New England Fishery Management Council

University of Massachusetts Dartmouth SMAST

Portfolio Approach to Inform New England Fisheries Management

IRA Initiative 4.4

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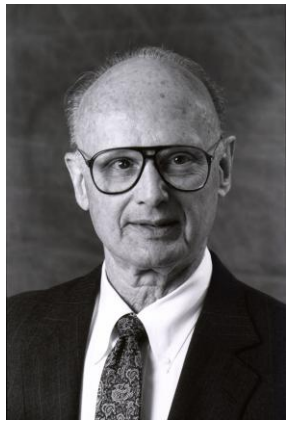
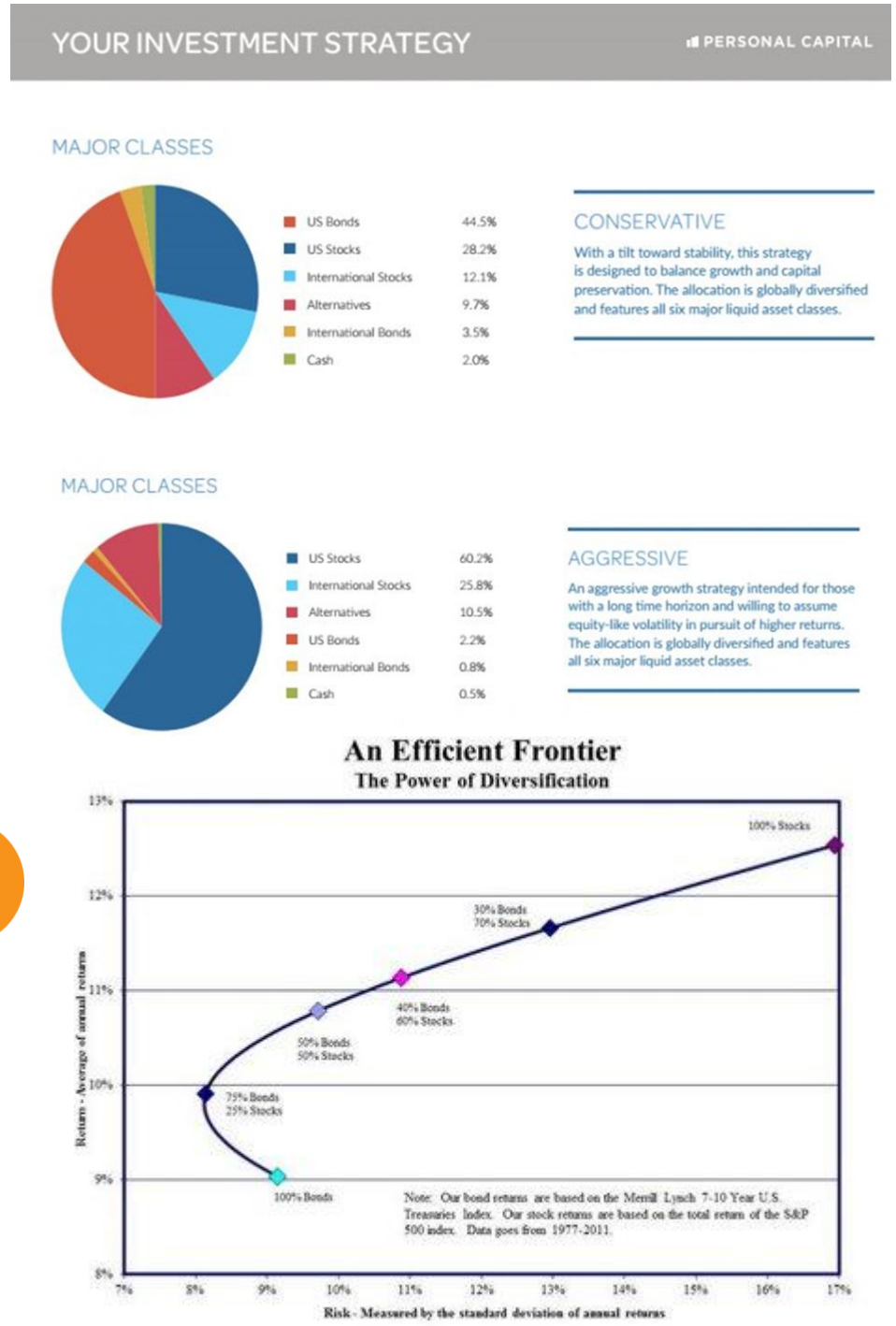
What is Modern Portfolio Theory?

