Quantifying Uncertainty in Catch Forecasts

Steve Cadrin

New England Fishery Management Council

Scientific & Statistical Committee*

**The views expressed here are not necessarily those of the New England Council or SSC.*

Workshop Prospectus

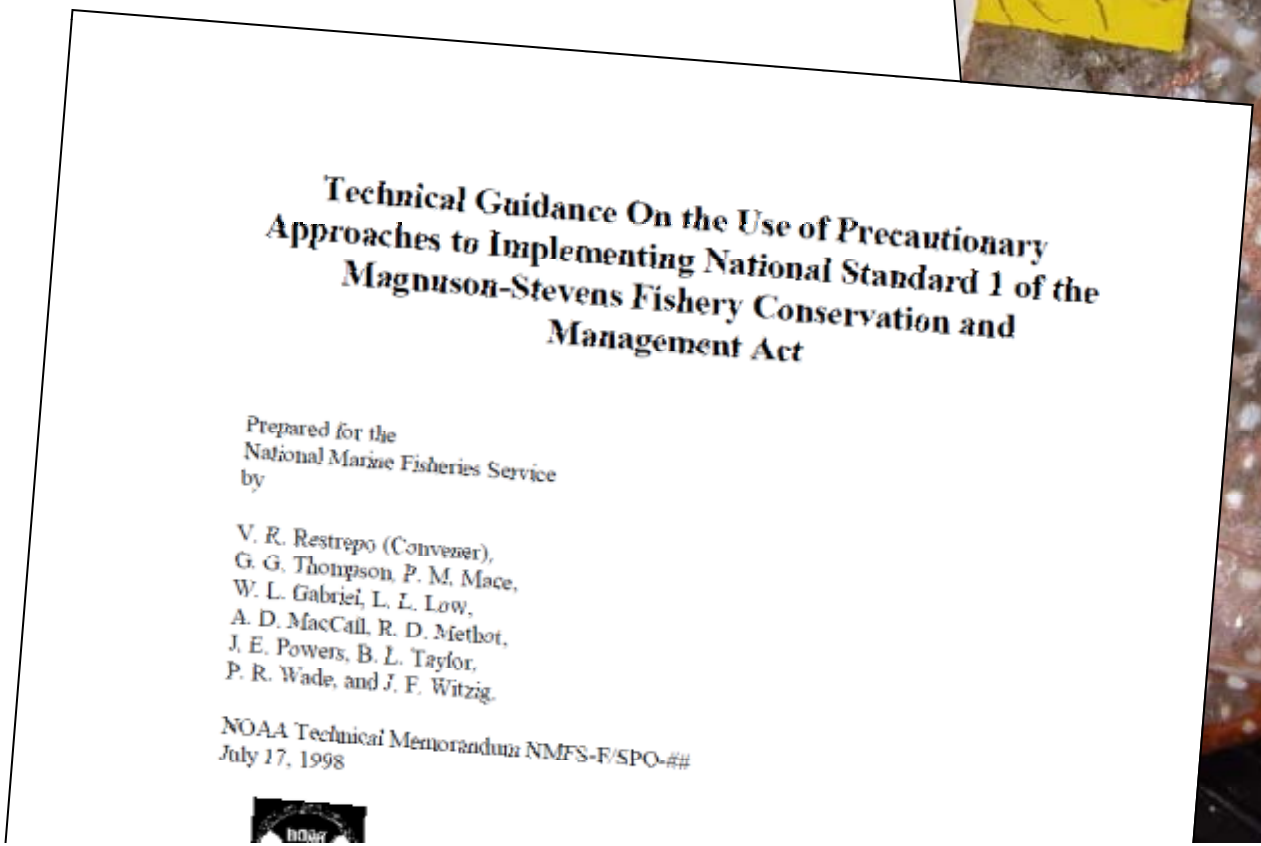
- *"The Magnuson Act and the subsequent Guidelines **substantially changed the nature of the scientific advice** needed to sustainably manage fisheries, and changed the manner in which this advice is communicated through the Scientific and Statistical Committees (SSCs) to the Councils.*
- *FORECASTS:*
  - *Stock assessments no longer solely look back at the last fishing year to determine "Did overfishing occur?"*
  - *Now they must also look forward to the upcoming fishing year(s) and determine the level of catch that would prevent overfishing.*
  - *What are the data and modeling needs to accomplish these forecasts?*
  - *In some cases this includes projecting stock rebuilding trends for overfished stocks."*

Acceptable Biological Catch (*ABC*)

- National Standard guidelines suggest that *ABC* should account for scientific uncertainty in the overfishing limit *OFL*, the product of projected stock size (B_{exp}) and MSY exploitation rate (μ_{MSY}).

2008 National SSC Workshop

- Restrepo et al. (1998) was maintained as the technical guidance for implementing National Standard 1.



Technical Guidance On the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act

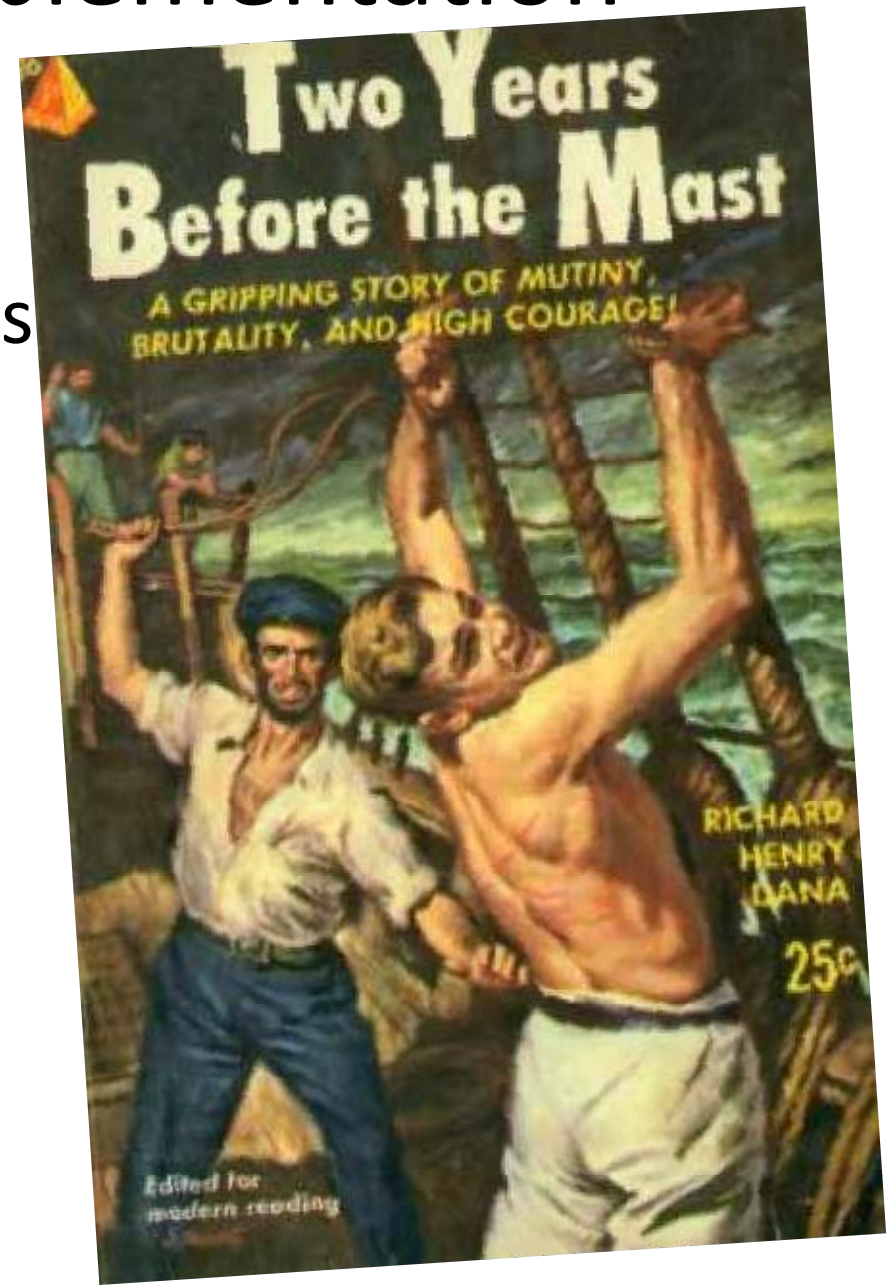
Prepared for the
National Marine Fisheries Service
by

V. R. Restrepo (Convener),
G. G. Thompson, P. M. Mace,
W. L. Gabriel, L. L. Low,
A. D. MacCall, R. D. Methot,
J. E. Powers, B. L. Taylor,
P. R. Wade, and J. F. Witzig.

