The Dream and the Reality: challenges with modeling marine mammals for the New England Fishery Management Council's herring MSE

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USGS science for a changing world

MSE Workshop, Providence RI

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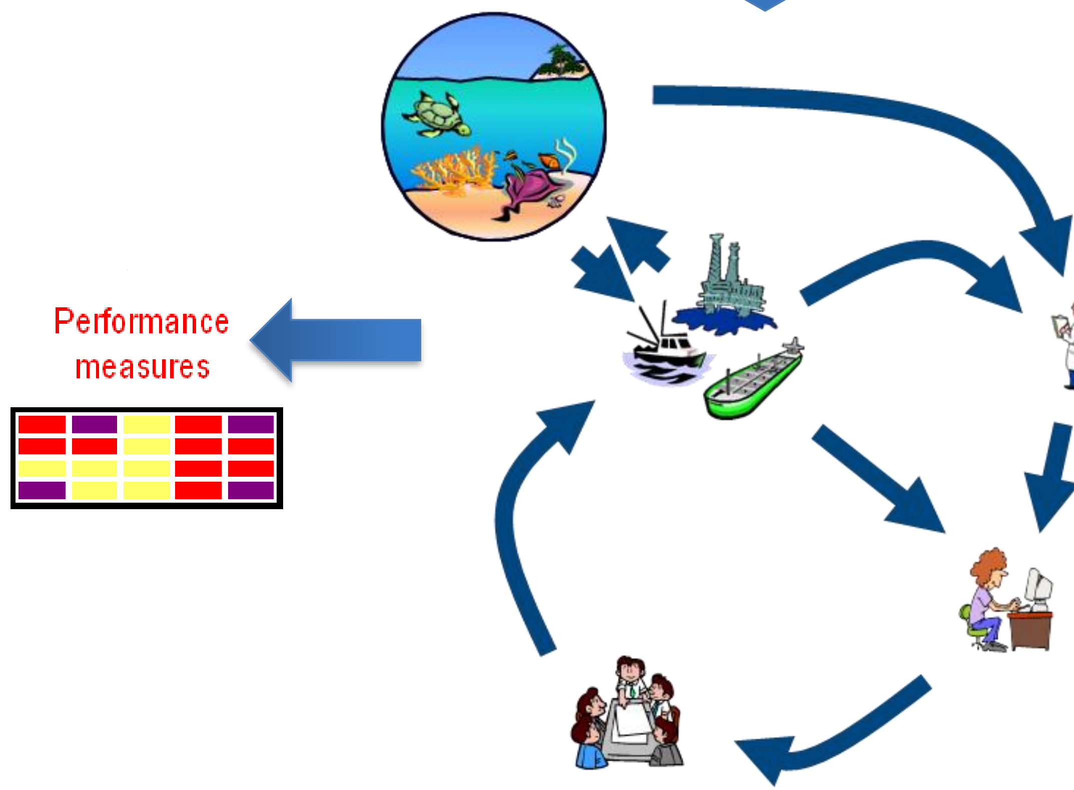
Management Strategy Evaluation: A *process* that includes an analysis

Council/stakeholder process
Specifies MSE objectives,
Performance measures,
Range of strategies

Scientists develop tools

Council Decision Support:

- **Tradeoffs** between objectives
- Potential management strategy **performance** considering
  - key interactions
  - risks
  - uncertainties



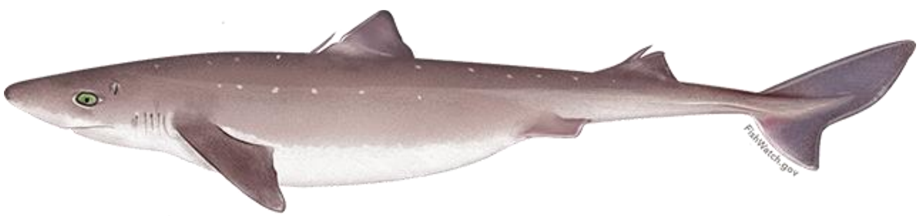
Fisheries management: NEFMC

Herring as Forage

20% of diet for some fish

In times and places, 50% of tuna and seabird diet

Marine mammal consumption ≈ fishery catches



Human Interest

Most catch goes to lobster fishery as bait

Tuna fishery

Whale watch cruises

Bird sanctuaries (USFWS)

