A Model of
Quota Arbitrage in Multispecies Fisheries

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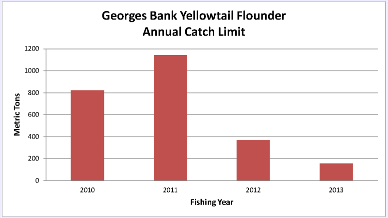
Motivation

- Multispecies fisheries
  - Substantial heterogeneity in species value
- Large intra-annual fluctuations in TACs
  - Circumstantial evidence of targeting weak stock
  - Choke effect does not materialize
- Lag in Management
- Increasing avenues for coordination



- Assume N Identical harvesters.
- Individual's expected catch of species $j \in \{1, \ldots, M\}$, given by $y_j = y(\gamma_j x, s_j)$.
  - x is an aggregate input applied to all species
  - $\gamma_j > 0$ is the marginal productivity of effort for species j.
- Let $c(x; \theta)$ denote operating costs under technology θ,
  - $\pi(x, s; \theta) = \sum_j p_j y(\gamma_j x, s_j) - c(x; \theta)$.

- Let species k denote the bycatch species, $p_k = 0$.
- Technologies $\theta \in \{\underline{\theta}, \bar{\theta}\}$, with $\gamma_k(\bar{\theta}) > \gamma_k(\underline{\theta})$ (i.e. $\bar{\theta}$ allows more direct targeting of species k).
- Assume $c(x; \bar{\theta}) > c(x; \underline{\theta})$ and $c_x(x; \bar{\theta}) > c_x(x; \underline{\theta})$.
- Harvesters face a penalty of $\phi(z)$, if quota overages for bycatch species, $z > 0$.
    - $\phi' > 0, \phi'' > 0$

- Individuals harvesters that maximize expected profits each season solve

$$V(s, Q_k; \theta^*) = \max_{x,\theta} \ \pi(x, s; \theta) - E\left[\phi(Ny(\gamma_k(\theta)x, s_k) + \xi_k - Q_k)\right]$$

  - $s = (s_1, \ldots, s_M)$ is a vector of stock abundances
  - Q_k the season TAC for species k
  - ξ_k a zero-mean random variable with density f_k in $[\underline{\epsilon}_k, \bar{\epsilon}_k]$.

- Harvesters would never adopt $\bar{\theta}$ as it increases operating costs and the expected penalty, $V(s, Q_k; \underline{\theta}) \geq V(s, Q_k; \bar{\theta})\ \forall s, Q_k$.

- Optimal input choice $x^*(s, Q_k, \underline{\theta})$ given by

$$\frac{\partial \pi}{\partial x} - E\left[\phi'\right] N \left(\frac{\partial y}{\partial x_k}\right) \gamma_k(\underline{\theta}) \leq 0$$

- where $x_k = \gamma_k x$. From comparative statics, $\partial x^* / \partial Q_k > 0$, $\partial x^* / \partial s_k < 0$, and $\partial x^* / \partial s_j > 0$ for $j \neq k$.

- In the current season a reduction in the TAC is announced for the next season
  - ρQ_k with $\rho \in (0, 1)$.
  - ρ is independent of current period harvest.
- Transition equations: $s_{jt+1} = g_j(s_{jt} - Ny(\gamma_j x_t, s_{jt}) - \xi_{jt}), \forall\ M$
  - g_j are concave functions.
- $\boldsymbol{\xi} = (\xi_1 \ldots \xi_M)$ are random variables with joint distribution f and marginal densities f_j in $[\underline{\epsilon}_j, \bar{\epsilon}_j]\ \forall\ j$.

In the first period harvesters solve:

$$V(s_t, Q_k, \theta_t^*) = \max_{x_t, \theta_t} \pi(x_t, s_t; \theta_t) - E[\phi] + \beta E[V(s_{t+1}, \rho Q_k, \underline{\theta})]$$

subject to

$$\begin{aligned} s_{1t+1} =& g_1(s_{1t} - Ny(\gamma_1 x_t, s_{1t}) - \xi_{1t}) \\ \vdots \quad & \quad \vdots \quad\quad \vdots \\ s_{Mt+1} =& g_M(s_{Mt} - Ny(\gamma_M x_t, s_{Mt}) - \xi_{Mt}) \end{aligned}$$

- Optimal input choice x_t^* given by

$$\frac{\partial \pi}{\partial x_t} - E\left[\phi'\right] N \left(\frac{\partial y}{\partial x_{kt}}\right) \gamma_k(\theta_t) + \beta E \left\{ \sum_{j=1}^{M} \left(\frac{\partial V_{t+1}}{\partial s_{jt+1}}\right) \left(\frac{\partial s_{jt+1}}{\partial x_t}\right) \right\} \leq 0$$

- If third term > 0, harvesters will harvest bycatch species k above the myopic level.

