Cooperative and Non-Cooperative Strategies for Management of Bering Sea Pollock

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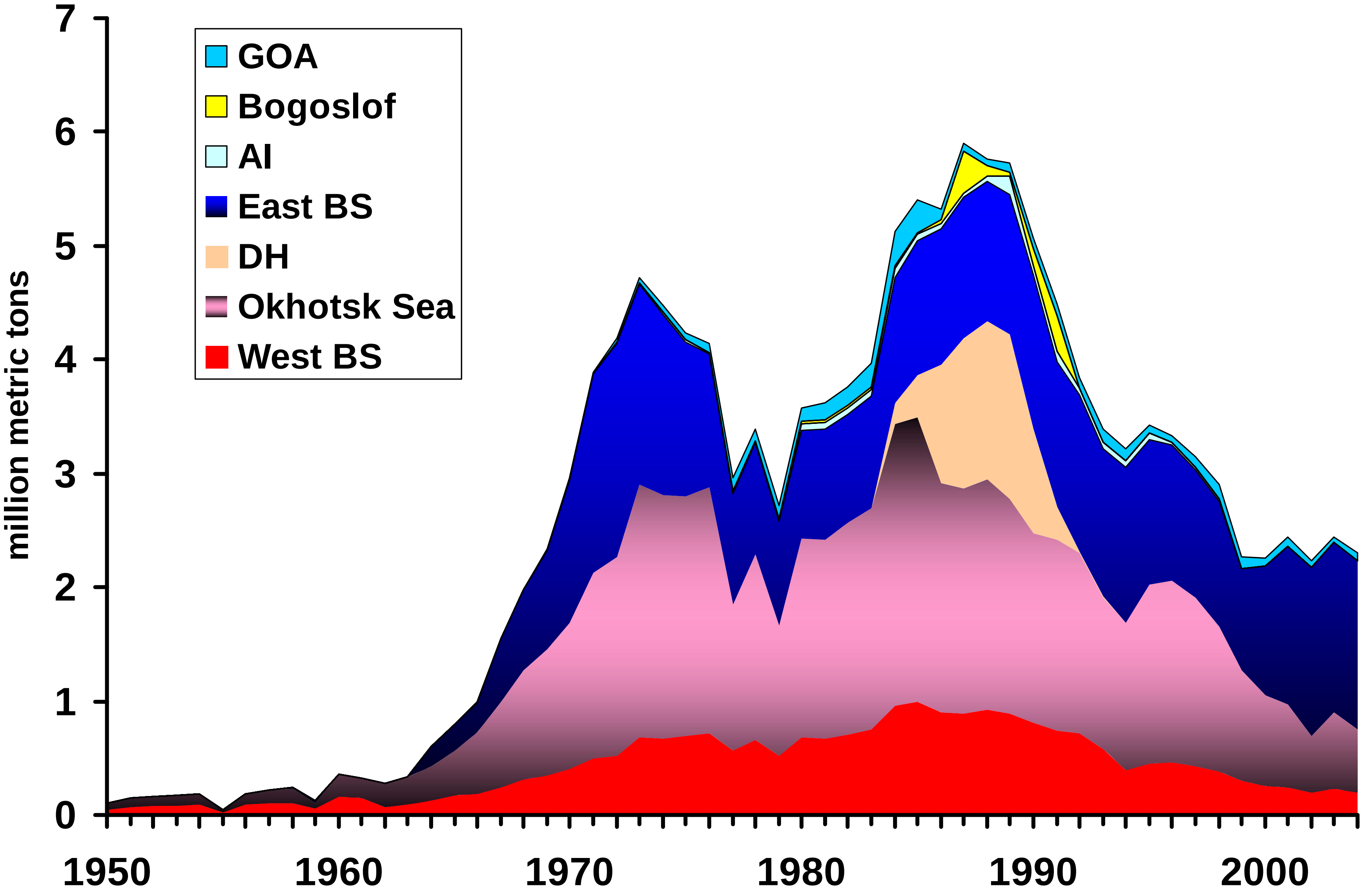
- Exposure of straddling stocks to discordant management regimes compromises sustainability.
- Coordinated management of straddling stocks is particularly difficult when:
  - the stock is migratory, the spatial distribution of the stock varies across the boundary, or biomass and recruitment are highly variable;
  - management/social objectives differ, there are differences in the degree of risk aversion, or time preferences or expectations about future access to the stock differ; or
  - product prices, input costs, or access to capital differ.