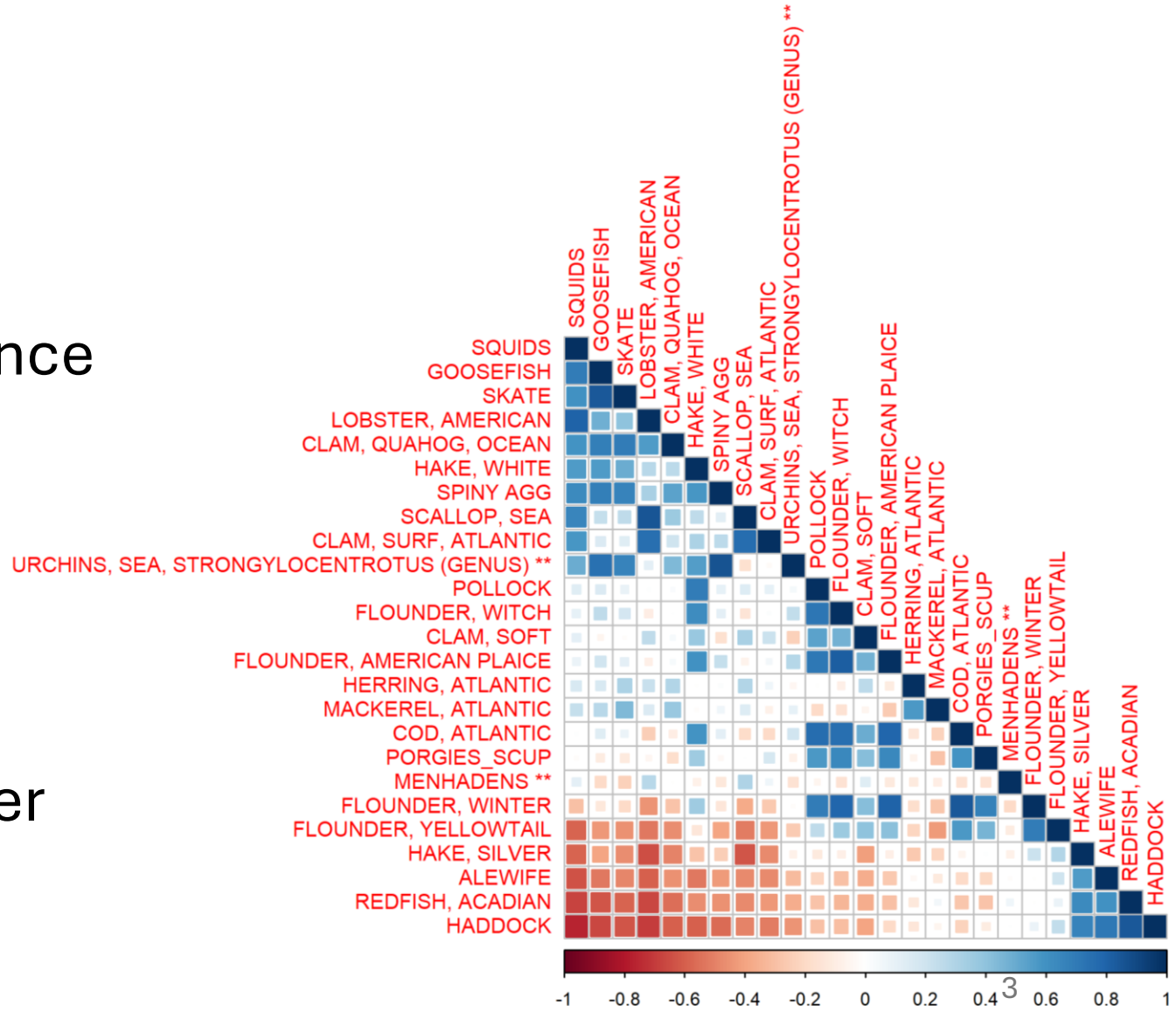


- Developed by Markowitz (1952) for selecting financial investments
- **Diversifying** in **uncorrelated** or **negatively correlated** assets can reduce **risk** or increase revenue for desired level of risk
  - Financial Risk ~ Volatility (variability) of returns/revenue/money
    - More **variable** assets are more risky
- Revolutionary at time and still widely applied in finance



