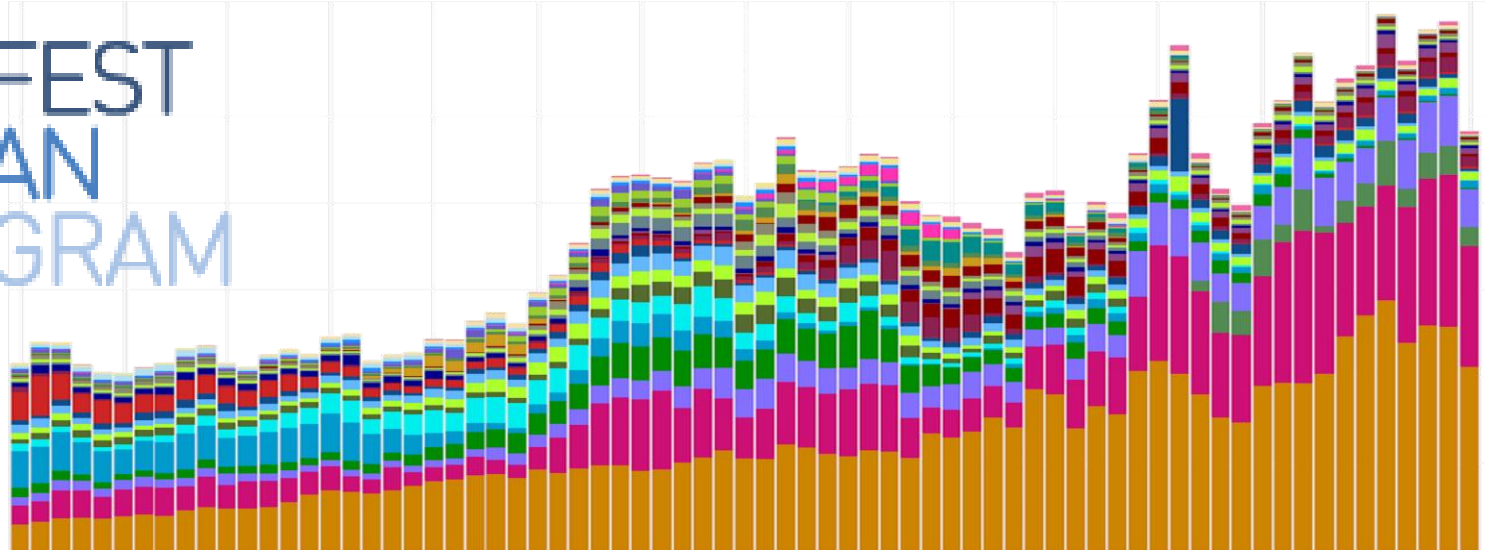
Using Portfolio Theory to Improve the Management of Living Marine Resources: *A Demonstration for New England Fisheries*



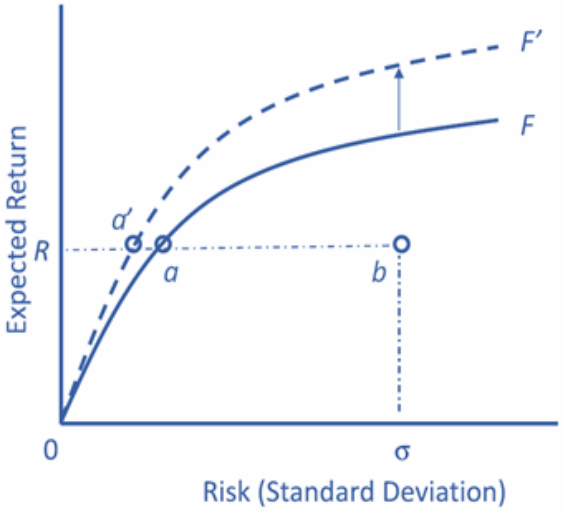
Jason Link, Fiona Edwards, Lauran Brewster, Steve Cadrin

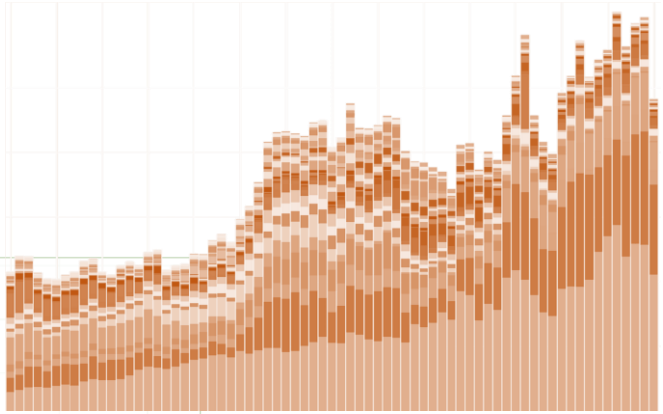
March 29, 2023

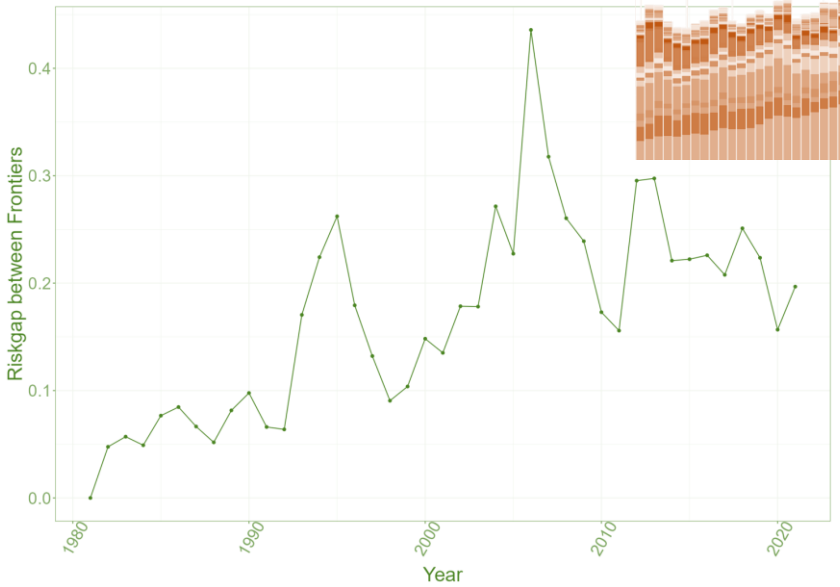
New England Fishery management Council, Scientific & Statistical Committee

Outline

1. Introduction to portfolio theory · Jason Link
2. Data exploration and portfolio asset selection – Fiona Edwards
3. Portfolio results – Lauran Brewster
4. Discussion/next steps – Steve Cadrin

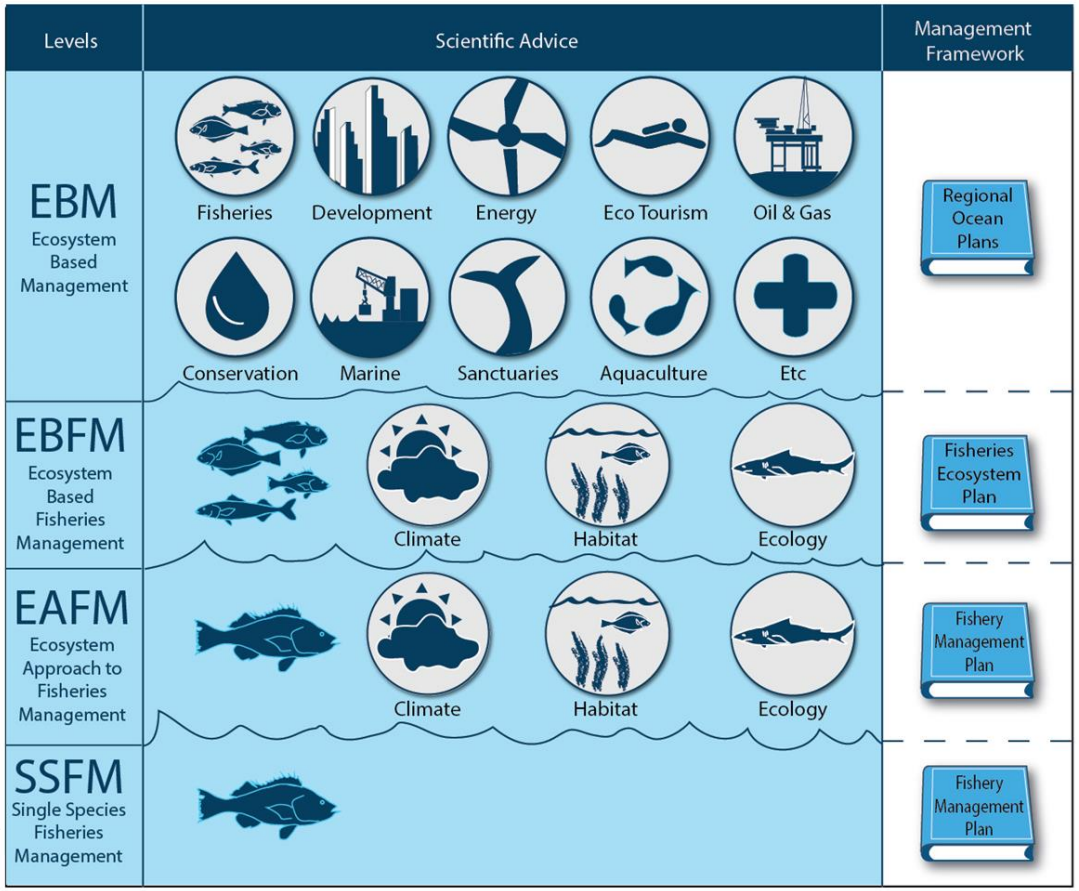






Fishery Management based on Single Species

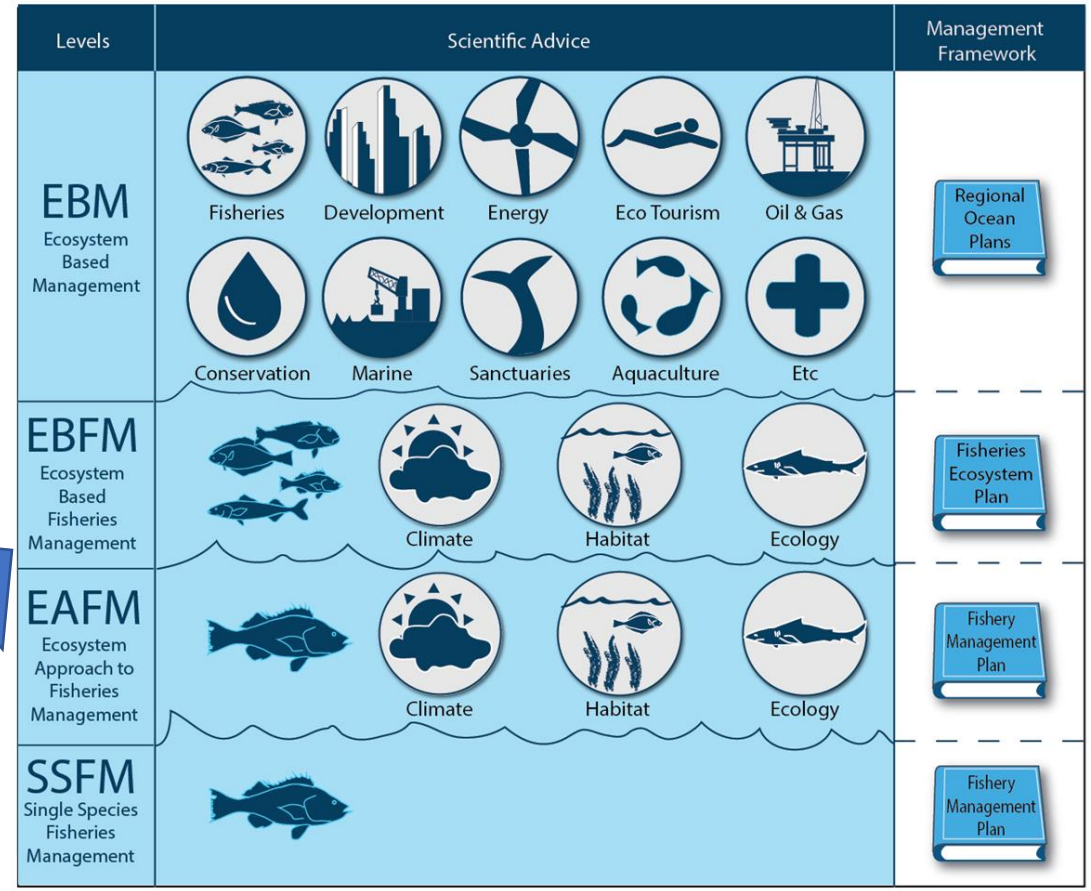
- Fishery management usually focuses on single species or populations with limited or no consideration of the entire fishery system.
- This approach has resulted in many positive outcomes, but it can be risky
- The risks extend into economic, social and even governance considerations