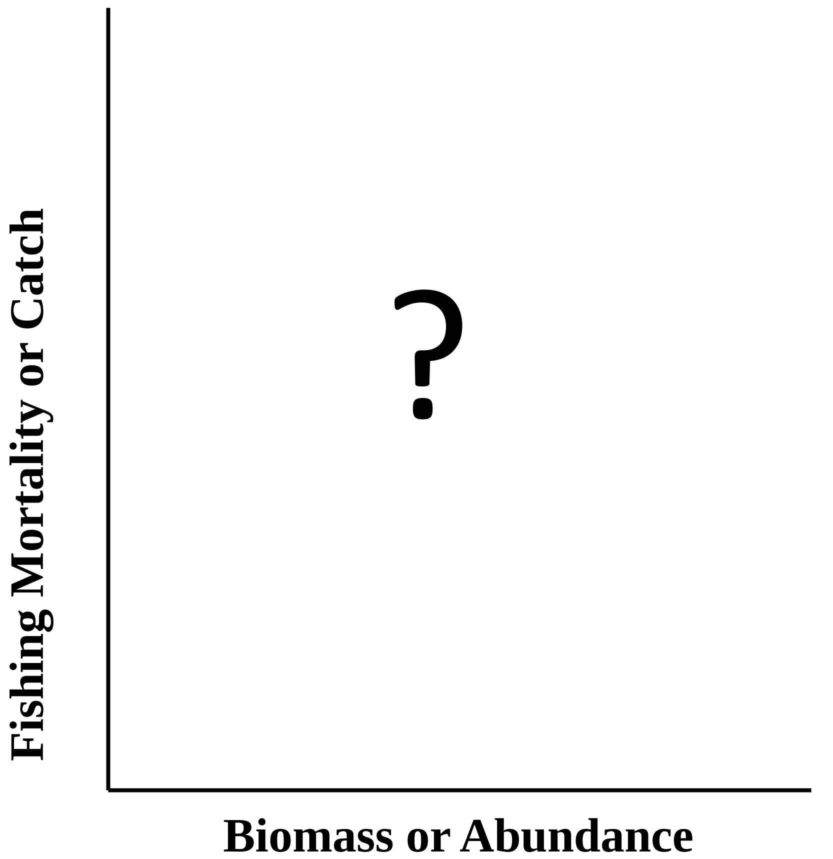
Groundfish fishery

ENGOs

How many herring are harvested is of great interest! – Subject of lawsuits

How Many Herring to Harvest?

Harvest Control Rules (the management strategy of interest):



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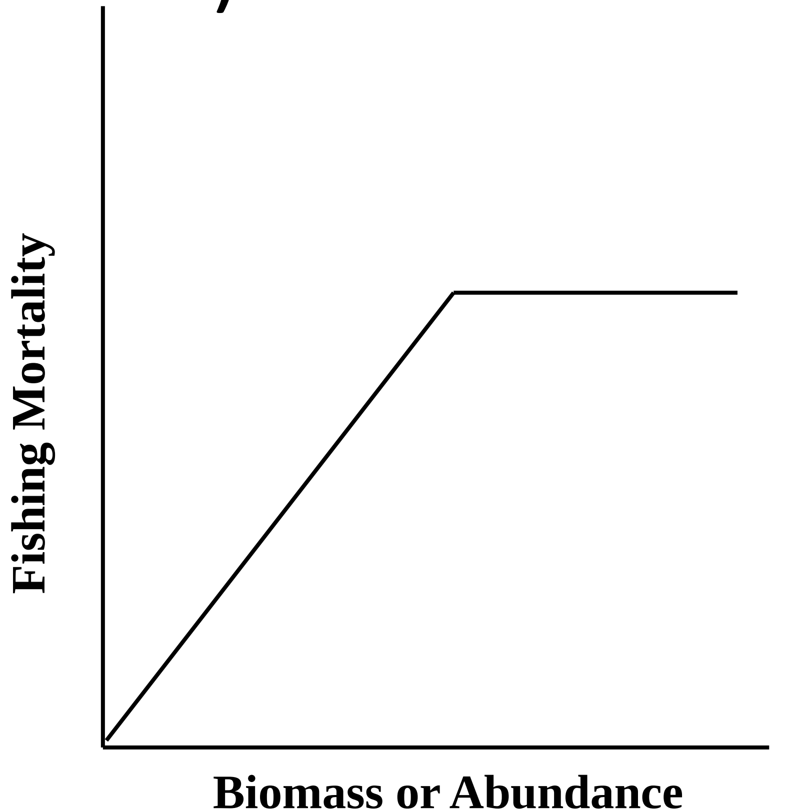


