# Using the end-to-end model Atlantis to test the performance of EwE

Erla Sturludottir and Gunnar Stefansson
University of Iceland

19 September 2017
ICES ASC Miami

MareFrame

MINOUW

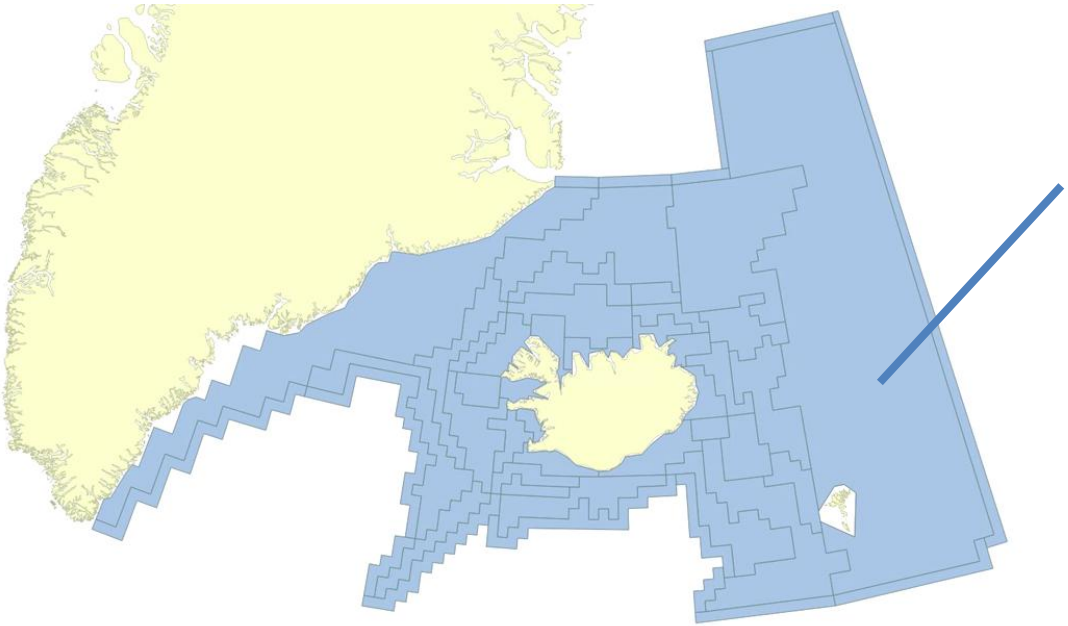
# Ecosystem Approach to Fisheries Management

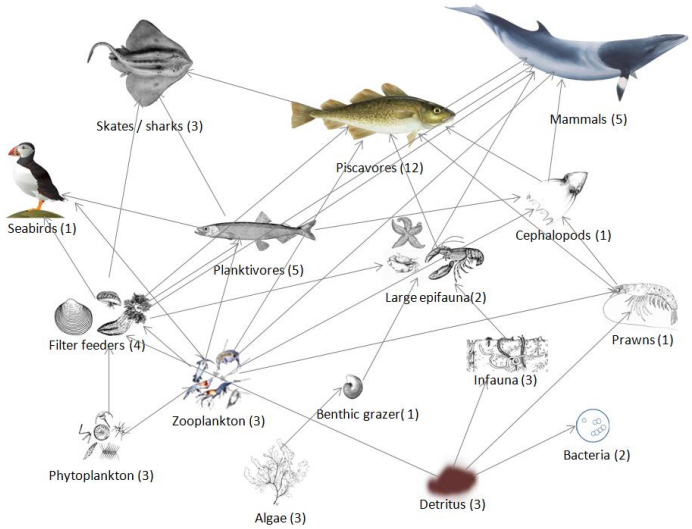
- **Fisheries management today**
  - Single species stock assessment
  - Effect of fishing on target species
- **EAFM**
  - Effect of fishing on the ecosystem
  - Multi-species or ecosystem models
  - Socio-economic factors