Ecosystem-Based Fisheries Management

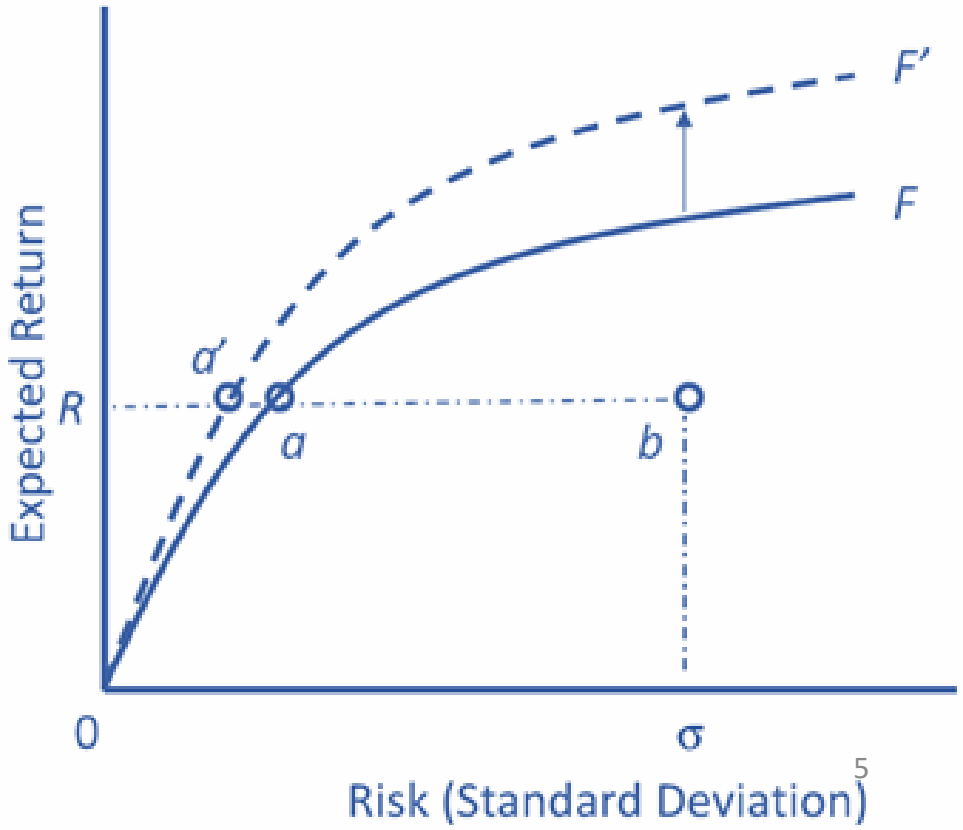
- Fishery managers are tasked with making many decisions, including harvest rates, biomass targets, and the spatial distribution of protections.

- To meet all the legal mandates for managing marine fisheries, an ecosystem approach is not only allowable, but advisable.



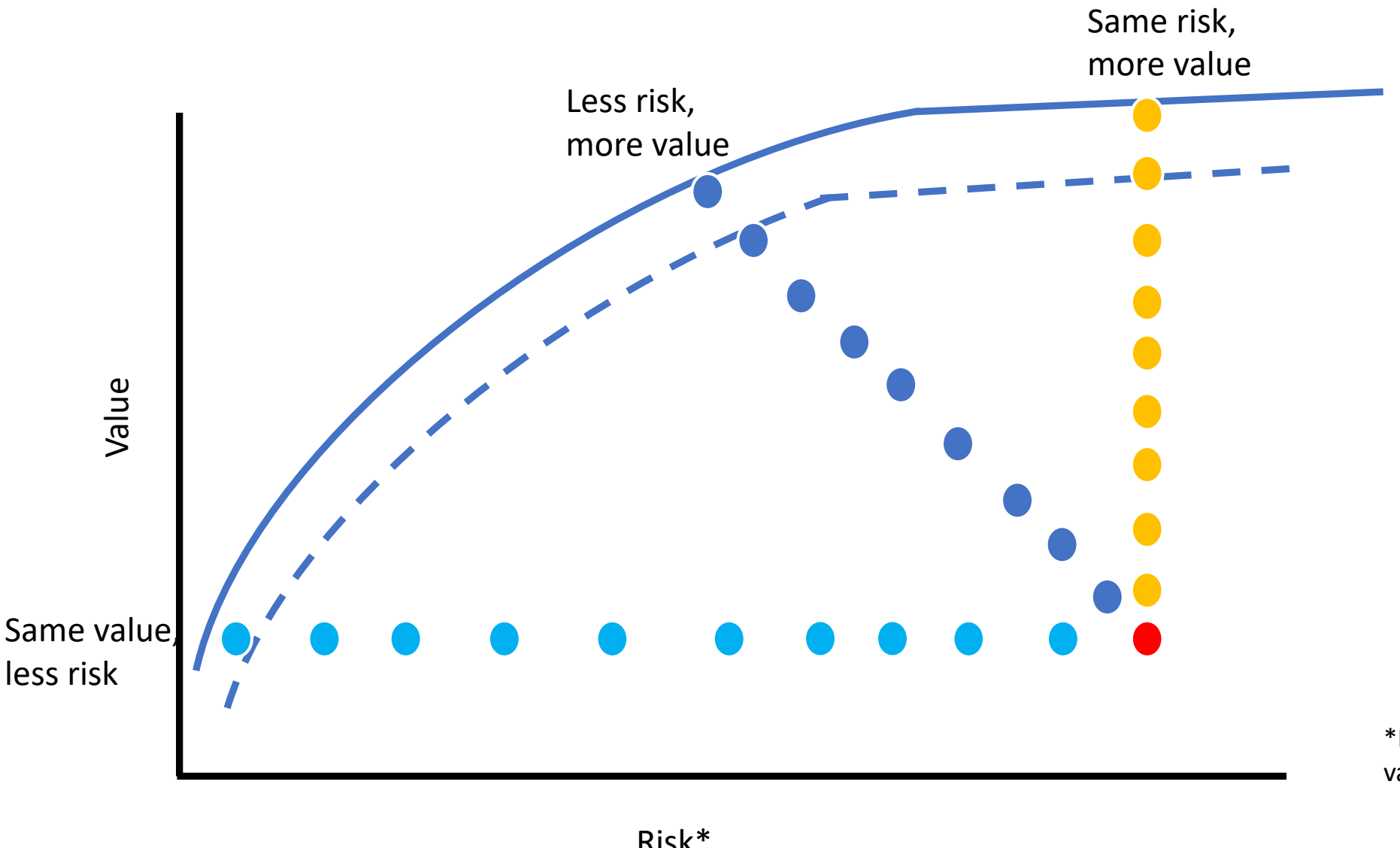
Multispecies Portfolio Management

- Theoretical studies demonstrate that the further away from the "efficiency frontier" that a set of aggregated landings is, the more risk is incurred, and the less economic yield is obtained.
- Also that more aggregated estimates of efficiency frontier (F') outperform single stock-based approaches (F)



Jin et al. 2016

- As with a financial stock portfolio, the emergent properties of a diverse portfolio of management units will be more stable than any one unit on its own.
- Theoretical studies demonstrate that the further away from the "efficiency frontier" that a set of aggregated landings is, the more risk is incurred, & the less economic yield is obtained.



*Beyond ACL, OFL, etc., but variance of value

Determining a Data Download Protocol

- Data Is Available for Download Online: https://www.fisheries.noaa.gov/foss/f?p=215:200:9126899293308:Mail:NO:::

- Data Download Parameters:

  Data Set: Commercial

  All Years: 1950–2021

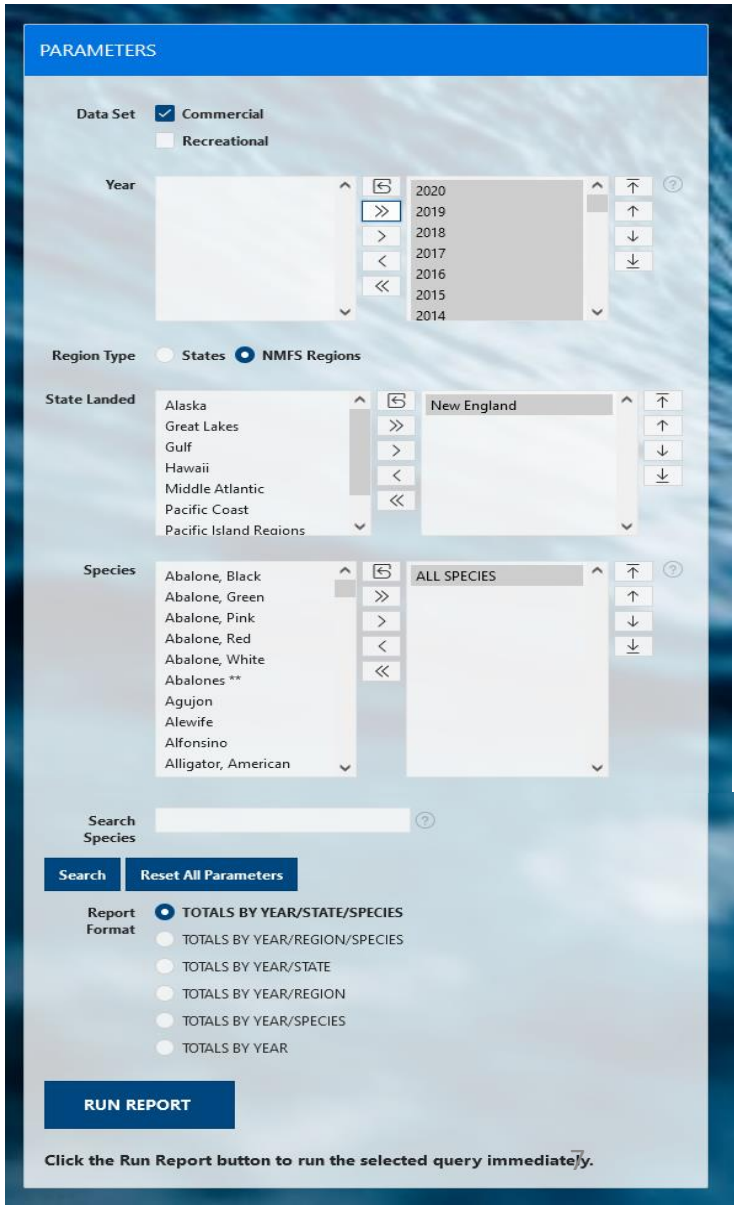
  Region Type: NMFS Regions

  Region: New England

  Species: All Species

  Report Format: Totals by Year/State/Species

- As region is unable to be selected by both States and NMFS Regions for Region Type, selecting the report format as Totals by Year/State/Species allows for inclusion of state landings information for New England



Initial Exploration of the Raw Dataset

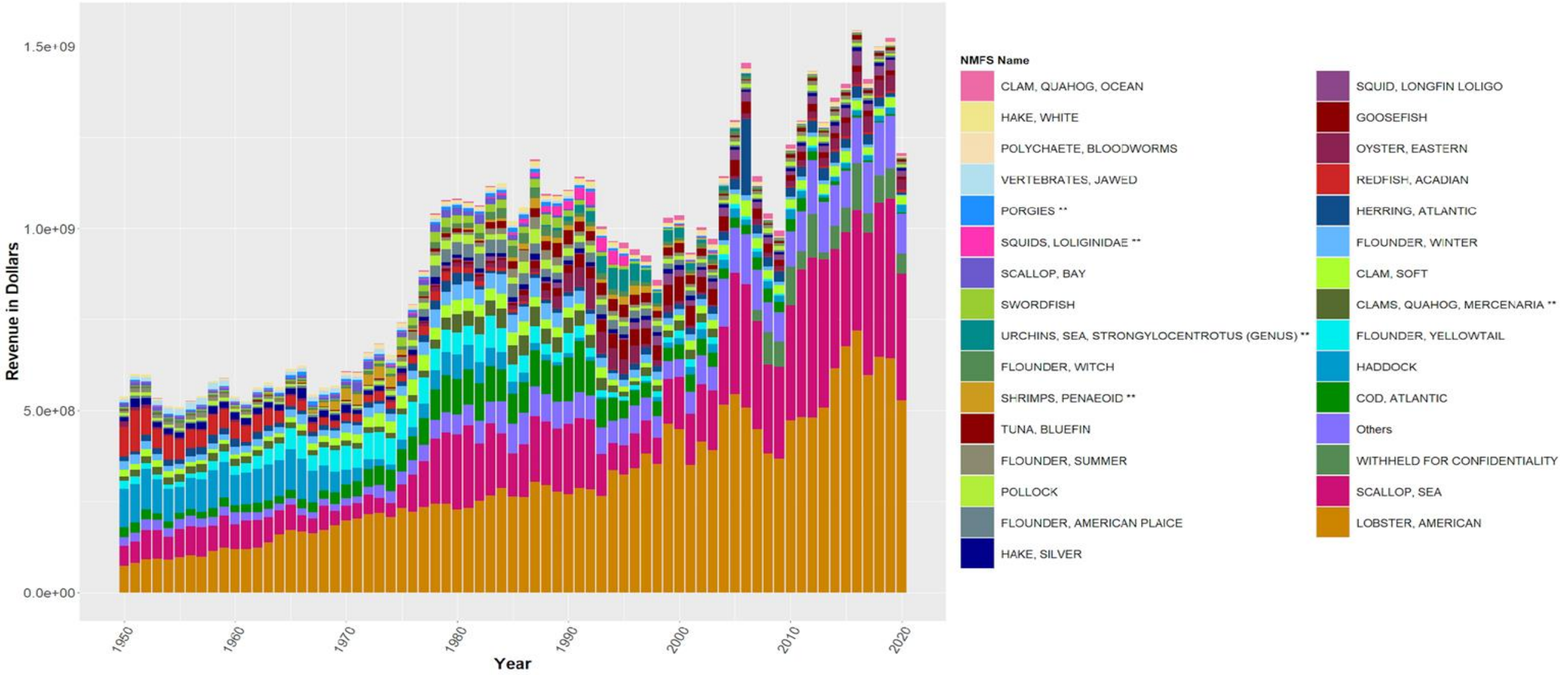
- The raw data file has…
  - 20,869 rows, 11 columns
  - Landings for 322 unique NMFS names
  - Provides landings information for 1950 through 2021

