Economic Benefits of Multi-Species Management

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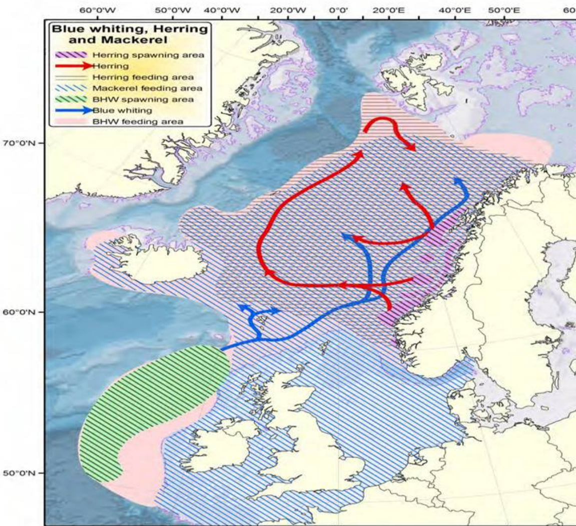
The Pelagic Fisheries in the Northeast Atlantic: Herring, Mackerel and Blue Whiting

- Main feeding areas
- Seasonal variation production
- Highly migratory
- Changes in time and space
- Spatial and diet overlap
- Ecological impact on ecosystem



Motivation

- Develop an empirically based multi-species dynamic optimization model
- The problem is looked upon from a sole-owner perspective
- Numerical methods used to determine optimal policies in terms of maximising net present value

Motivation

- Empirical results that may assist policy-makers
- Help resolve conflicts of interest
- Identify loss by continuing with single-species management instead of multi-species approach

Discrete surplus-growth, multi-species optimization model with competition between species

The sole owners objective

$$\max_{0 \leq X \leq S} \sum_{t=0}^{\infty} \sum_{i=1}^{3} \Big\{ D(H_{i,t}) H_{i,t} \times (1 - \Omega) \Big\} \delta^t, \tag{1}$$

where

$$D(H_{i,t}) = p_i - \gamma H_{i,t} \tag{2}$$

relationship between price obtained and quantity landed, and

$$\Omega = \frac{\beta_i}{1 - b_i} (S_{i,t}^{1-b_i} - X_{i,t}^{1-b_i}) \tag{3}$$

costs defined as a fraction of income.

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Elements of the State Vector, S_t, and Transition Vector, $S_t = G(S_{t-1}, X_{t-1})$

Stock	State Transition Equation $g_i(S_{t-1}, X_{t-1})$ 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	$g_3(S_{t-1}, X_{t-1}) = X_{3,t-1} + \alpha_3 X_{3,t-1}^{m_3} \left(1 - \frac{X_{1,t-1}+X_{2,t-1}+X_{3,t-1}}{K}\right)$

For comparison three single-species counterparts of the multi-species model are derived

Single species growth, $G(X)$, can be described by the well-known logistic growth function:

$$G(X_{i,t}) = r_i X_{i,t} - \frac{r_i}{K_i} X_{i,t}^2, \tag{4}$$

r_i the intrinsic growth rates and K_i the individual carrying capacities for herring, mackerel, and blue whiting , $i = 1, 2, 3,$ respectively.

An implicit equation for the optimal stock size, $X_i^\star$, (*Golden Rule*) deduced from optimal control theory is simply:

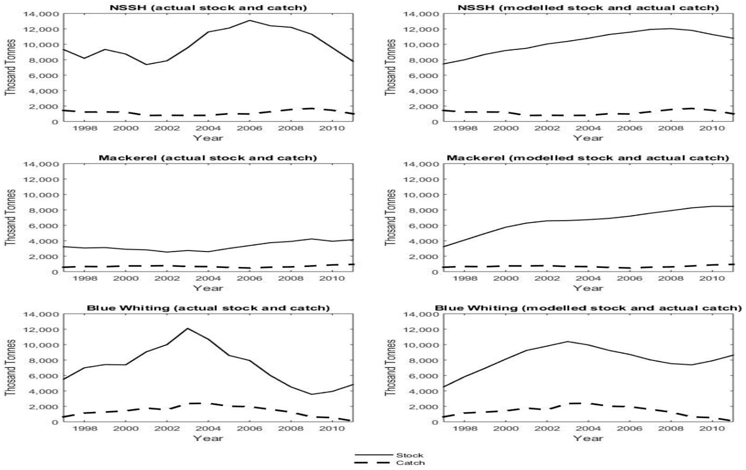
$$\rho = \frac{\partial G(X_i^\star)}{\partial X_i^\star} + \frac{\partial \pi_i / \partial X_i^\star}{\partial \pi_i / \partial H_i^\star}, \tag{5}$$

where π is a function of X and H.

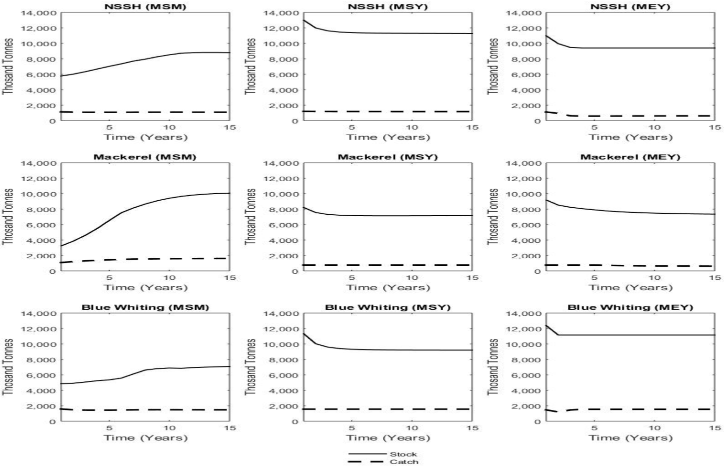
Model Subscripts, Variables, and Parameters

Symbol	Definition	Herring	Mackerel	Blue Whiting	Unit
i	Subscript	1	2	3	Stock/fishery
t	Time				Year
π_i	Revenue				million NOK
Π	Present value				million NOK
α_i	Growth rate	.000324	.099182	.000428	
K	Carrying capacity		29,807		Thousand tonnes
m_i	Modification term	1.85	1.25	1.9	
p_i	Price, intercept	5.49	10.61	2.46	Norwegian kroner
γ_i	Price, slope	-.0017	-.0016	-.00064	
β_i	Cost parameter	.00124	.00124	.00174	
b_i	Catch elasticity	.174	.174	.295	
ρ	Discount rate		5.0		%
r_i	Intrinsic growth rate	.35	.42	.31	
K_i	Carrying capacity	14,303	7,327	19,963	Thousand tonnes
MSY_i	Maximum sustainable yield	1,250	765	1,569	Thousand tonnes
MEY_i	Maximum economic yield	1,127	763	1,547	Thousand tonnes

Actual Catch and Stock Size and Actual Catch and Modelled Stock Sizes (1997-2011)



Stock Sizes and Catch Levels over a 15-Year Period



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Net Present Values (million NOK)

Table: Comparing Actual Policy (and actual stock sizes, 1997-2011) with Actual Policy and Modelled Stocks, Optimal Policy (MSM), MSY, and MEY over 15 Years

Stock	Actual Policy and Stocks	Actual Policy	MSM	MSY	MEY
Herring	30,031	30,035	30,632	31,811	25,916
Mackerel	54,783	56,543	78,928	62,317	59,003
Blue Whiting	17,000	17,060	19,339	20,219	20,296
Total	101,814	103,638	128,899	114,347	105,214

Conclusions

- Compare actual management in the period 1997 - 2011 with optimal management over the same period
- Discounted NPV could have been 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
- A step toward addressing straddling fisheries issues in a multi-species context