# Atlantis

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

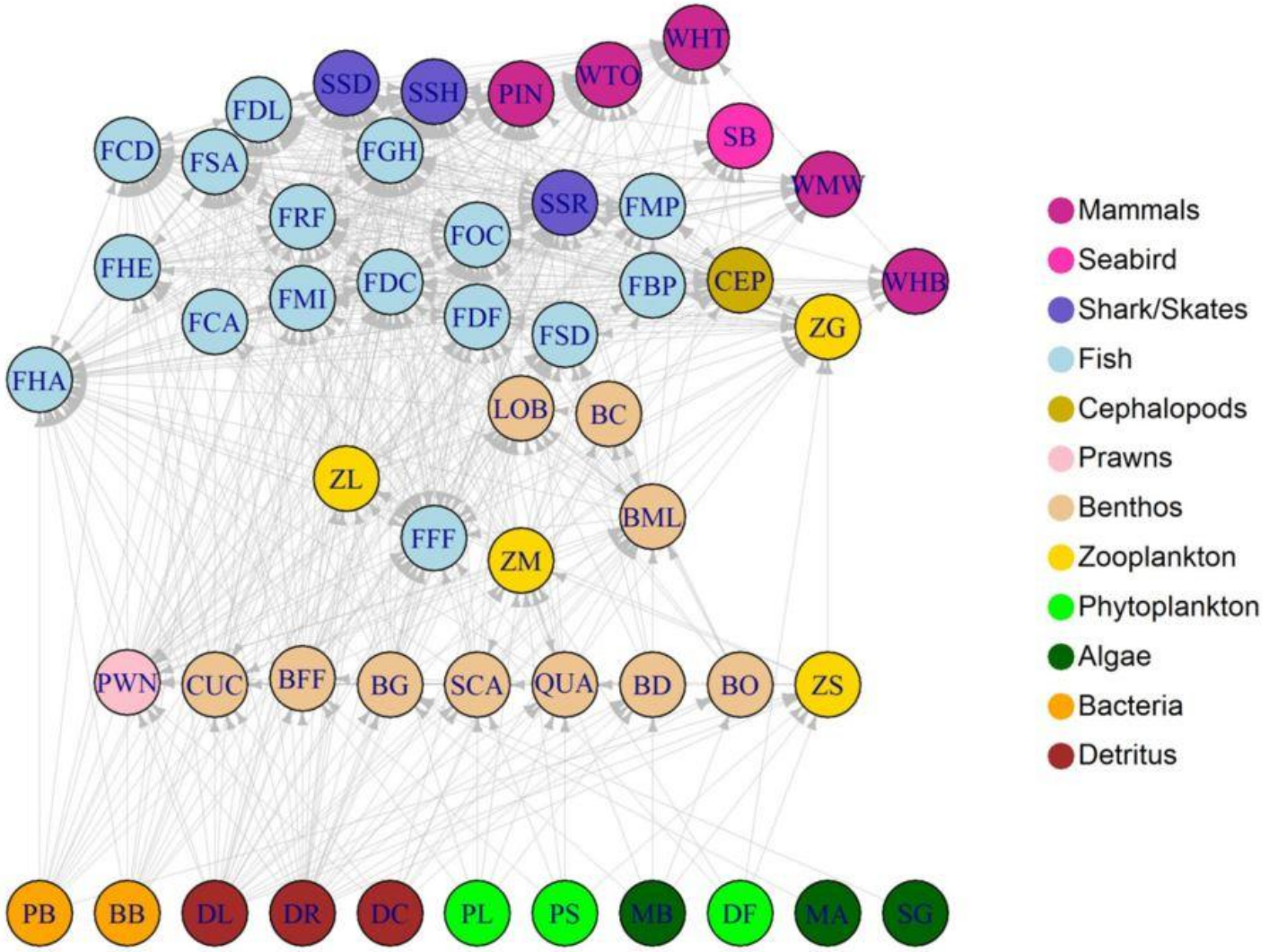
# The Icelandic Atlantis model






- 10 Ageclasses
- SSB-Recruitment
- Feeding curve
- Selectivity

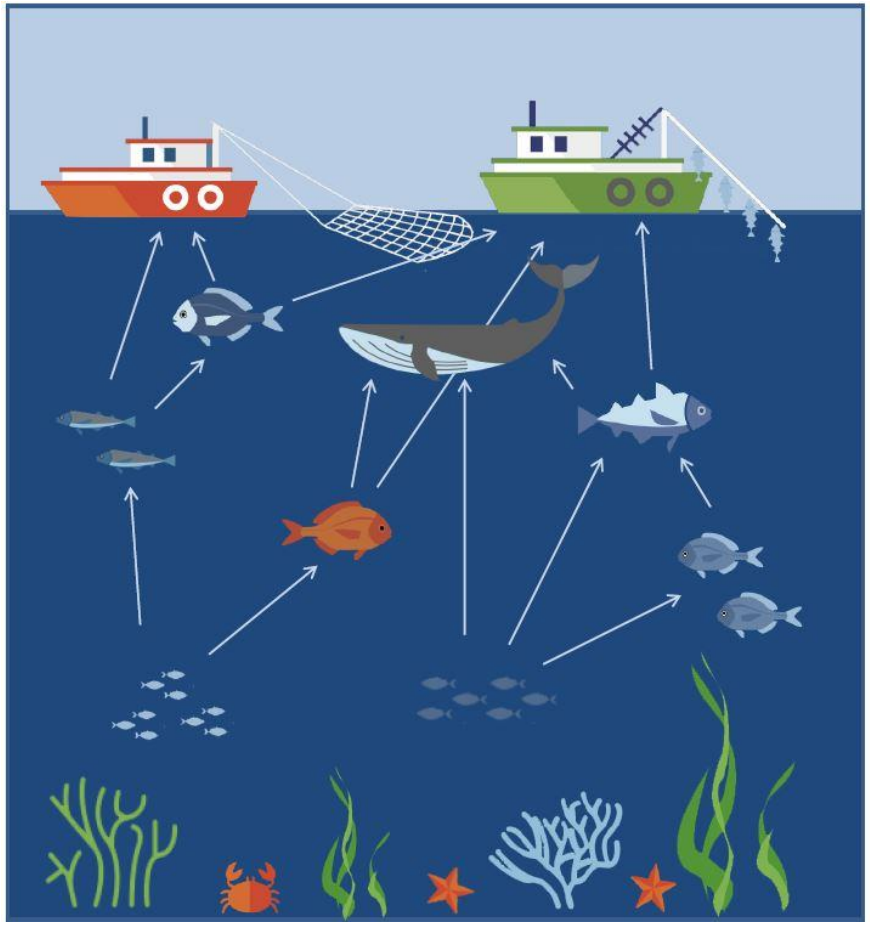
# Food web from the Atlantis model



# Ecopath with Ecosim (EwE)

- **Ecopath: a static, mass-balanced snapshot of the system.**

- **Ecosim: a time dynamic simulation module.**



# The Ecopath part

- **The Ecopath equations**

$$P_i = Y_i + M2 + E_i + BA_i + MO_i$$

$$M2_i = \sum_{j=1}^{n} Q_j * DC_{ij} \qquad M0_i = P_i(1 - EE_i)$$

- **Parameters in Ecopath: B, P/B, Q/B, EE and DC**

# The Ecosim part

- **Balanced Ecopath model is the start**

- **The growth rate in Ecosim is defined as:**

$$\frac{\partial B_i}{\partial t} = g_i \sum_j^n c_{ji} - \sum_j^n c_{ij} + E_i - (M0_i + F_i)B_i$$

$$c_{ij} = Q_{ij} * \frac{V_{ij} * Y_j}{V_{ij} - 1 + Y_j} * \frac{D_{ij} * Y_i}{D_{ij} - 1 + Y_i}$$

# Performance of EwE

- Atlantis used as an operating model
- Data from Atlantis imported into EwE
- Can EwE mimic the Atlantis ecosystem?