We tested thousands of shapes

Atlantic Herring MSE Process

2016

January – May
- Planning with Council
- Stakeholder Workshop 16-17 May

May - November
- Model develop ment
- Analysis
- Visualizat ion (I)
- Planning with Council

December
- Stakeholder Workshop 7-8 Dec.
- Analysis to Council

2017

January – March
- Reporting to Council
- Peer Review 13-15 March

March - September
- Narrow Options
- Visualization (II)
- Council Review

October - January
- Public Comment
- Council Decision

Stakeholder Workshop #1

Objectives & Metrics

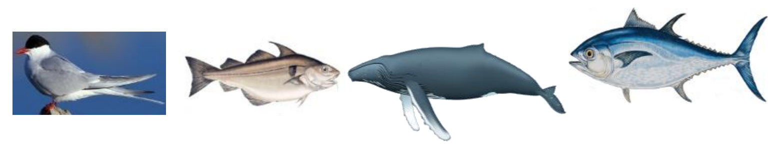
Objective		Performance Metric
Fundamental	**Means**	
• Maintain sufficient herring population for forage needs • Prevent overfishing of herring	• Ensure that catch limits allow sufficient herring for predators	• % years herring SSB > B_{MSY} • % years herring SSB < ½ B_{MSY} • % years herring SSB is 30-75% of B_0 • $B_{target} > B_{MSY}$ • Are predators at their ~B_{MSY} when not overfished? • Weight/length or fat content of predator groups (birds, tuna, whales, demersal fish) and herring • Degree of herring surplus production • Maintain B_{MSY} at 4x natural mortality
• Maximize yield for herring fleet • Maximize profit for herring fleet	• Achieve Maximum Sustainable Yield or Optimum Yield	• F relative to F_{ref} • Proportion of years ABC > the catch associated with F_{MSY} • Average annual catch • Minimum number of years fishery closes • Revenue or cost over time • Profit per ton or unit effort
• Ensure herring catch temporal stability	• Limit annual variation in quota	• Fluctuations in catch from one time step to the next
• Maintain a herring population with normal size/age structure	• Ensure appropriate fishing selectivity/ intensity	• Herring age structure • Common tern productivity of 0.8[a]
• Maintain predator abundance/ condition	• Ensure that catch limits allow sufficient herring for predators • Establish a forage set-aside	• Abundance or condition of some generic herring predators