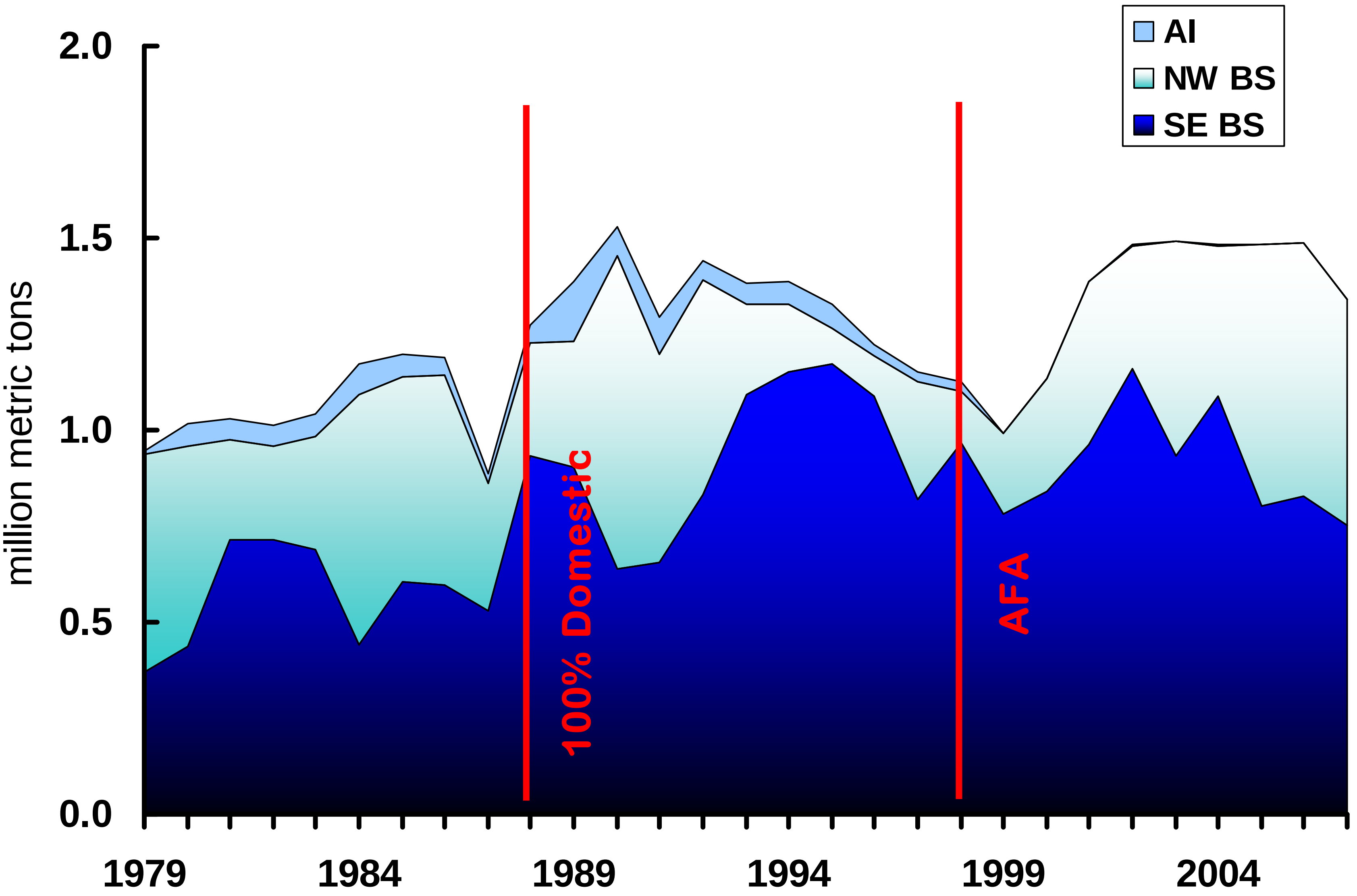
The December 2010 SAFE reports that the EBS pollock stock is above B_{MSY} and below the OFL.

