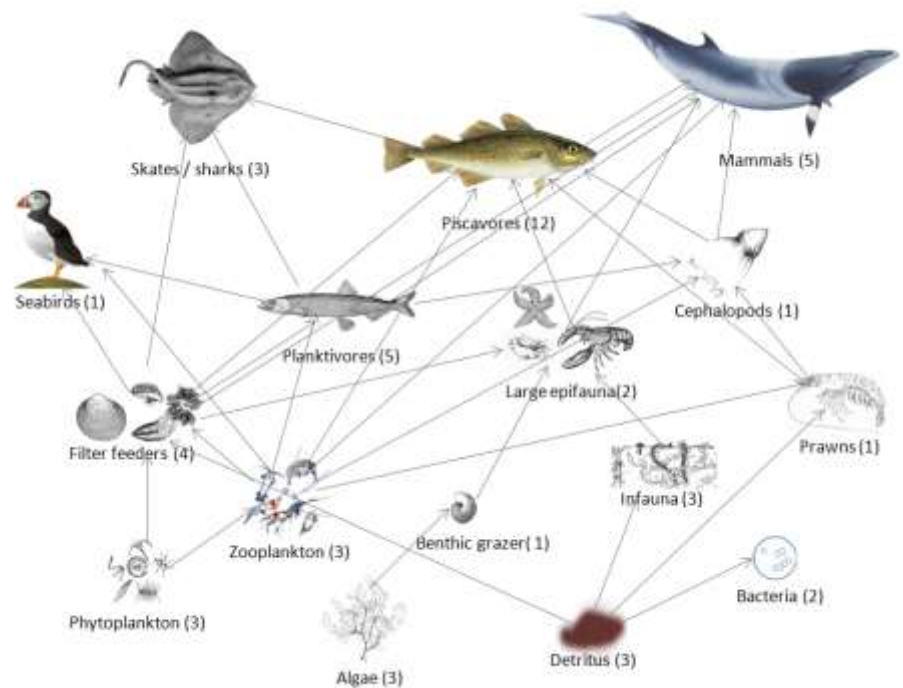
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- **Functional groups**
- **Consumption**
- **Predation**
- **Growth**
- **Reproduction**
- **Movement**
- **Migration**



# The functional groups

- **51 functional group**
  - **25 vertebrates**
    - 16 fish
    - 3 shark/skates
    - 5 mammal
    - 1 seabird
  - **16 invertebrate groups**
  - **5 primary producers**
  - **2 bacteria**
  - **3 detritus**





# The biology model

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- **Vertebrates**
  - **10 age classes**
    - Numbers per age within ageclass
  - **Weight in mg N**
    - Reserved weight
    - Structural weight
- **Invertebrates**
  - **2 ageclasses**
  - **Biomass pools**  
 $\text{mg N m}^{-3}$