NOAA Technical Memorandum NMFS-F/SPO-##
July 17, 1998

Two Years of Implementation

- The process of developing catch recommendations to meet the 2010-11 deadlines taught us the practical implications of 2009 guidelines.
- The guidelines express precaution in the *OFL-ABC* buffer, so a ‘precautionary approach’ should not be used to derive *OFL*.



Uncertainty in Forecasts

- Overfishing limit
  - Estimating F_{MSY}
  - F_{MSY} Proxies
  - Estimating uncertainty in F_{MSY}
- Projected stock size
  - Estimation error
  - Model error
- Desired probability of overfishing
  - P^*
  - Risk-Based Optimum Yield
- Conclusions

$$\hat{OFL} = \hat{B}_{\exp} \cdot \hat{\mu}_{MSY}$$

$$ABC = \hat{OFL} - \sigma_{OFL} z_{P^*}$$

Estimating F_{MSY}

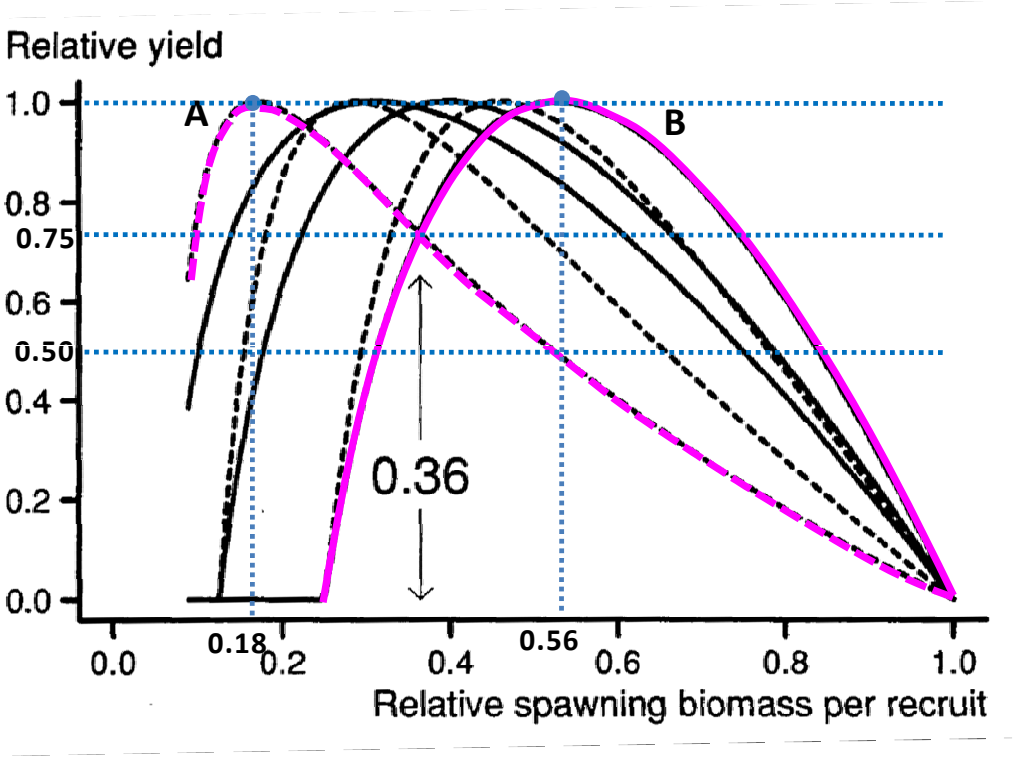
- Population Model:
  - Biomass dynamics
    - ~~Equilibrium (e.g., Schaefer 1954, Fox 1975)~~
    - Non-equilibrium (e.g., Polachek et al. 1993)
  - Age-Structured
    - Equilibrium (e.g., Beverton et al. 1984)
    - Non-equilibrium (e.g., Mace 2001) **– consistent with *OFL***
- Estimation Method:
  - Using assessment results (e.g., Jacobson et al. 2002, Sissenwine and Shepherd 1987)
  - In the assessment model (e.g., Prager 1994, Methot 2000) – **integrated estimate of *OFL* uncertainty**

A Precautionary Approach to F_{MSY} Proxies

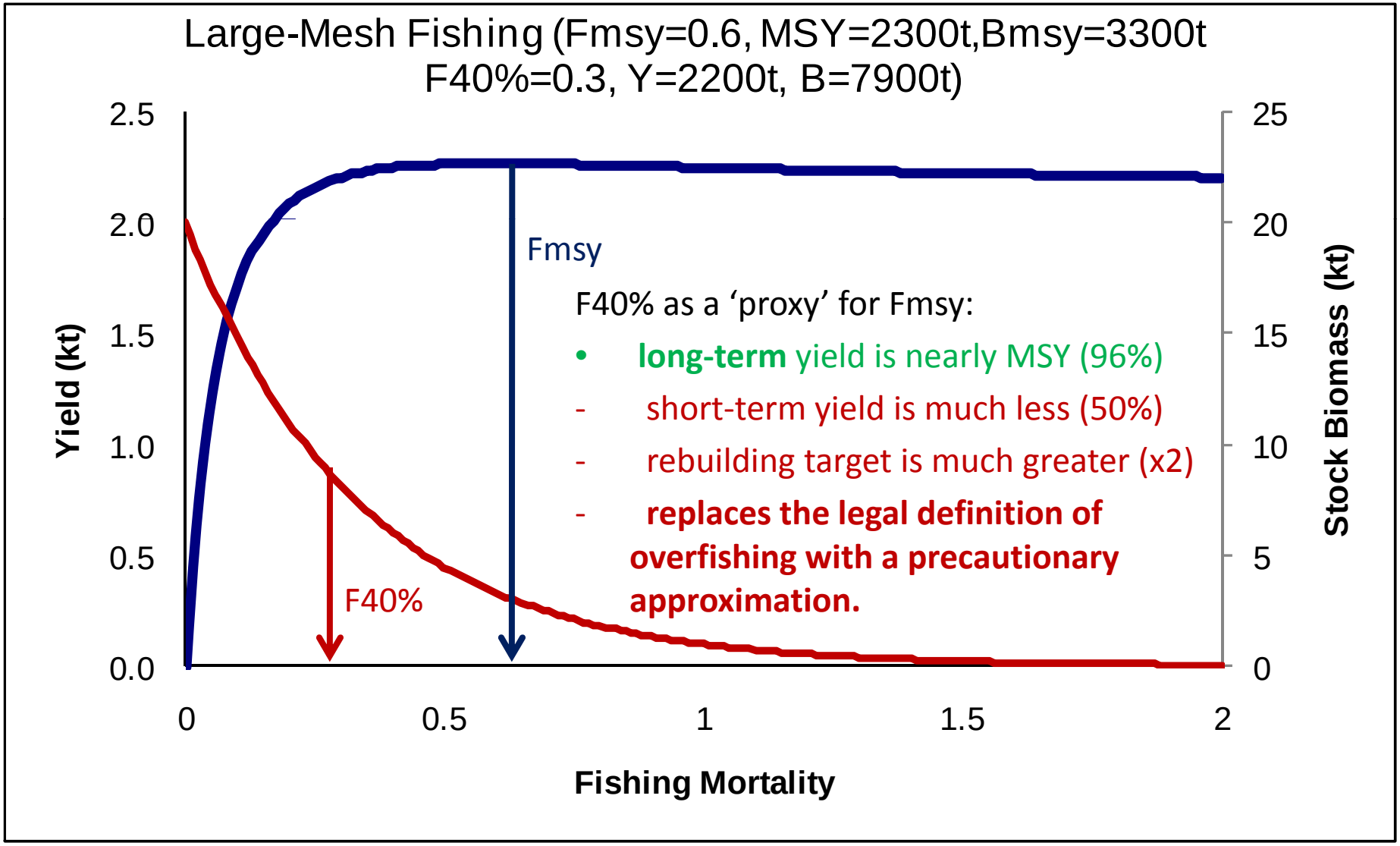
- Guidelines allow for **"cases in which MSY cannot be estimated directly"** (Restrepo et al. 1998):
  - F_{max} is '**unreasonably large'** for some sets of growth and mortality parameters.
  - $F_{0.1}$ is a '**conservative or cautious proxy for F_{MSY}.**'
  - A prominent class of reference points are $F_{\%SPR}$
    - $F_{20\%}$ to $F_{30\%}$ used to characterize recruitment overfishing.
    - $F_{30\%}$ to $F_{40\%}$ used as proxies for F_{MSY} .
    - $F_{50\%}$ to $F_{60\%}$ recommended for long-lived species with low reproductive output.