However, a variable portion of the EBS pollock stock is extends into the Russian EEZ where it is subject to a discordant management regime.

Pollock Catches—North Pacific

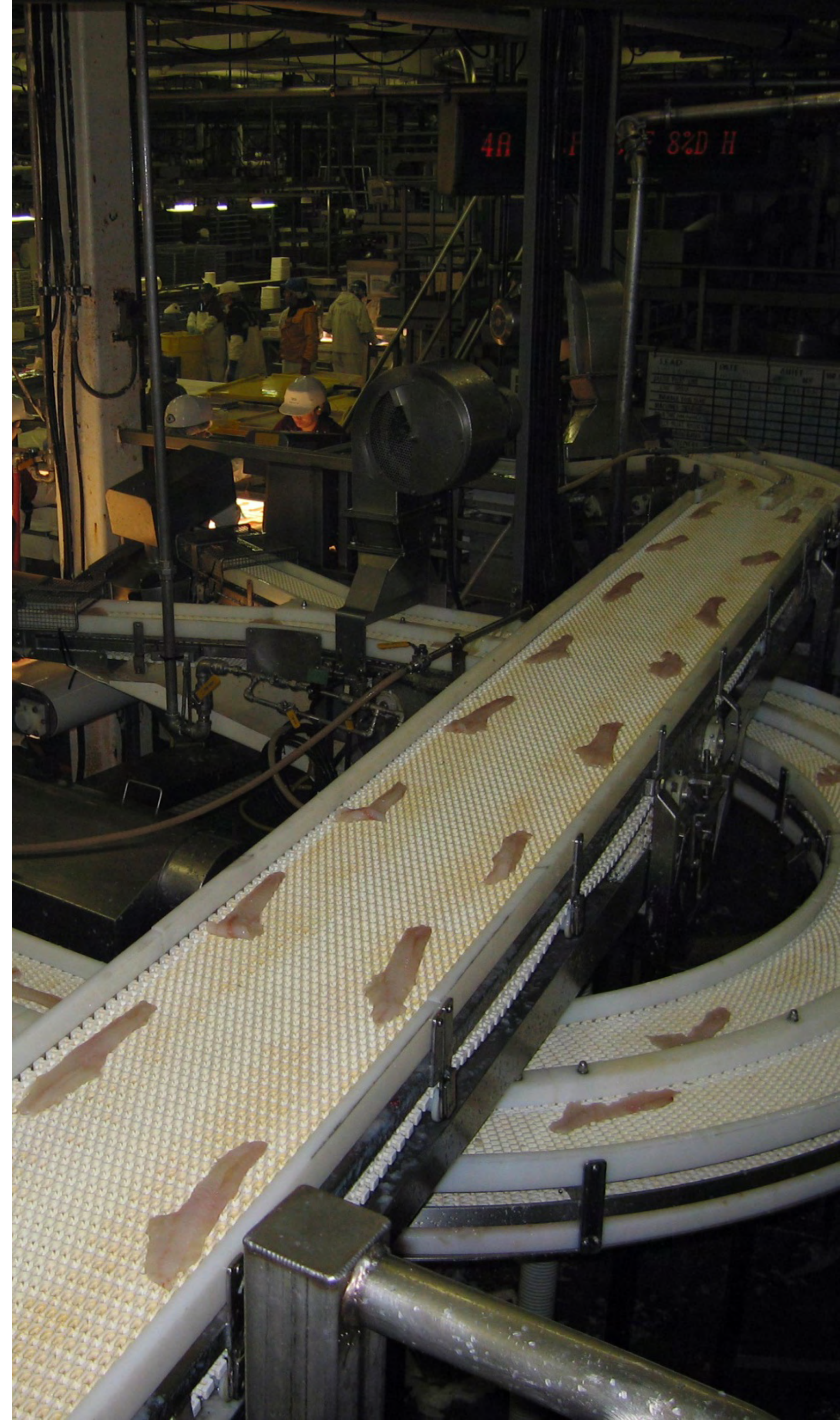


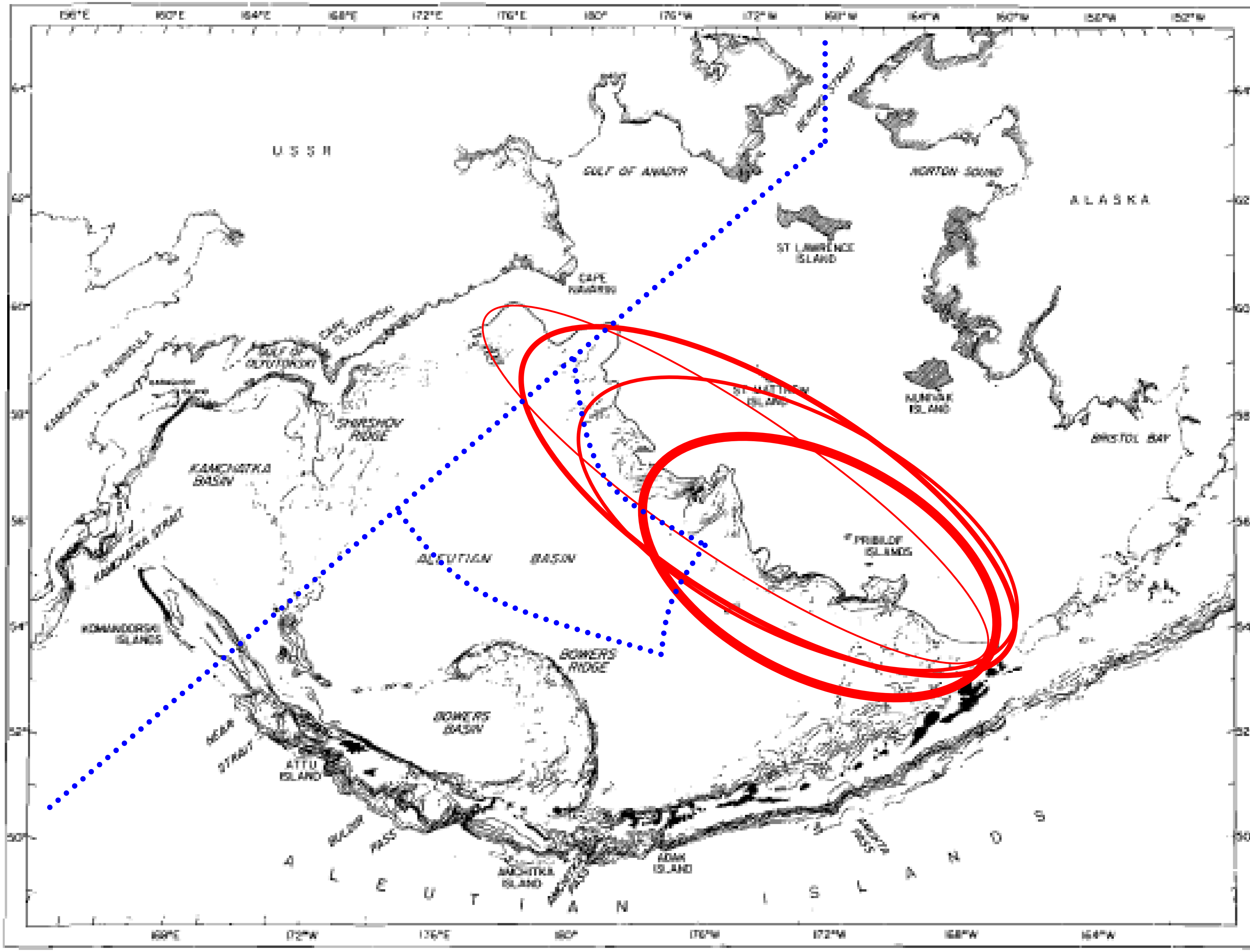
Pollock Catches—Eastern Bering Sea



The abundance and spatial distribution of EBS pollock varies.