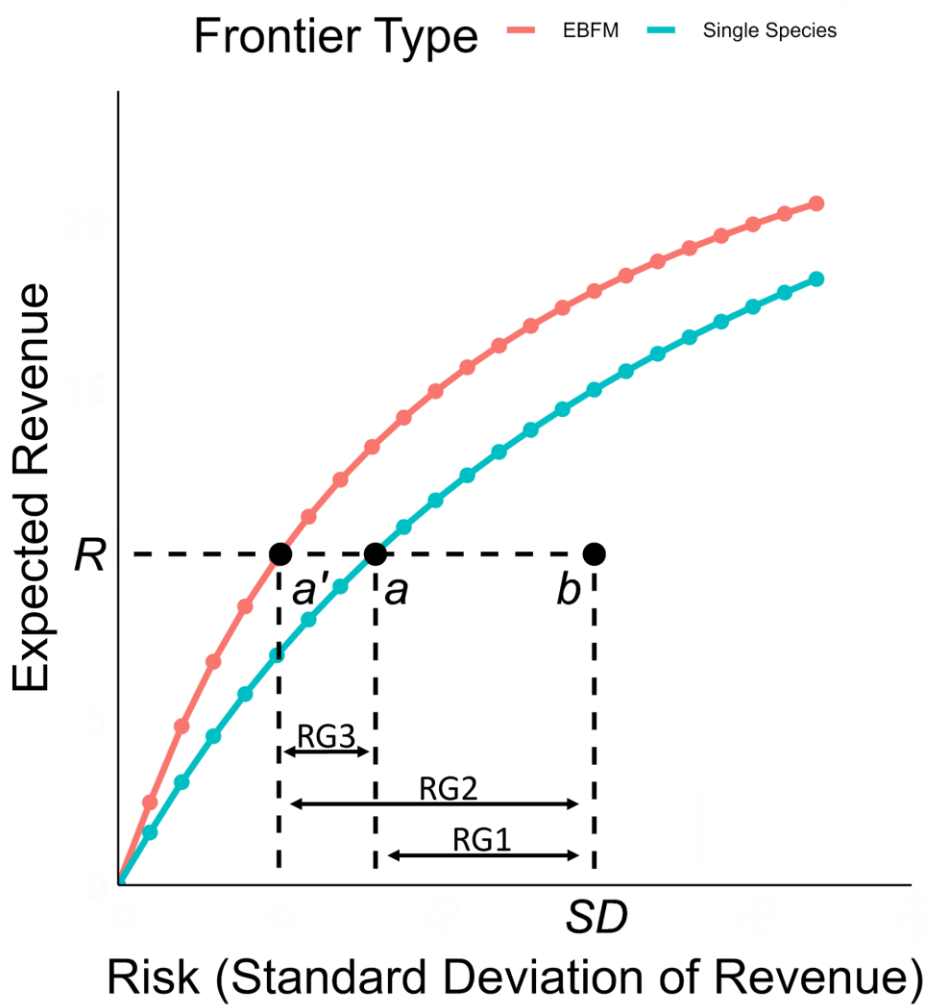
Applications to Fisheries Management

- We can treat fish stocks as financial assets
  - Can be harvested to produce economic returns indefinitely
- Fisheries revenue has covariance due to species interdependencies, market economics, climate, etc.
- Take advantage of this covariance to identify optimal harvest strategies that consider risk-return tradeoffs



Key Terms

Some Jargon	
Portfolio	*a combination of assets (e.g., stocks and bonds), in this case fish stocks*
Efficient Frontiers	*graphical representation of portfolios that maximize returns for the risk assumed*
Targets (e.g., a)	*target revenue values defined by the user*
Risk	*Risk of not realizing the target revenue (foregone revenue or increased risk); take the smallest possible risk of failure in achieving the target revenue*
Realized revenue (b)	*the revenue that was earned*
Risk gap	*the difference in risk between two values (e.g., realized revenue and a frontier)*
Negative covariance	*Inverse relationship between portfolio species, which manifests as negative covariance in revenue.*