# Scenarios tested

- **Scenario 1: Best possible knowlegde**
- **Scenario 2: Error added to the data**
- **Scenario 3: Missing data???**

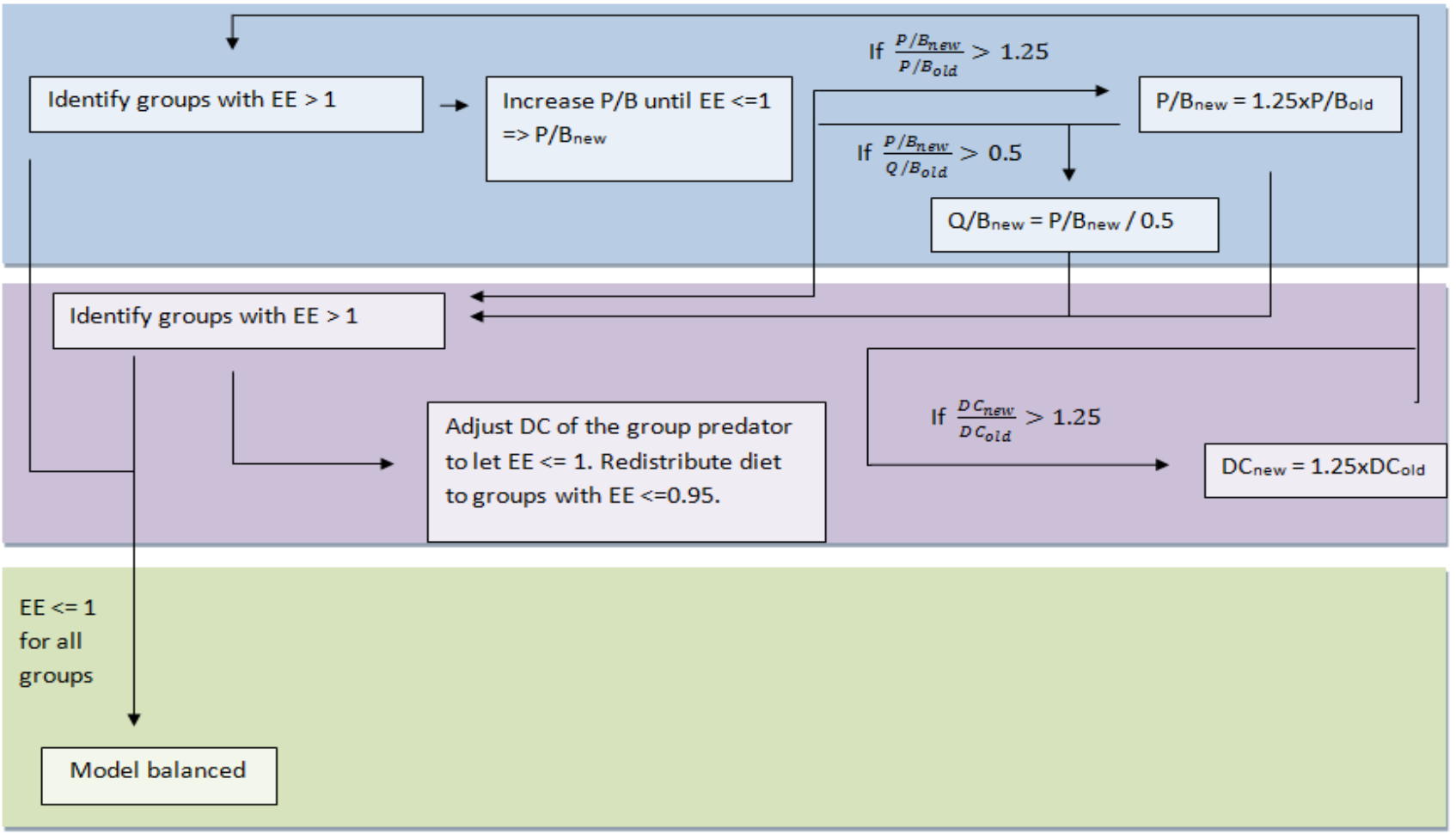
# Building an Ecopath model

- The value of parameters calculated from Atlantis
- Balancing needed before moving to the Ecosim part
- No estimation of parameters
- Usually done manually => subjective
- Not obvious what parameters to change
- Here done automatically with iterations