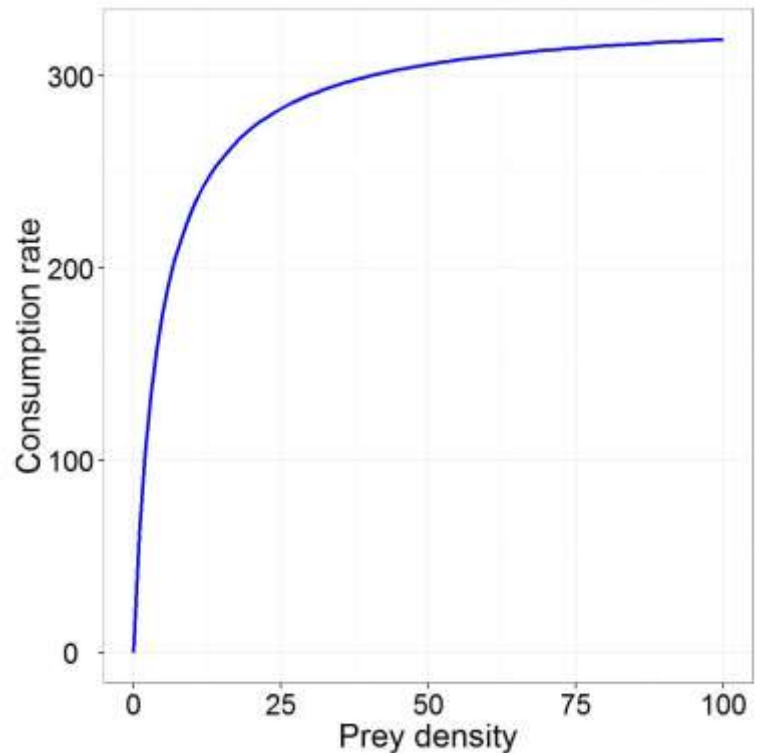


# Consumption

- Holling type II
- Gape limitation
- Prey availability

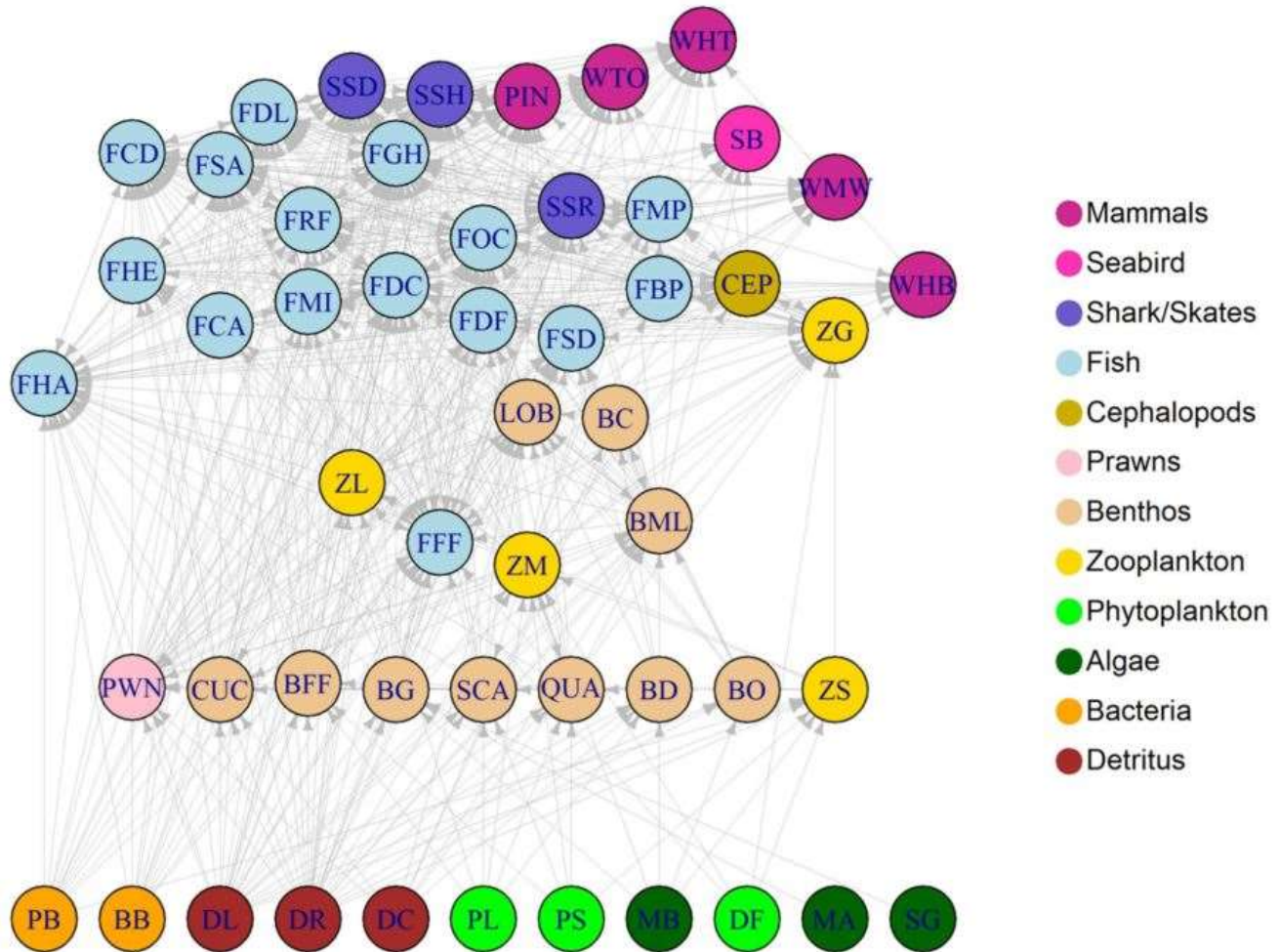


$$Q_{ij} = \frac{a_{ij} \cdot Prey_i \cdot C_j}{1 + \frac{C_j}{\mu_j} \sum_k Prey_k \cdot \epsilon_{ij} \cdot a_{ij}}$$