	A	B	C	D	E	F	G	H	I	J	K
1	Year	State	NMFS Name	Pounds	Metric Tor	Dollars	Confident	Collection	Scientific	Tsn	Source
2	2020	CONNECTICUT	BASS, BLACK SEA	85,613	39	229,805	Public	Commerci	Centropris	167687	ACCSP
3	2020	CONNECTICUT	BASS, STRIPED	1,309	1	5,724	Public	Commerci	Morone sa	167680	ACCSP
4	2020	CONNECTICUT	BLUEFISH	25,038	11	29,495	Public	Commerci	Pomatom	168559	ACCSP
5	2020	CONNECTICUT	BONITO, ATLANTIC	210	0	382	Public	Commerci	Sarda sard	172409	ACCSP
6	2020	CONNECTICUT	BUTTERFISH	139,025	63	129,287	Public	Commerci	Peprilus tr	172567	ACCSP
7	2020	CONNECTICUT	CARP, COMMON	297	0	148	Public	Commerci	Cyprinus c	163344	ACCSP
8	2020	CONNECTICUT	CATFISH, BLUE	1,007	0	387	Public	Commerci	Ictalurus f	163997	ACCSP
9	2020	CONNECTICUT	CATFISH, WHITE	8	0	4	Public	Commerci	Ameiurus	164037	ACCSP
10	2020	CONNECTICUT	CATFISHES, BULLHEAD **	971	0	1,631	Public	Commerci	Ictaluridae	163995	ACCSP
11	2020	CONNECTICUT	COBIA	8	0	4	Public	Commerci	Rachycent	168566	ACCSP
12	2020	CONNECTICUT	COD, ATLANTIC	4,492	2	7,735	Public	Commerci	Gadus mo	164712	ACCSP
13	2020	CONNECTICUT	CONCHS **	183,913	83	463,391	Public	Commerci	Strombida	72554	ACCSP
14	2020	CONNECTICUT	CRAB, BLUE	369	0	1,222	Public	Commerci	Callinecte	98696	ACCSP
15	2020	CONNECTICUT	CRAB, GREEN	130	0	65	Public	Commerci	Carcinus m	98734	ACCSP
16	2020	CONNECTICUT	CRAB, HORSESHOE	41,814	19	34,632	Public	Commerci	Limulus po	82703	ACCSP
17	2020	CONNECTICUT	CRAB, JONAH	323	0	312	Public	Commerci	Cancer bo	98678	ACCSP
18	2020	CONNECTICUT	CUNNER	30	0	31	Public	Commerci	Tautogola	170481	ACCSP
19	2020	CONNECTICUT	DOLPHINFISH	60	0	174	Public	Commerci	Coryphaen	168791	ACCSP
20	2020	CONNECTICUT	DORY, BUCKLER	2,816	1	1,883	Public	Commerci	Zenopsis c	166284	ACCSP
21	2020	CONNECTICUT	EEL, AMERICAN	2,959	1	13,516	Public	Commerci	Anguilla r	161127	ACCSP
22	2020	CONNECTICUT	EEL, CONGER	194	0	92	Public	Commerci	Conger oc	161326	ACCSP
23	2020	CONNECTICUT	FLOUNDER, AMERICAN PI	20,677	9	21,913	Public	Commerci	Hippoglos	172877	ACCSP
24	2020	CONNECTICUT	FLOUNDER, FOURSPOT	1,648	1	1,327	Public	Commerci	Paralichth	172739	ACCSP
25	2020	CONNECTICUT	FLOUNDER, SUMMER	370,467	168	1,114,283	Public	Commerci	Paralichth	172735	ACCSP
26	2020	CONNECTICUT	FLOUNDER, WINTER	22,150	10	36,152	Public	Commerci	Pseudopl	172905	ACCSP
27	2020	CONNECTICUT	FLOUNDER, WITCH	10,174	5	18,233	Public	Commerci	Glyptocep	172873	ACCSP
28	2020	CONNECTICUT	FLOUNDER, YELLOWTAIL	4,288	2	7,272	Public	Commerci	Limanda f	172909	ACCSP
29	2020	CONNECTICUT	GOOSEFISH	96,935	44	55,859	Public	Commerci	Lophius ar	164499	ACCSP
30	2020	CONNECTICUT	HADDOCK	15,010	7	11,253	Public	Commerci	Melanogra	164744	ACCSP
31	2020	CONNECTICUT	HAKE, RED	58,949	27	20,357	Public	Commerci	Urophycis	164730	ACCSP
32	2020	CONNECTICUT	HAKE, SILVER	466,445	212	393,183	Public	Commerci	Merlucciu	164791	ACCSP
33	2020	CONNECTICUT	HAKE, WHITE	187	0	175	Public	Commerci	Urophycis	164732	ACCSP
34	2020	CONNECTICUT	HAKES, MERLUCCIUS (GEN	5	0	4	Public	Commerci	Merlucciu	164790	ACCSP
35	2020	CONNECTICUT	HAKES, RED AND WHITE *	61	0	76	Public	Commerci	Urophycis	164729	ACCSP
36	2020	CONNECTICUT	HALIBUT, ATLANTIC	215	0	1,222	Public	Commerci	Hippoglos	172933	ACCSP

Exploration of the Raw Dataset

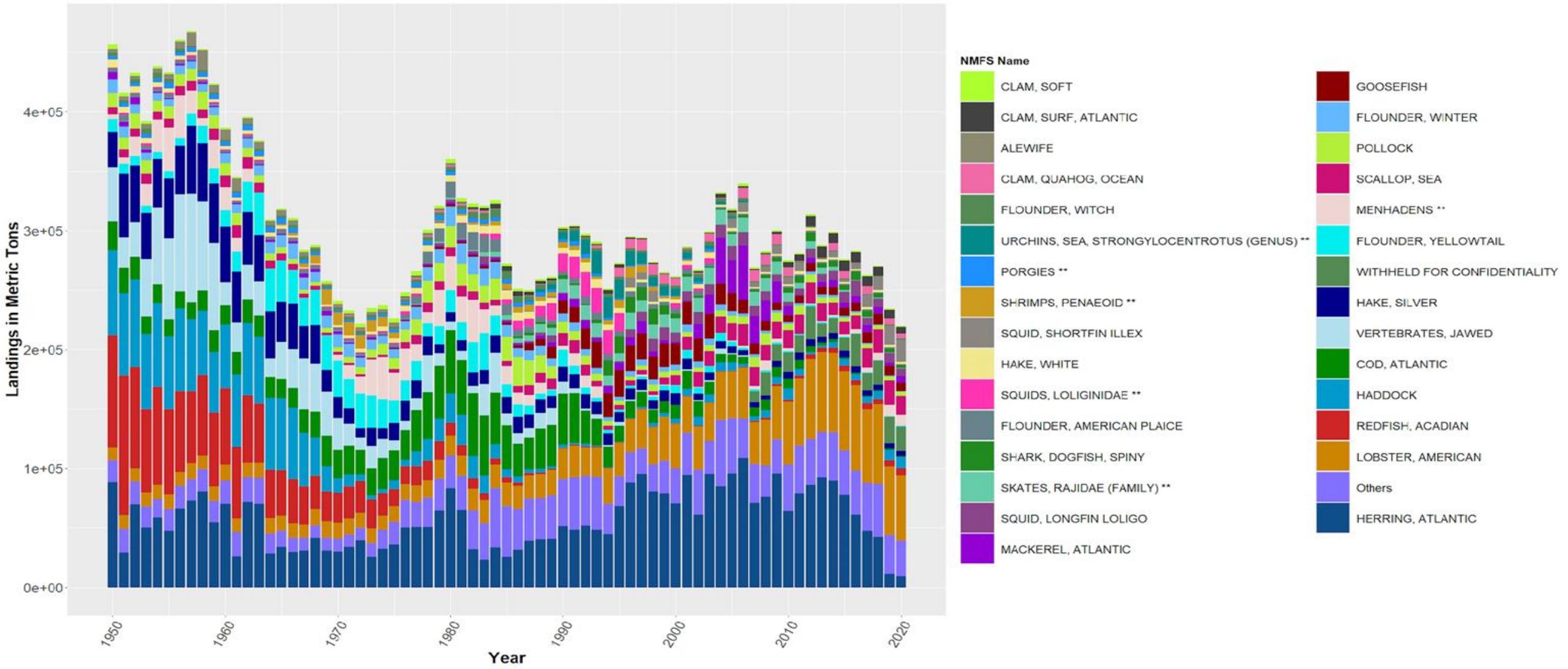
- Both public and confidential landings exist in the dataset, as confidential landings provide no landing/revenue value they were removed.
- Dataset was examined prior to manipulation in R to examine species-specific NMFS Names for some species in more recent years (i.e., Monkfish having the NMFS Name Goosefish)
- Data gaps
  - Aggregated spp.**
    - Phased out in favor of species-specific reporting
      - e.g., CATFISHES-BULLHEADS, OTHER ** not reported since 2006
  - Withheld for confidentiality
    - *“Query results with no pounds or dollars shown indicate that landings are present in our database for the selected species but are confidential and have been grouped into "WITHHELD FOR CONFIDENTIALITY" with other confidential landings in each state”.*

The Top-Ranking Landings/Revenue



Top 30 Species by Landings Revenue in Dollars Standardized to 2021 Value, plus "Others".

Top-Ranking Landings/Revenue



Top 30 Species by Landings Weight in Metric Tons, plus "Others".

