Considering economic efficiency in ecosystem-based management: The case of horseshoe crabs in Delaware Bay

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Ecosystem Based Management

Approaches:

- BIO-EBFM: Add ecosystem considerations to existing management
- ECON-EBFM: Management maximizes economic efficiency considering a broader array of ecosystem services

Research Question

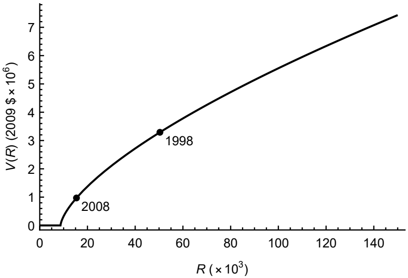
How do outcomes from BIO-EBFM and ECON-EBFM compare?

- We also explore OA and optimal SSFM

Research Approach

	Inefficient	**Efficient**
Single Species	Open Access	Optimal SSFM
Ecosystem	BIO-EBFM	ECON-EBFM

$$V_t = w(R_t - R_m)^{\alpha}$$



Contributions

1. We add to the economics literature on the welfare gains from EBFM
2. We use a simple model to explore a range of welfare outcomes from a regulated open access fishery
3. We apply methods from time-series econometrics to decompose the shadow price of horseshoe crabs

Model: OA

$$\dot{E}_t = \gamma E_t(\Pi_t/E_t) = \gamma E_t(pqC_t - \delta E_t), \quad t \in [-T_1, 0],$$

$$\dot{C}_t = g_c C_{t-\tau} \exp(-C_{t-\tau}/K_c^*) - \eta_c C_t - qC_t E_t,$$

$$\dot{R}_t = g_r R_t \left(1 - \frac{R_t}{K_{r,t}^*(C_t)}\right)$$

Model: BIO-EBFM

$$
\begin{aligned}
\max_{E_t,\, t\in[0,T]} \int_0^T & qC_tE_t dt \\
\text{subject to} \quad & \dot{C}_t = g_c C_{t-\tau} \exp(-C_{t-\tau}/K_c^*) - \eta_c C_t - qC_tE_t, \quad t \in [0,T], \\
& \dot{R}_t = g_r R_t \left(1 - \frac{R_t}{K_{r,t}^*(C_t)}\right), \quad t \in [0,T], \\
& qE_t \leq F_{MSY}, \quad t \in [0,T], \\
& E_t \leq 0 \quad \text{if } R_t < \Theta_r, \quad t \in [0,T], \\
& E_t, C_t, R_t \geq 0, \quad t \in [0,T], \\
& C_t = \phi_t, \quad t \in [-\tau, 0], \quad \text{and} \quad R_0 = \psi_0.
\end{aligned}
$$

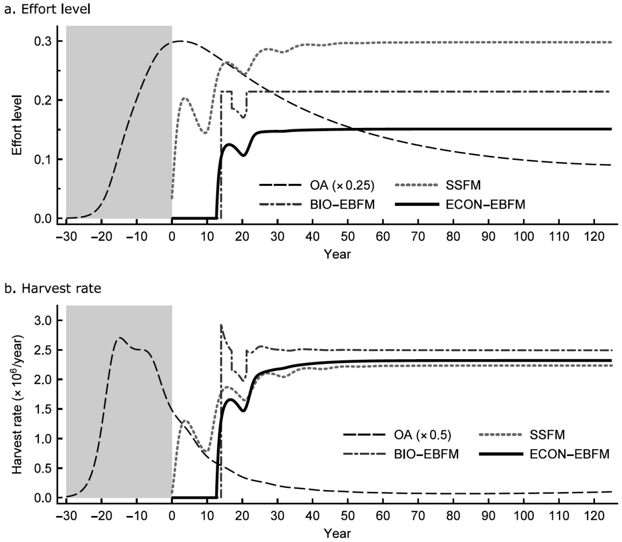
Model: ECON-EBFM

$$
\begin{aligned}
\max_{E_t,\, t\in[0,T]} \; & \int_0^T e^{-\rho t} \left(\Pi_t(C_t, E_t) + V_t(R_t)\right) dt \\
\text{subject to} \quad & \dot{C}_t = g_c C_{t-\tau} \exp(-C_{t-\tau}/K_c^*) - \eta_c C_t - q C_t E_t, \quad t \in [0, T], \\
& \dot{R}_t = g_r R_t \left(1 - \frac{R_t}{K_{r,t}^*(C_t)}\right), \quad t \in [0, T], \\
& E_t, C_t, R_t \geq 0, \quad t \in [0, T], \\
& C_t = \phi_t, \quad t \in [-\tau, 0], \quad \text{and} \quad R_0 = \psi_0,
\end{aligned}
$$