Analytical Aspects

Multiple operating models represent uncertainty
Defined in Workshop #1

Herring N, B, Wt

Sarah



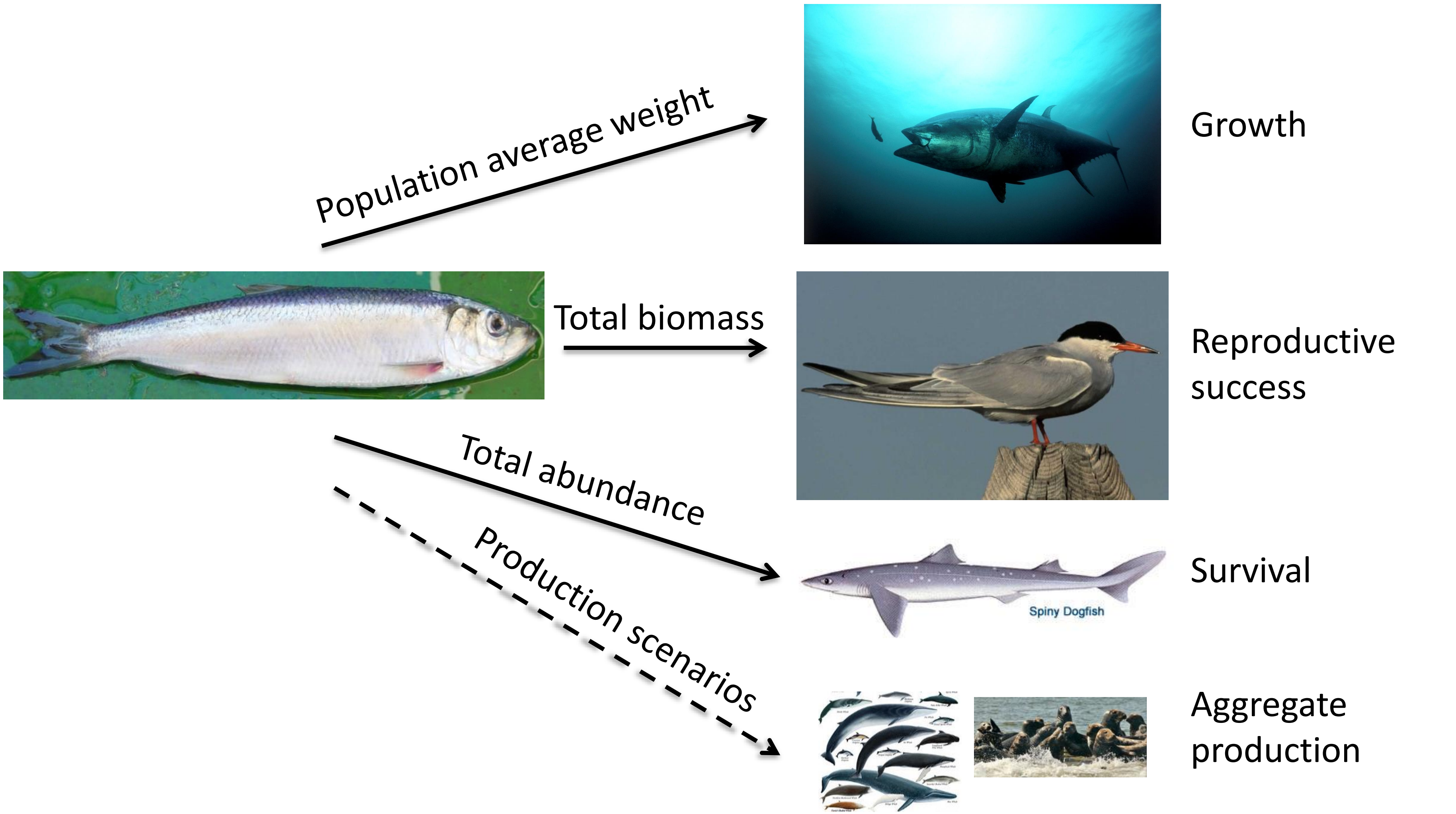
Herring Fishery Yield

Min-Yang

Herring recruitment (high or low?)
Herring natural mortality (high or low?)
Herring growth (good or poor?)
Herring assessment error/bias (yes or no?)

Evaluate ABC control rules for each OM

Herring control rules → predators?