A Precautionary Approach to F_{MSY} Proxies

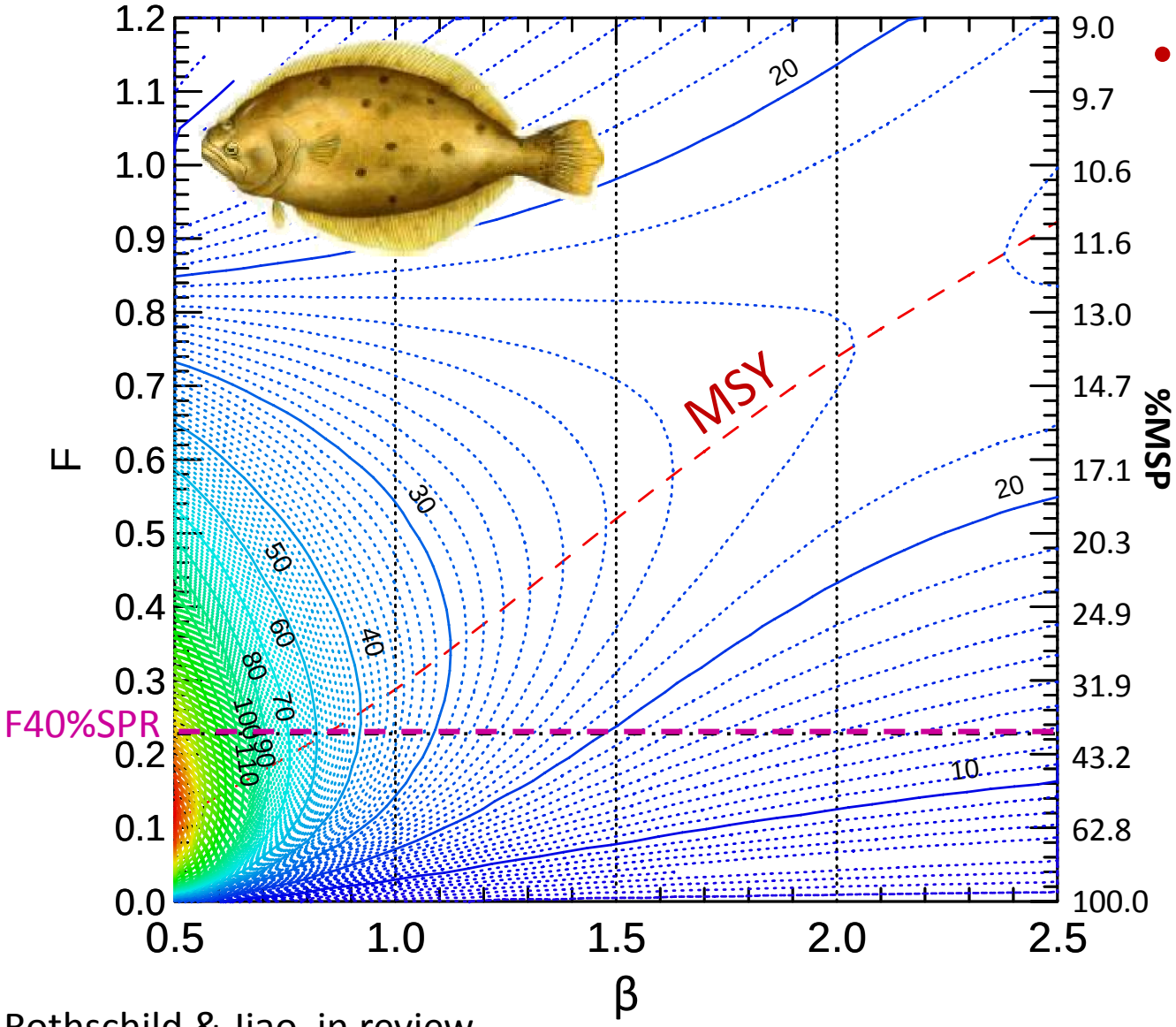
- Clark (1993) estimated MSY for a wide range of life histories and found that maintaining stocks at ~36% of maximum produced at least 75% of MSY.
- Common implementation of %SPR proxies is precautionary (40% for gadids, flatfish, etc.; 50% for redfish, rockfish, etc.)



