AN EMPIRICAL ANALYSIS OF PORTFOLIO MANAGEMENT AS A TOOL FOR IMPLEMENTING ECOSYSTEM-BASED FISHERY MANAGEMENT

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Outline

- Portfolio analysis for fisheries
- Accounting stance(s)
- SSL (2008, 2003) framework
- Data and revenue weights
- Efficient frontiers and actual risk-return portfolios
- Risk-gaps
- Ecological productions units (EPUs) and fishing ports
- Summary and future plans

Portfolio Analysis for Fisheries

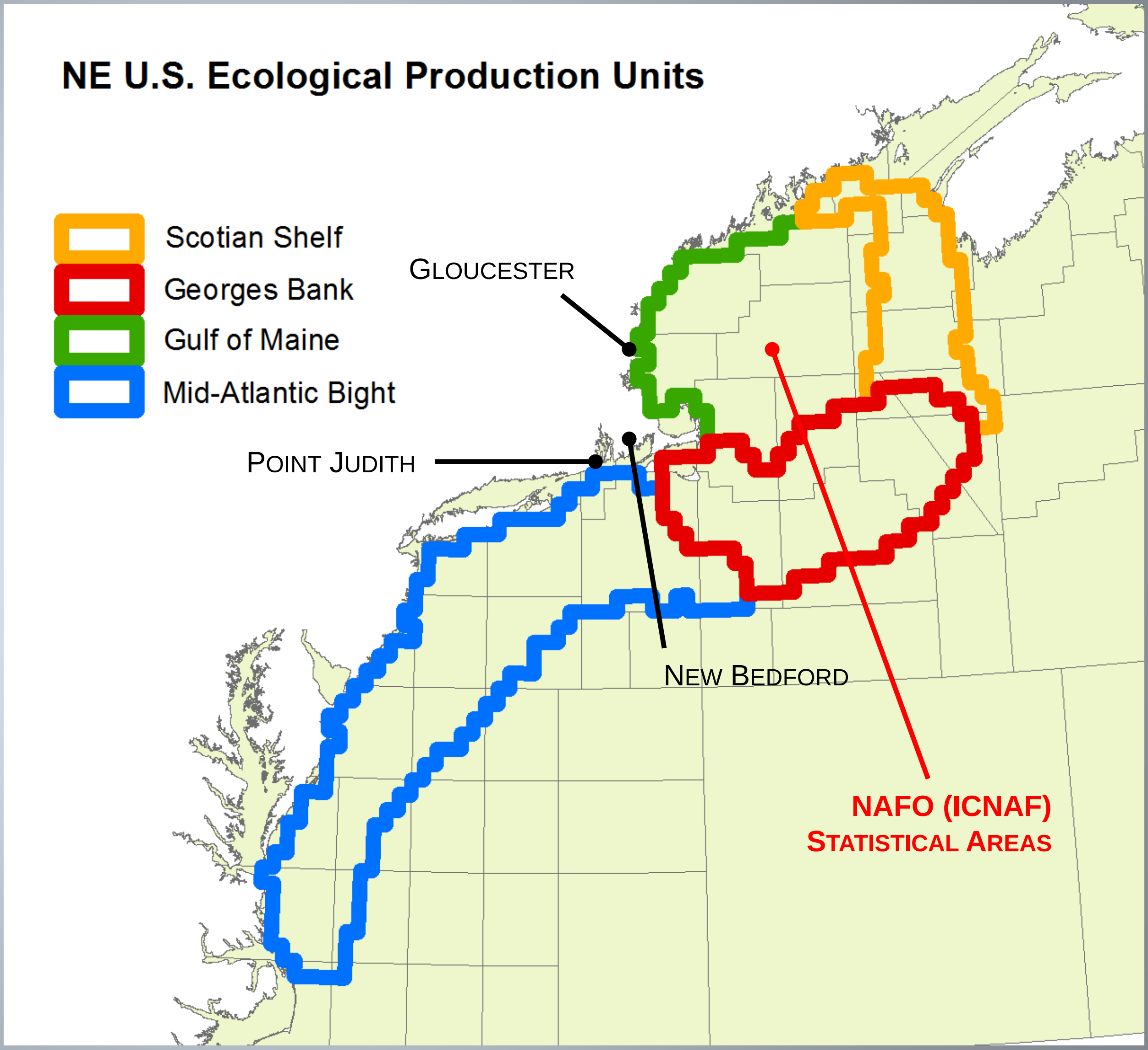
- Fish stocks are akin to financial "assets"
- Revenues from harvests are returns to assets
- Managers' "utility" depends upon mean returns and their associated variance (risk)
- Ecological interactions among commercial species imply correlations (+/-) among yields

=> Ecosystem–Based Fishery Management

- [*N.b.*, Not modeling ecological processes and structures explicitly, however]
- Can take advantage of negatively correlated returns to reduce the risk for any feasible mean return

Accounting Stance(s)

- Northeast LME: combined Northeast and Mid-Atlantic regions: ME to NC
- 4 ecological production units (EPUs)
- 3 commercial fishing ports
- Others?