Portfolio Selection: Species Managed by the NEFMC

- Northeast Multispecies (groundfish):
- Atlantic cod (*Gadus morhua*)
- Haddock (*Melanogrammus aeglefinus*)
- Yellowtail flounder (*Limanda ferruginea*)
- Pollock (*Pollachius virens*)
- American plaice (*Hippoglossoides platessoides*)
- Witch flounder (*Glyptocephalus cynoglossus*)
- White hake (*Urophycis tenuis*)
- Windowpane flounder (*Scophthalmus aquosus*)
- Winter flounder (*Pseudopleuronectes americanus*)
- Acadian redfish (*Sebastes fasciatus*)
- Atlantic halibut (*Hippoglossus hippoglossus*)
- Atlantic wolffish (*Anarhichas lupus*)
- Ocean pout (*Macrozoarces americanus*) note: in data appears as ZOARCES

Northeast Skate Complex: note: in data skates are grouped together and listed by family name (Rajidae)

- Barndoor skate (*Dipturis laevis*)
- Clearnose skate (*Raja eglanteria*)
- Little skate (*Leucoraja erinacea*)
- Rosette skate (*Leucoraja garmani*)
- Smooth skate (*Malacoraja senta*)
- Thorny skate (*Amblyraja radiata*)
- Winter skate (*Leucoraja ocellata*)

Small-Mesh Multispecies (Whiting):

- Whiting/Silver Hake (*Merluccius bilinearis*)
- Red hake (*Urophycis chuss*)
- Offshore Hake (*Merluccius albidus, blackeye whiting*)

Sea Scallop:

- Atlantic Sea Scallop (*Placopecten magellanicus*)

Monkfish:

- Monkfish (*Lophius americanus*)

Red Crab:

- Atlantic Deep-Sea Red Crab (*Chaceon quinquedens*)

Atlantic Herring:

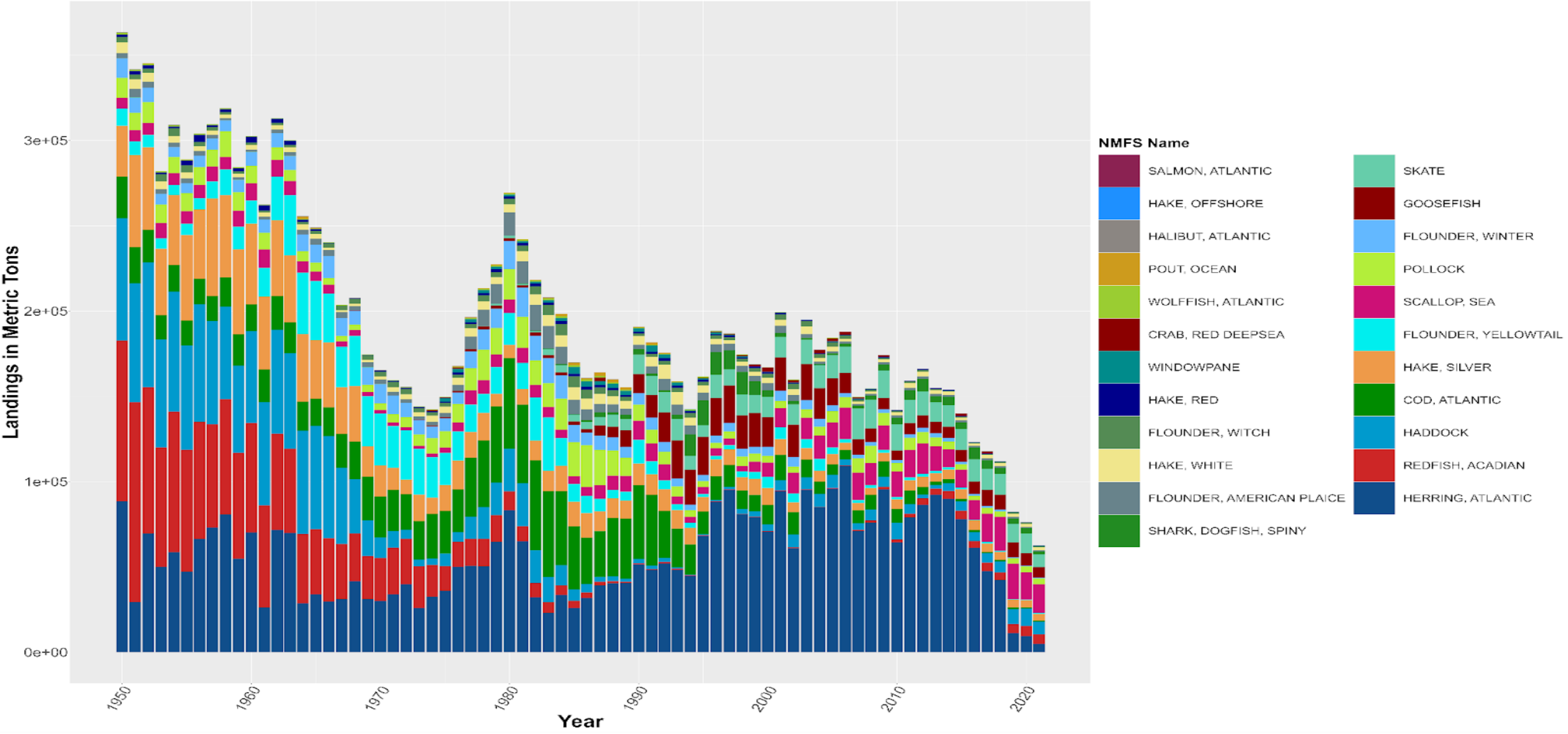
- Atlantic Herring (*Clupea harengus*)

Spiny Dogfish:

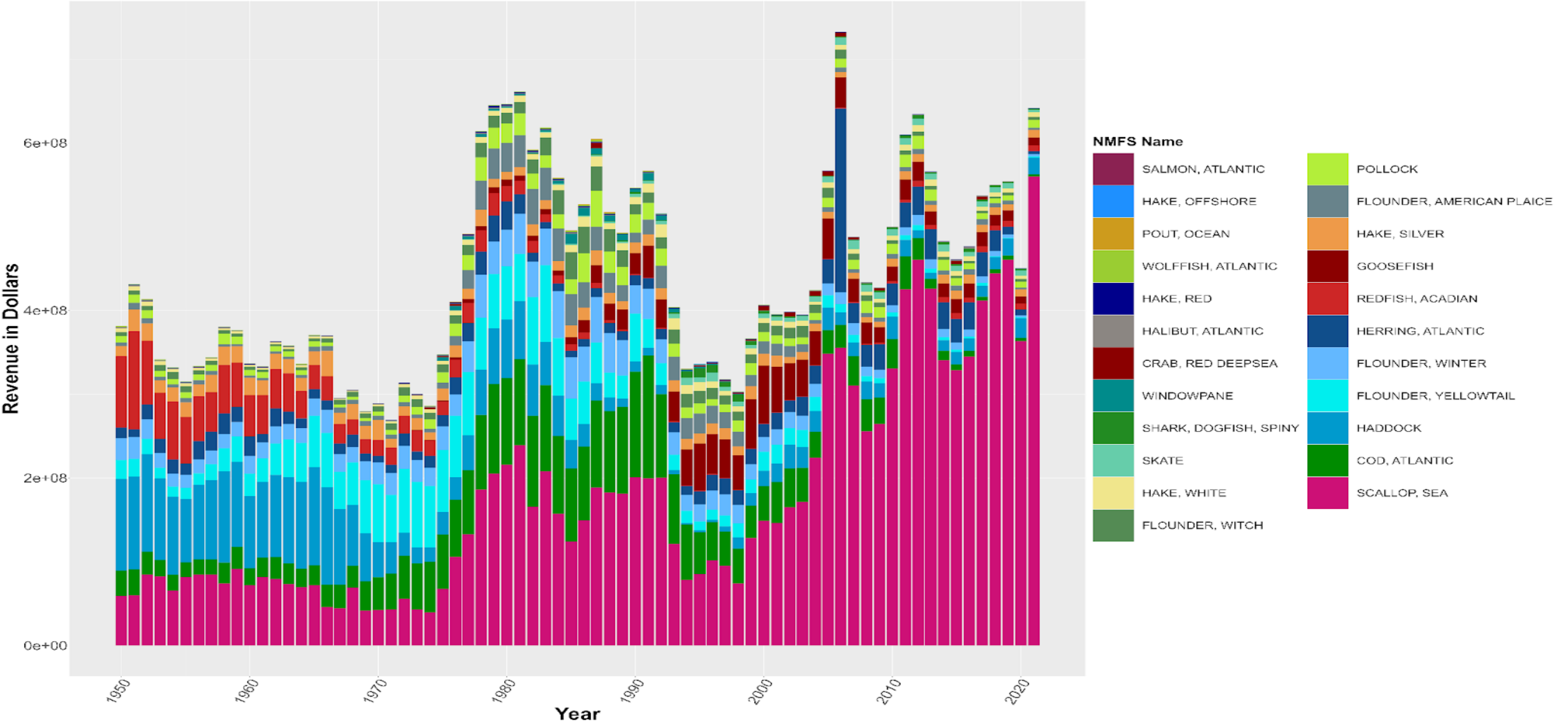
- Atlantic Spiny Dogfish (*Squalus acanthias*)

Atlantic Salmon:

- Atlantic Salmon (*Salmo salar*)



Landings Weight (Metric Tons) for all species managed under a fishery management plan (FMP) by the New England Fisheries Management Council. As skates have historically been aggregated through the entirety of the time series with species-specific reporting appearing only recently all council managed skate species were combined with the historical aggregation as "SKATE".



Landings In Revenue (Dollars Standardized to 2021 Value) for all species managed under a fishery management plan (FMP) by the New England Fisheries Management Council. As skates have historically been aggregated through the entirety of the time series with species-specific reporting appearing only recently all council managed skate species were combined with the historical aggregation as "SKATE".

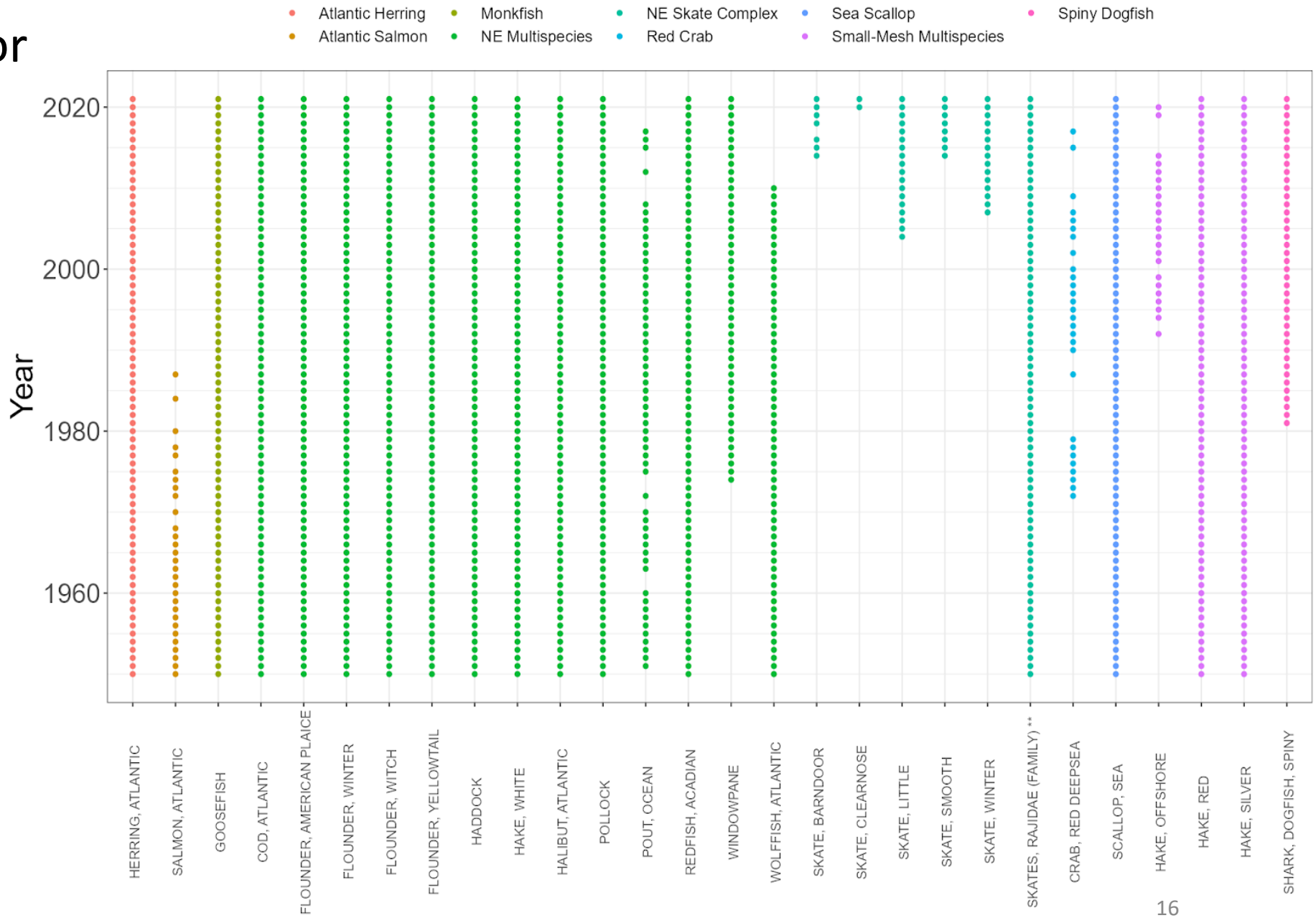
Data preparation prior to analyses

- We explored a candidate portfolio for New England Fisheries Management Council (NEFMC) managed species.
  - We standardized all revenue to the respective 2021-dollar value.
  - We focused on landings in metric tons to avoid zeros in landings weight records

- As frontier analysis requires consecutive years of data, we examined the presence of these species in the time series to determine if any data gaps were present.