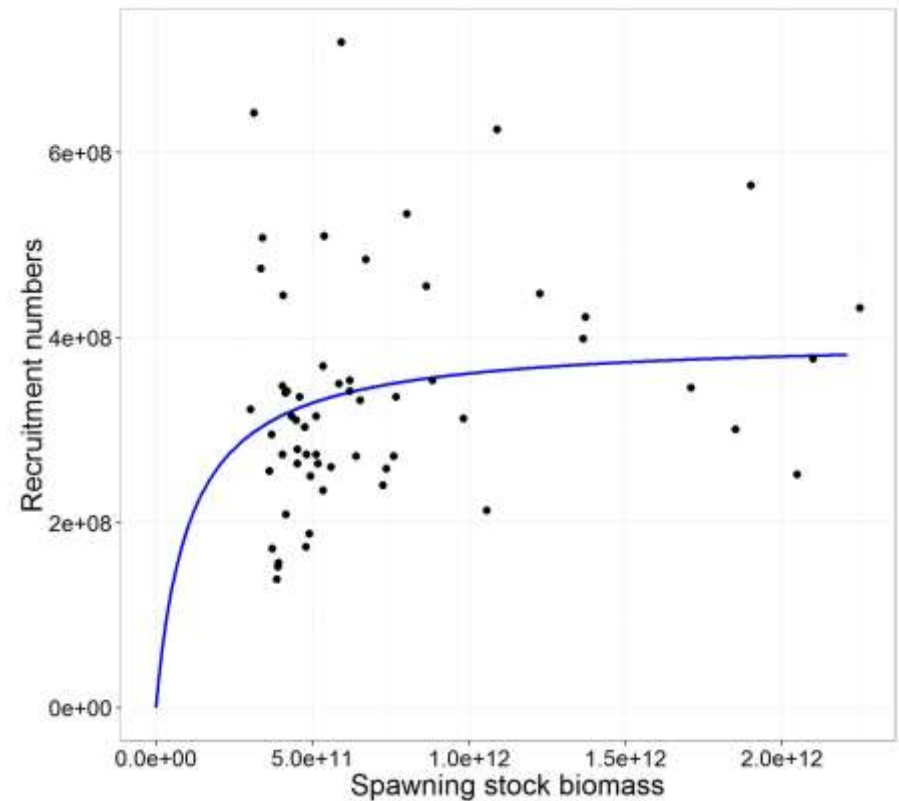
# The food web



# Reproduction

- Beverton – Holt
- Fixed number per adult

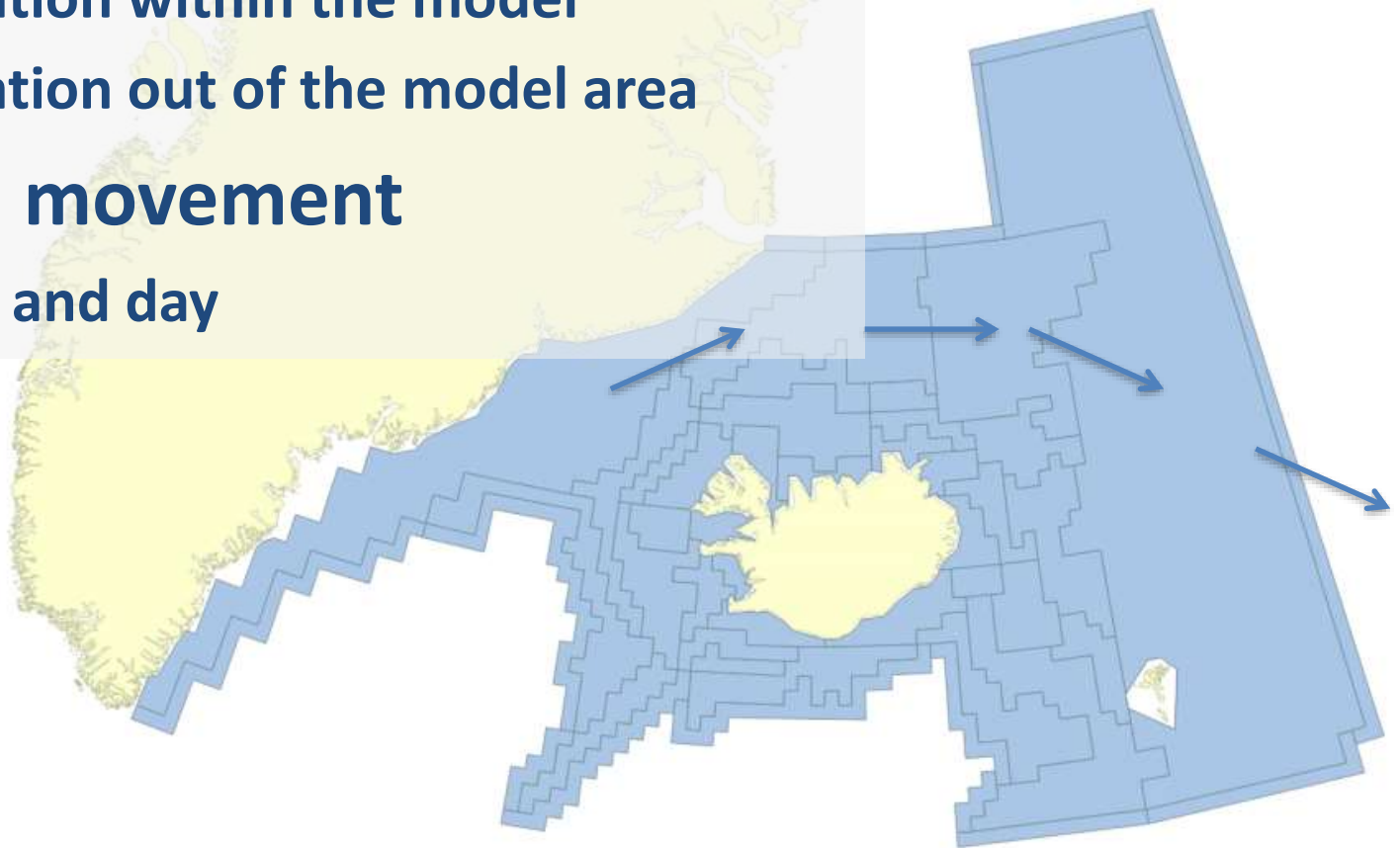
$$N_{\text{Rec}} = \frac{SSB \cdot \alpha}{\beta + SSB}$$