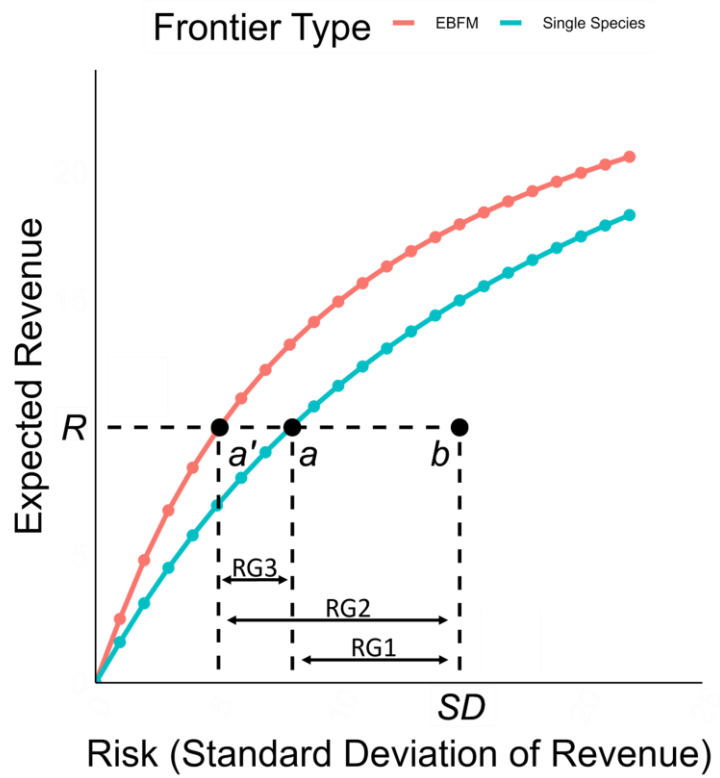


Economic Frontier Analysis

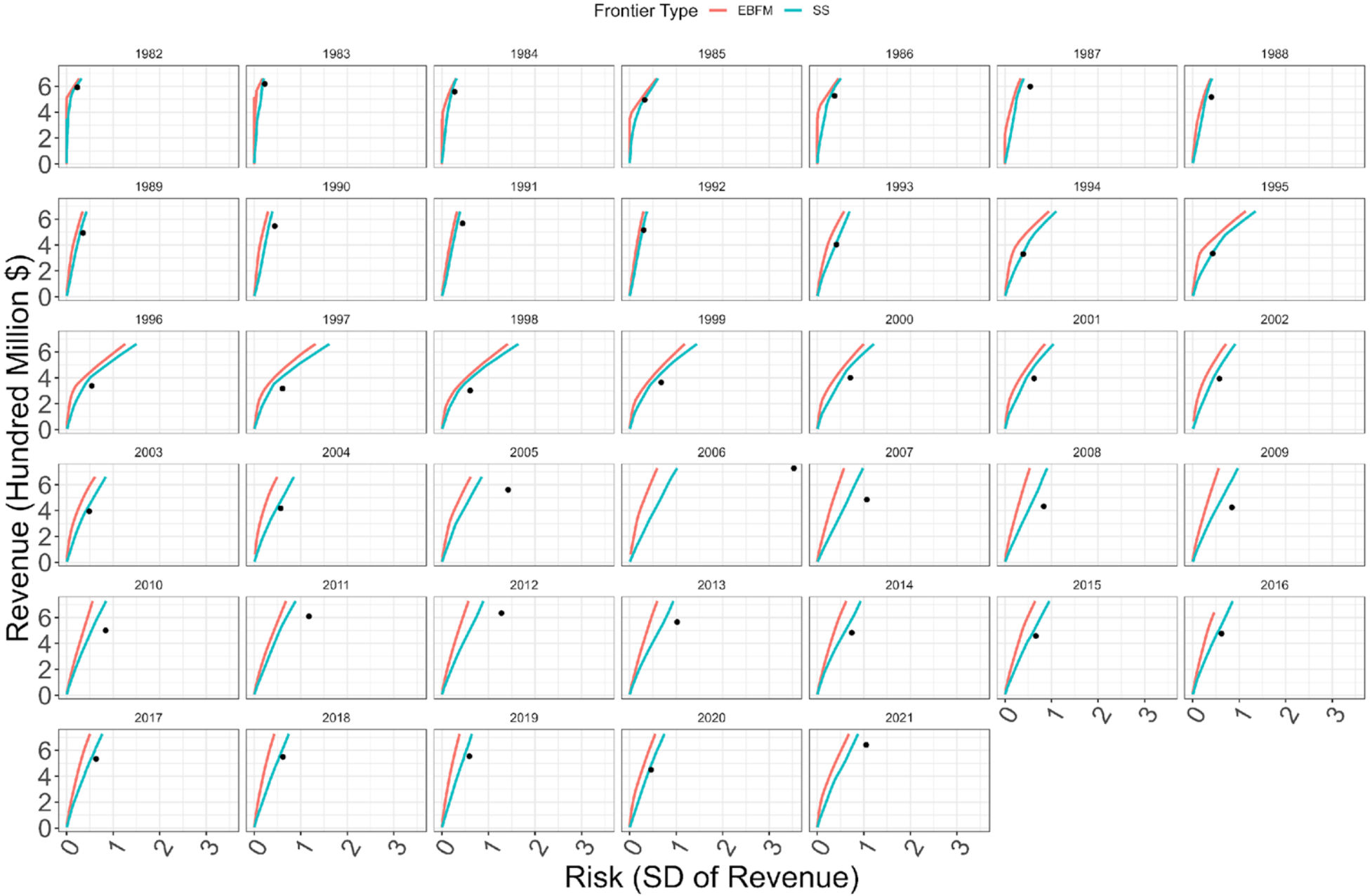
1. Calculate expected Revenue and Landings (Omega)
2. Calculate covariance
3. Set biological constraints and maximum weights
4. Set a range of potential target revenues
5. Use quadratic optimizer to minimize revenue variance at each target
6. Obtain optimal harvest weights, risk, and risk gap
7. Use efficient frontier to consider risk return tradeoffs