Data preparation prior to analyses

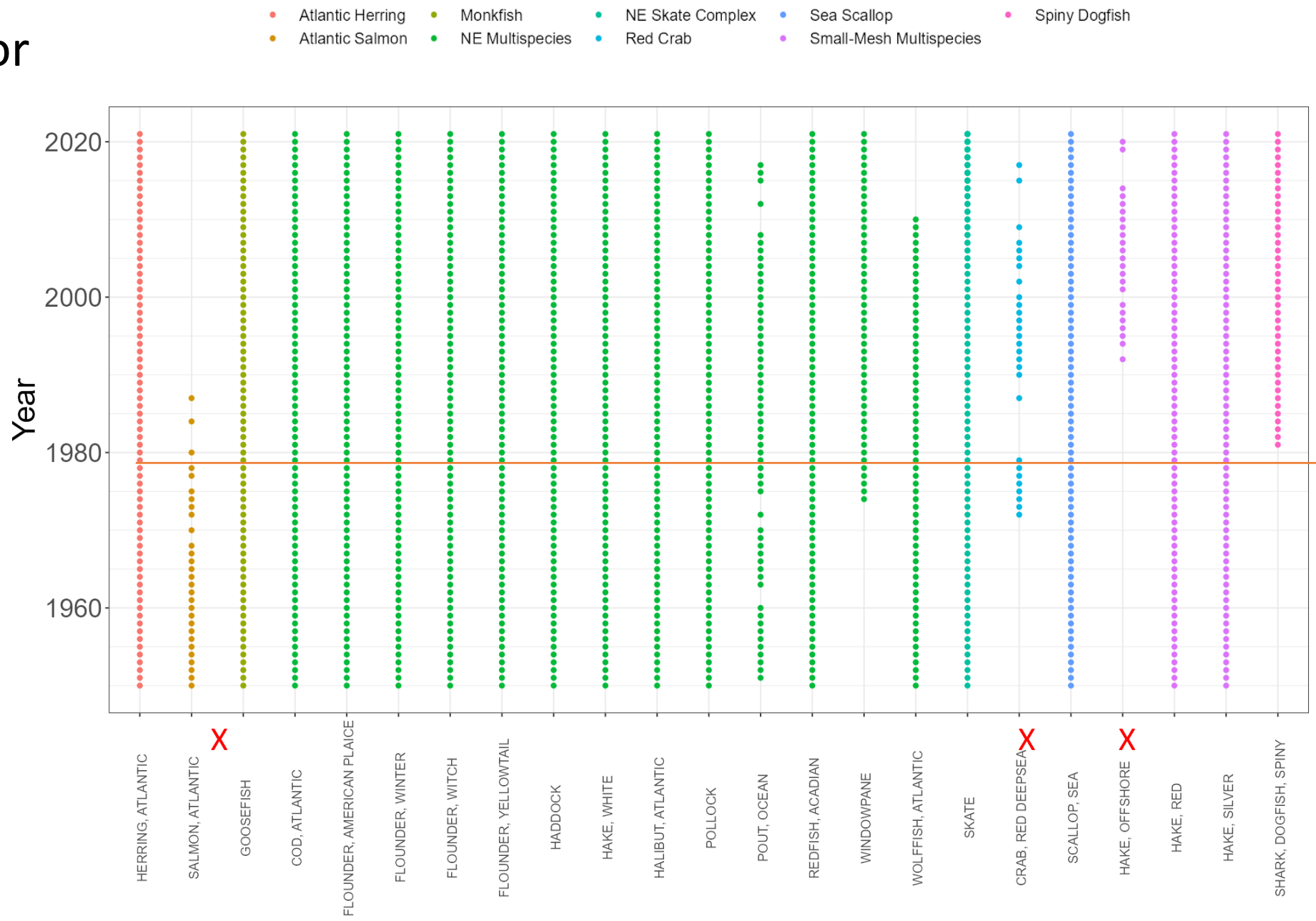
- Species with data gaps were examined further
- Five courses of action were considered for each species:
  1. Aggregate
  2. Truncate
  3. Drop
  4. Interpolate
  5. Add zeros