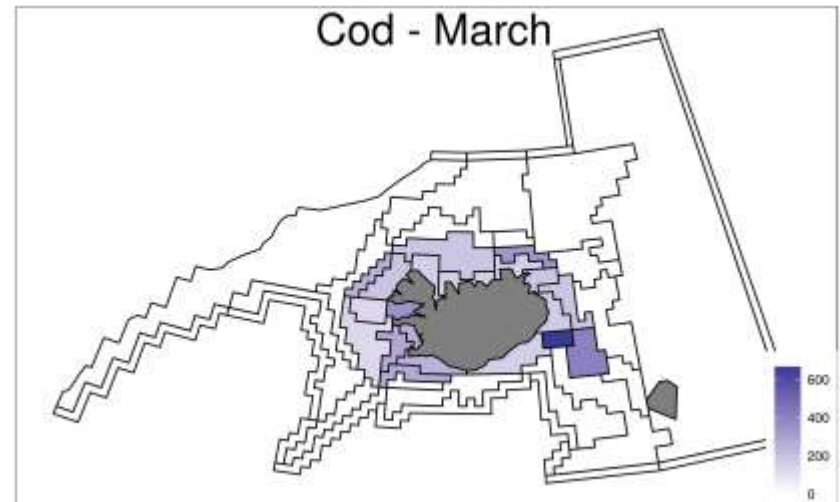
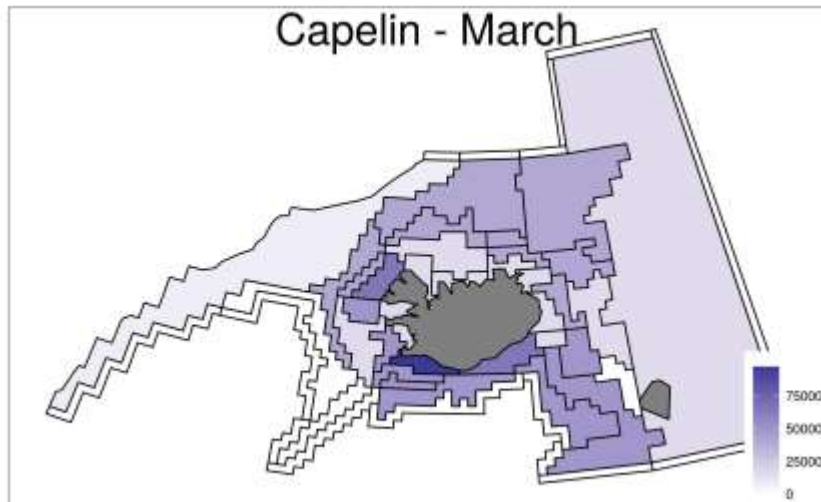
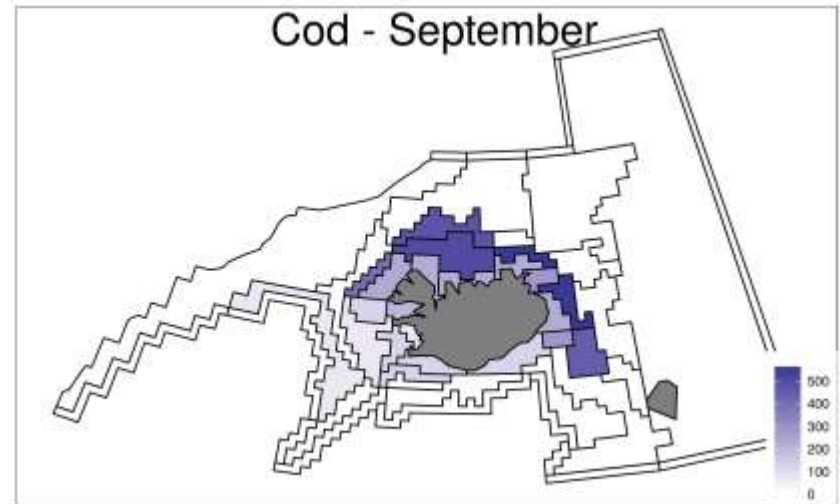
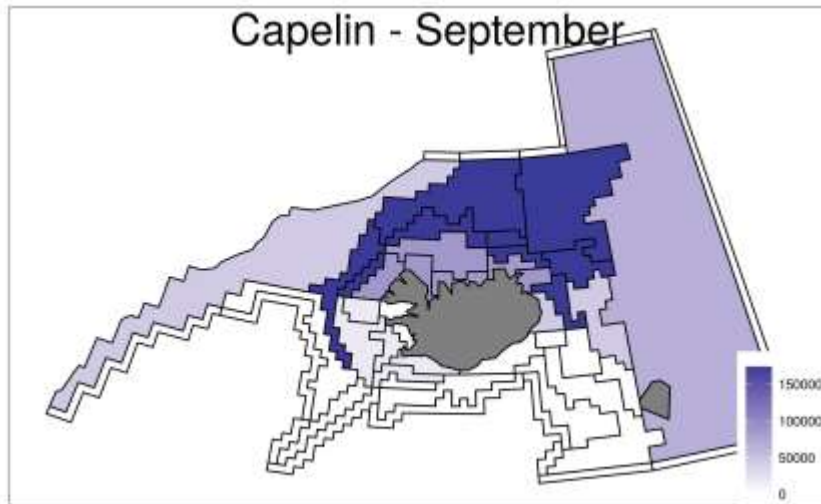
# Migration and movement