# Unbalanced model

| Group | type | TL | Biomass | PB | QB | EE | GE | Removals |
|---|---|---|---|---|---|---|---|---|
| Cod 0-4 | 0 | 4.07 | 366493 | 0.37 | 4.44 | 0.59 | 0.08 | 6537 |
| Cod 4+ | 0 | 4.28 | 1523327 | 0.49 | 2.01 | 0.61 | 0.25 | 448843 |
| Haddock 0-4 | 0 | 3.38 | 107812 | 0.58 | 3.33 | 0.51 | 0.18 | 8672 |
| Haddock 4+ | 0 | 3.35 | 80137 | 0.92 | 1.93 | 0.74 | 0.48 | 50415 |
| Saithejuv 0-4 | 0 | 4.17 | 82634 | 0.38 | 3.11 | 0.74 | 0.12 | 1361 |
| Saithe 4+ | 0 | 4.26 | 371033 | 0.37 | 1.49 | 0.78 | 0.25 | 53280 |
| Redfish | 0 | 3.91 | 1836558 | 0.09 | 0.97 | 2.15 | 0.10 | 0 |
| Greenland Halibut | 0 | 4.27 | 571364 | 0.16 | 1.89 | 1.47 | 0.09 | 6105 |
| Flatfish | 0 | 2.88 | 225305 | 0.30 | 1.74 | 0.22 | 0.17 | 19981 |
| Herring 0-4 | 0 | 3.69 | 417900 | 0.51 | 1.30 | 1.42 | 0.40 | 4749 |
| Herring 4+ | 0 | 3.69 | 471015 | 0.39 | 0.87 | 1.53 | 0.45 | 29929 |
| Capelin | 0 | 3.50 | 5899716 | 1.17 | 3.03 | 0.61 | 0.39 | 121793 |
| Migratory pelagic | 0 | 3.53 | 1253964 | 0.51 | 1.71 | 0.56 | 0.30 | 0 |
| Other Codfish | 0 | 3.89 | 115588 | 0.47 | 1.88 | 0.94 | 0.25 | 19333 |
| Demersal Commerical | 0 | 3.72 | 255543 | 0.31 | 1.90 | 1.40 | 0.16 | 19572 |
| Other Demersal Fish | 0 | 3.46 | 534144 | 0.58 | 1.79 | 0.32 | 0.32 | 0 |
| Sandeel Fish | 0 | 3.47 | 1273289 | 0.58 | 3.22 | 0.55 | 0.18 | 0 |
| Long Lived Demersal | 0 | 4.42 | 115273 | 0.15 | 1.31 | 0.85 | 0.12 | 0 |
| Large Pelagic Fish | 0 | 3.95 | 87526 | 0.15 | 1.33 | 1.54 | 0.12 | 0 |
| Small Pelagic Fish | 0 | 3.61 | 106630 | 0.51 | 2.39 | 2.05 | 0.21 | 0 |
| Small Sharks | 0 | 4.50 | 117525 | 0.09 | 1.06 | 1.29 | 0.08 | 0 |
| Skates | 0 | 4.06 | 61269 | 0.15 | 1.12 | 0.53 | 0.14 | 0 |
| Large Sharks | 0 | 4.60 | 111533 | 0.05 | 0.95 | 3.34 | 0.05 | 0 |
| Seabird | 0 | 4.30 | 29786 | 0.11 | 1.38 | -0.03 | 0.08 | 0 |
| Pinniped | 0 | 4.67 | 1835 | 0.13 | 1.48 | 2.61 | 0.09 | 0 |
| Minke Whale | 0 | 4.09 | 69106 | 0.10 | 1.58 | 0.11 | 0.06 | 0 |
| Whale Baleen | 0 | 3.64 | 389033 | 0.08 | 0.82 | 0.29 | 0.10 | 15025 |
| Whale Tooth | 0 | 4.82 | 408143 | 0.06 | 1.85 | 0.17 | 0.03 | 1414 |
| Whale Tooth Other | 0 | 4.69 | 11323 | 0.16 | 0.45 | 0.15 | 0.35 | 0 |

# Automatic balancing process

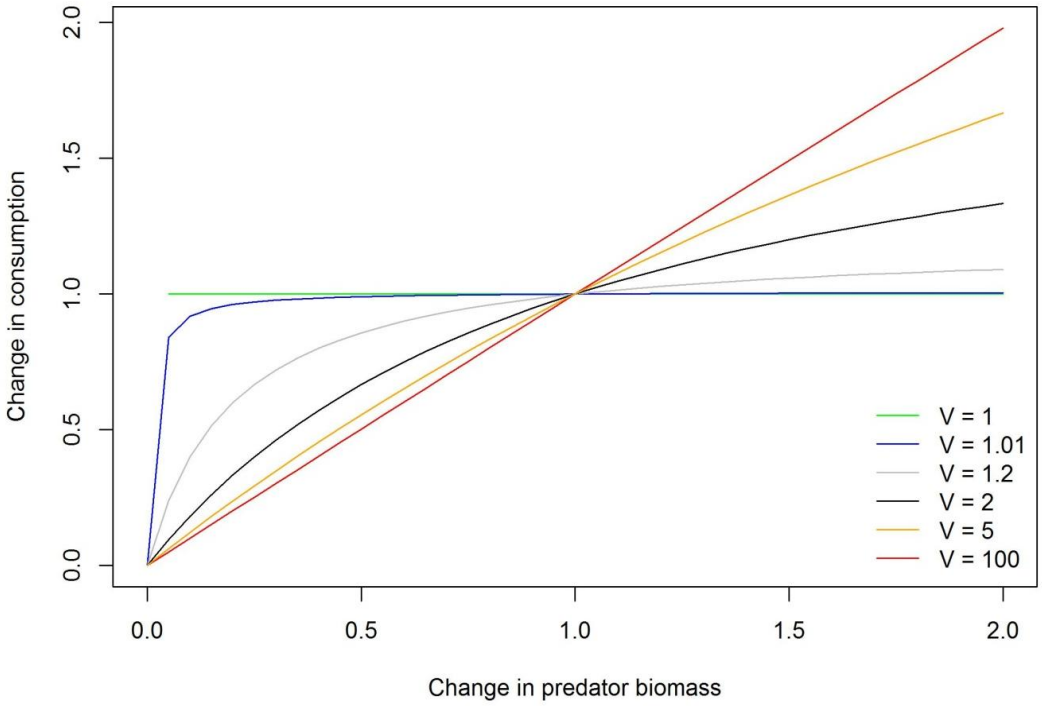


# Fitting the Ecosim model

- Fitted to time-series of biomass and catches.
- Vulnerability parameters in predator-prey interactions estimated
- 671 parameters!

$$c_{ij} = Q_{ij} * \frac{V_{ij} * Y_j}{V_{ij} - 1 + Y_j} * \frac{D_{ij} * Y_i}{D_{ij} - 1 + Y_i}$$