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

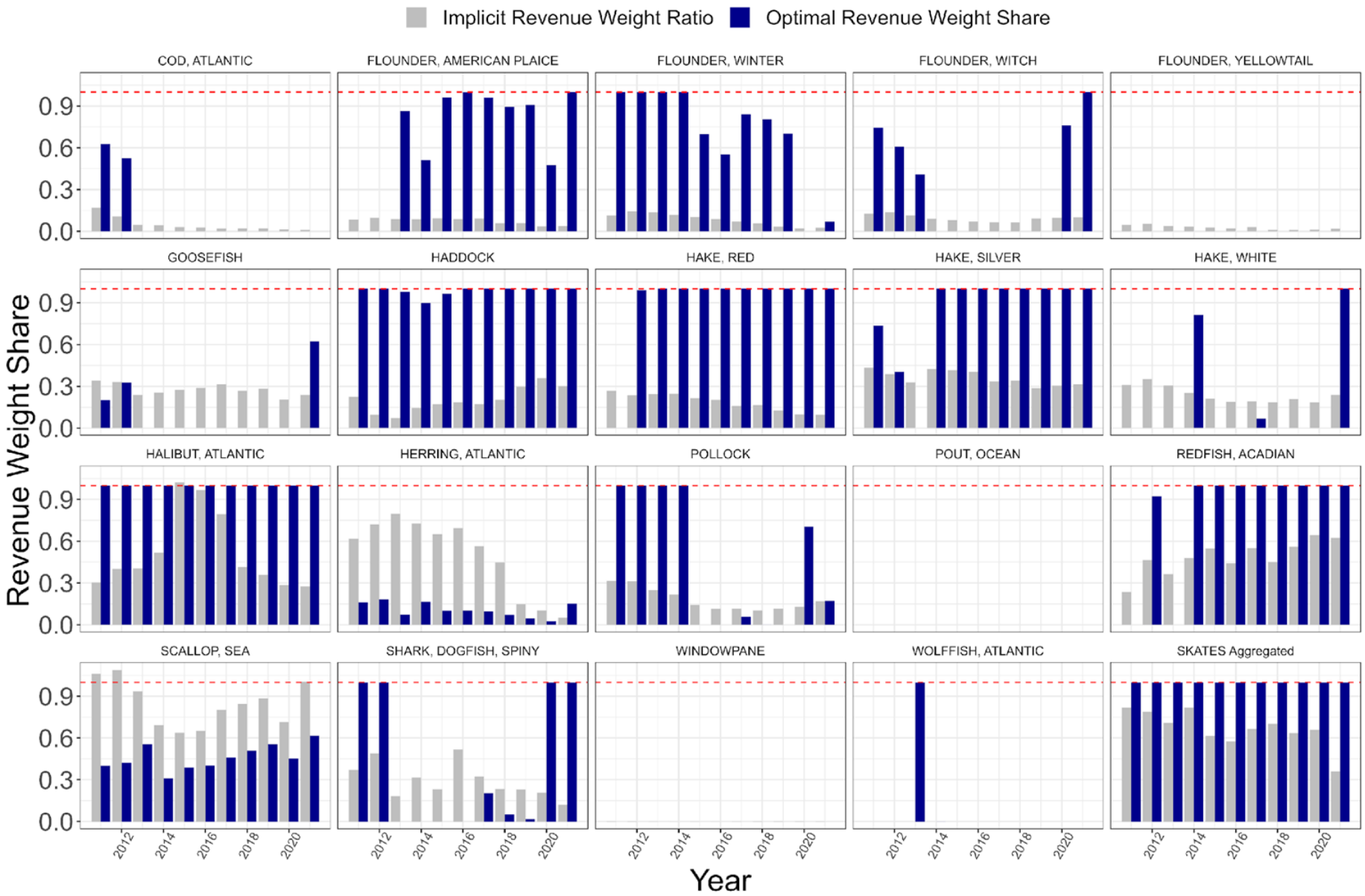
$$\Sigma_{i,j,t} = \frac{\sum_{k=1}^{t} \lambda^{t-k+1} \left(r_{i,k} - \mu_{i,t}\right)\left(r_{j,k} - \mu_{j,t}\right)}{\sum_{k=1}^{t} \lambda^{t-k+1}}$$