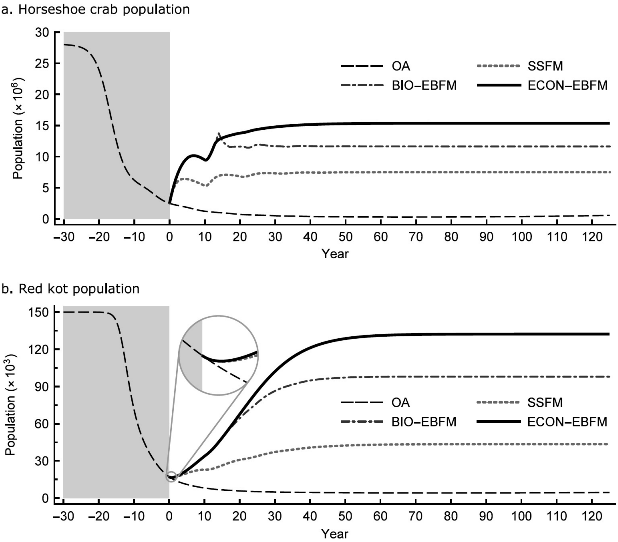
Solution: ECON-EBFM

- λ_t decomposed into:
  1. $\lambda_{1,t}$: $+ \Uparrow$ immediate HSC harvest
  2. $\lambda_{2,t}$: $- \Downarrow$ instantaneous HSC growth rate
  3. $\lambda_{3,t}$: $+ \Uparrow$ HSC recruitment at time $t + \tau$
  4. $\lambda_{4,t}$: $+ \Uparrow$ red knots
- We calculate mutations of λ_t by setting cumulative historical impacts of some components to zero

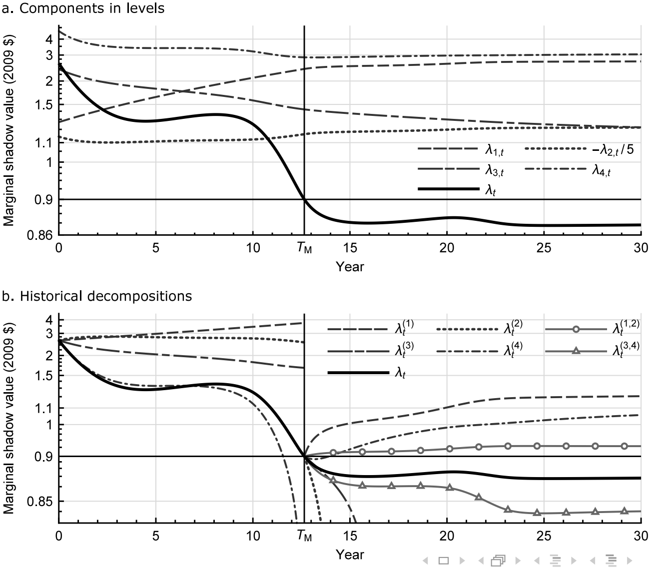
Results: Trajectories



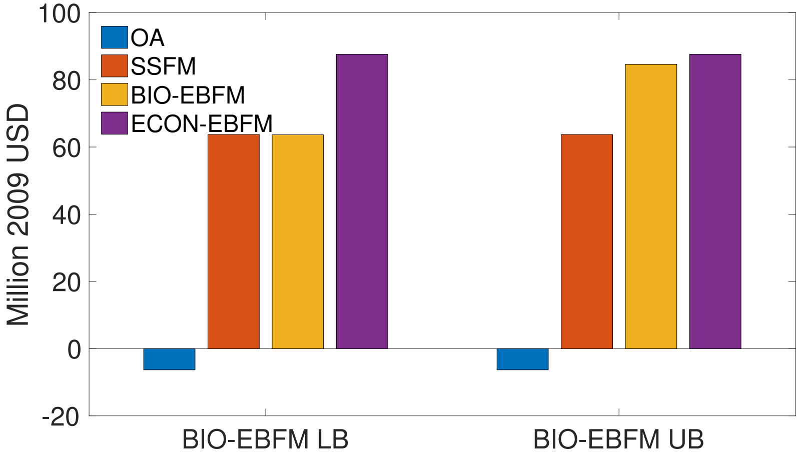
Results: Trajectories



Results: Decomposition



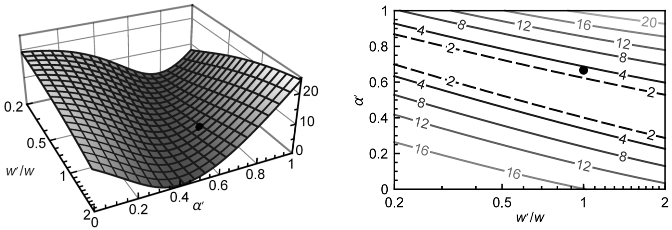
Results: NPV



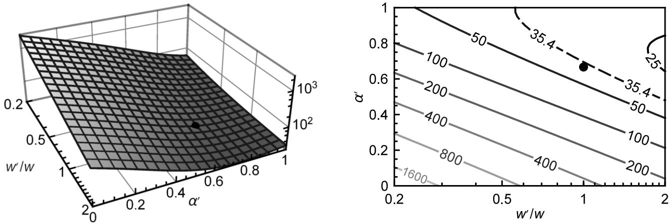
100
80
60
40
20
0
-20
Million 2009 USD
OA
SSFM
BIO-EBFM
ECON-EBFM
BIO-EBFM LB
BIO-EBFM UB

Results: Sensitivity Analysis

a. No rent dissipation under BIO–EBFM



b. Complete rent dissipation under BIO–EBFM



Thank you

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