F_{MSY} and $F_{\%Spawner\ per\ Recruit}$



Comparison of $F_{40\%}$ and F_{MSY}

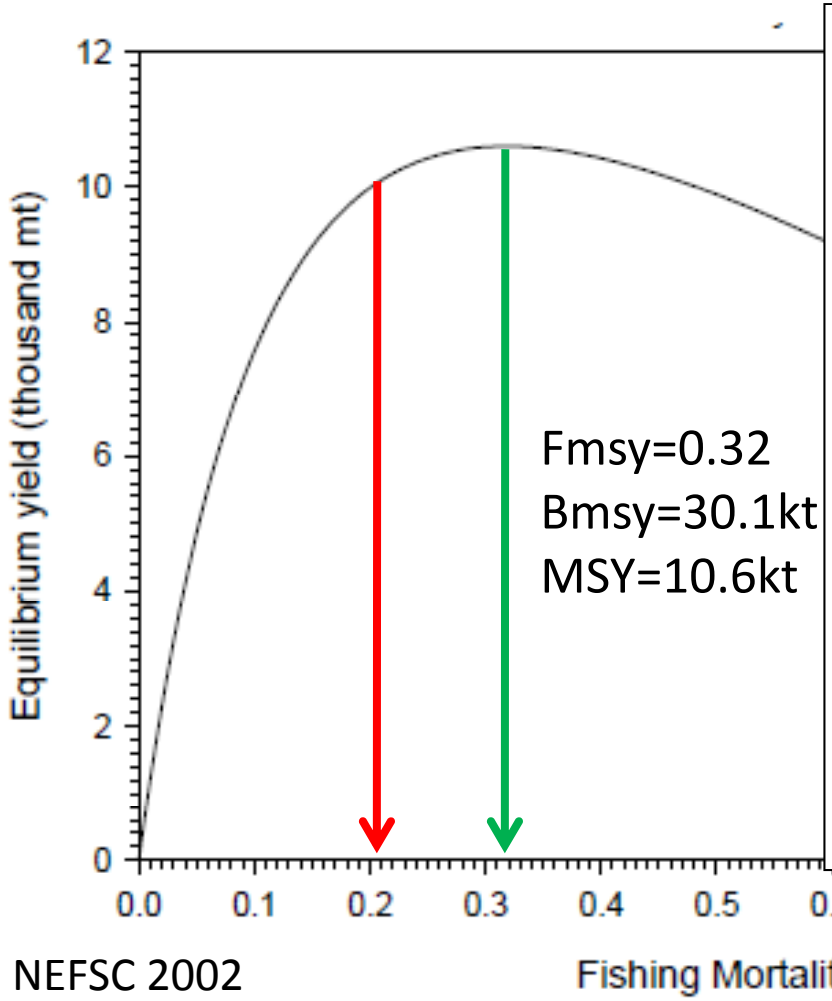


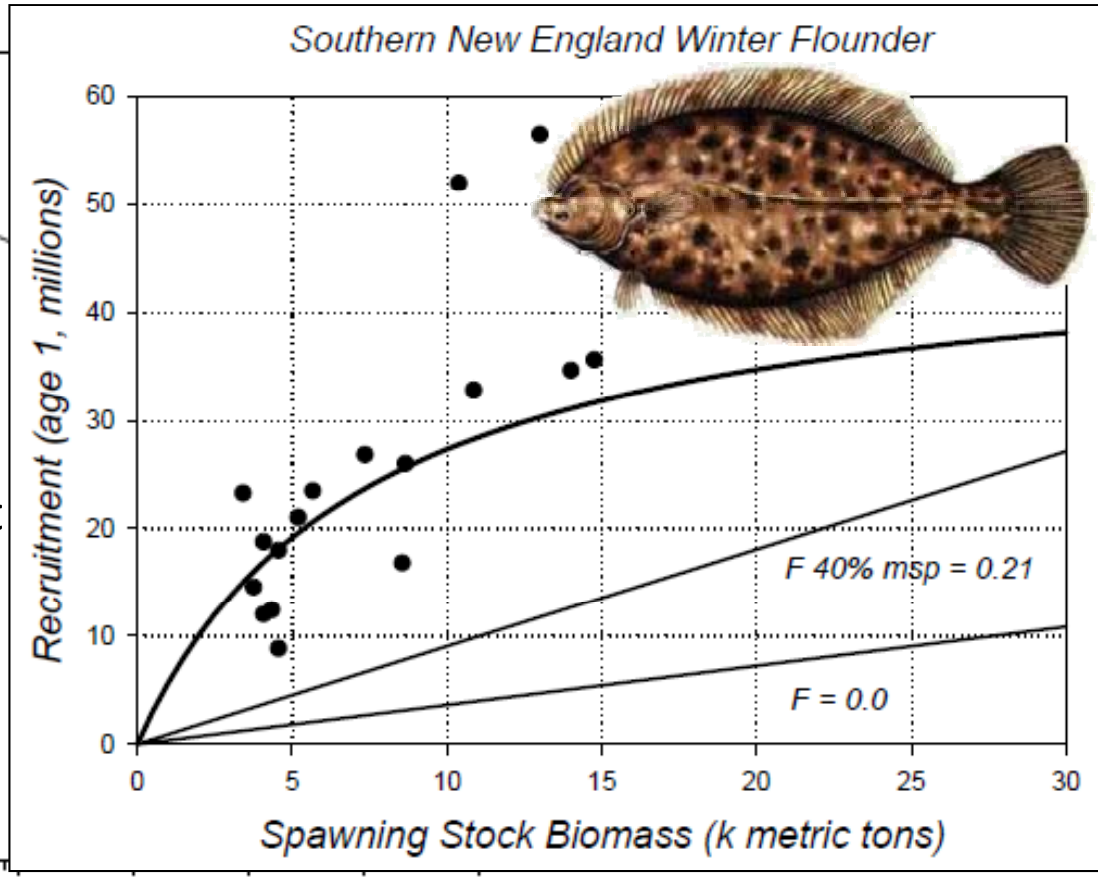
Rothschild & Jiao, in review

- MSY of summer flounder is much greater than yield at $F_{40\%}$ (and $F_{40\%}$ is much less than F_{MSY}) as the stock-recruit function becomes more domed (expressed as the Shepherd stock-recruit shape parameter, β)

Overfishing Reference Points

- Southern New England Winter Flounder: $F_{40\%}$ is less than F_{MSY}, and $B_{40\%}$ (39kt) is greater than B_{MSY} (30kt).

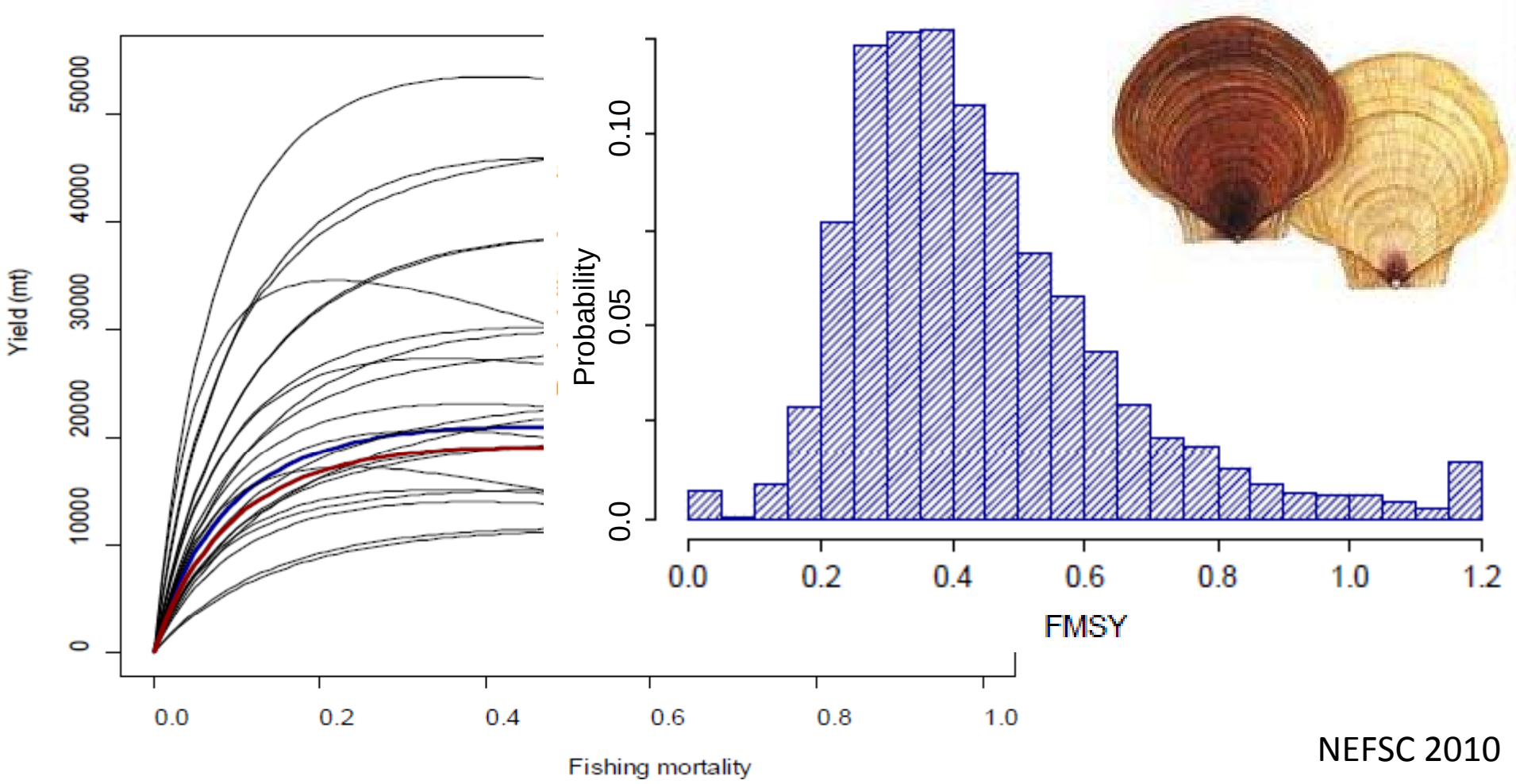




NEFSC 2002

Alternative for Poorly Defined F_{MSY}

- New England sea scallop - Monte Carlo randomization of yield curve (NEFSC 2010).



NEFSC 2010

The Overfishing Definition

- Magnuson Act: "*Overfishing*" means "*a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis*." (F_{MSY}).
- If *ABC* is to represent the Council's desired risk tolerance of overfishing, *OFL* should be based on F_{MSY} whenever possible rather than a proxy for F_{MSY}.
  - Probability of catch>*OFL* is confounded by proxies.
  - If F_{MSY} is poorly defined, uncertainty can be evaluated rather than replacing it with a precautionary proxy.