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- **Horizontal movement**
  - Migration within the model
  - Migration out of the model area
- **Vertical movement**
  - Night and day



# Spatial distribution



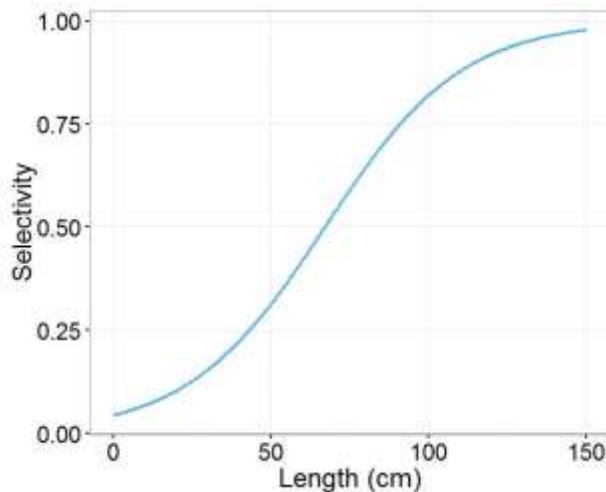
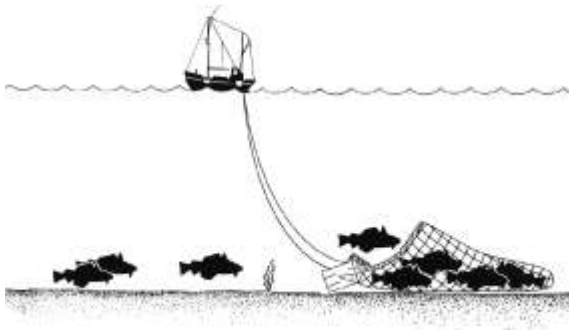
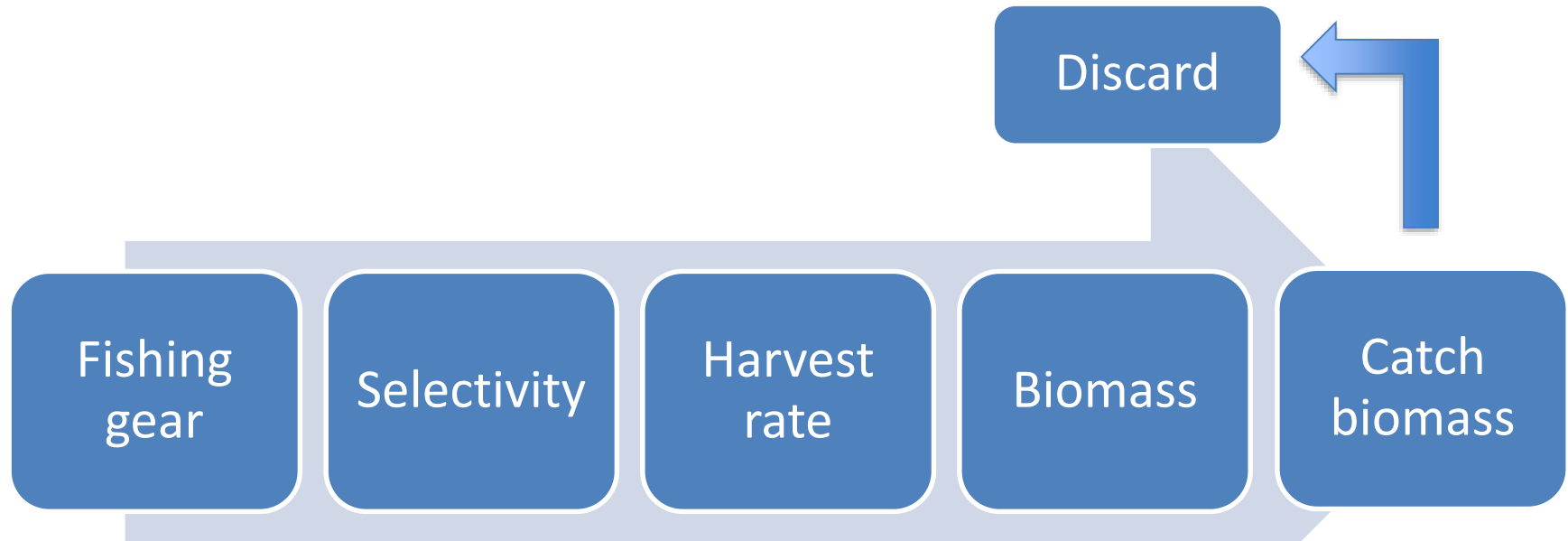
# The fisheries model

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- **Fisheries**
  - **Multiple fleets**
    - **Gear**
    - **Target**
    - **Selectivity**



# Fishing in Atlantis





# Skill assessment

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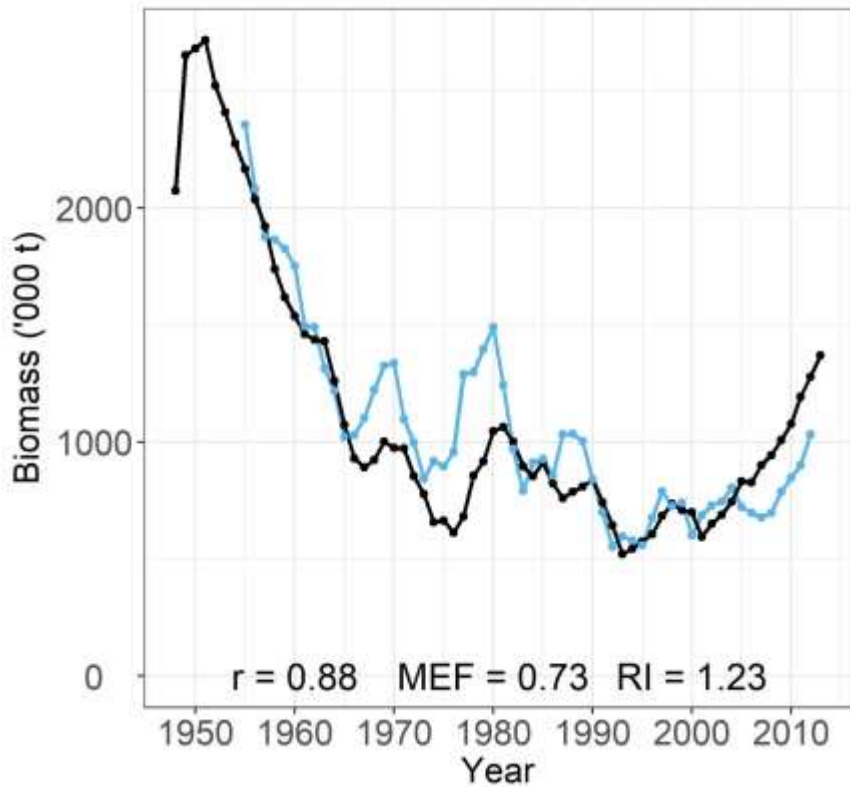
$$r = \frac{\sum_{i=1}^n (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^n (O_i - \bar{O})^2 \sum_{i=1}^n (P_i - \bar{P})^2}}$$