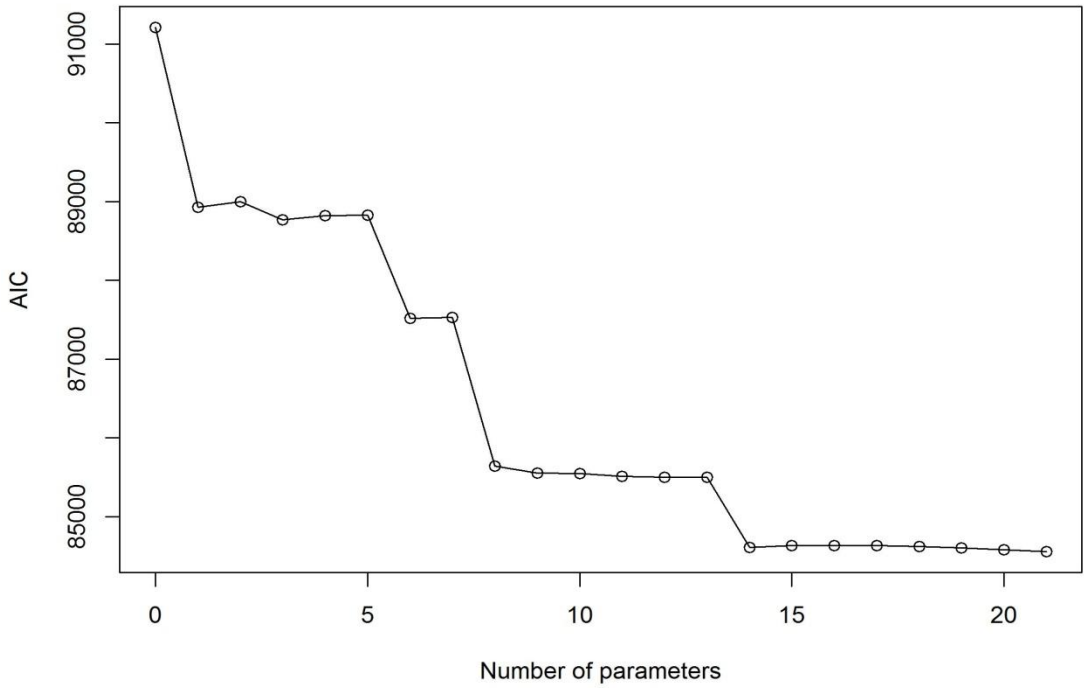
Predator-prey interactions



# The fitting

- Not possible to do simultaneously
- Done iteratively
- Minimizing SS

$$SS = \sum_{i=1}^{2} \sum_{g=1}^{G} \sum_{t=1}^{T} \left(y_{gti} - \hat{y}_{gti}\right)^2$$



# Performance when hindcasting

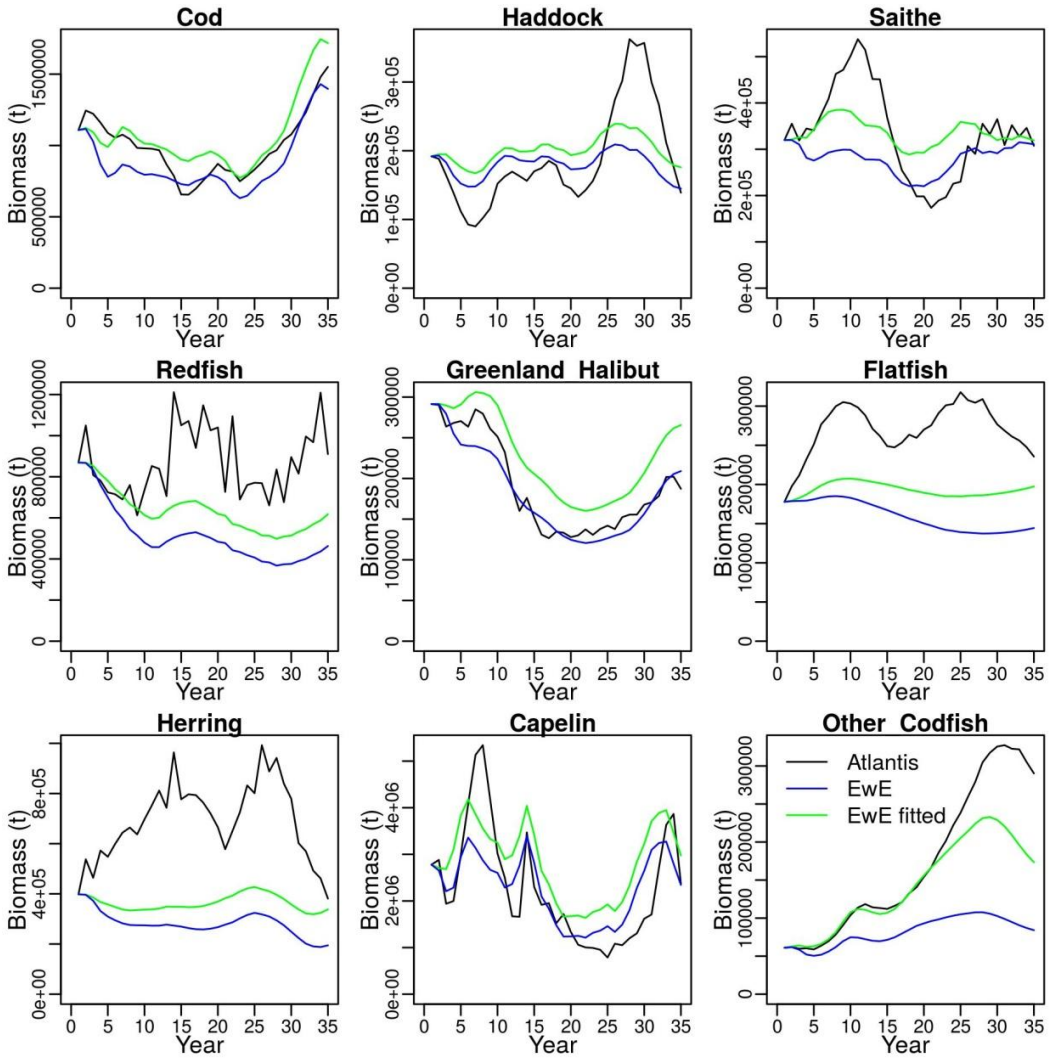
| Average | | |
|---|---|---|
| r | RI | MEF |
| ~~0.49~~ → 0.64 | ~~1.6~~ → 1.4 | ~~-2.6~~ → -1.1 |