PORTFOLIO FRAMEWORK

- Reduced form "exponential smoothing" framework due to Sanchirico, Smith and Lipton (SSL 2008, 2003)
- Choose vector of weights, ***w***, ,in each year, *t*, to minimize the variance of the portfolio with feasible revenues, r_i, among *i* species groups
- Manager specifies *R*, *λ*, ***γ***, and ***B***:
- R_t is an overall revenue target in each year; simulated by a set of "efficient" portfolios
- ***λ*** is a "decay" parameter, governing the extent to which the historical covariation of species-group revenues enters into the analysis
- ***γ*** is a "sustainability" parameter for each species group, governing the availability of exploitable biomass (or sustainable yield), ***B***

$$min_{w_t} w_t' \Sigma_t w_t\,,\ s.t.\ w_t{}'\mu_t \ \geq R_t,$$

$$w_{i,t} \leq W_{i,t}\ \forall\, i$$

$$\Sigma_{i,j,t} = \frac{\sum_{k=1}^{t} \lambda^{t-k+1}(r_{k,i} - \bar{r}_{t,i})(r_{k,j} - \bar{r}_{t,j})}{\sum_{k=1}^{t} \lambda^{t-k+1}}$$

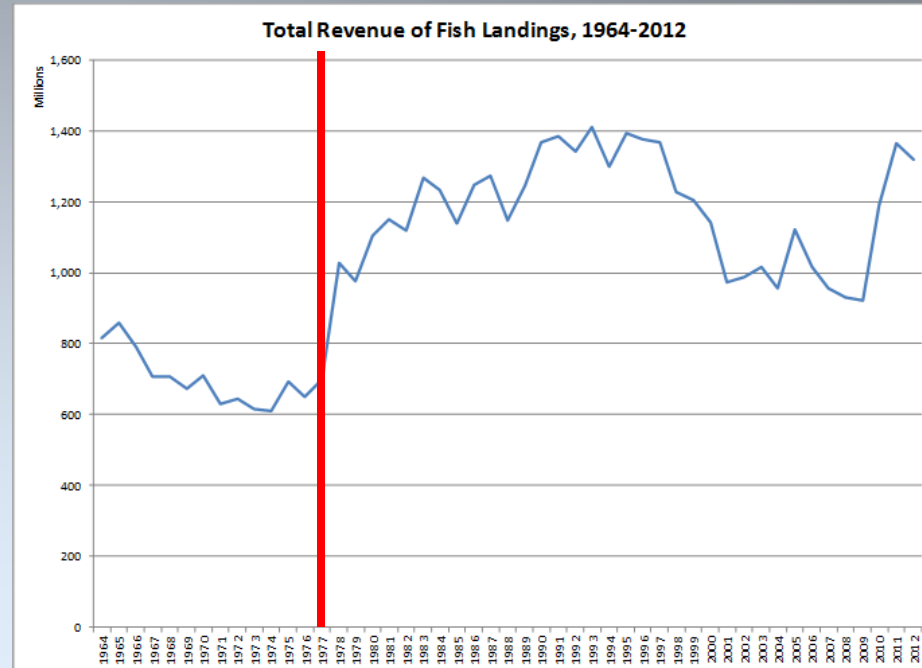
$$\bar{r}_{i,t} = \frac{\sum_{k=1}^{t} \lambda^{t-k+1} r_{k,i}}{\sum_{k=1}^{t} \lambda^{t-k+1}}$$

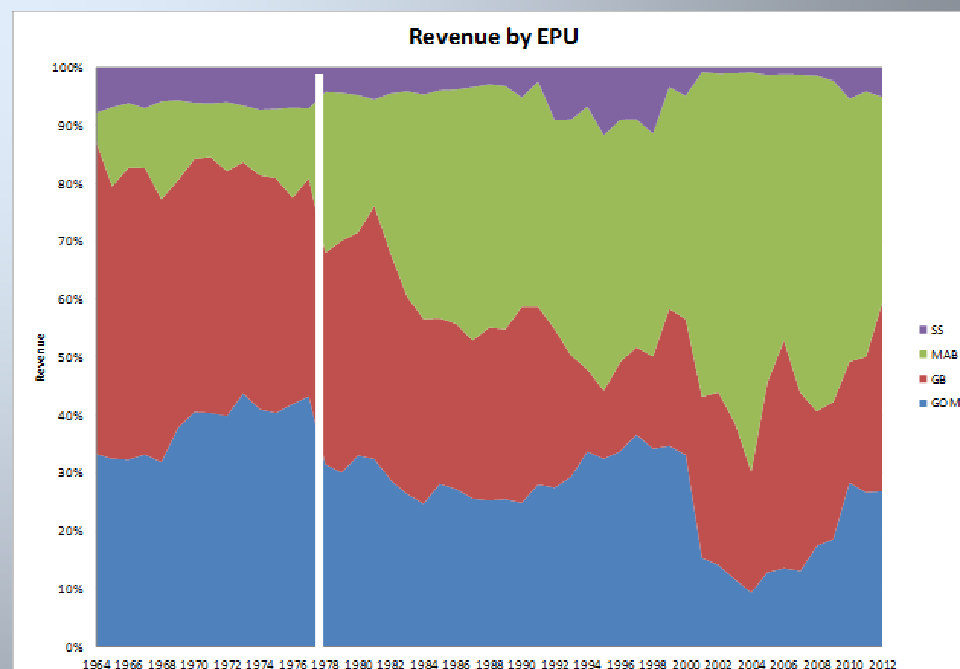
$$W_{i,t} = \frac{\gamma_{i,t} B_{i,t}}{\Omega_{i,}}$$

$$\Omega_{i,t} = \frac{\sum_{k=1}^{t} \lambda^{t-k+1} p_{k,i}\, y_{k,i}}{\sum_{k=1}^{t} \lambda^{t-k+1}\, p_{k,i}}$$