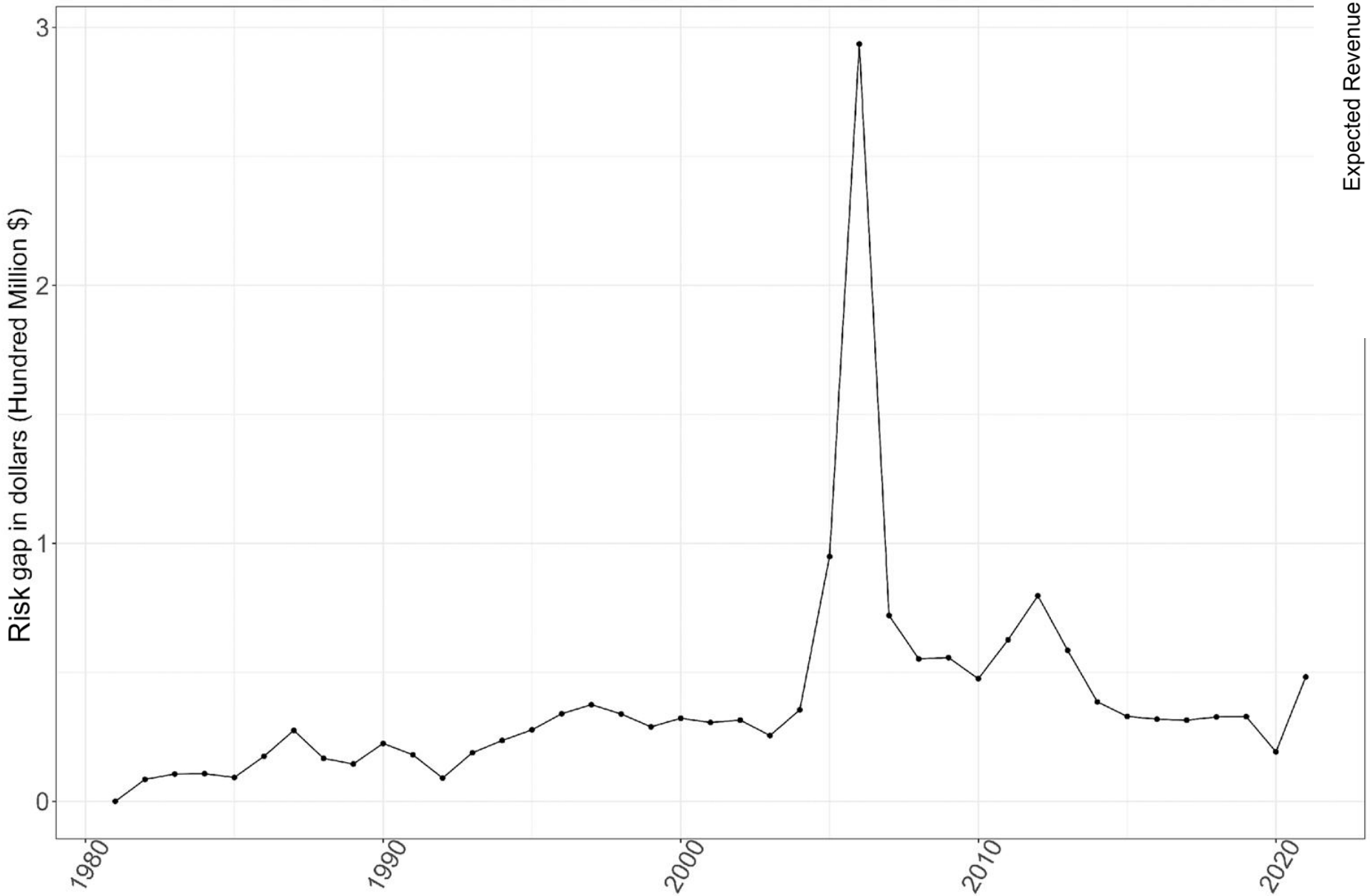
Application to Fisheries:

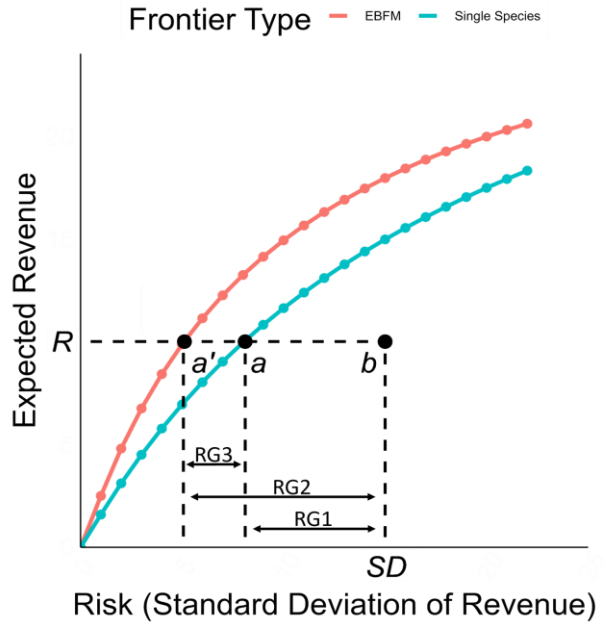


Application of Portfolio Analysis to US Fisheries

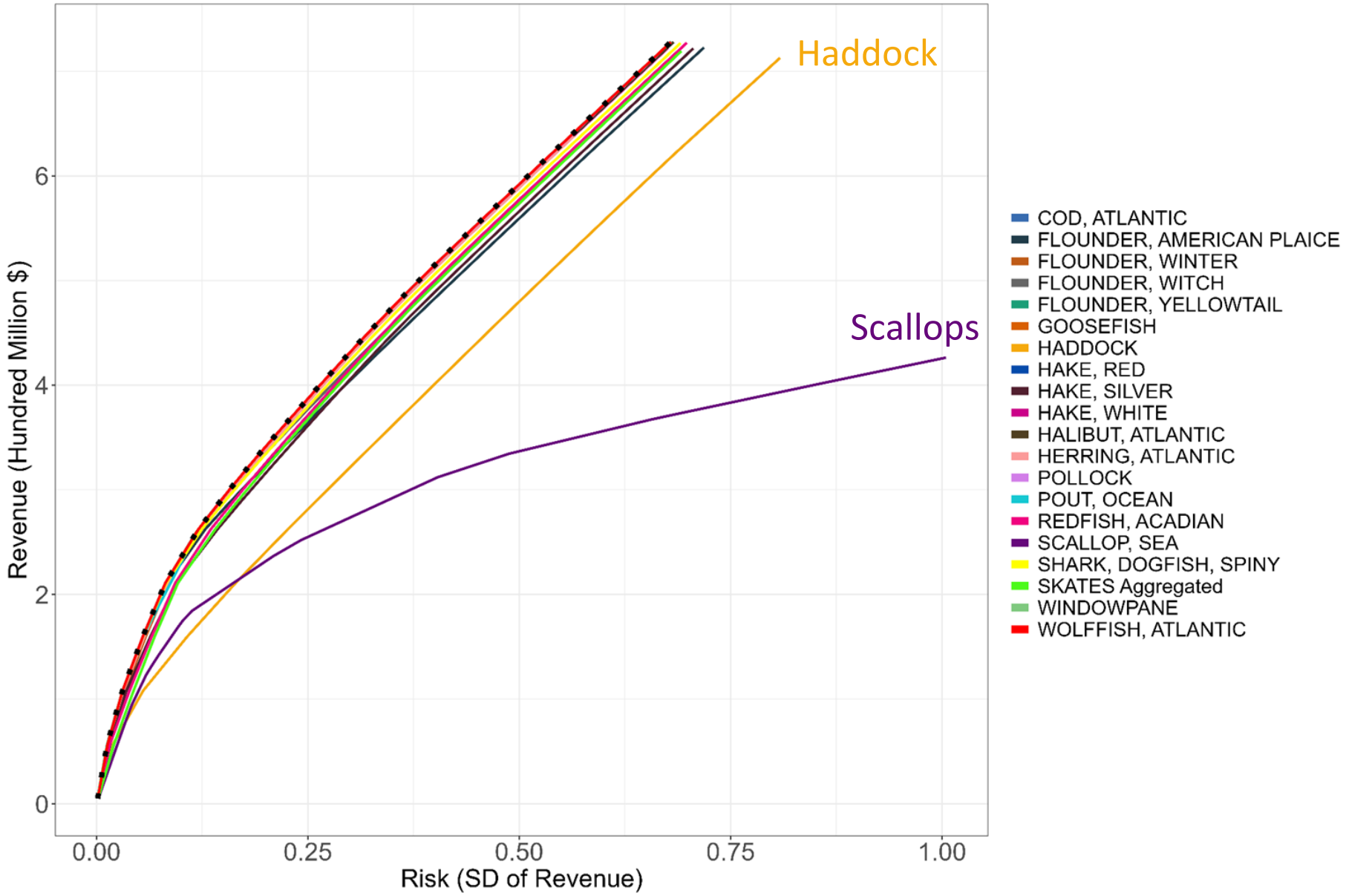


Risk Gap (RG2)