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

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

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

| r | RI | MEF |
|---|---|---|
| 0.84 → 0.95 | 2.04 → 1.24 | -0.60 → 0.69 |

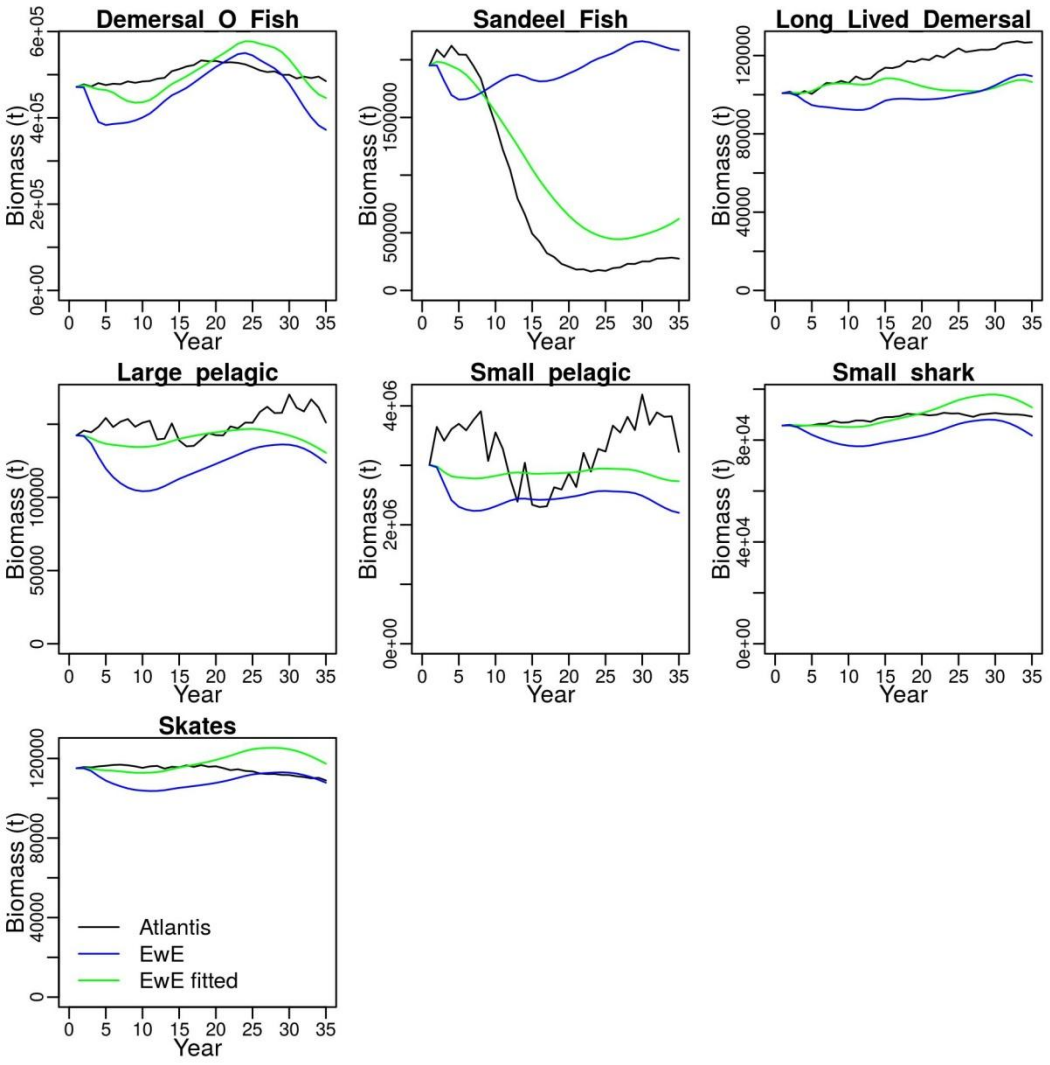


# Performance when hindcasting

| Average | | |
|---|---|---|
| r | RI | MEF |
| 0.14 → 0.26 | 1.78 → 1.24 | -7.32 → -2.72 |

| Sandeel | | |
|---|---|---|
| r | RI | MEF |
| -0.69 → 0.98 | 5.33 → 2.03 | -2.56 → 0.82 |

| Large Pelagic | | |
|---|---|---|
| r | RI | MEF |
| 0.40 → -0.07 | 1.24 → 1.10 | -10.5 → -1.65 |