DATA

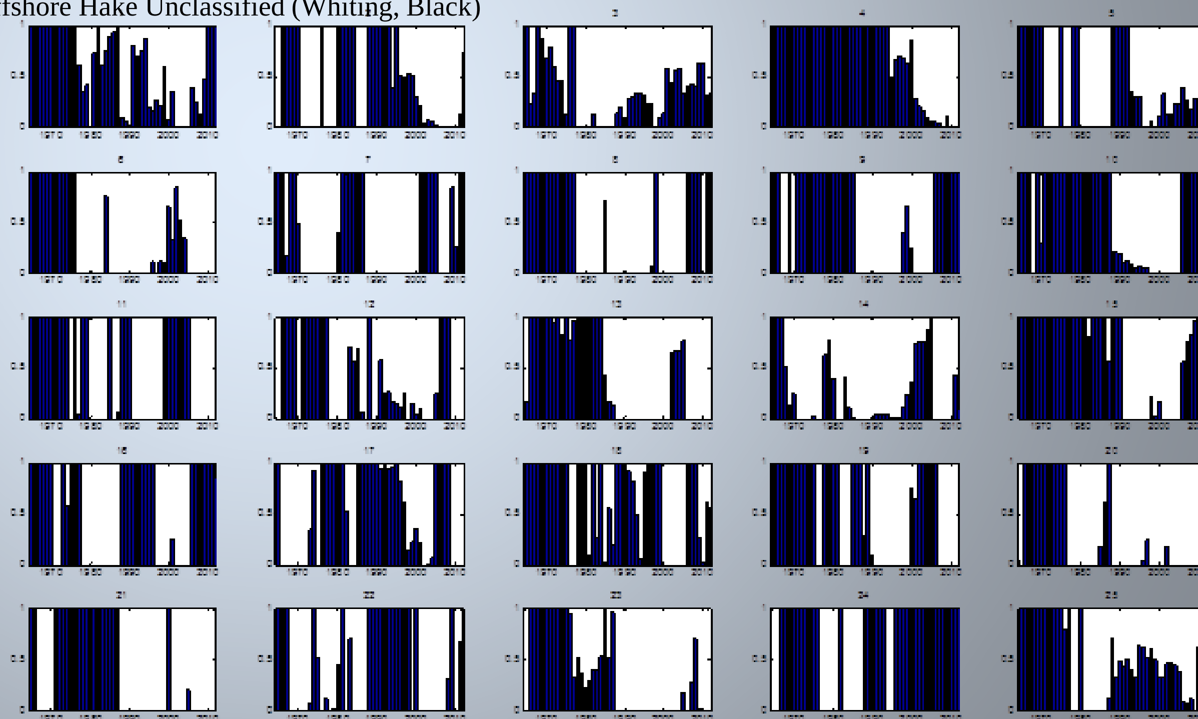
- 25 species groups as specified in ATLANTIS model (Link *et al*. 2010)
- Comprises US catches of all fish and shellfish during 1964-2012 (49 years)
- Years prior to FCMA (1976) involve significant extractions by foreign fleets
- Catches and exvessel prices => revenues ($ 2012)