At times the center of abundance distributes to the north and west, where an increased portion of the stock is exposed to harvesting by vessels in the Russian EEZ.




U S S R
GULF OF ANADYR
NORTON SOUND
ALASKA
ST LAWRENCE ISLAND
CAPE NAVARIN
CAPE OLYUTORSKI
GULF OF OLYUTORSKI
KAMCHATKA PENINSULA
SHIRSHOV RIDGE
ST MATTHEW ISLAND
NUNIVAK ISLAND
BRISTOL BAY
KAMCHATKA BASIN
KAMCHATKA STRAIT
PRIBILOF ISLANDS
ALEUTIAN BASIN
KOMANDORSKI ISLANDS
BOWERS RIDGE
BOWERS BASIN
ATTU ISLAND
AMCHITKA ISLAND
ADAK ISLAND
A L E U T I A N I S L A N D S

Governance and industrial organization of the US pollock fishery differs markedly from the governance and industrial organization of Russian Federation EEZ pollock fisheries.

Since 1999, the US fisheries have operated under a rights-based governance structure that has allowed firms to form cooperatives to contractually sub-allocate shares of the total allowable catch (TAC) to individual vessels.

While the US EEZ pollock fishery has become highly capitalized, profitable, and geared to value-added production, conditions in the Russian Far East have not been conducive to investment needed to modernize fishing or processing capital.

The lack of investment in modern processing technology means that the same volume of fish harvested in Russian Federation EEZ waters yields a lower quality and lesser quantity of product than it would yield if harvested in the US EEZ.

These effects are exacerbated to the extent that the portion of the eastern Bering Sea pollock stock that distributes into the Russian EEZ consists of disproportionate numbers of younger fish.

Management of a harvested stock can be characterized as a constrained stochastic dynamic optimization, e.g.,

$$max\ \mathsf{E}(\mathbf{Utility}) = \mathsf{E}\sum_{t=0}^{\infty}\left(\tfrac{1}{1+r}\right)^{t} g(\mathbf{x}_t, \mathbf{y}_t, \mathbf{h}_t, \mathbf{w}_t)$$

$$s.t. \qquad \mathbf{x}_t = f\left(\mathbf{X}_{t-l}, \mathbf{Y}_{t-k}, \mathbf{H}_{t-j}, \mathbf{W}_{t-i}\right) + \boldsymbol{\varepsilon}_t$$

$$\mathbf{H}_t \le g(\mathbf{X}_{t-l}, \mathbf{Y}_{t-k}, \boldsymbol{\Omega})$$

$$\mathbf{x}_t \ge 0 \quad \mathbf{x}_t \ge \mathbf{v}_t \ge 0$$

or

$$min\ \mathsf{E}(\mathbf{Regret}) = \left(\tfrac{1}{1+r}\right)^{t} \sum_{t=0}^{\infty} g^*(\mathbf{x}_t - \mathbf{x}^*, \mathbf{y}_t - \mathbf{y}^*, \mathbf{v}_t - \mathbf{v}^*, \mathbf{w}_t - \mathbf{w}^*)$$

$$s.t. \qquad \mathbf{x}_t = f\left(\mathbf{X}_{t-l}, \mathbf{Y}_{t-k}, \mathbf{V}_{t-j}, \mathbf{W}_{t-i}\right) + \boldsymbol{\varepsilon}_t$$

$$\mathbf{H}_t \le g(\mathbf{X}_{t-l}, \mathbf{Y}_{t-k}, \boldsymbol{\Omega})$$

$$\mathbf{x}_t \ge 0 \quad \mathbf{x}_t \ge \mathbf{v}_t \ge 0$$

A common approach to solution of constrained optimization problems involves expressing the problem in Lagrangian form—as a higher-dimension unconstrained optimization—and solving the system of first order or Kuhn-Tucker conditions.

Management of a straddling stock can be characterized as a two-party game.

Solutions to two-party games depend on conjectures about the extent to which each party engages in strategic behavior.

Under quasi-competitive behavior, each party sets a harvest management strategy that ignores the strategy set by the other party.