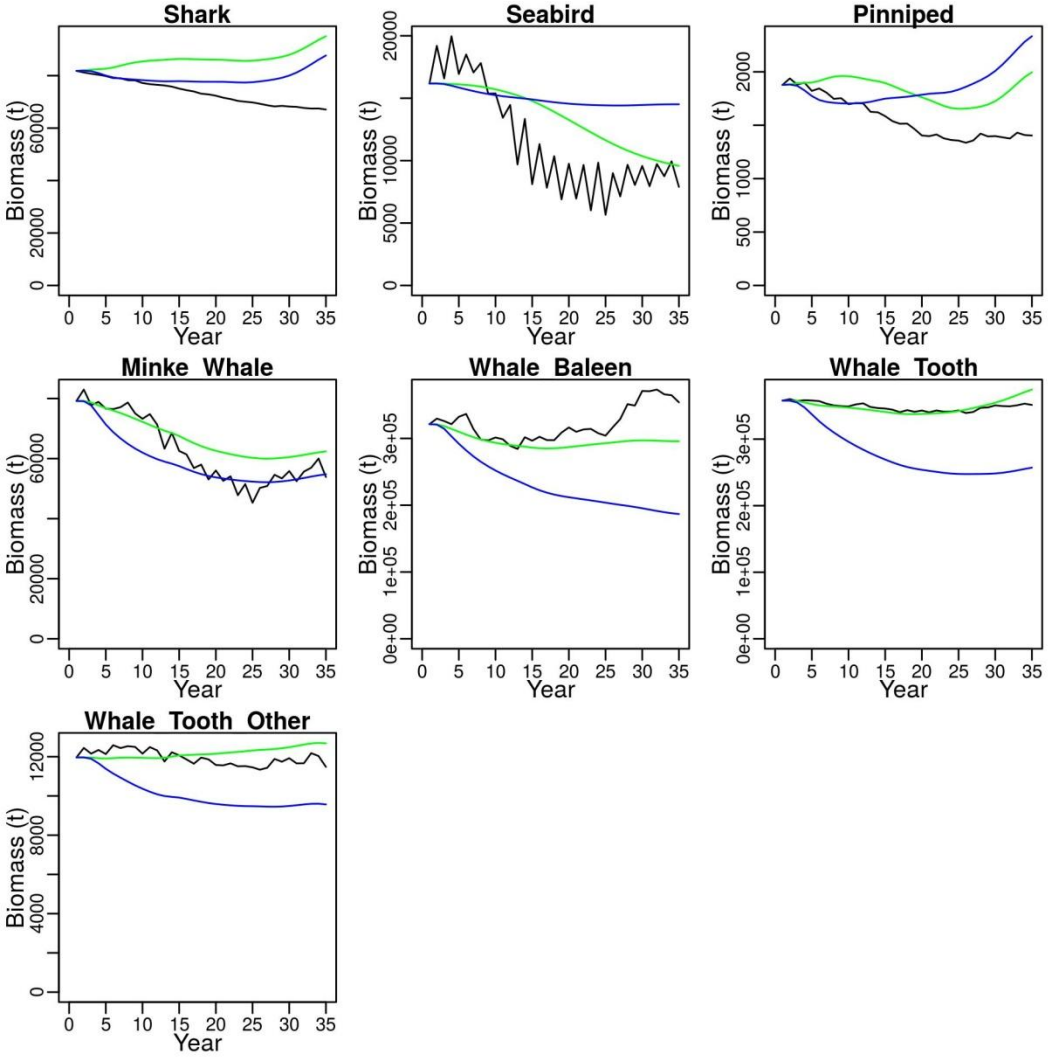


# Performance when hindcasting

| Average | | |
|---|---|---|
| r | RI | MEF |
| 0.34 → 0.29 | 1.29 → 1.16 | -30.3 → -1.74 |

| Minke Whale | | |
|---|---|---|
| r | RI | MEF |
| 0.90 → 0.97 | 1.10 → 1.12 | 0.69 → 0.65 |

| Shark | | |
|---|---|---|
| r | RI | MEF |
| -0.17 → -0.79 | 1.11 → 1.20 | -2.04 → -8.61 |