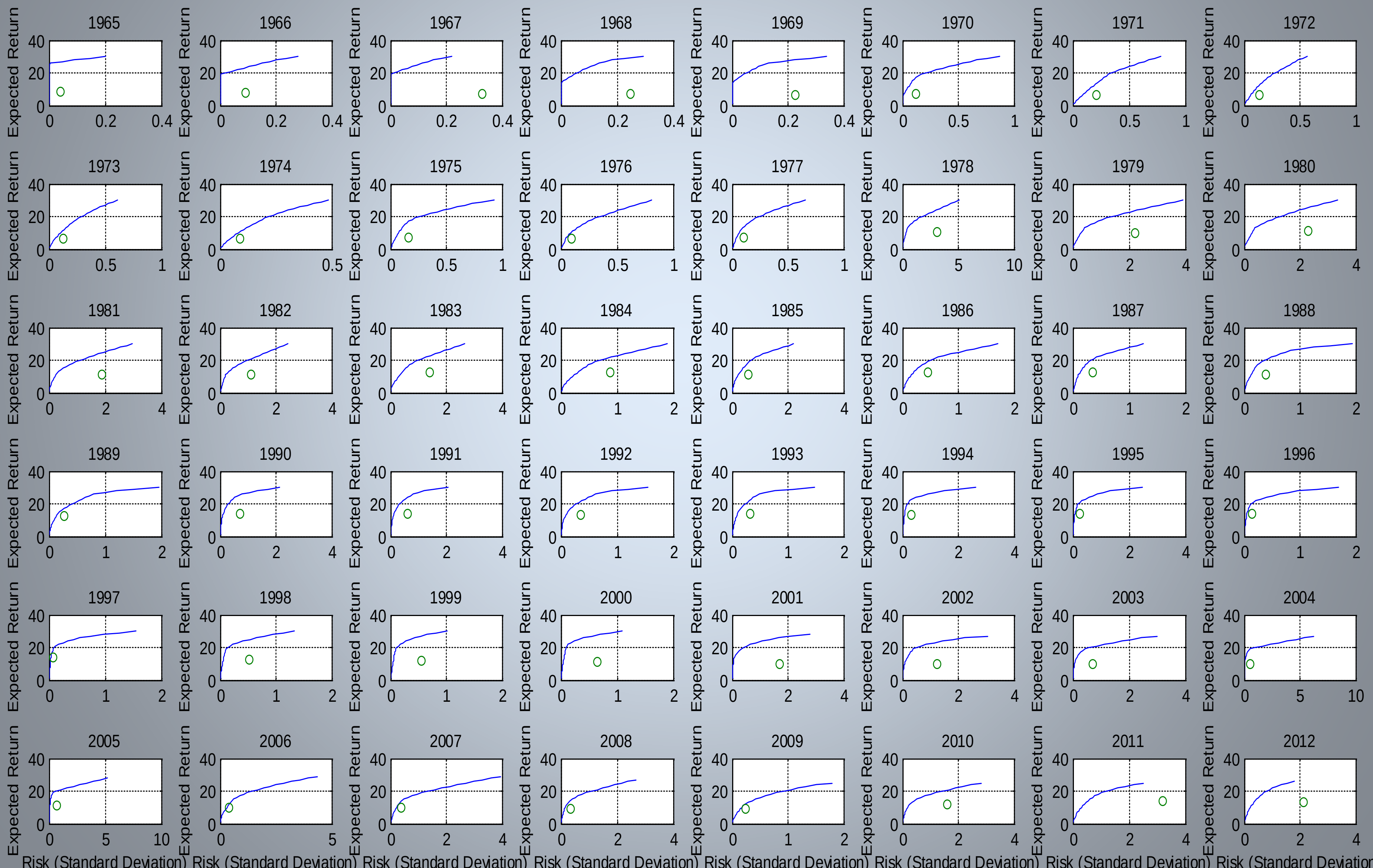


Revenue Weights (@ ~50% of max R_t)

	Group	Species
1	BFF1	Clams (Hard, Soft, Unclassified, Ocean Quahog)
2	BFF3	Blue Mussel, Oyster, Bay Scallop
3	BFS	Sea Scallop
4	BML	Lobster
5	BMS	Crabs (Blue, Lady, Green, Red, Jonah, Rock, Cancer, Spider, Snow, Horseshoe), Whelk
6	CEP	Squid (Loligo, Illex)
7	FBP	Bay Anchovy, Butterfish, Chub Mackerel, Atlantic Silverside, Spanish Mackerel
8	FDB	Silver Hake (Whiting)
9	FDC	Atlantic Croaker, Cusk, Drum (Black, Red), American Eel, Grenadiers, Hake (Atlantic, Red), John Dory, Opah, Ocean Pout, Scup, Black Sea Bass, Gray Sea Trout (Weakfish), Spotted Sea Trout, Spot, Striped Bass, Atlantic Sturgeon, Tautog, Tilefish (Blueline, Sand, Golden, Unclassified), White Perch, Offshore Hake Unclassified (Whiting, Black)
10	FDC2	Atlantic Pollock
11	FDC7	Ocean Perch (Redfish)
12	FDD	Goosefish
13	FDE1	Menhaden
14	FDF	Yellowtail Flounder
15	FDO	Haddock
16	FDS	Atlantic Cod
17	FPL	Atlantic Mackerel
18	FVB2	Summer Flounder (Fluke)
19	FVB3	Winter Flounder
20	FVB4	Witch Flounder (Gray Sole)
21	FVB6	American Plaice (Dab)
22	FVD	Atlantic White Hake
23	FVT3	Marlin (White, Blue), Swordfish
24	PWN2	Shrimp (Brown, Atlantic, Gulf of Marine, Crangon, Unclassified)
25	SSK1	Skates (Rosette, Little, Winter, Barndoor, Smooth, Thorny, Clearnose)