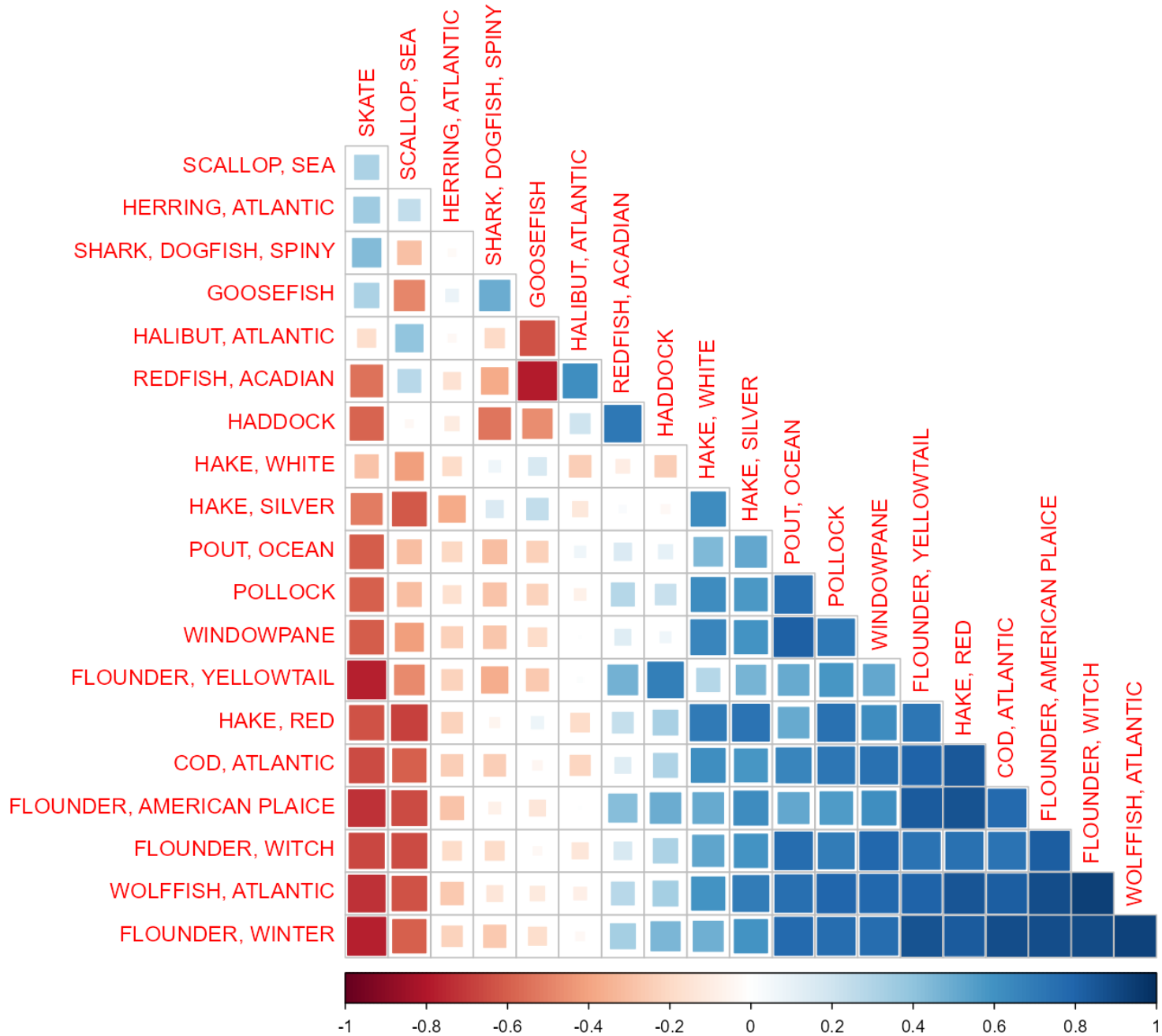


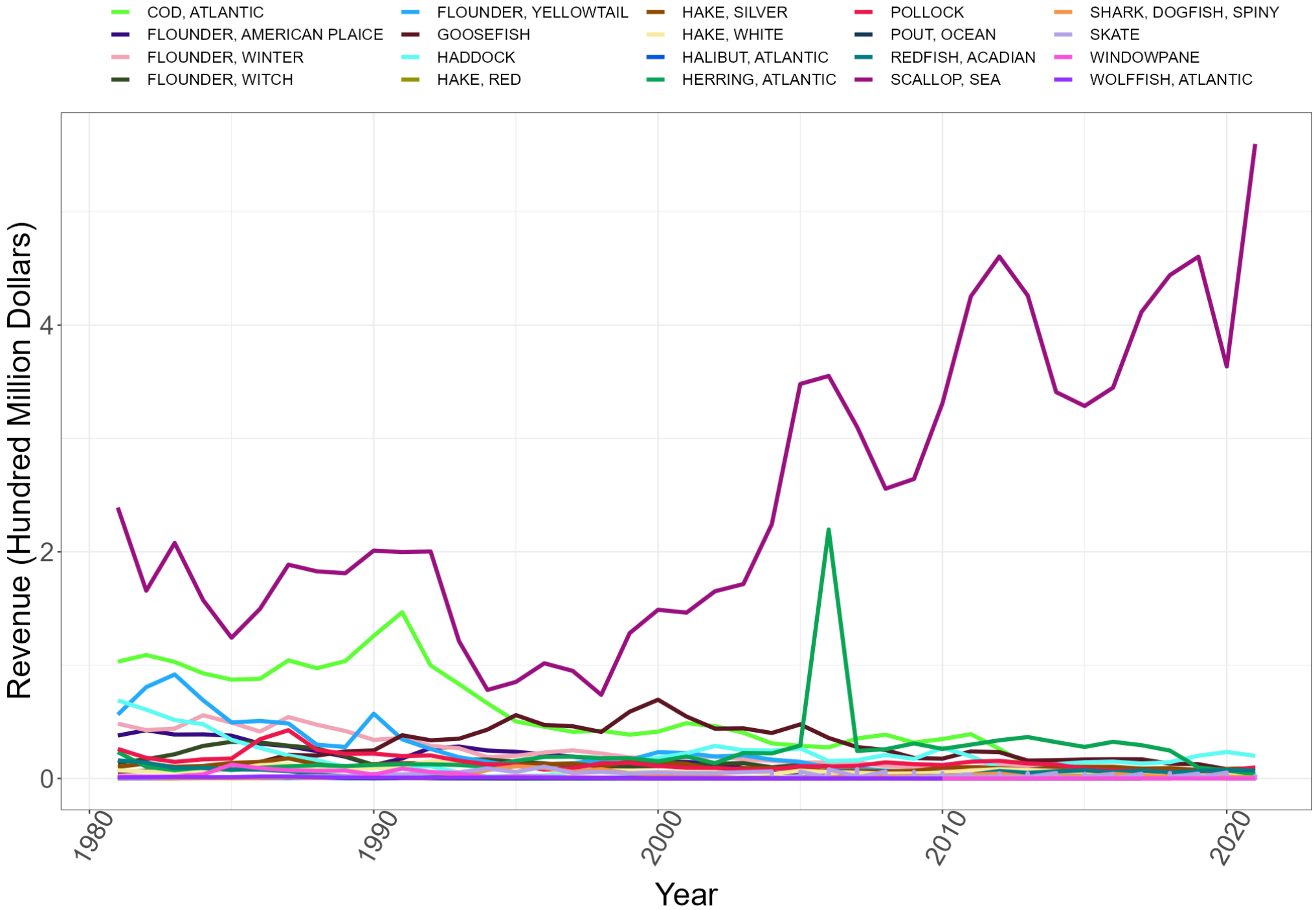
Data preparation prior to analyses

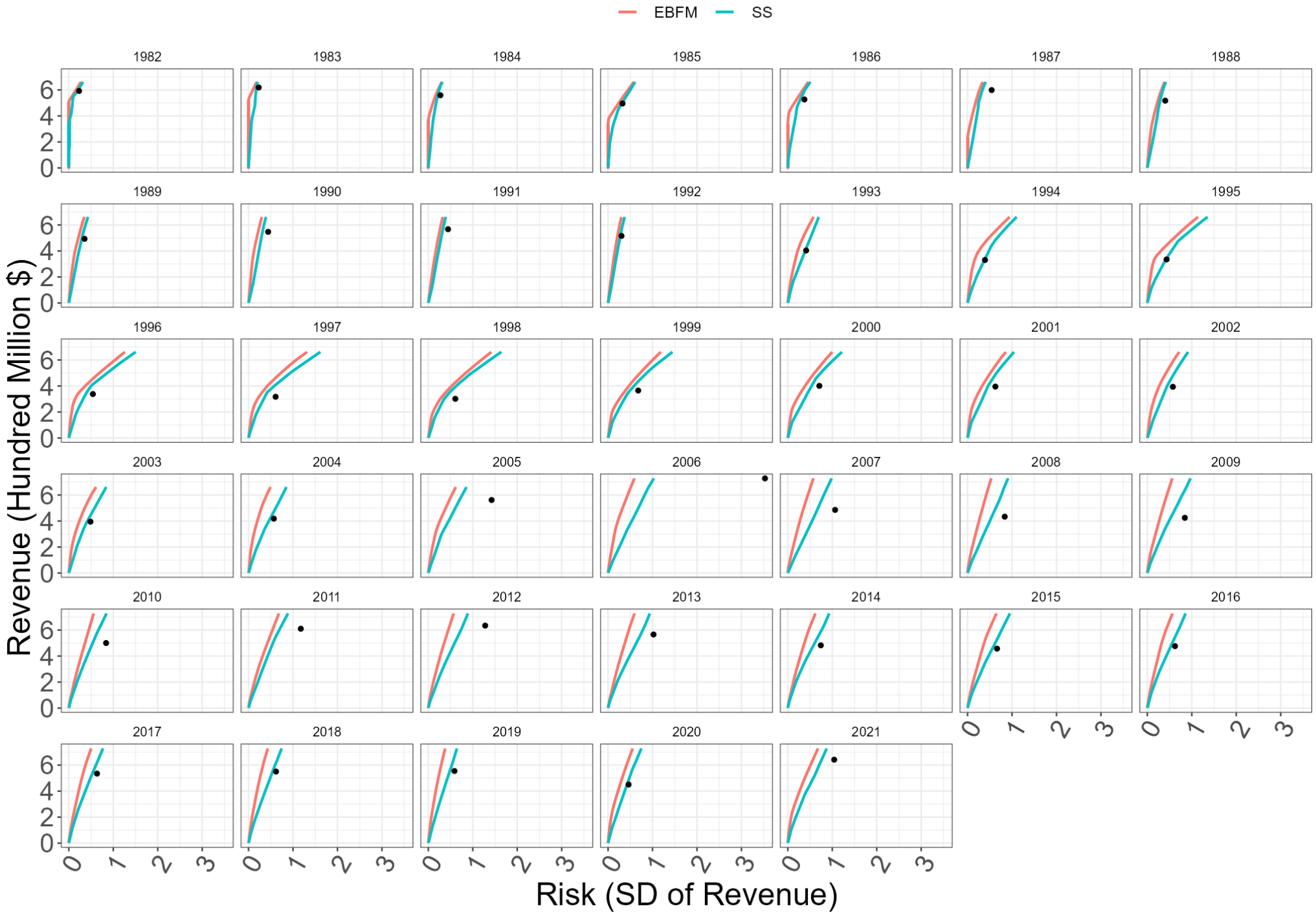
- Truncate to >1980 because of spiny dogfish
- Drop
  - Atlantic Salmon
  - Atlantic Deep-Sea Red Crab
  - Hake, Offshore

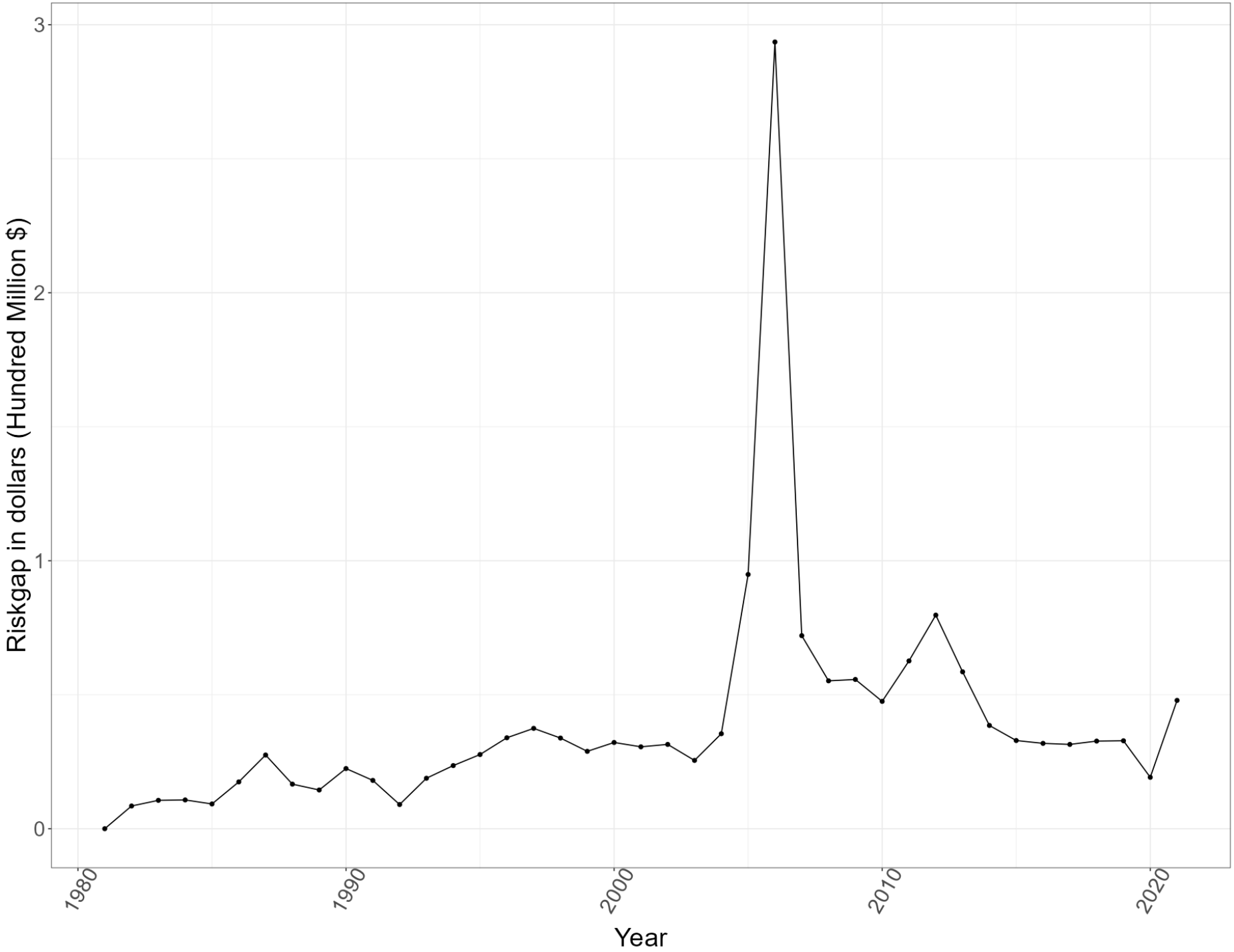
Portfolio by spp (except SKATES).

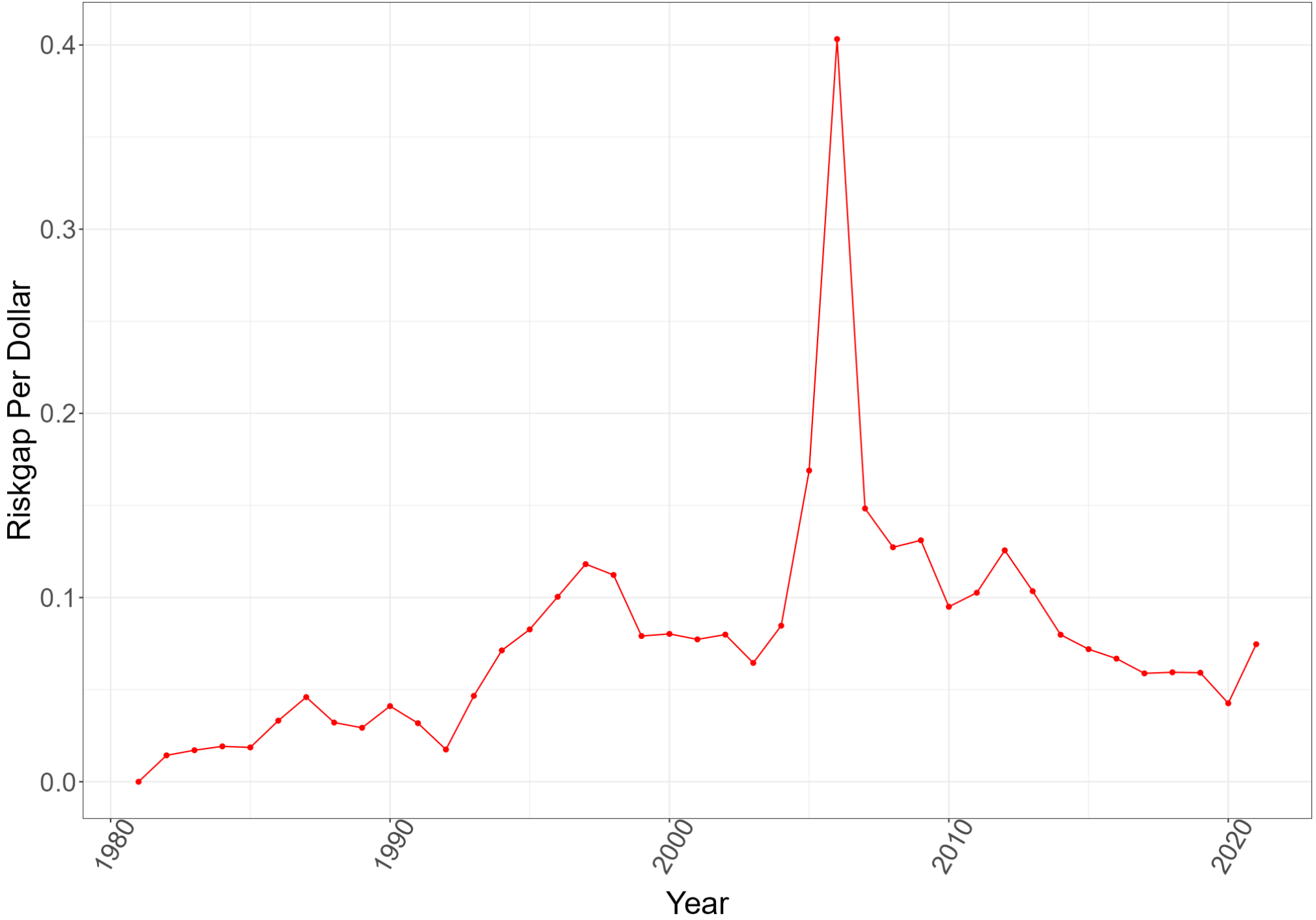


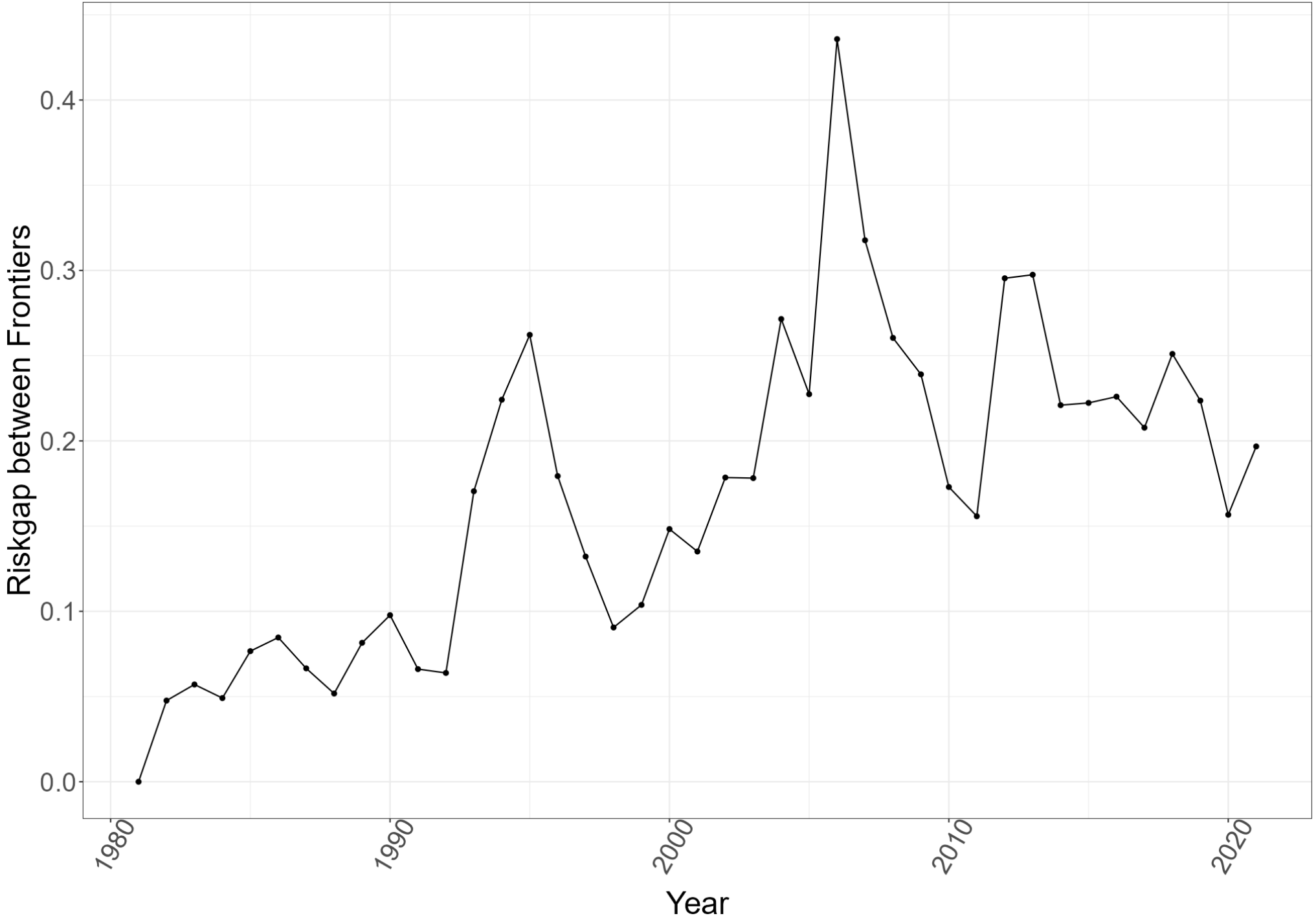

SKATE
SCALLOP, SEA
HERRING, ATLANTIC
SHARK, DOGFISH, SPINY
GOOSEFISH
HALIBUT, ATLANTIC
REDFISH, ACADIAN
HADDOCK
HAKE, WHITE
HAKE, SILVER
POUT, OCEAN
POLLOCK
WINDOWPANE
FLOUNDER, YELLOWTAIL
HAKE, RED
COD, ATLANTIC
FLOUNDER, AMERICAN PLAICE
FLOUNDER, WITCH
WOLFFISH, ATLANTIC
FLOUNDER, WINTER
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

