# Marine food webs, environmental variability, and coastal state conflicts

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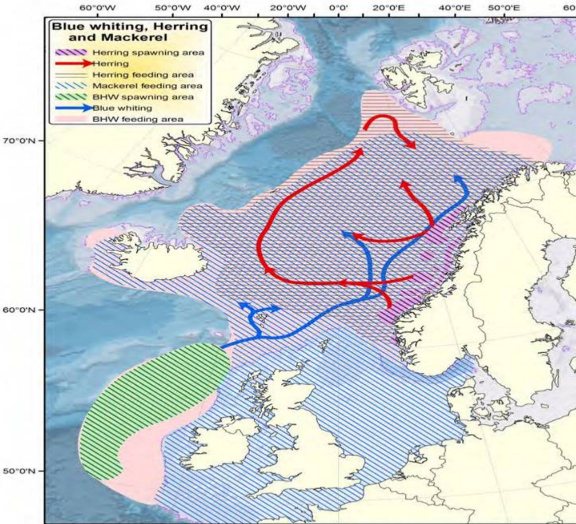
# The Pelagic Fisheries in the Northeast Atlantic: Herring, Mackerel and Blue Whiting

- Main feeding areas
- Highly migratory / straddling
- Changes in time and space
- Warmer water and available food
- Spatial and diet overlap
- Ecological impact on ecosystem



# Motivation

- Develop an empirically based multi-species dynamic optimization model
- Apply game theory
- Empirical results may assist policy-makers
- Help resolve conflicts of interest

# Fisheries

- Russia, Norway, Iceland, the Faroe Islands, and the EU
- 3 stocks harvested by the same countries / people
- Productive stocks
- Social and economic importance

# Failures to reach and maintain agreements

Herring

- 1997 - 2002: quota and sharing agreement
- 2003-2006: disagreement over quota allocations
- 2007-2012: agreement
- 2013 - 2016: unilateral quotas

Blue whiting

- 1998-2005: harvest increase
- TAC since 1994
- harvests exceeded TAC
- 2006: agreement

Mackerel

- Change in migration pattern
- 2008: Appeared in Iceland EEZ
- Unresolved dispute with Norway, the Faroe Islands and the EU
- Faroese withdrew temporally from cooperation

# Discrete surplus-growth, multi-species optimization model with competition between species. Common carrying capacity $K$

$$\max_{0\leq X\leq S} \sum_{t=0}^{\infty} \sum_{i=1}^{3} \Big\{ p_{a,i} * H_{a,i,t}) - c_{a,i}(S_{i,t}, X_{i,t} \Big\} \delta^t, \qquad (1)$$

subject to

| Stock | State Transition Equation for Stock $i$ as Function of $S_{t-1}$ and $X_{t-1}$ |
|---|---|
| Herring | $g_1(S_{t-1}, X_{t-1}) = X_{1,t-1} + \alpha_1 X_{1,t-1}^{m_1} \left(1 - \frac{X_{1,t-1}+X_{2,t-1}+X_{3,t-1}}{K})\right)$ |
| Mackerel | $g_2(S_{t-1}, X_{t-1}) = X_{2,t-1} + \alpha_2 X_{2,t-1}^{m_2} \left(1 - \frac{X_{1,t-1}+X_{2,t-1}+X_{3,t-1}}{K})\right)$ |
| Blue Whiting | $g_3(S_{t-1}, X_{t-1}) = X_{3,t-1} + \alpha_3 X_{3,t-1}^{m_3} \left(1 - \frac{X_{1,t-1}+X_{2,t-1}+X_{3,t-1}}{K})\right)$ |

# Set-Up

- 3 players
- Target escapement
- Non-linear programming
- Challenging
- Simplify further

# Management issues

- New members / coastal states
- Quota share disputes
- Brexit?

# Preliminary results

- Ekerhovd & Steinshamn 2016
- First step addressing straddling fisheries issues in a multi-species context
- From a sole-owner perspective
- Value about 25% higher if the stocks had been optimally managed from a multi-species perspective
- Put more harvest pressure on mackerel relative to the other two species