Predator models

Are

- Focused on evaluating stock-wide herring ABC harvest control rules applied annually
- Developed balancing Council/ stakeholder specifications and time constraints of MSE
- Based on information from the Northeast US shelf and most recent stock assessments

Are not

- Spatial, do not address local scale or seasonal dynamics
- New or full stock assessments
- Accounting for any impacts on predators other than changes due to herring control rules
- Intended to predict actual predator population dynamics

Two components of predator modeling

Predator population model

- Delay-difference dynamics
- Information required:
  - Stock-recruitment relationship
  - Natural mortality rate
  - Fishing mortality rate
  - Initial population size
  - Weight at age
- Assessments or observations

Herring→predator relationship

- What about herring…
  - Total abundance? Biomass?
  - Certain ages or sizes?
- Affects what about the predator
  - Predator growth
  - Predator reproduction
  - Predator survival
- And how? Base on observations

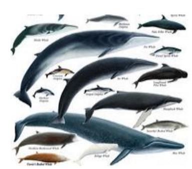
	Highly migratory	Seabird	Groundfish	Marine mammal
Stakeholder preferred species	Bluefin tuna	Common tern	Not specified	Not specified
Species modeled	Bluefin tuna (western Atlantic stock)	Common tern (Gulf of Maine colonies as defined by GOM Seabird Working Group)	Spiny dogfish (GOM and GB Atlantic cod stocks also examined)	None, data limited (Minke & humpback whales, harbor porpoise, harbor seal examined)
Stock-recruitment (or adults, recruits)	Porch and Lauretta 2016, ICCAT 2015	Derived from GOMSWG data	Rago and Sosebee 2010	No time series data for our region
Natural mortality	ICCAT 2015	Nisbet 2002	Rago and Sosebee 2013, 2015	Derivable from Waring et al. 2015?
Fishing mortality	ICCAT 2015	n/a	Rago 2016	Waring et al. 2015?
Initial population	ICCAT 2015	GOMSWG data	Rago 2016	Waring et al. 2015?
Weight at age	Restrepo et al. 2010	Nisbet 2002	Rago et al. 1998	General literature

Herring control rules → predators?

Similar growth response across all control rules (but differed with herring growth!)

Poorer reproductive success for three control rule types

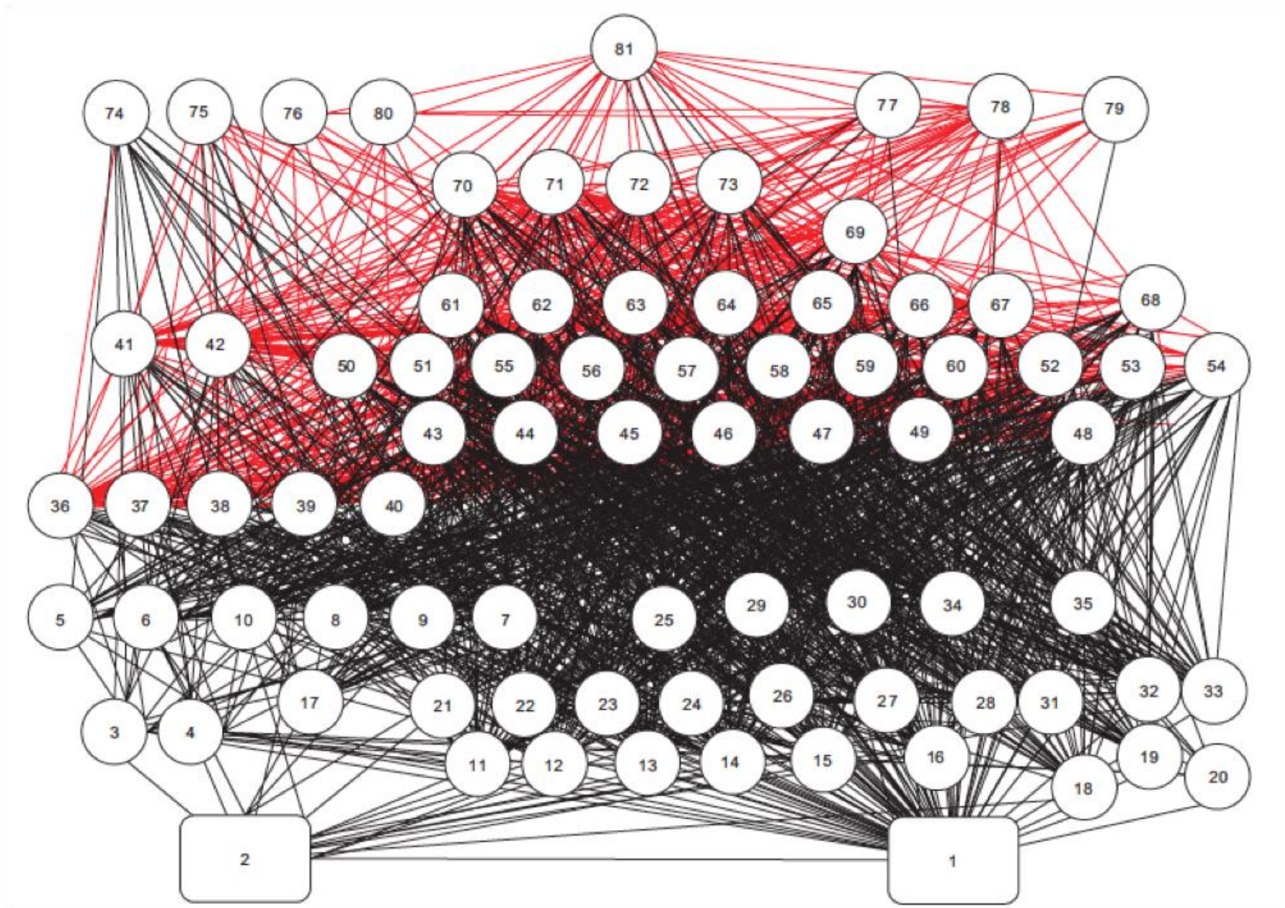
Poorer stock status for three control rule types