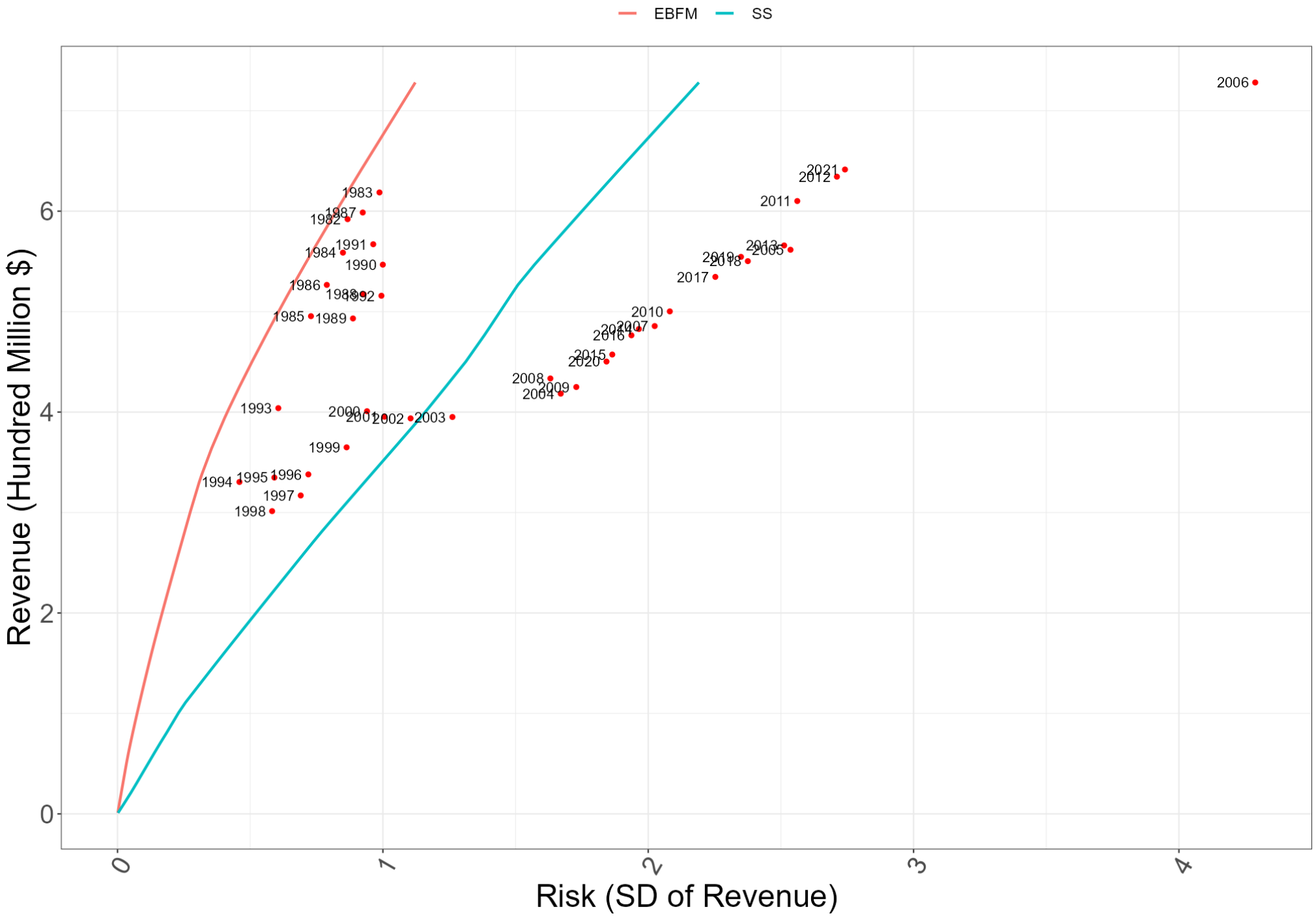

COD, ATLANTIC
FLOUNDER, AMERICAN PLAICE
FLOUNDER, WINTER
FLOUNDER, WITCH
FLOUNDER, YELLOWTAIL
GOOSEFISH
HADDOCK
HAKE, RED
HAKE, SILVER
HAKE, WHITE
HALIBUT, ATLANTIC
HERRING, ATLANTIC
POLLOCK
POUT, OCEAN
REDFISH, ACADIAN
SCALLOP, SEA
SHARK, DOGFISH, SPINY
SKATE
WINDOWPANE
WOLFFISH, ATLANTIC
Revenue (Hundred Million Dollars)
0
2
4
1980
1990
2000
2010
2020
Year


EBFM
SS
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Revenue (Hundred Million $)
Risk (SD of Revenue)


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

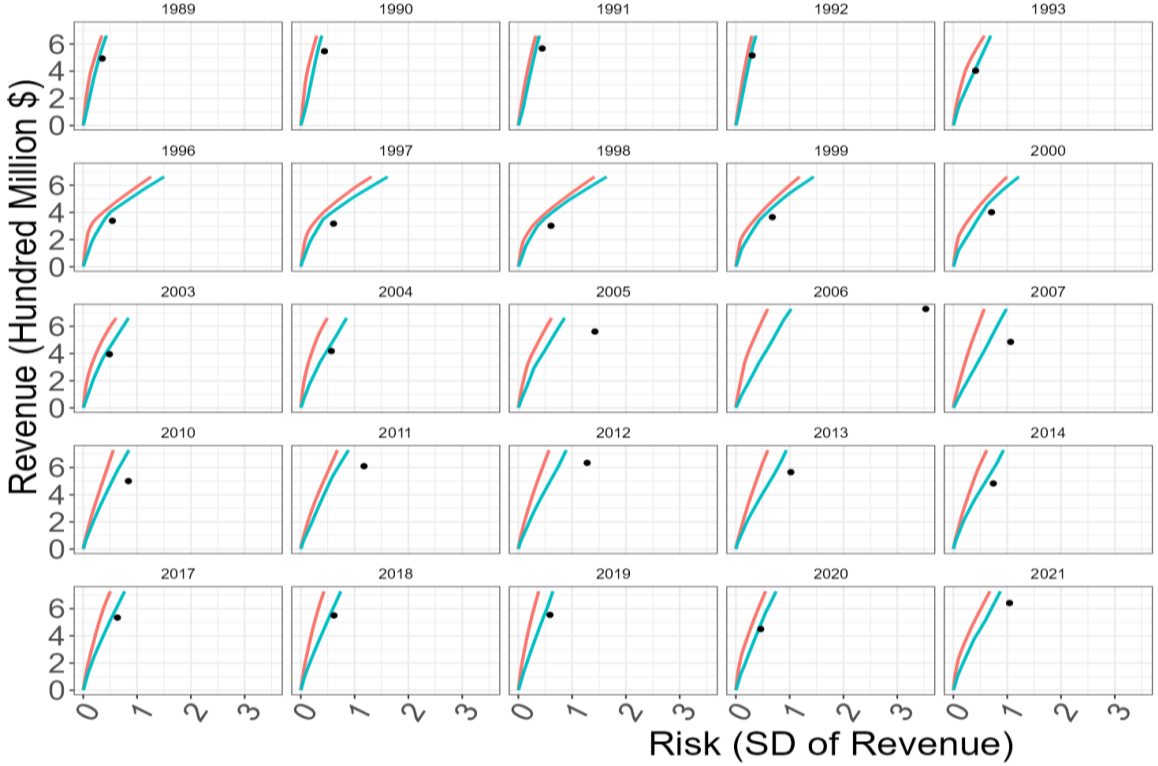

0.4
0.3
0.2
0.1
0.0
Riskgap Per Dollar
1980
1990
2000
2010
2020
Year

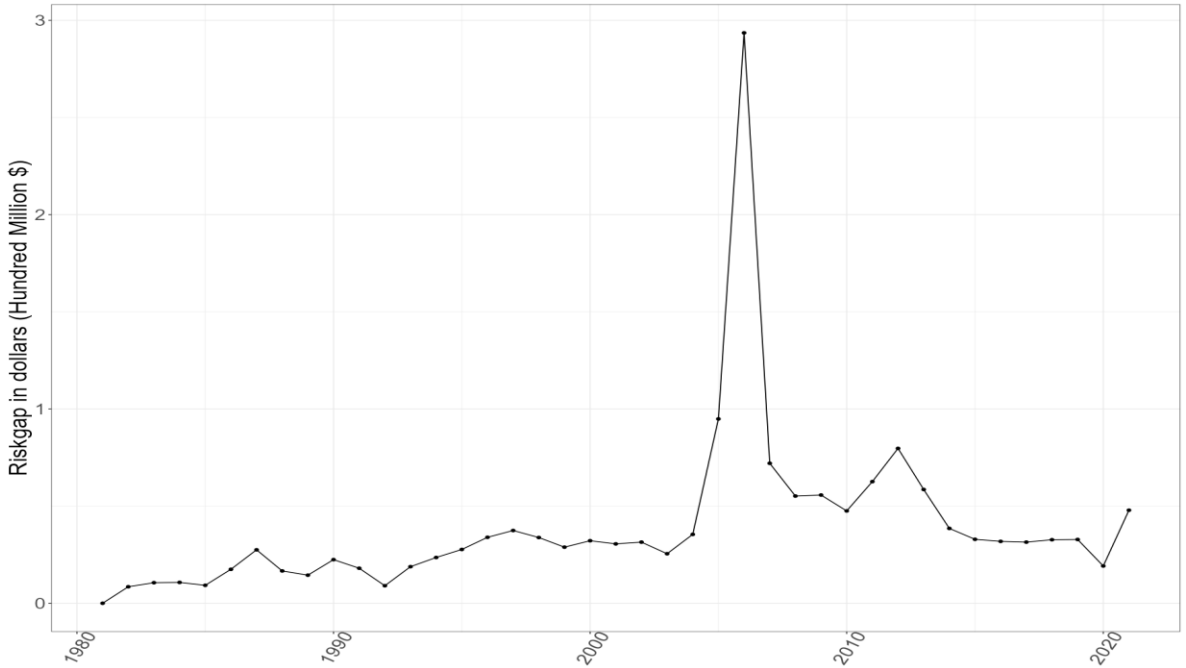

Riskgap between Frontiers
0.0
0.1
0.2
0.3
0.4
1980
1990
2000
2010
2020
Year


EBFM
SS
Revenue (Hundred Million $)
Risk (SD of Revenue)
0
2
4
6
0
1
2
3
4
2006
2021
2012
2011
1983
1987
1982
1991
1984
1990
1986
1992
1985
1989
2013
2005
2019
2018
2017
2010
2007
2016
2015
2020
2008
2009
2004
1993
2000
2001
2002
2003
1999
1994
1995
1996
1997
1998