Uncertainty in Forecasts

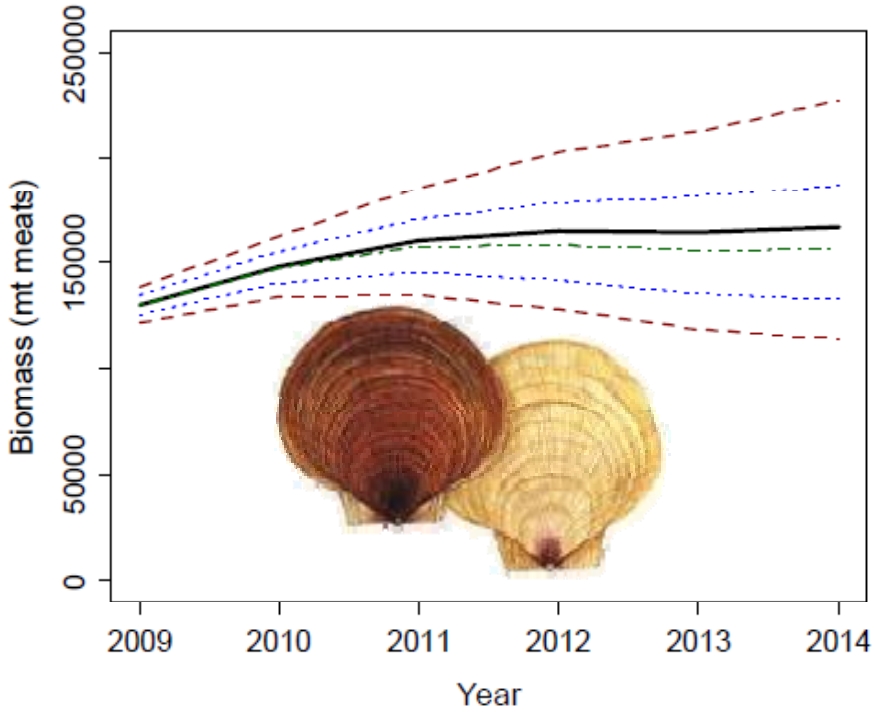
- Overfishing limit
  - Estimating F_{MSY}
  - F_{MSY} Proxies
  - Estimating uncertainty in F_{MSY}
- **Projected stock size**
  - **Estimation error**
  - **Model error**
- Desired probability of overfishing
  - P^*
  - Risk-Based Optimum Yield
- Conclusions

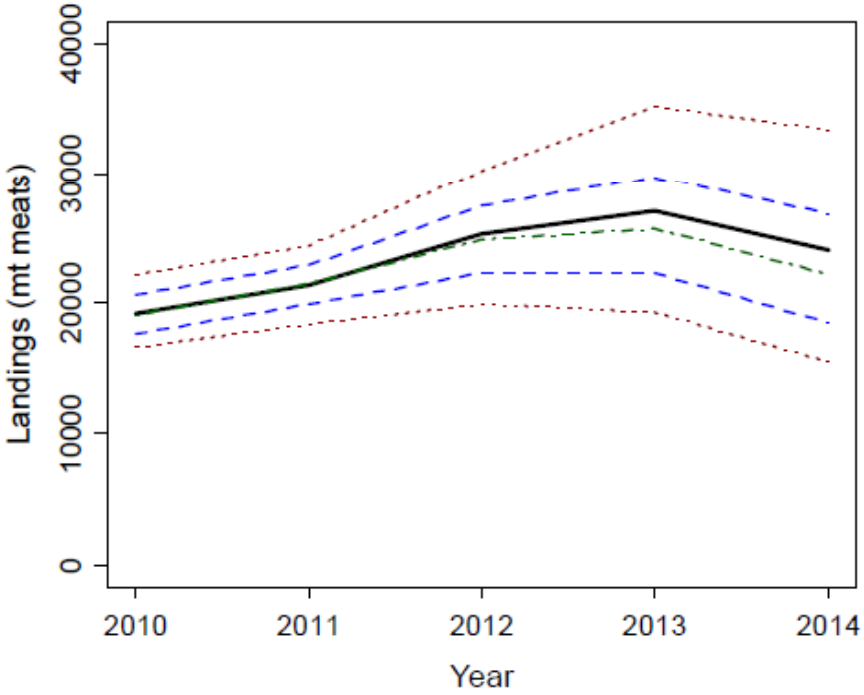
$$\hat{OFL} = \hat{B}_{\exp} \cdot \hat{\mu}_{MSY}$$

$$ABC = \hat{OFL} - \sigma_{OFL} z_{P^*}$$

Estimation Error

- Most stock assessment models quantify statistical uncertainty in recent and projected stock size estimates at $F=F_{MSY}$ (*OFL* and its distribution).

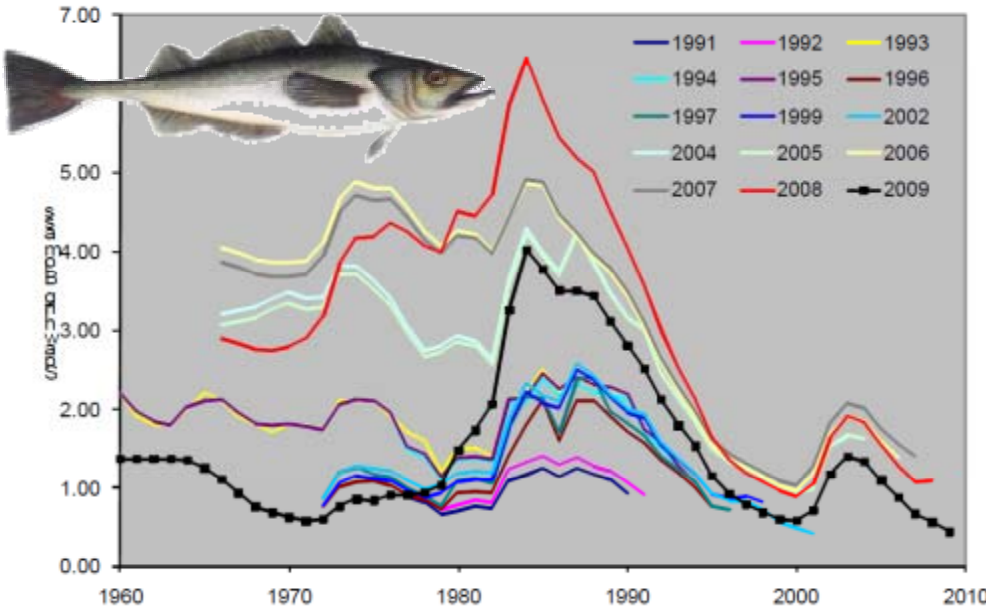


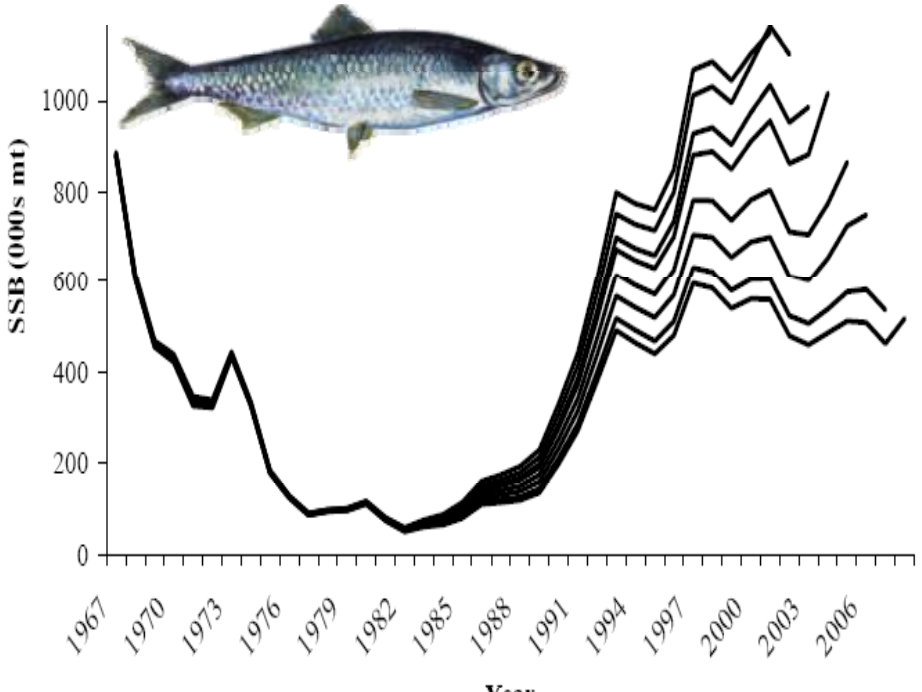


NEFSC 2010

Model Error

- Estimation error assumes that the model is correct, but historical or retrospective inconsistencies can indicate model specification error.