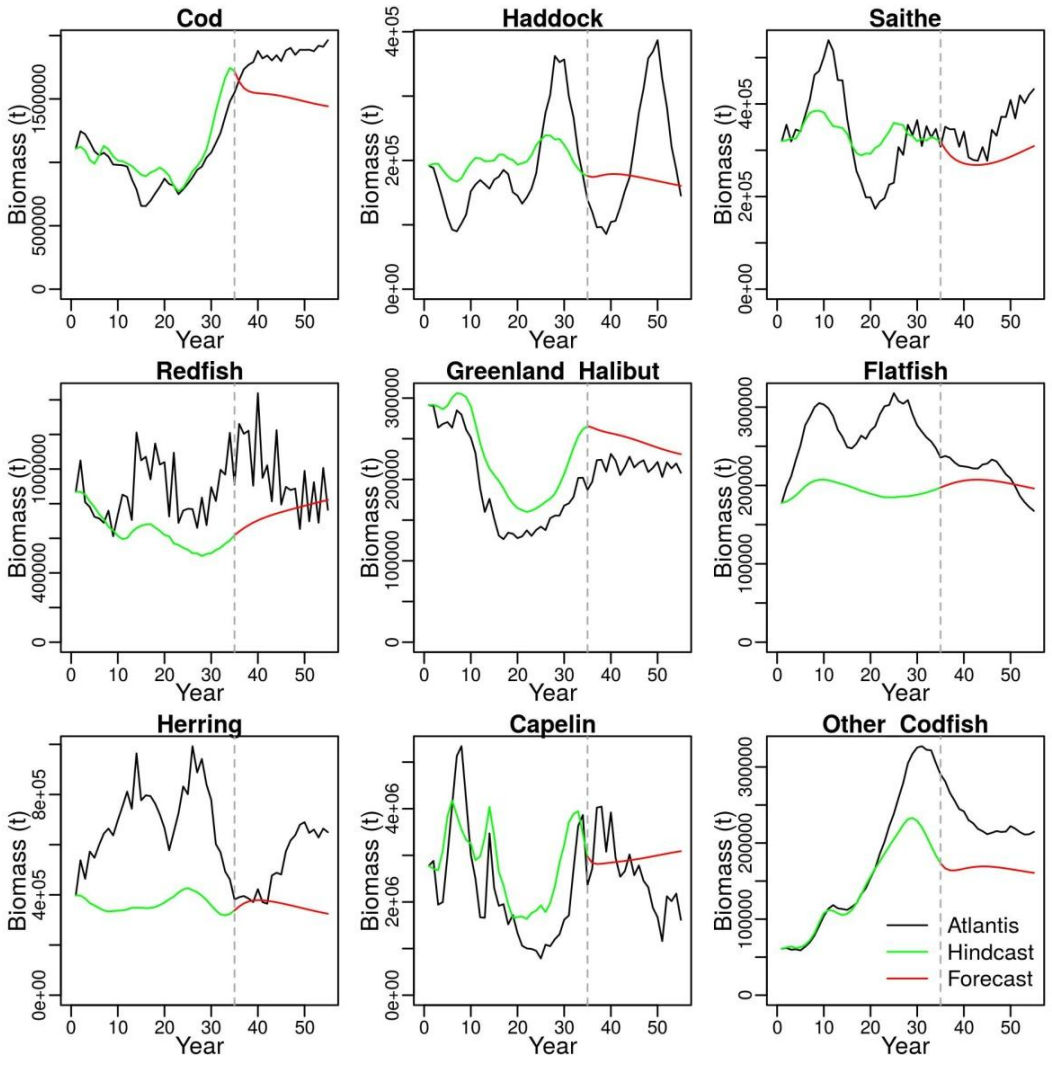


# Performance when forecasting

| Average | | |
|---|---|---|
| r | RI | MEF |
| 0.64 → -0.25 | 1.41 → 1.36 | -1.07 → -4.11 |

| Cod | | |
|---|---|---|
| r | RI | MEF |
| 0.88 → -0.95 | 1.15 → 1.23 | 0.55 → -12.5 |

| Other Codfish | | |
|---|---|---|
| r | RI | MEF |
| 0.95 → 0.25 | 1.24 → 1.40 | 0.69 → -7.36 |

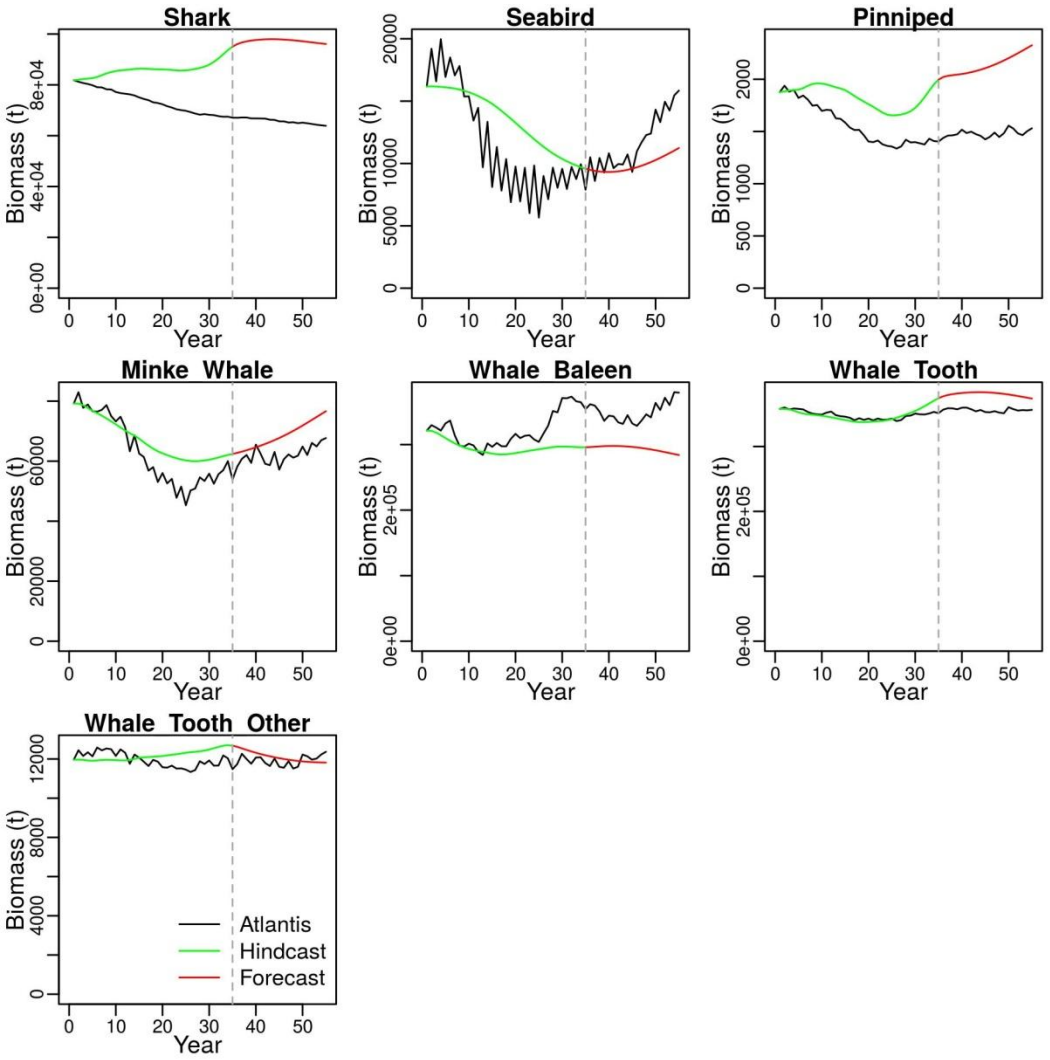


# Performance when forecasting

| Average | | |
|---|---|---|
| r | RI | MEF |
| 0.29 → 0.19 | 1.16 → 1.22 | -1.74 → -185 |

| Minke Whale | | |
|---|---|---|
| r | RI | MEF |
| 0.97 → 0.71 | 1.12 → 1.12 | 0.65 → -3.66 |

| Shark | | |
|---|---|---|
| r | RI | MEF |
| -0.79 → 0.13 | 1.20 → 1.48 | -8.61 → -861 |



# Did groups with better fit have better prediction?

- Done iteratively
- Minimizing SS

# Conclusion

- It is possible to make a simple EwE model that fits reasonably to data.
- But that does not necessary make the model good for predictions.

# Acknowledgement

This project has received funding from the European Union's Seventh Framework Programme for research, technological developement and demonstration under grant agreement no. 613571 and from the European Commission's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 634495 for the project Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries (MINOUW)

MARINE RESEARCH INSTITUTE

MareFrame

SIGILLUM UNIVERSITATIS ISLANDIAE

MINOUW