$$RI = \exp \sqrt{\frac{1}{n} \sum_{i=1}^n \left( \log \frac{O_i}{P_i} \right)^2}$$

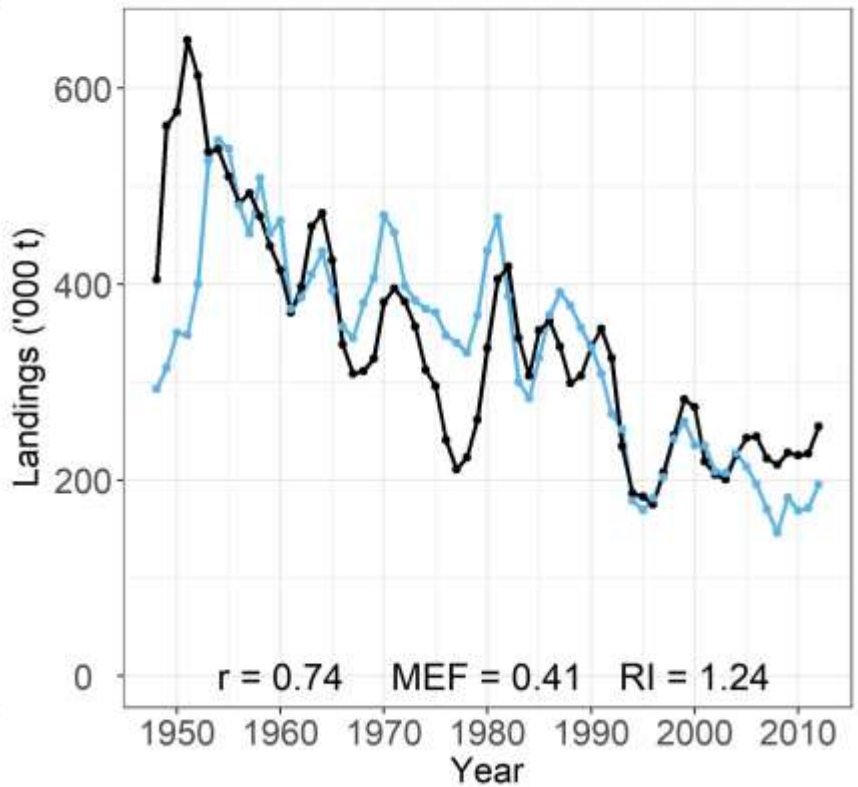
$$MEF = \frac{\sum_{i=1}^n (O_i - \bar{O})^2 - \sum_{i=1}^n (P_i - O_i)^2}{\sum_{i=1}^n (O_i - \bar{O})^2}$$

# Cod

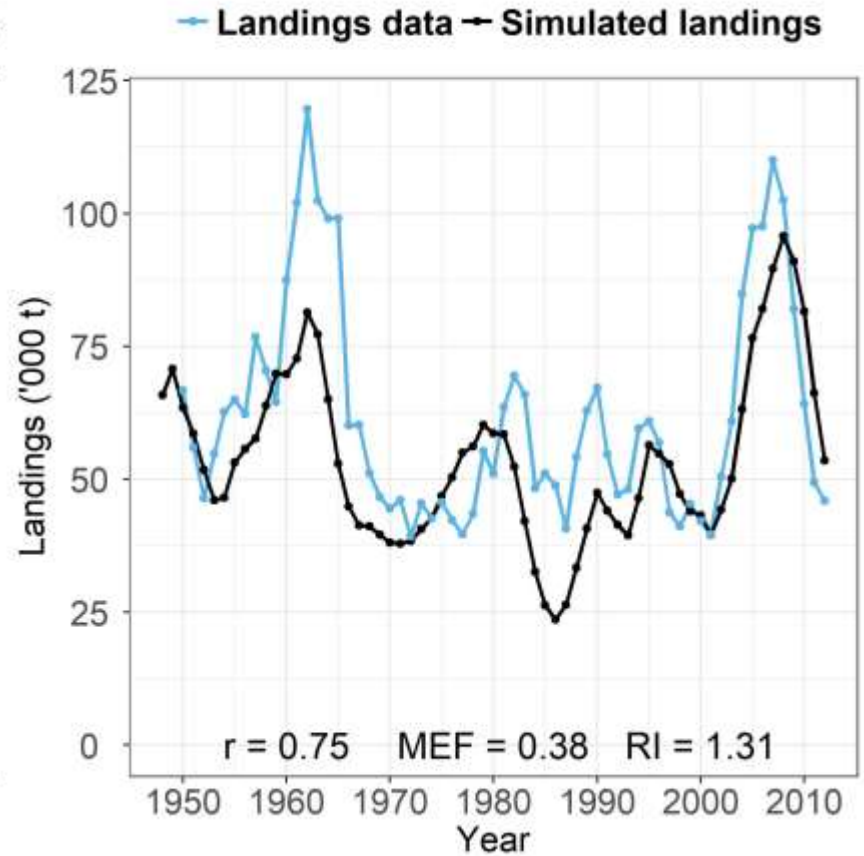
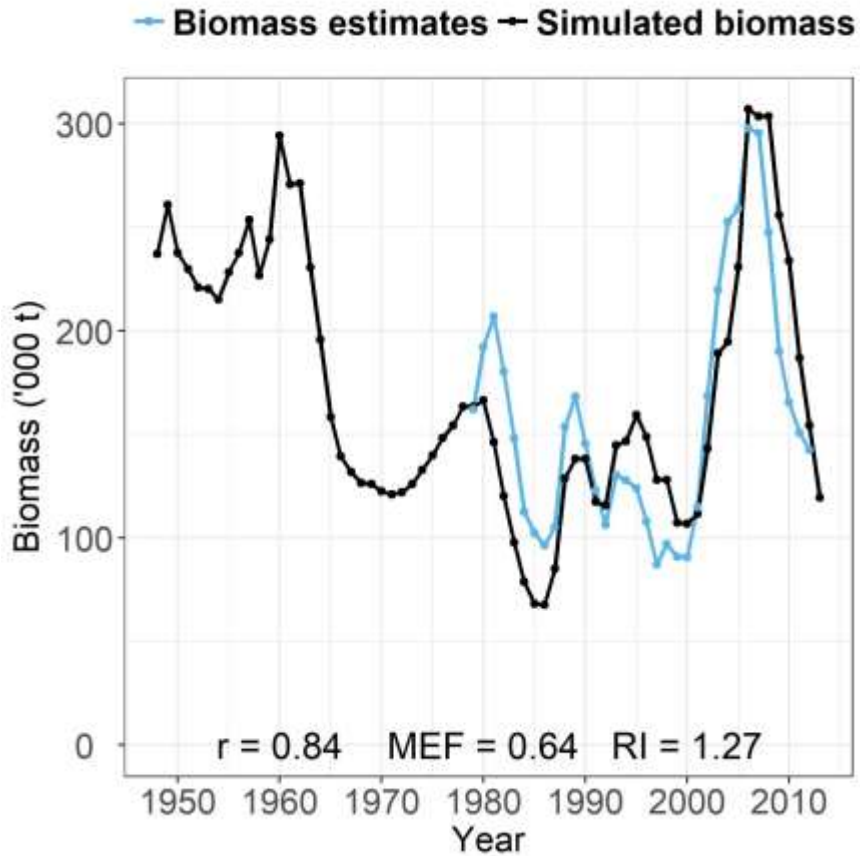
— Biomass estimates — Simulated biomass