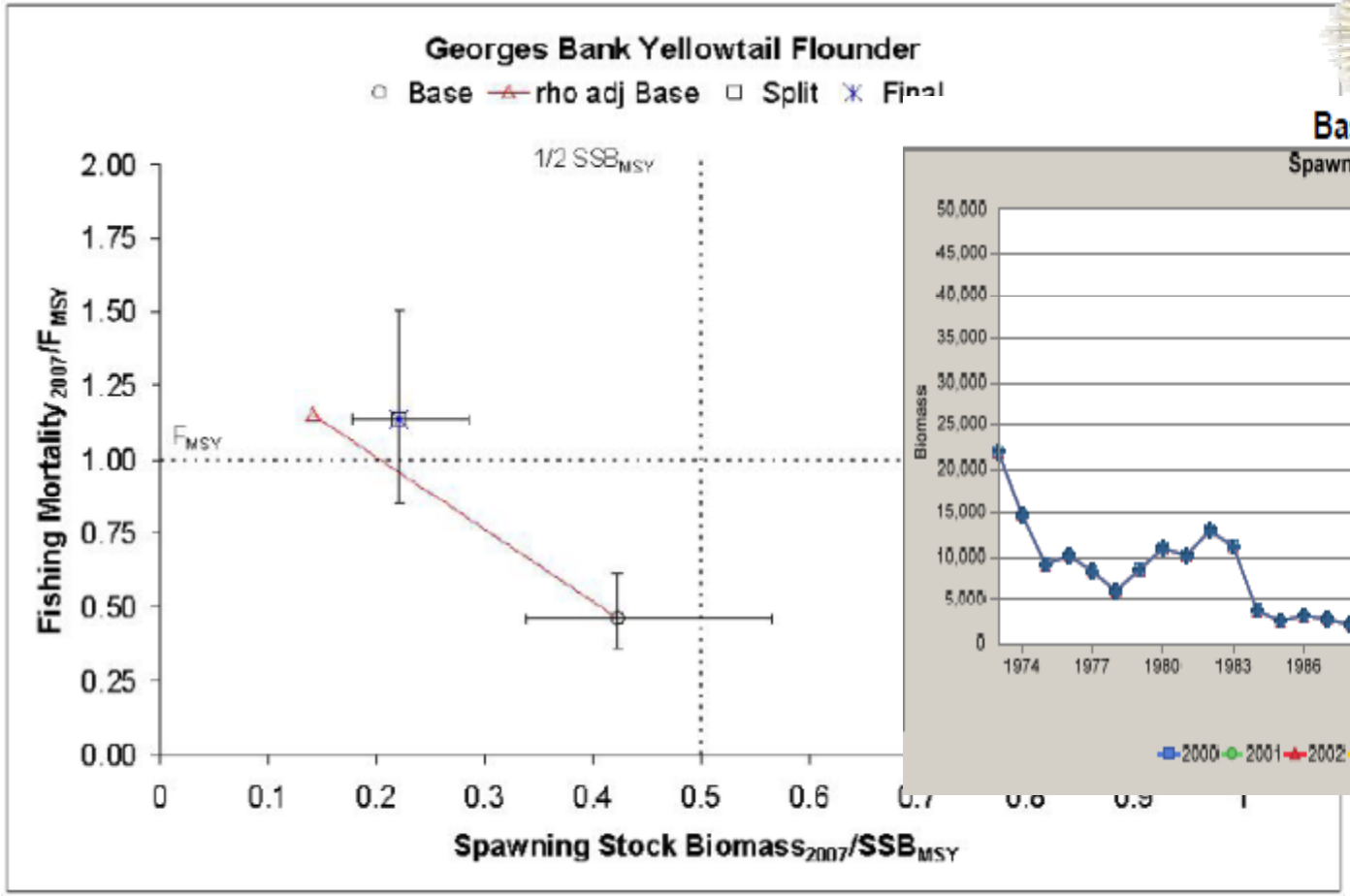
$$ABC = O\hat{F}L - \sigma_{OFL} z_{P*}$$

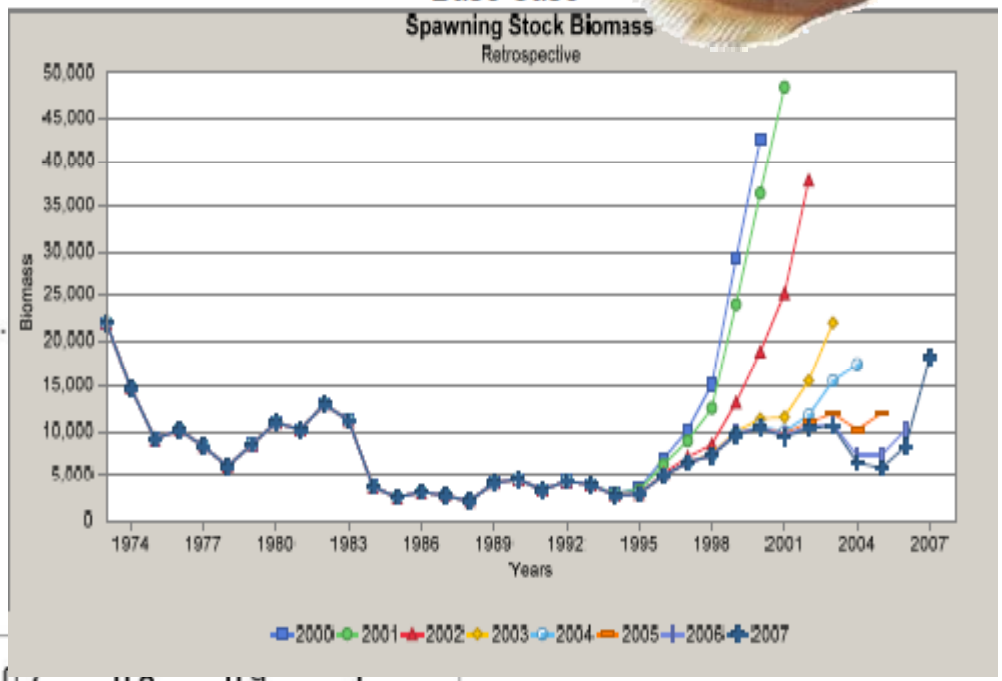
$$ABC = OFL\left(1 - \rho_{B\exp}\right)$$

Witherell, 2010

Retrospective Adjustments

- New England groundfish assessments considered unadjusted models, ‘split models’ and retrospective adjustments.