Unable to test specific control rules

Predator challenges

- Complex food web, generalist predators
- Single prey signals weak
- Potentially important feedbacks and interactions not addressed



Food web model simulations for marine mammals

Contextual information that could not be formally integrated in the MSE

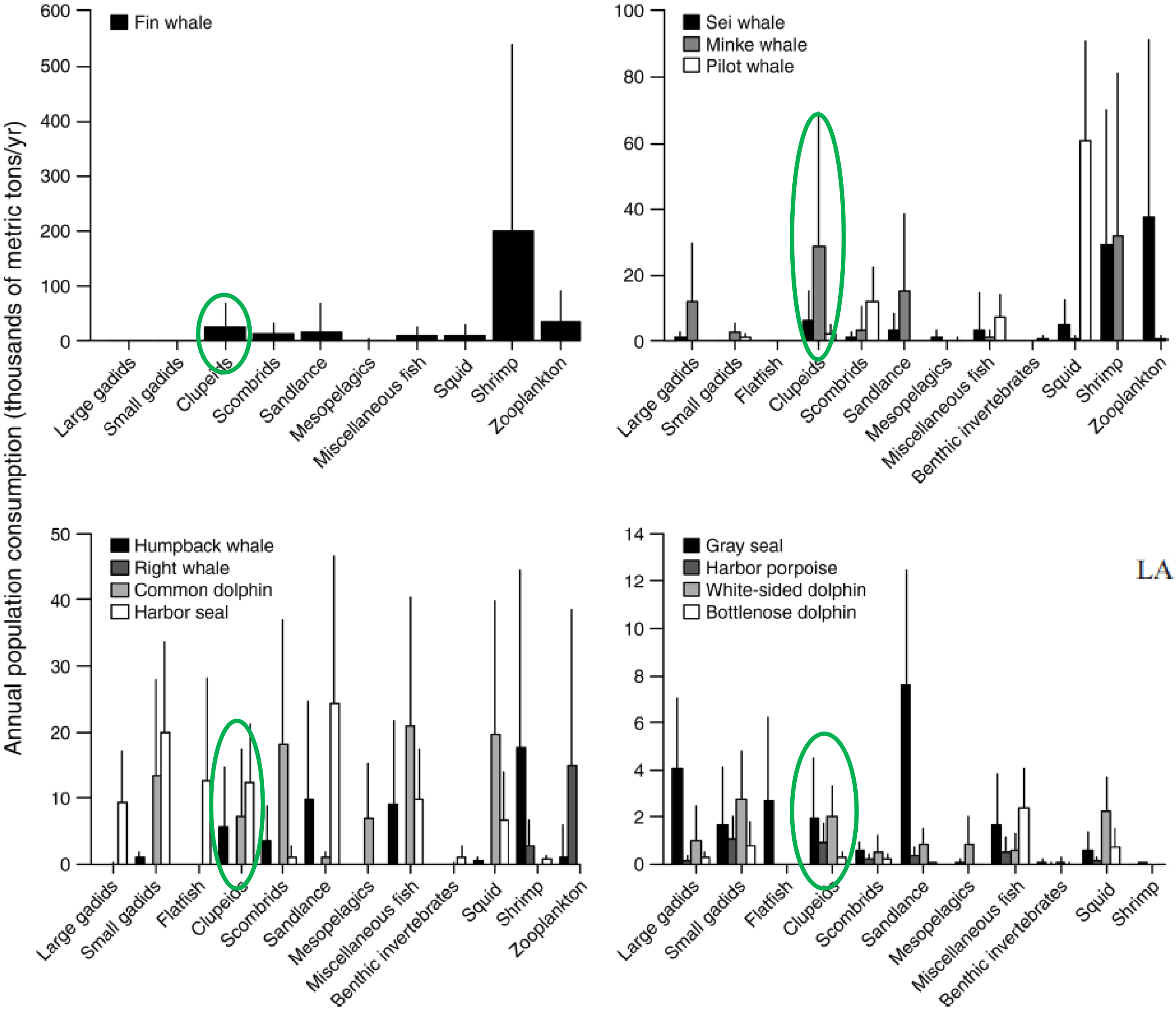
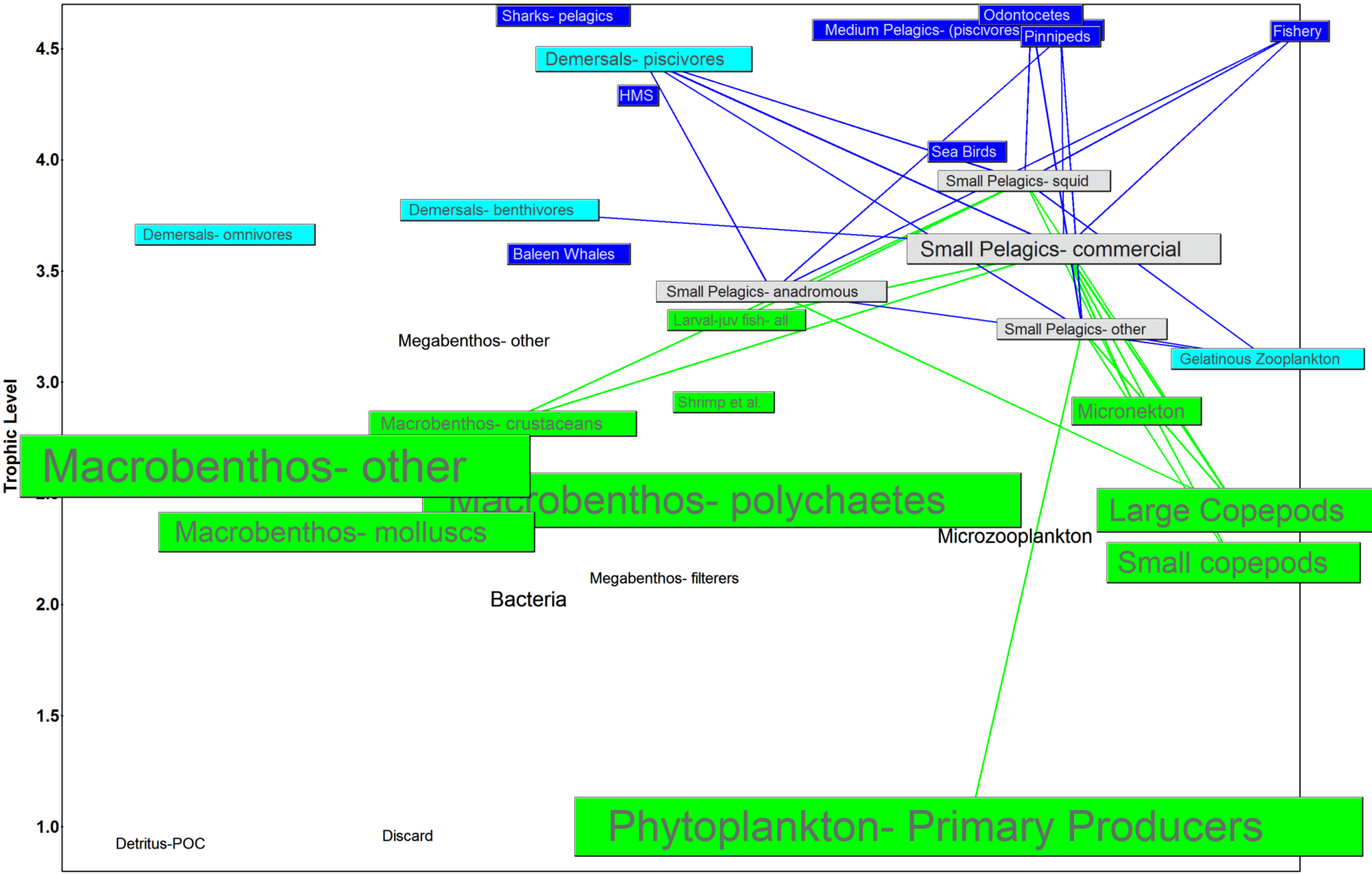