Risk gap in dollars (Hundred Million $)
3
2
1
0
1980
1990
2000
2010
2020

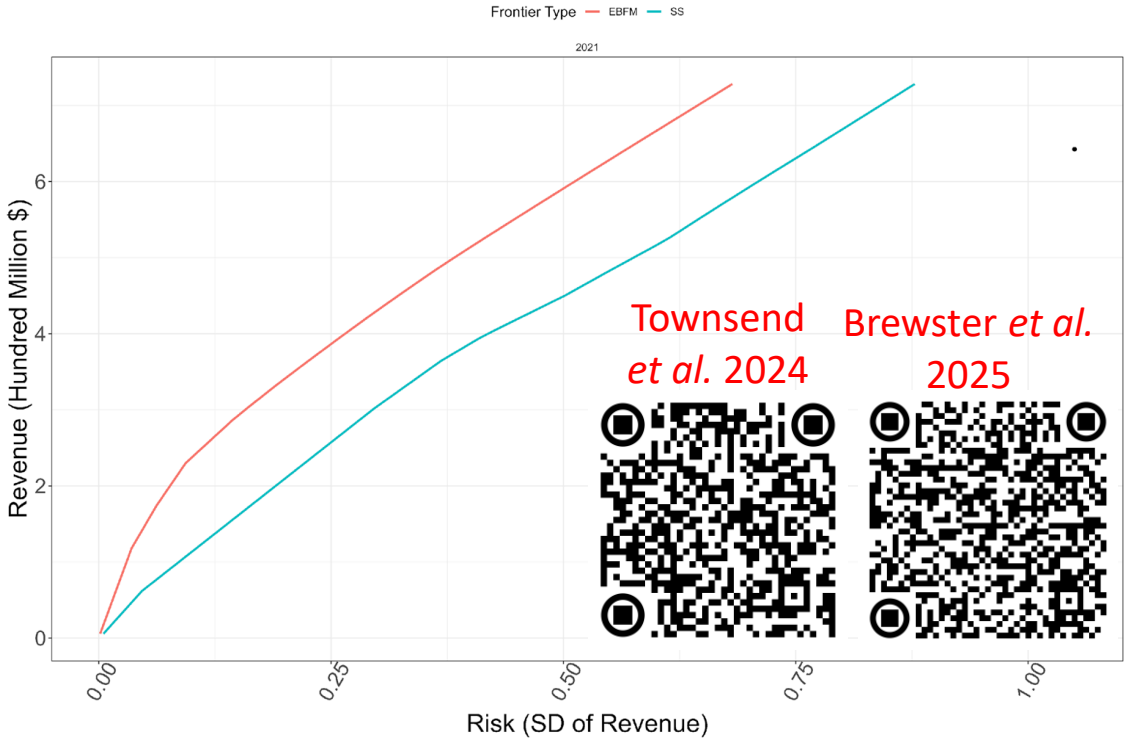

Frontier Type
EBFM
Single Species
Expected Revenue
R
a'
a
b
RG3
RG2
RG1
SD
Risk (Standard Deviation of Revenue)

Sensitivity Analysis: Portfolio Composition



Conclusions

- Frontier analysis can evaluate economic benefits of coordinated multi species management
- With more coordinated management:
  - risk could be reduced or
  - ↑ returns can be obtained for the same risk
  - i.e., coordinated management has economic benefits for all applications, to varying degrees (lower risk at each target revenue)
- Managing risk can improve economic and biological stability
- Can help identify flexible harvest strategies



Questions for the CESC

- What species to include in the overall portfolio?
  - Portfolio configurations: gear/fleet, other suggestions?
  - Definite, Maybe, No
- What alternative permit structures are being considered?
  - If broken down into fleets/gear types, what species mixes to consider?

Atlantic Cod	Sea Scallop	Soft Clam	Bluefish	Bluefin Tuna
Haddock	Monkfish	Surf Clam	Striped Bass	Swordfish
Yellowtail Flounder	Atlantic Herring	Northern Quahog	American Eel	Urchins
Pollock	Skates	Ocean Quahog	Butterfish	Oysters
American Plaice	Silver Hake (Whiting)	Summer Flounder	Bay Scallop	Atlantic Mackerel
Witch Flounder	American Lobster	Scup	Whelk/Conch	Longfin Squid
White Hake	Spiny Dogfish	Black Sea Bass	Alewife	Shortfin Squid
Winter Flounder	Windowpane Flounder	Red Hake	Jonah Crab	Shrimp (Pandalid)
Acadian Redfish	Ocean Pout	Offshore Hake	Red Crab	
Atlantic Halibut	Atlantic Wolffish	Menhaden	Atlantic Rock Crab	

Top Species by Total Revenue (1996–2024)

Ranks 1–20			Ranks 21–40		
Rank	Species	Revenue (2024 USD)	Rank	Species	Revenue (2024 USD)
1	AMERICAN LOBSTER	$12,275,173,617	21	SKATES	$207,233,660
2	SEA SCALLOP	$9,634,652,648	22	WHITE HAKE	$192,082,145
3	MONKFISH	$907,695,794	23	ATLANTIC MACKEREL	$162,800,990
4	ATLANTIC COD	$792,603,792	24	SOFT CLAM	$160,119,689
5	LONGFIN SQUID	$759,361,384	25	SEA URCHINS	$155,263,782
6	ATLANTIC HERRING	$610,750,901	26	SCUP	$146,983,341
7	QUAHOG	$588,731,161	27	SHRIMP (PANDALID)	$130,930,564
8	HADDOCK	$551,298,103	28	WHELKS	$117,971,822
9	ATLANTIC SALMON	$415,181,759	29	OYSTERS	$114,854,840
10	WINTER FLOUNDER	$378,512,877	30	ACADIAN REDFISH	$114,642,598
11	BLUEFIN TUNA	$367,230,159	31	RED CRAB	$114,048,202
12	POLLOCK	$329,338,399	32	STRIPED BASS	$99,792,888
13	SURF CLAM	$304,205,015	33	SPINY DOGFISH	$83,921,692
14	SUMMER FLOUNDER	$303,647,143	34	SWORDFISH	$83,129,548
15	YELLOWTAIL FLOUNDER	$278,142,964	35	BLACK SEA BASS	$74,969,704
16	SILVER HAKE	$268,589,619	36	BUTTERFISH	$69,482,672
17	AMERICAN PLAICE	$259,526,880	37	HAGFISH	$60,418,000
18	SHORTFIN SQUID	$256,417,809	38	ROCK CRAB	$31,896,376
19	JONAH CRAB	$229,068,550	39	BAY SCALLOP	$31,105,200
20	WITCH FLOUNDER	$226,660,536	40	MUSSELS	$30,667,091