- Marginal benefits in $t+1$ given by

$$\frac{dE[V_{t+1}]}{dx_t} = NE\left\{ \overbrace{\phi' g_k' \left(\frac{\partial y_{kt}}{\partial x_{kt}}\right) \gamma_k(\theta_t)}^{\Delta^{-}\text{in penalty in } t+1} - \overbrace{\sum_{j \neq k} g_j' p_j \gamma_j \left(\frac{\partial y_{jt}}{\partial x_{jt}}\right) \left(\frac{\partial y_{jt+1}}{\partial s_{jt+1}}\right)}^{\Delta^{-}\text{in profits in } t+1} \right\}$$

- where the first term is increasing in θ_t and decreasing in ρ.
- $dE[V_{t+1}]/dx_t > 0$ for abundant stocks $j \neq k$ (i.e. g_j' small).
- Provided the TAC Q_k in period 1 is large enough, $\partial x_t^* / \partial \rho < 0$.

The Model

Harvesters with Foresight: Two periods

- $\Delta\left(E[\phi_t(x_t, \theta_t, Q_k)] + E[\phi_{t+1}(x_t, \theta_t, \rho Q_k)]\right) > \Delta c(x_t, \theta_t)$ is a sufficient condition for $\theta_t^* = \bar{\theta}$ to hold.

- Note that for large N the result is not a Nash equilibrium.

    - Absent an enforceable commitment, the following strategy represents a profitable deviation: $\theta_t^* = \underline{\theta}$ & $x_t^* = x_t^{*\ myopic}$

- Thus, strategic targeting of (future) choke species more likely in settings of existing coordination among harvesters (and credible threats against deviations from coordination).

When could we expect intertemporal arbitrage of quota to occur?

- There must be jointness in production.
- Small number of participants makes coordination feasible (free-riding easy to detect).
- Large announced reduction in next season's TAC and slack quota in the current period, allows for increase in effort and the re-targeting of low-value species.
- Higher effort and re-targeting this period must not impair stock abundance of valuable species next season.

- NOTE: This is an issue of perverse incentives, not illicit behavior.
- In the U.S., overfished stocks must be rebuilt in as short a time as possible and in a period not to exceed 10 years.
- In practice, reubuilding plans lead to drastic reductions in TACs.
- This work shows that policymakers should be mindful of the timing and implementation of TAC reduction announcements.
- To avoid strategic targeting of the species to be rebuilt, TAC reductions for the upcoming season may be accompanied by additional catch restrictions in the current period or smaller intra-annual changes.

Questions?

Yellowtail Flounder in New England

Table: Biomass for main New England Stocks

Stock	2010 Spawning Stock Biomass (mt)	2011 Spawning Stock Biomass (mt)	2012 Spawning Stock Biomass (mt)
GB Cod	6,108	5,231	4,066
GOM Cod	8,638	5,617	2,954
GB Winter Flounder	4,997	5,157	4,828
GOM Winter Flounder	6,341	6,666	3,337
GB Haddock	103,889	71,076	65,848
GOM Haddock	4,877	4,086	4,551

Yellowtail Flounder in New England

- Northeast Fishery sectors VIII, IX, and XIII 77% of the yellowtail flounder in 2011 (61% in 2010 and 73% in 2012).
- Total revenue per pound of yellowtail flounder landed decreased from $16.4 to $11.3 in 2011 in Georges Bank, but remained the same in the Gulf of Maine ($13.0).

Introduction

Could similar incentives arise in the context of multispecies fisheries?

- Recent history of fisheries management in New England has seen substantial interannual variability in TACs.
- Stocks deemed healthy one year have been retroactively identified as overfished soon thereafter.
- A lag exists between the updating of a stock's overfishing status and the prescribed implementation of rebuilding plans.
- This lag creates incentives for targeting a stock likely to be binding in the following year but with relatively high TACs in the current year.