Interpreting Risk Gaps

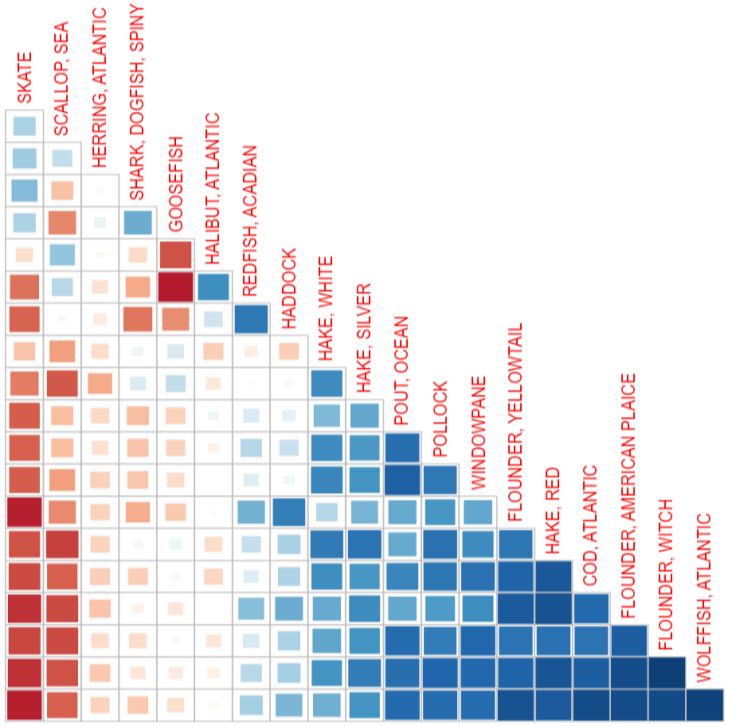
- Risk of foregone yield was greater than optimal multispecies yield.
- With more coordinated management,
  - risk could be reduced by more coordinated management, or
  - greater yield can be taken at the same risk
- The risk generally gap increased.
  - The peak in 2006 was primarily from a demand for herring bait.
  - With species-specific climate effects, we should expect different trends in productivity and even greater benefits from portfolio management

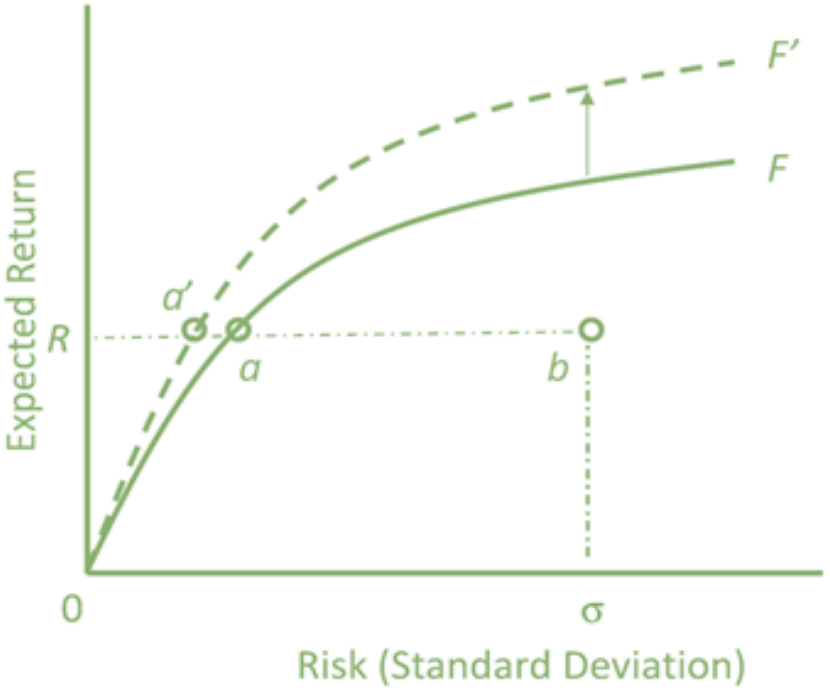




Conclusions

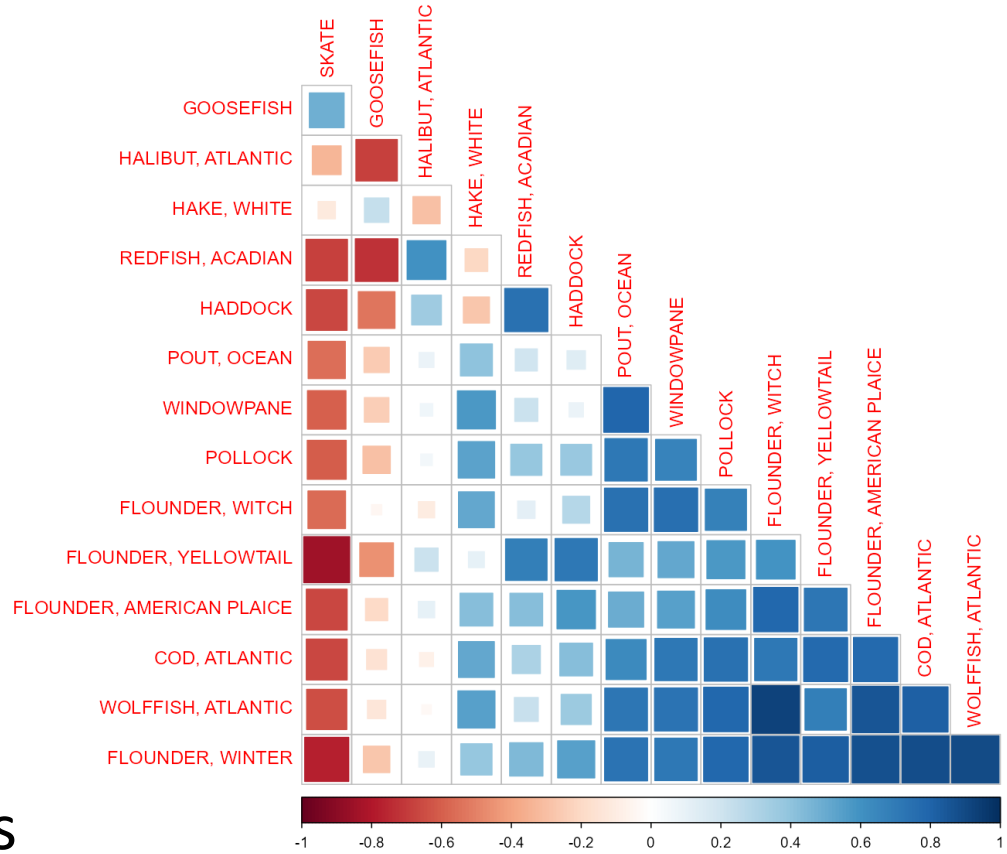
- Results suggest that portfolio diversity relies on coordinated management of groundfish and other species.
  - strong positive covariance in revenue among groundfish species
  - negative covariance with scallops, skates and monkfish
- Frontier analysis of the Council-managed species portfolio indicated that the same revenue could have been achieved with less risk of foregone yield.
- The results demonstrate that management systems benefit by allowing for flexibility to harvest abundant species by considering constraints of management strategies and tactics.

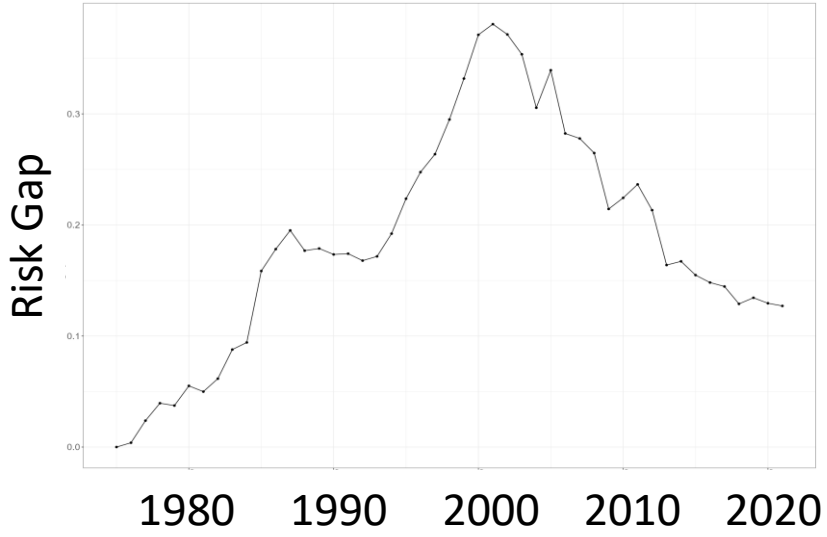




Alternative Portfolios

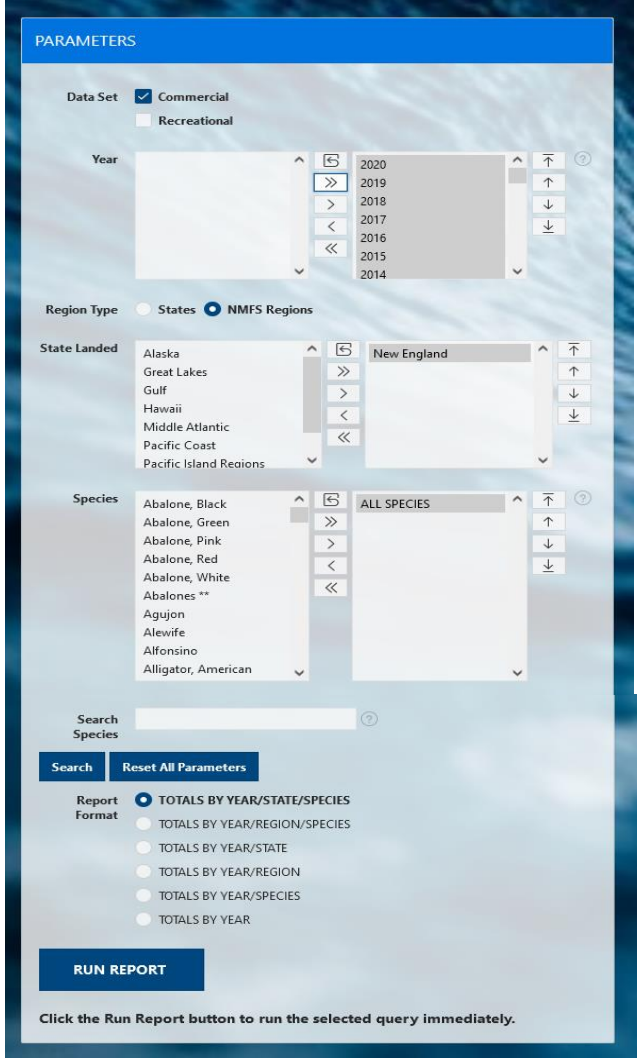
- The basis of portfolio management is interactions among species that produce asynchronous trends and negative covariance in annual landings or revenue:
  - technical (species caught by the same fishing gear),
  - ecological (predator-prey, competition),
  - market (product replacement), and
  - management (bycatch constraints).
- The Council could explore alternative multispecies portfolios for evaluation, e.g.:
  - expanded to include other important species that New England fishermen can target (e.g., American lobster, squids)
  - more restrictive portfolios (e.g., groundfish, monkfish, skates and dogfish).
  - Similar diversity in covariance should produce similar results.





Discussion – Data Challenges

- The demonstration used publicly available data that needed extensive data processing for frontier analysis.
  - Recoding inconsistent taxa labels (phased out species aggregations)
  - Years with no landings or revenue for some taxa
  - Some records masked for confidentiality
- Solutions:
  - Truncate the time series (1981 to characterize current fishery and historical productivity)
  - Re-aggregate taxa with substantial catch(skates)
  - Add ‘true zeros’ for no landings (ocean pout, wolffish)
  - Exclude taxa with little catch from the analysis (salmon, red crab, offshore hake)
  - Interpolate confidential data gaps (not needed for this portfolio)



- Replicating these analyses with confidential disaggregated data (e.g., dealer-logbook) would provide a more comprehensive series of landings and revenue, allow for more disaggregated taxa with more covariance for optimization, and support sub-regional analyses.

Discussion – Modeling, Next Steps & Thanks

- Convergence of frontier analysis is constrained by time decay factors, maximum annual catch per species, etc.
  - We're in the process of evaluating sensitivity of risk gaps to portfolio composition, time series, etc.
  - We welcome suggestions to improve optimizer tolerance and precision.
- Acknowledgments:
  - Funding from the Lenfest Ocean Program
  - Steering Committee: Howard Townsend, Geret DePiper, Lisa Kerr, Jeffrey Buckel, Douglas Lipton, John Walden, Chip Collier, Christopher Dumas, Scott Crosson, Michael Ruccio, and Rob Griffin.
  - Special thanks to Howard Townsend and Geret DePiper for help with frontier analyses.

LENFEST OCEAN PROGRAM