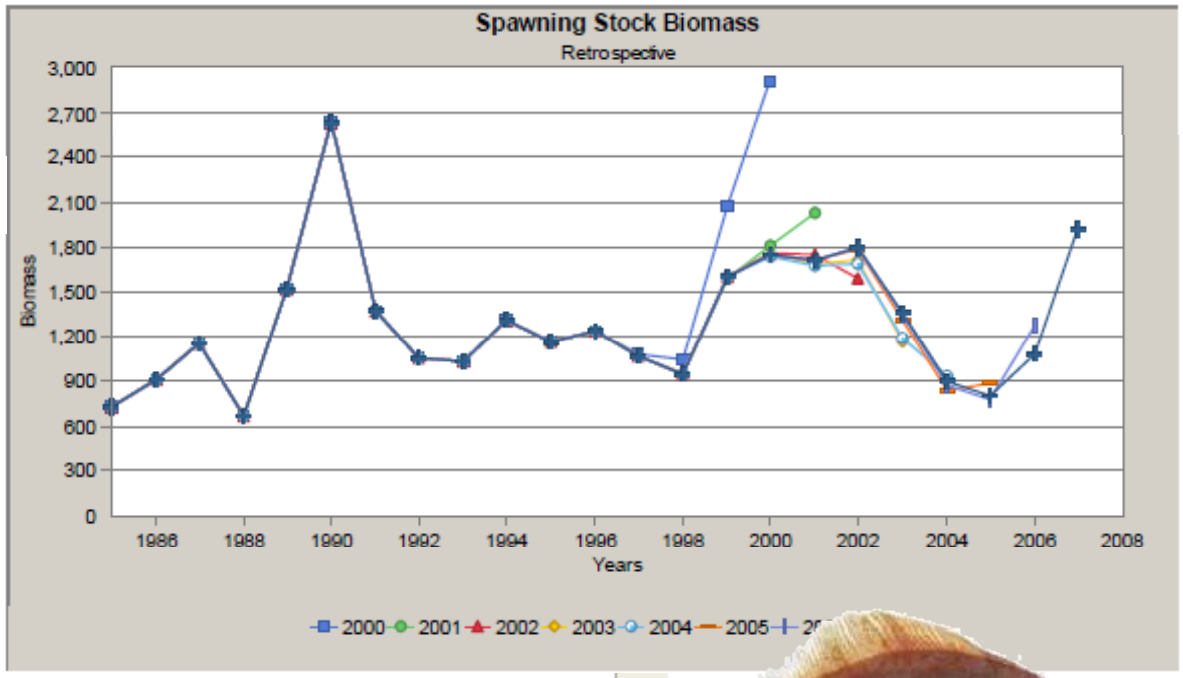


NEFSC 2008

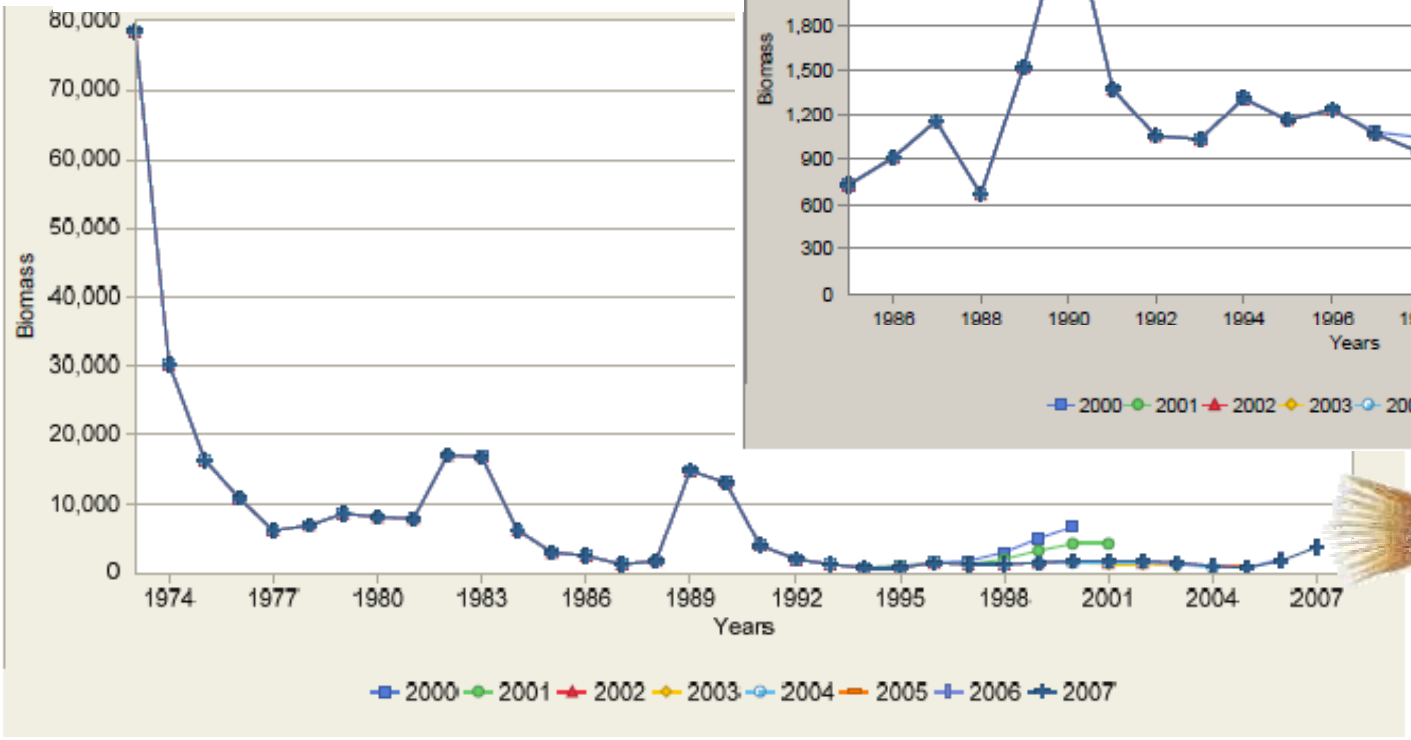
Retrospective Adjustments

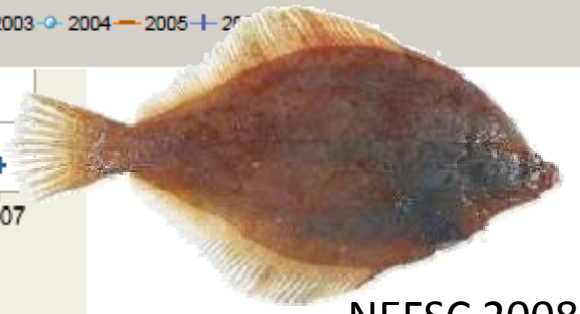
- Some retrospective patterns went away… meaning a retrospective adjustment would have imposed greater bias.

Cape Cod yellowtail



Southern New England yellowtail





NEFSC 2008

Accounting for Model Error

- Variability among models can be included in the evaluation of scientific uncertainty.
- If a retrospective pattern results from persistent, systematic bias:
  - identify source of bias and 'correct' the model, or
  - include retrospective inconsistency in the magnitude of scientific uncertainty.
- If a retrospective pattern appears to be a temporary mis-estimation (e.g., perception of a recent recruitment event):
  - inconsistency is not be expected in the future, so
  - do not adjust *OFL* or include in forecast uncertainty.