— Landings data — Simulated landings

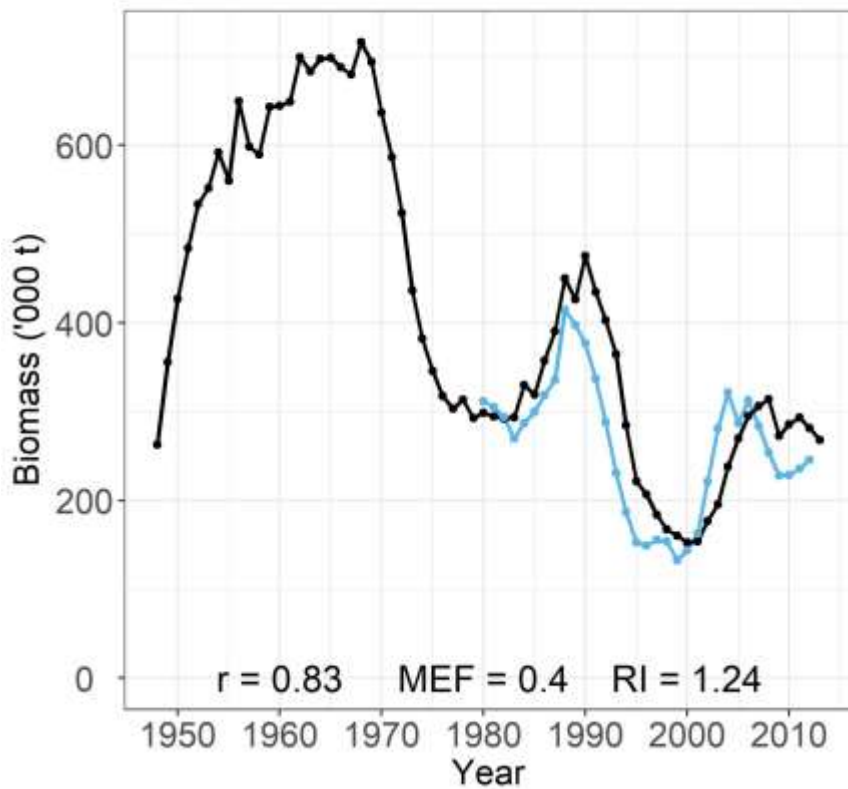


# Haddock

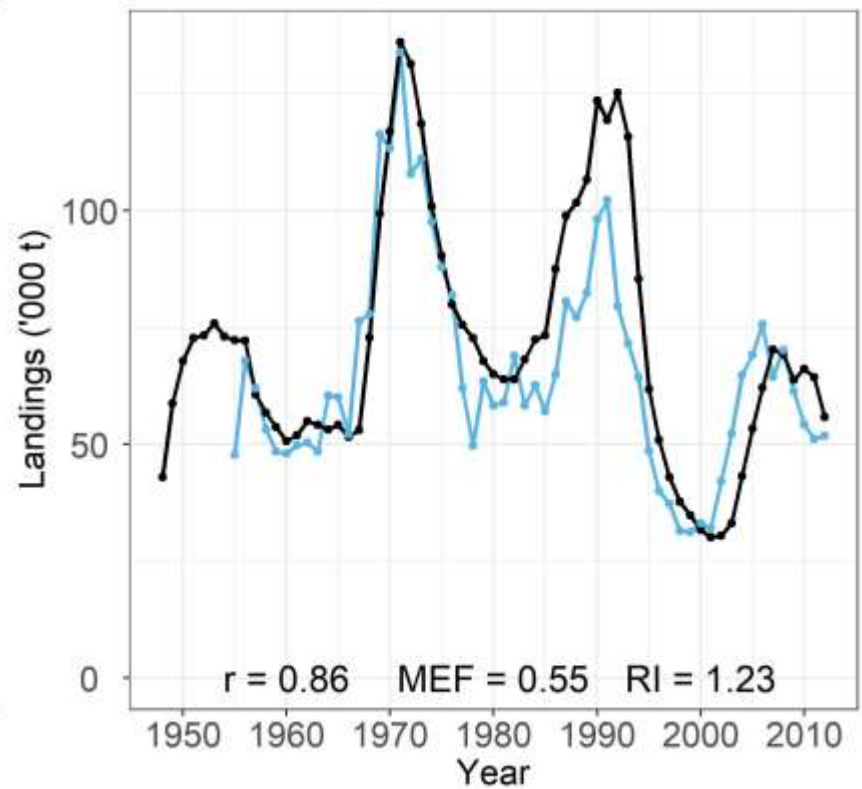


# Saithe

— Biomass estimates — Simulated biomass

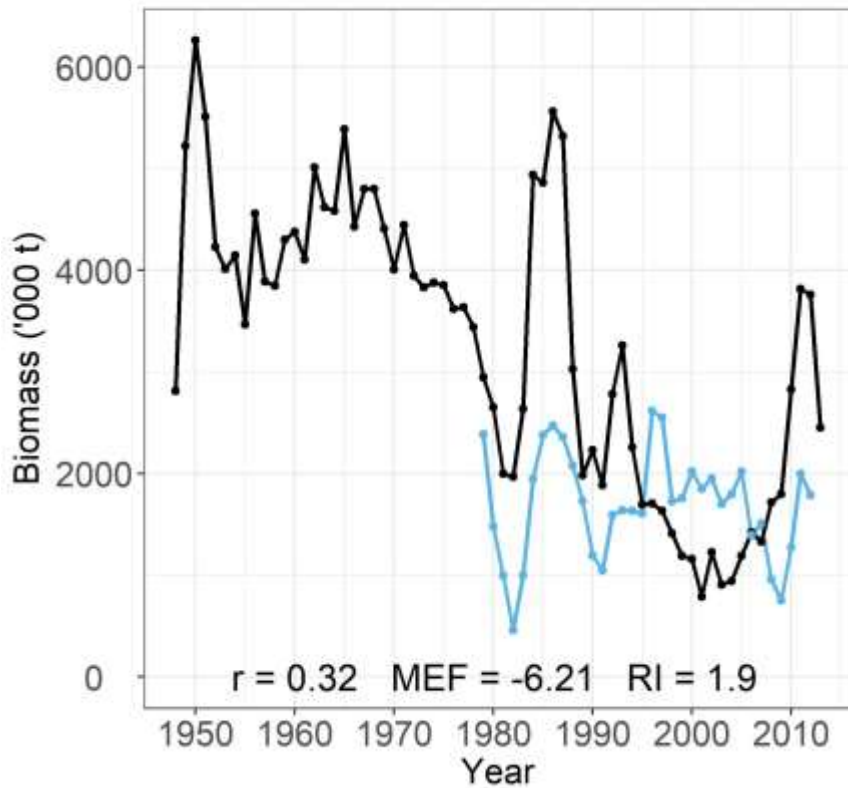


— Landings data — Simulated landings

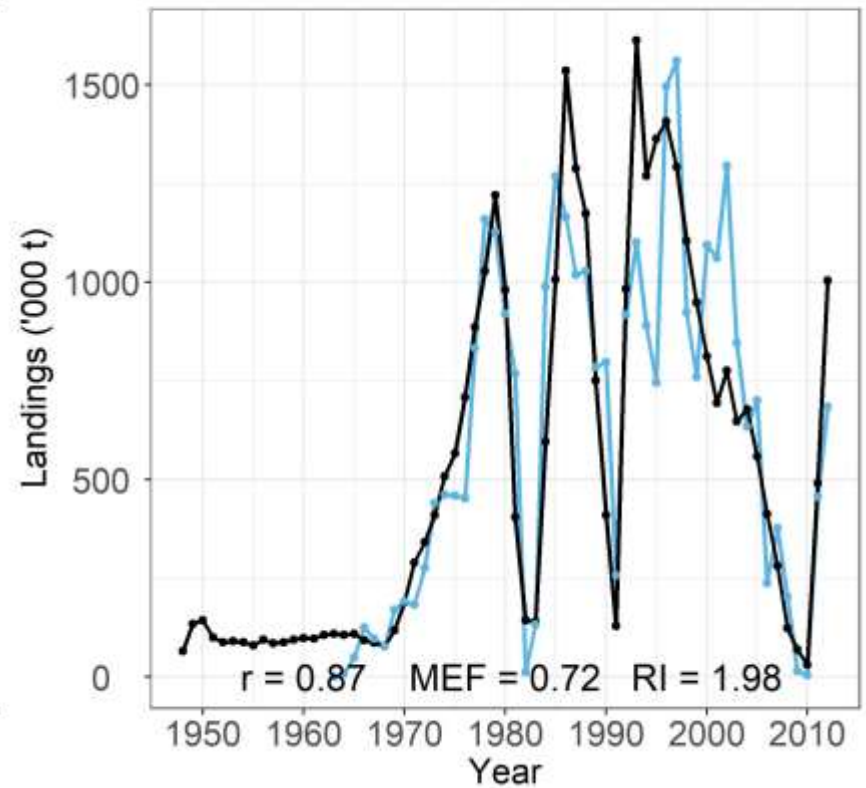


# Capelin

— Biomass estimates — Simulated biomass

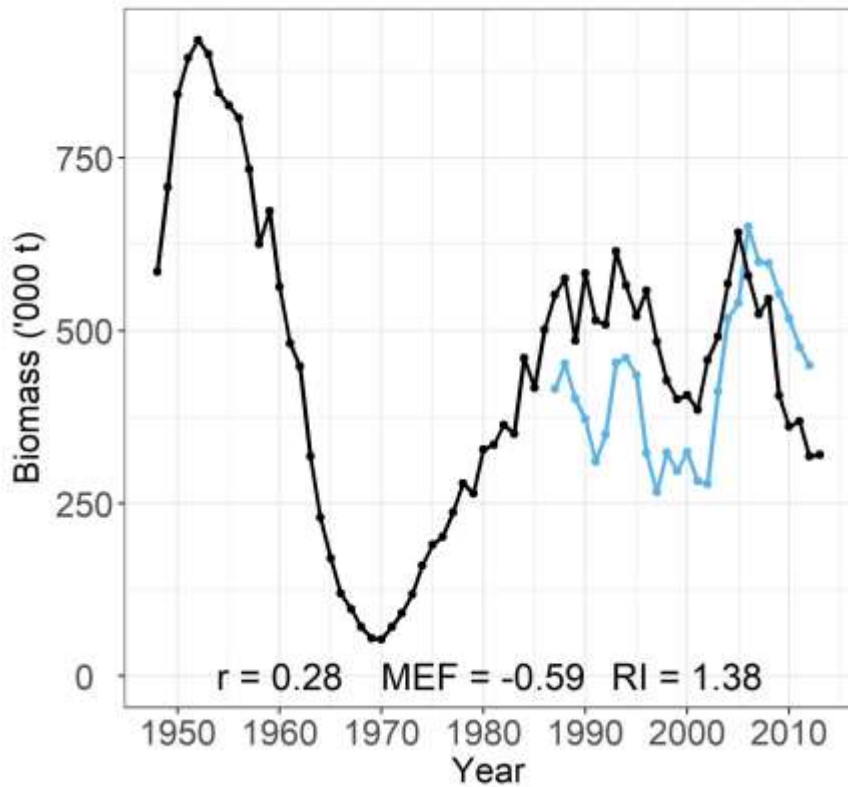


— Landings data — Simulated landings

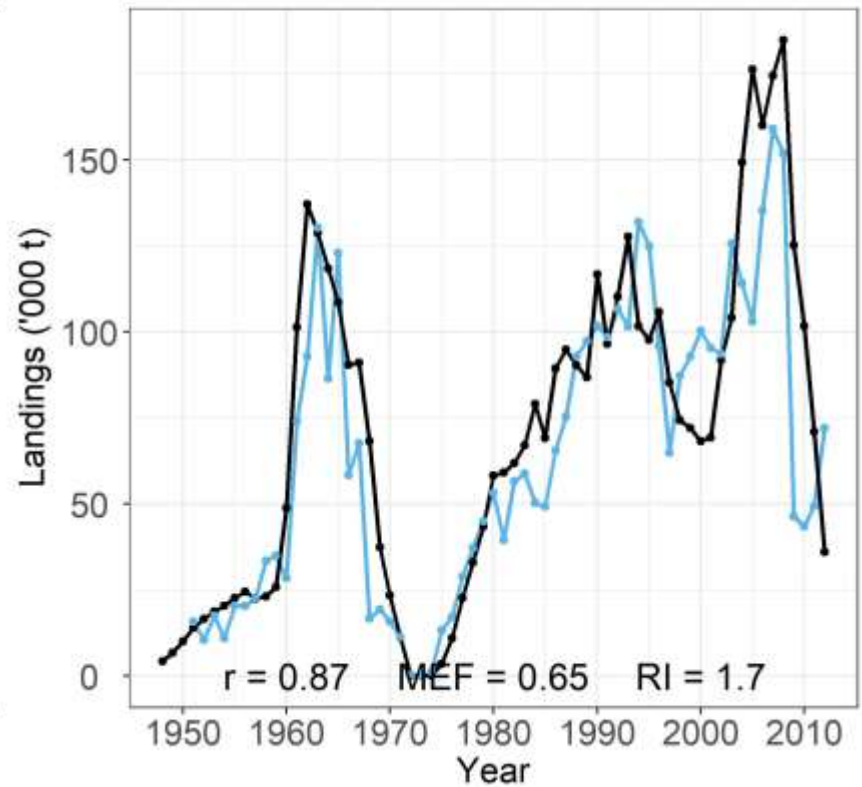


# Herring

— Biomass estimates — Simulated biomass



— Landings data — Simulated landings





# Use of Atlantis

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- **Supporting tool for EBFM**
  - **Understanding**
  - **Scenarios**
    - **Fishing pressure**
    - **Effect of discards**
  - **Management strategy evaluation**
  - **Operating model**

# Poster Session

## Sensitivity study

## Can EwE mimic the Atlantis ecosystem?

**Sensitivity study of the Icelandic Atlantis model**  
Erla Sturluddóttir and Gunnar Stefánsson  
Science Institute, University of Iceland

**Introduction**

- Sensitivity analysis of an ecosystem model can give insight into what parameters contribute to uncertainty in the output.
- It can also be helpful in understanding behaviour and functioning of the system.
- Sensitivity study of recruitment and growth parameters in the Icelandic Atlantis model was carried out.
- The Atlantis model
  - ↳ Oceanographic, biology and fisheries model
  - ↳ 52 functional groups and 10 age classes
  - ↳ 52 spatial boxes and 7 layers

**Methods**

- Maximum recruitment (R) in the Beverton-Holt function was altered by ±20%  

$$R_{i,t} = \frac{a \times X_{i,t}}{b + X_{i,t}}$$
- The maximum growth rate (mu\_max) in the Monod equation was altered by ±20% for zooplankton.  

$$C_{i,t} = \frac{C_{i,t-1} \times \mu_{max}}{1 + \frac{C_{i,t-1}}{K_i} (1 - \mu_{max})}$$
- Growth rate for phytoplankton altered by ±20%.
- Interactions between Z, PS and PL studied.

**Measure of sensitivity**

- Average biomass over the whole simulated period (95 years) used to measure sensitivity.
- Sensitivity of recruitment parameters measured with:  

$$S_{i,j} = \frac{E(D_{i,j}) + 0.0001}{E(D_{i,j})}$$
- Sensitivity of growth parameters and their interactions measured with percentage change in biomass.

**Sensitivity of recruitment parameters**

**Results**

- Changing the recruitment of a group had usually the most effect on the model.
- Mackerel and sandeel were sensitive to changes in recruitment of other groups.
- Redfish and saithe had strong effects on many of the other groups.
- Cod which is a top predator with large population size did not have much effect on other groups.
- Capelin and sandeel had the most effect on the lower trophic levels.