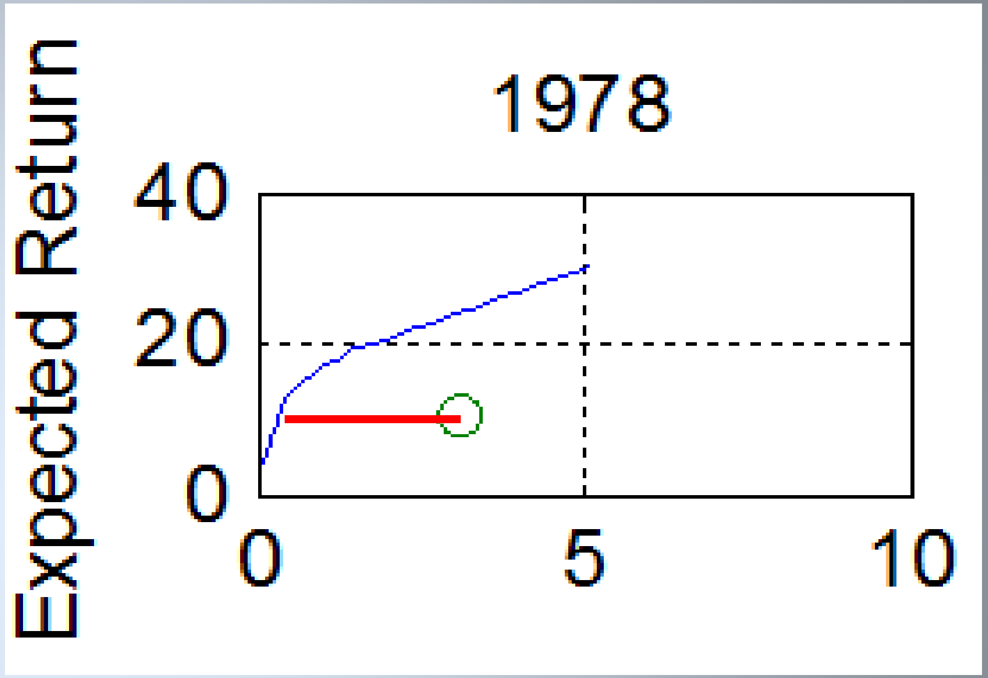


NE/LME Efficient Frontiers and Actual Portfolios
(1965-2012; λ = 0.549; γ = 1; B ~ all time maximum landings)



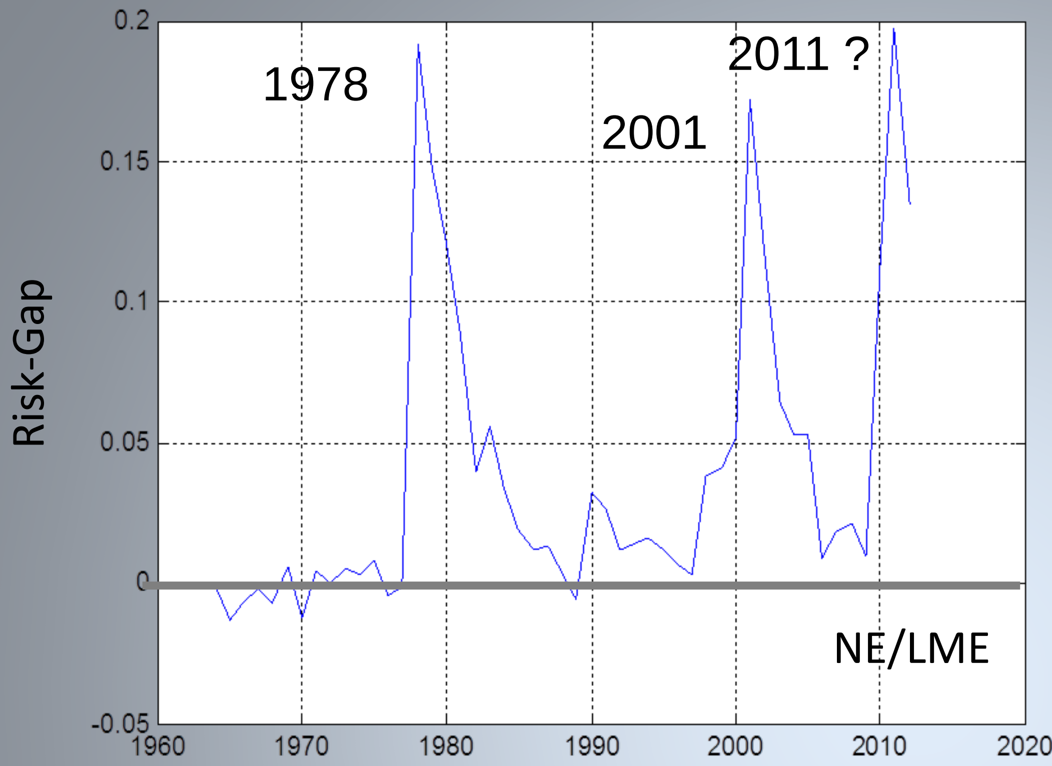
"Efficient" Frontier and Actual Risk-Return

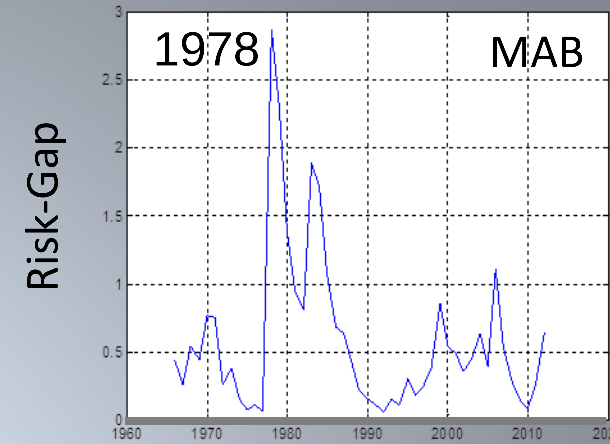
- Northeast Region commercial fishing risk-return tradeoff
- Vertical axis depicts the expected return ($100m, 2012)
- Horizontal axis depicts the risk level (s.d. of revenue)
- Green circle denotes the actual portfolio in that year.
- Red line is the "risk-gap" or the distance from the minimum risk to the realized risk (the "riskiness" of the actual portfolio). It is normalized by dividing by the actual return.