Uncertainty in Forecasts

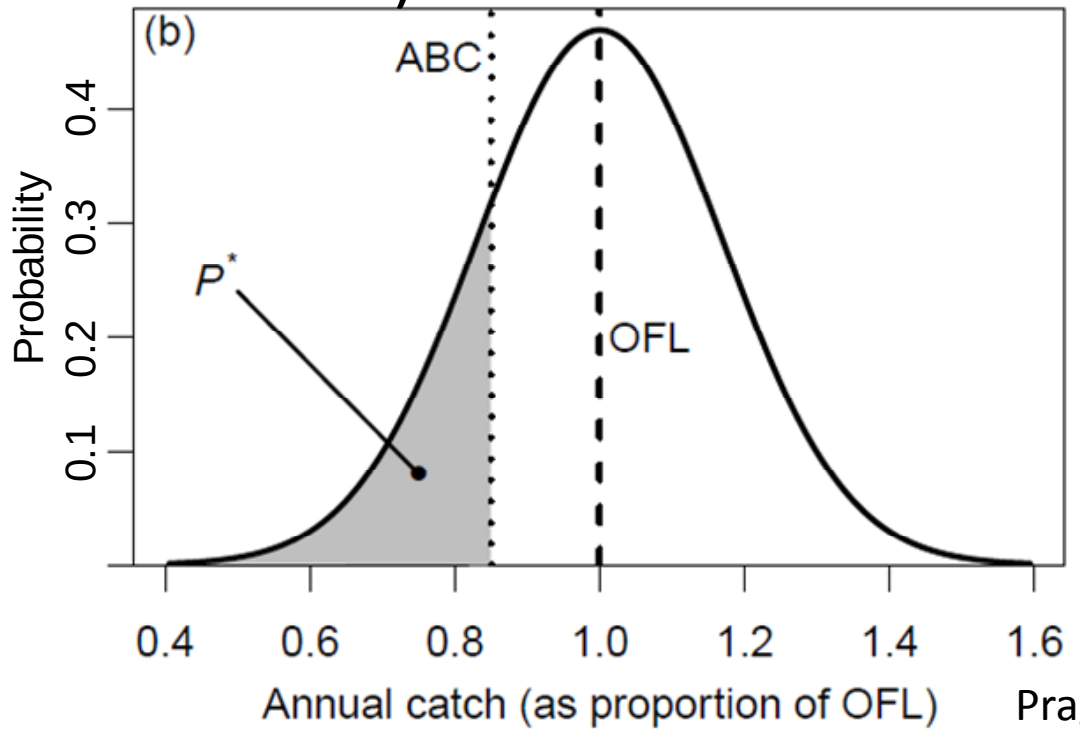
- Overfishing limit
  - Estimating F_{MSY}
  - F_{MSY} Proxies
  - Estimating uncertainty in F_{MSY}
- Projected stock size
  - Estimation error
  - Model error
- **Desired probability of overfishing**
  - ***P****
  - **Risk-Based Optimum Yield**
- Conclusions

$$\hat{OFL} = \hat{B}_{\exp} \cdot \hat{\mu}_{MSY}$$

$$ABC = \hat{OFL} - \sigma_{OFL} z_{P*}$$

Probability of Overfishing (*P**)

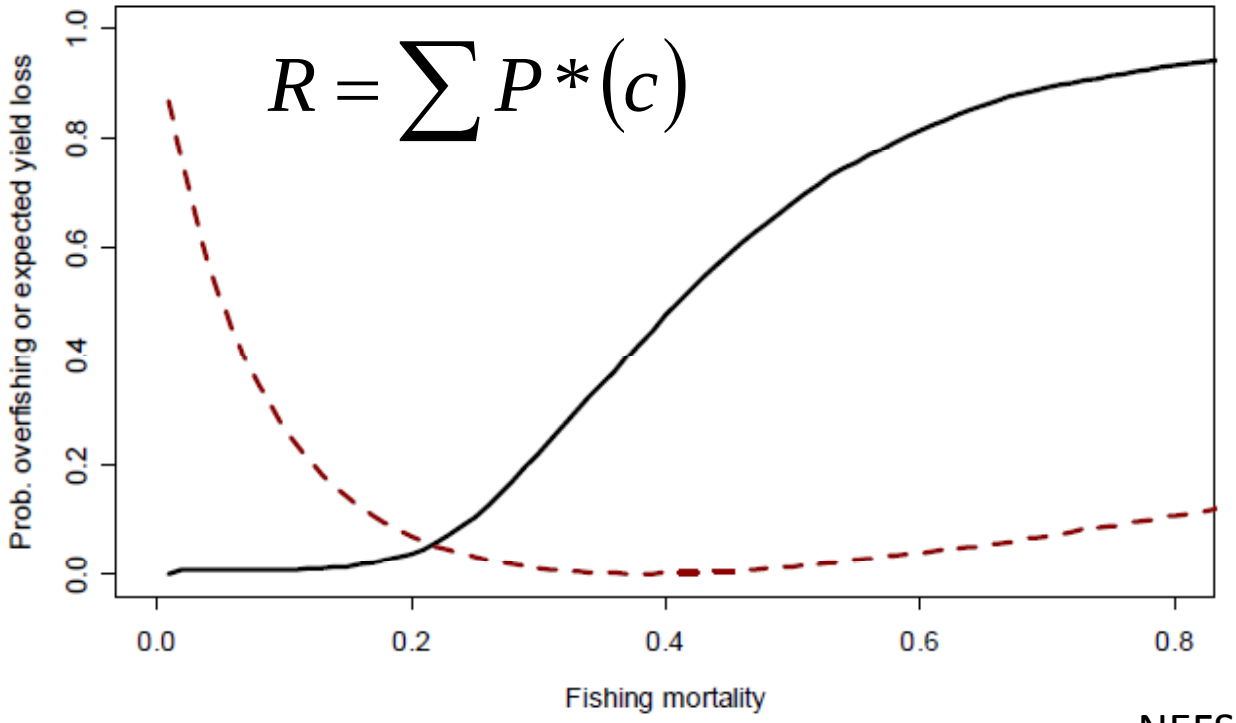
- If *ABC* is to be based on probability of overfishing:
  - *OFL* should be based on F_{MSY} (not a precautionary proxy)
  - *OFL* should not be adjusted for scientific uncertainty (e.g., retrospective inconsistency, precautionary assessment decisions).



Prager & Shertzer 2009

Risk-Based Optimum Yield

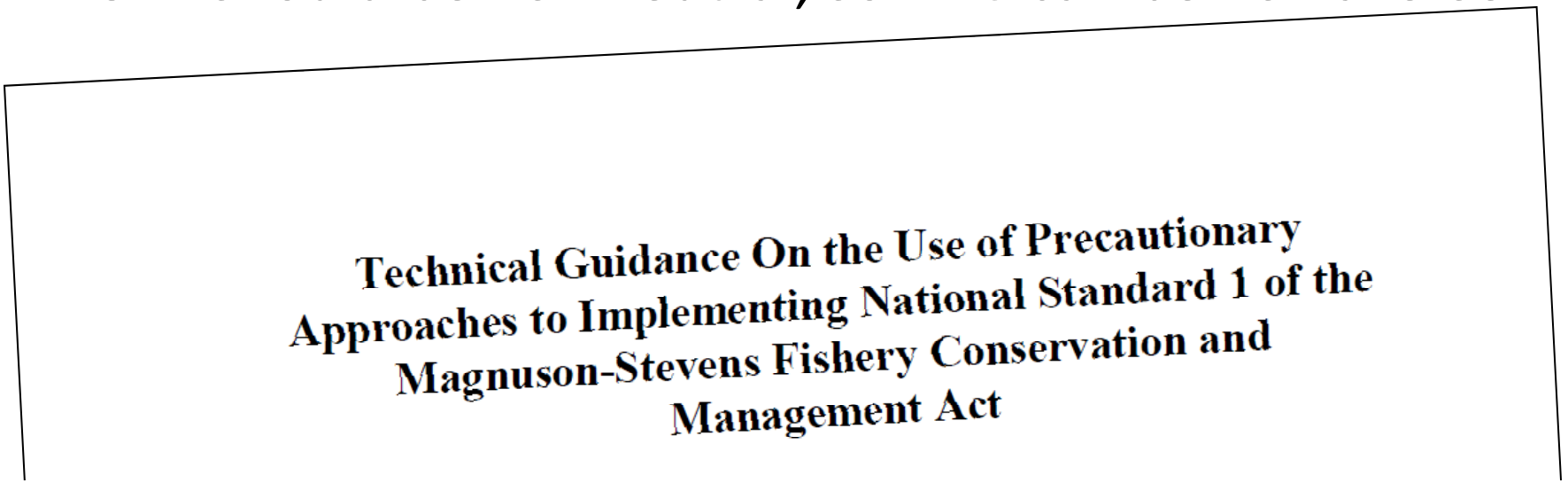
- Optimum yield can be based on probability of overfishing (P^*<50%) and other risks that account for "*any relevant economic, social, or ecological factor*" to "*provide the greatest overall benefit to the Nation.*"



NEFSC 2010

Conclusions

- New technical guidance is needed to express precaution in the desired risk of overfishing (*P**) rather than precautionary overfishing proxies or stock assessment decisions.
  - *OFL* should be based on direct estimates of F_{MSY} whenever possible.
  - *OFL* should be risk-neutral, so *ABC* can be risk-averse.


Technical Guidance On the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act