- Pico-phytoplankton was very sensitive to changes in recruitment.

**Sensitivity of growth parameters**

**Results**

- Altering the growth parameter of Z did not have much effect (not shown).
- Fish groups feeding on zooplankton were sensitive to changes in phytoplankton growth rate.
- Increasing the growth rate of PL had positive effects on all fish groups except mackerel and blue whiting.
- Decreasing the growth rate of PS had positive effects on dino-flagellates that otherwise became extinct.
- The sensitivity study shows the functioning of the system and will be helpful for further work with the Atlantis model.

**Can EwE mimic the Atlantis ecosystem?**  
Erla Sturluddóttir and Gunnar Stefánsson  
Science Institute, University of Iceland

**Introduction**

- Atlantis model has been converted for Icelandic waters.
- Atlantis used as an operating model to test the performance of a simple ecosystem model, Ecopath with Ecosim (EwE).
- Difficult to test the performance of ecosystem models because the true ecosystem is never known.
- In this study the Atlantis ecosystem is known.

**The Atlantis model**

- Oceanographic model
- Biology model
- Fisheries model
- Time step: 12 hours

- ↳ 52 groups
- ↳ 10 age classes
- ↳ 52 spatial boxes
- ↳ 7 layers

**Methods**

- EwE model with no age-classes and no spatial component constructed.
- Parameters and harvest rates calculated from the Atlantis model.
- Automatic balancing process and time-series fitting by estimating the vulnerability in the predator-prey interactions.
- Simulated biomass compared to the true Atlantis biomass using three metrics: modal efficiency (MEF), reliability index (RI) and correlation (C).

**Atlantis model version 1**

**Results**

- Time-series fitting improved the fit of the model, especially when looking at MEF and RI.
- Positive correlation between simulated biomass from the EwE model and the true Atlantis biomass for the fish groups.
- The EwE model was not able to mimic the biomass of the mackerel and top predator groups.
- Most groups that had high correlation in hindcast also had high correlation in forecast.

**Atlantis model version 2**

**Results**

- Not as good fit as for version 1, except for the mackerel and top predator.
- Positive correlation between simulated biomass from the EwE model and the true Atlantis biomass for the fish groups.
- Negative correlation in forecasts for the lower-level groups.
- High correlation in hindcast did not result in high correlation in forecast.
- It was possible to make a simple EwE model that was able to mimic the Atlantis ecosystem.
- The forecasting ability of the model was however not reliable.

# Acknowledgement

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