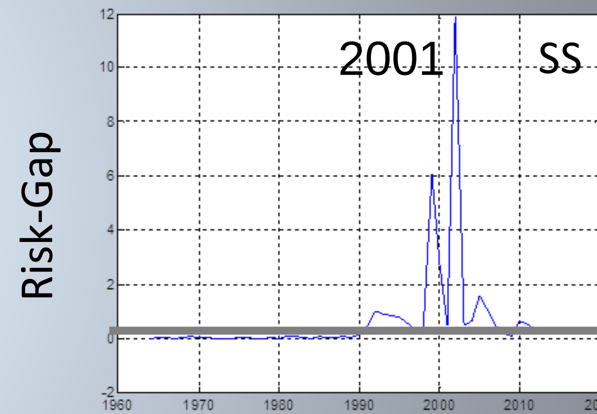


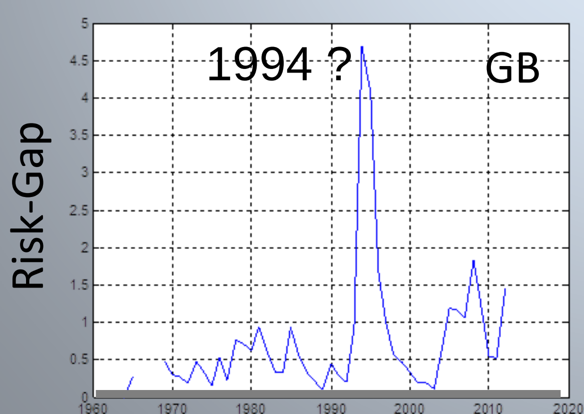
Risk-Gap (normalized) $= \dfrac{\sqrt{\tilde{w}'_t \Sigma_t \tilde{w}} - \sqrt{\hat{w}'_t \Sigma_t \hat{w}_t}}{\tilde{w}'_t \mu_t}$

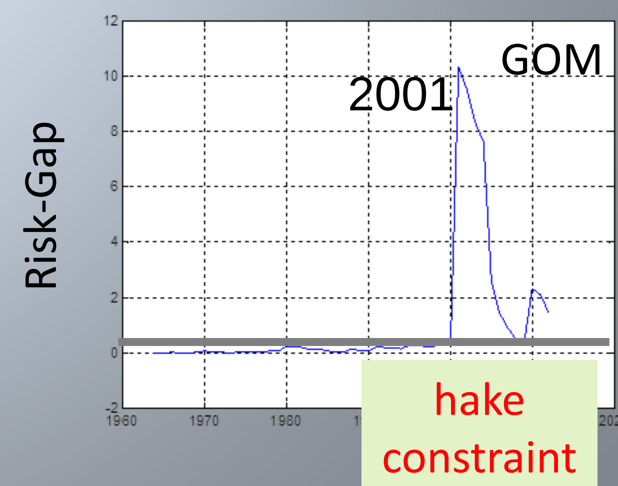
μ is mean revenue


Risk-Gap
1978
2001
2011 ?
NE/LME
0.2
0.15
0.1
0.05
0
-0.05
1960
1970
1980
1990
2000
2010
2020