The status quo for EBS pollock is a quasi-competitive solution: we do our thing, the Russians do their thing, and we both pretend that it does not matter that we are harvesting a stock that diffuses across the convention line.

Photo: USCG

Different cooperative and non-cooperative solutions to the constrained optimization can be represented by varying the objective function. For example, if the objective is to maximize net revenue, for a quasi-competitive equilibrium, net revenue can be expressed as:

$$NR_{US} = P_{US}(Q_{US}) - TC_{US} \quad \text{and} \quad NR_{RF} = P_{RF}(Q_{RF}) - TC_{RF}$$

and the first-order conditions for an optimal equilibrium solution are:

$$\frac{\partial TC_{US}}{\partial(Q_{US})} = P_{US} \quad \text{and} \quad \frac{\partial TC_{RF}}{\partial(Q_{RF})} = P_{RF}$$

The solution to independent optimization by each party is unlikely to be biologically feasible or to maximize the sum of net revenues across both nations.

Under a collusive strategy, players optimize the value of their joint product.

In the context of Bering Sea pollock, this would amount to the US and Russia agreeing to a joint management strategy that maximized the total net benefits of harvests without concern about the distribution of benefits between nations.

For a collusive equilibrium, net revenue can be represented as:

$$NR = P_{US}(Q_{US}) + P_{RF}(Q_{RF}) - TC_{US} - TC_{RF}$$

and the first-order conditions for an optimal equilibrium solution are:

$$\frac{\partial(TR_{US} + TR_{RF})}{\partial Q_{US}} = \frac{\partial TC_{US}}{\partial Q_{US}} \quad \text{and} \quad \frac{\partial(TR_{US} + TR_{RF})}{\partial Q_{RF}} = \frac{\partial TC_{RF}}{\partial Q_{RF}}$$

This solution will be biologically tenable and will maximize total value from the straddling stock, with catches distributed between the two nations such that marginal net revenues are maximized.

Cournot-Nash equilibria, Stackleberg equilibria, and Stackleberg disequilibria represent conjectures under which each party recognize that its benefits are conditional on the other's choices, but they stop short of maximizing their joint product.

In the case of Bering Sea pollock, these solutions represent a recognition that there are biological and pecuniary externalities associated with independently adopted harvest management strategies and that the optimal choice of a management strategy for the US EEZ pollock fishery will depend on the management strategy that the Russian Federation adopts and vice versa.

For a Cournot-Nash equilibrium, net revenue is the same as for the quasi-competitive equilibrium,

$$NR_{US} = P_{US}(Q_{US}) - TC_{US} \qquad \text{and} \qquad NR_{RF} = P_{RF}(Q_{RF}) - TC_{RF}$$

however, the first-order conditions are:

$$\frac{\partial(TR_{US})}{\partial Q_{US}} = \frac{\partial TC_{US}}{\partial Q_{US}} \qquad \text{and} \qquad \frac{\partial(TR_{RF})}{\partial Q_{RF}} = \frac{\partial TC_{RF}}{\partial Q_{RF}}$$

Where the US treats Q_{RF} as fixed and the Russian Federation treats Q_{US} as fixed.

For a Stackelberg equilibrium with the US as leader, net revenue and the first-order conditions are the same as for the Cournot-Nash equilibrium, however, the US treats Q_{RF} as a function of Q_{US}.

Similarly, for a Stackelberg equilibrium with the Russian Federation as leader, net revenue and the first-order conditions are the same as for the Cournot-Nash equilibrium, however, the Russian Federation treats Q_{US} as a function of Q_{RF}.

v.

Inter alia, the optimal strategy will depend on:

- stock abundance and stock distribution,
- the relative value of product (roe, surimi, fillet),
- product recovery rates,
- differences in the magnitude of harvesting and processing costs,
- the enforceability of catch limits at fishery and individual participant levels, and
- the character of governance regimes.

For his PhD, James will derive empirical solutions to conjectural variations for the management of the straddling stock of EBS pollock under varying conditions related to the magnitude and distribution of biomass, product prices, and harvest costs with a goal of identifying conditions where it is critical to switch between various cooperative and non-cooperative strategies.

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