Risk-Gap
1978
MAB

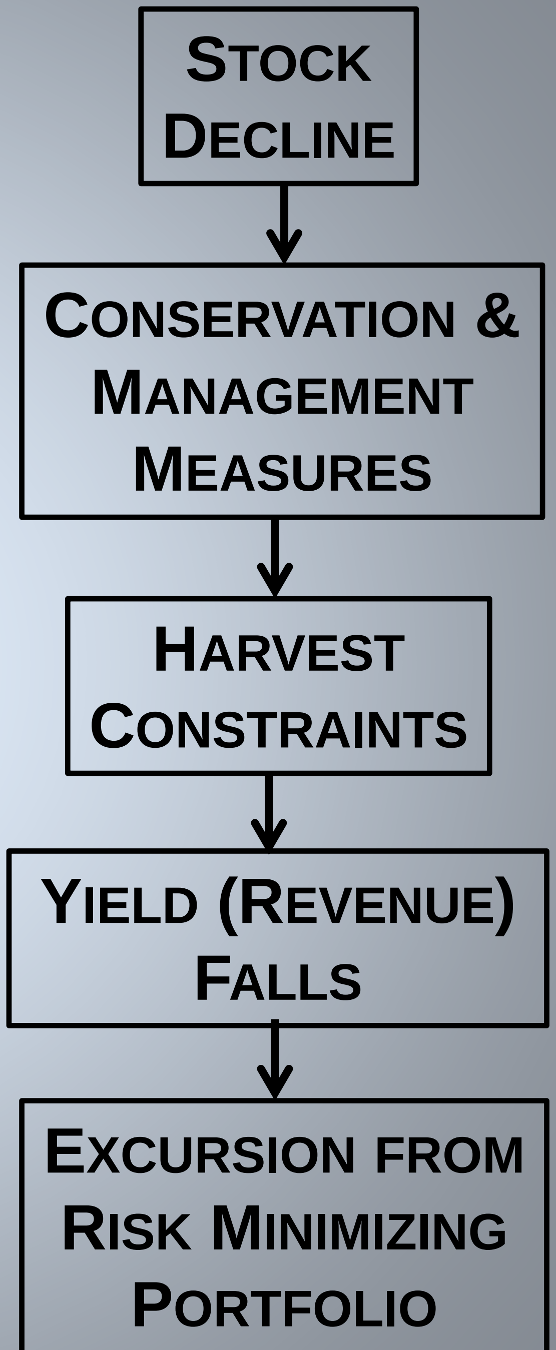

Risk-Gap
2001
SS


Risk-Gap
1994 ?
GB

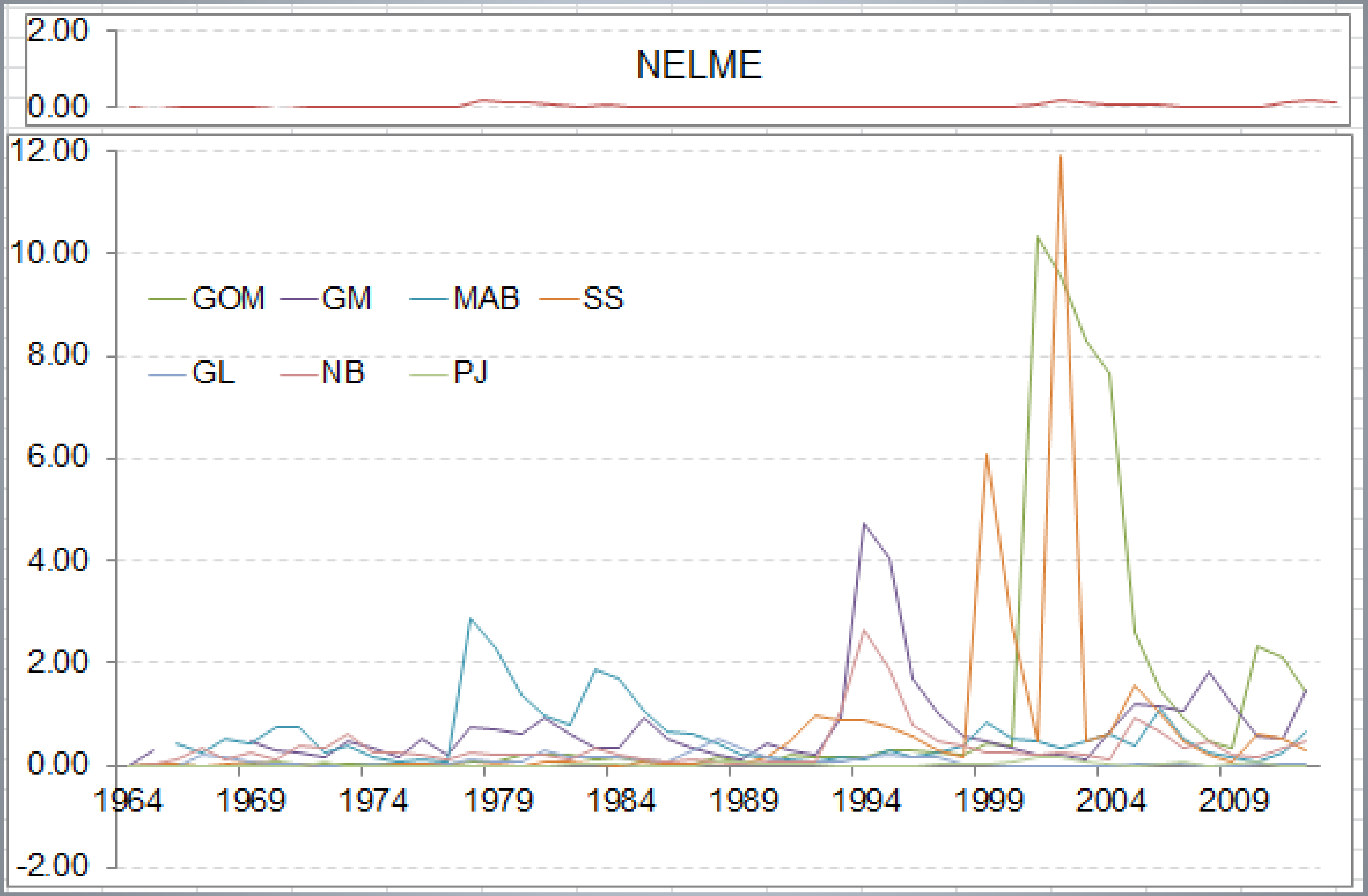

Risk-Gap
2001
GOM
hake
constraint

Risk Gaps

- Excursions from risk minimizing portfolio
- Harvests are not "optimal" in the portfolio sense (riskier)
- Increased riskiness at EPU levels may be "compensated for" at broader LME scale
- Increased riskiness at port levels may be balanced over ports
- Excursions appear to be short-lived
- **Causation is an area for future research**

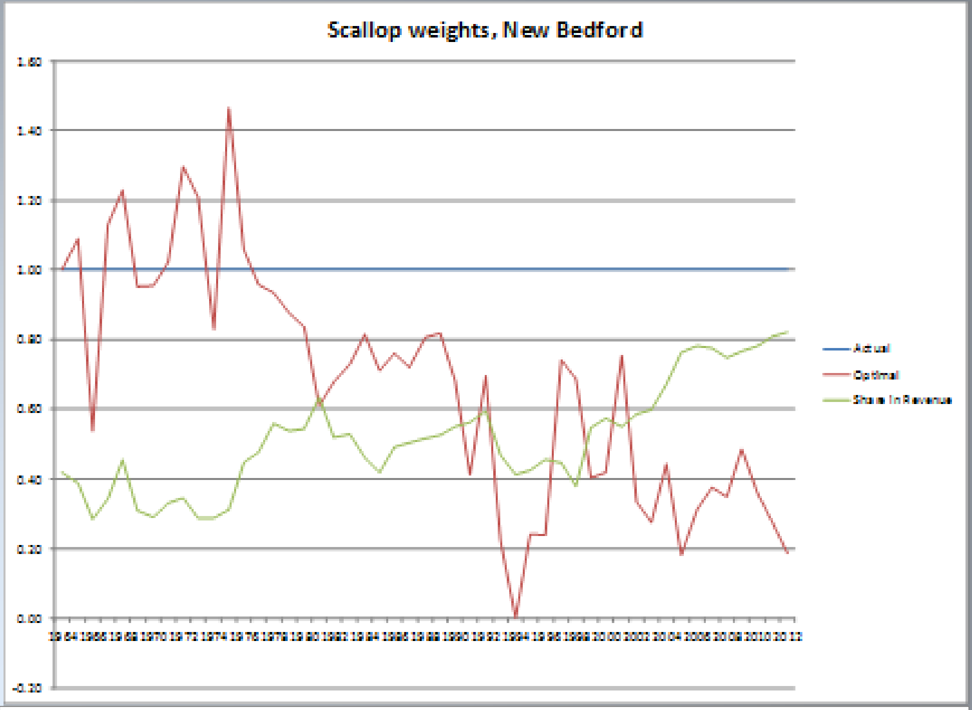


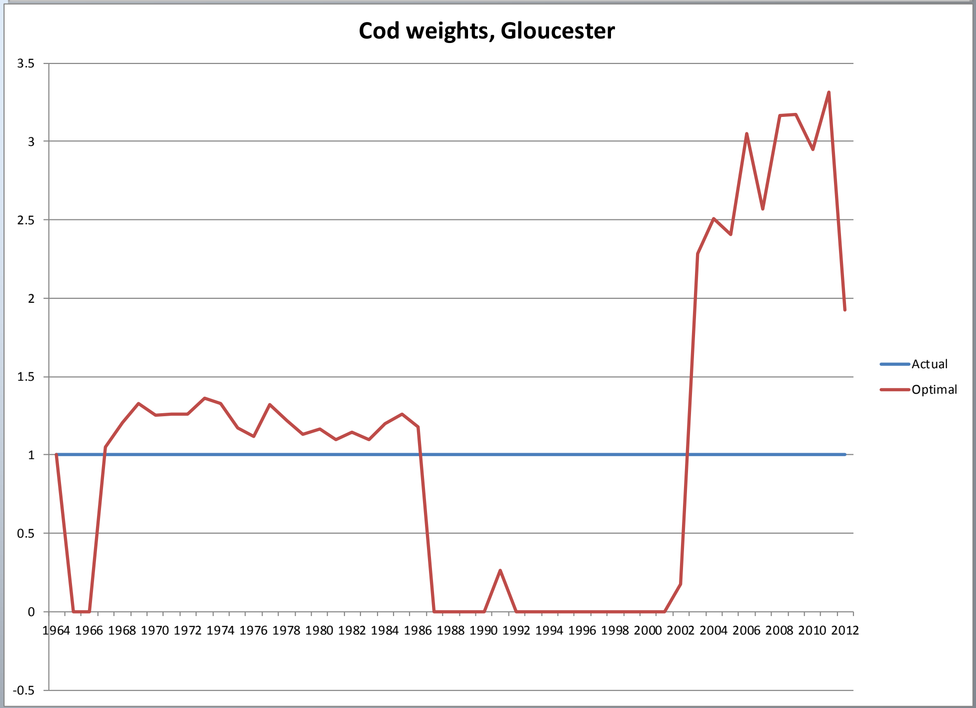
Risk-Gap Compensation at Broader Scales



Management at the Community Level

- <u>New Bedford</u>: Low "optimal" weights for sea scallops relative to actual weights may call for further diversification (diversification into groundfish may be restricted by the depletion of cod stocks)
- <u>Gloucester</u>: Low optimal weights for Atlantic cod relative to actual weights preceded Am. 13 and limits on DAS due to declining stocks; model calls for increased yields of cod, but cod is now depleted and unavailable





Summary and Future Plans

- At broader geographic scales, NE/LME fisheries have been prosecuted at levels that appear to minimize risks for realized returns
- "Excursions" from the efficient frontier are likely the consequence of unanticipated stock depletions leading to regulatory harvest constraints, thereby forcing fleets to take on risk
- Want to explore further the relationship between regulatory policies and excursions
- Excursions seem short-lived, as fleets appear to adjust to new constraints within a few years
- EBFM using the portfolio approach could be enhanced with a better understanding of the underlying ecological structure; in particular, modeling the available biomass *B*