FIG. 4. Annual consumption of prey groups by marine mammal species on the Northeast U.S. continental shelf. Vertical bars represent the 80% CIs.


Trophic Level
4.5
4.0
3.5
3.0
2.0
1.5
1.0
Sharks- pelagics
Odontocetes
Medium Pelagics- (piscivores
Pinnipeds
Fishery
Demersals- piscivores
HMS
Sea Birds
Small Pelagics- squid
Demersals- benthivores
Demersals- omnivores
Baleen Whales
Small Pelagics- commercial
Small Pelagics- anadromous
Larval-juv fish- all
Small Pelagics- other
Megabenthos- other
Gelatinous Zooplankton
Shrimp et al.
Micronekton
Macrobenthos- crustaceans
Macrobenthos- other
Macrobenthos- polychaetes
Large Copepods
Microzooplankton
Macrobenthos- molluscs
Small copepods
Megabenthos- filterers
Bacteria
Phytoplankton- Primary Producers
Detritus-POC
Discard

Data uncertainty rating → distributions for parameters

Group	Biomass	Prod/Bio	Cons/Bio	Diet
Trans Kill	0.80	0.30	0.60	0.80
Sperm bk	0.80	0.60	0.60	0.80
Resident K	0.50	0.30	0.60	0.80
Porpoises	0.50	0.60	0.60	0.80
Gray Wha	0.50	0.60	0.60	0.80
Humpback	0.50	0.20	0.60	0.80
Fin Whale	0.50	0.60	0.60	0.80
Sei whales	0.80	0.60	0.60	0.80
Right whal	0.80	0.60	0.60	0.80
Minke wha	0.50	0.60	0.60	0.80
Sea Otters	0.50	0.60	0.60	0.80
N. Fur. Se	0.50	0.40	0.70	0.70
N. Fur. Se	0.50	0.40	0.80	0.70
Central S.S	0.10	0.40	0.70	0.60
Central S.S	0.10	0.40	0.80	0.60
West S.S.I	0.10	0.40	0.70	0.60
West S.S.I	0.10	0.40	0.80	0.60
Resident s	0.50	0.60	0.60	0.70
Shearwate	0.80	0.60	0.60	0.80
Murre	0.50	0.60	0.60	0.80
Kittiwake	0.50	0.60	0.60	0.80
Auklet	0.50	0.60	0.60	0.80
Puffin	0.50	0.60	0.60	0.80
Fulmar	0.50	0.60	0.60	0.80
Storm Pet	0.50	0.60	0.60	0.80
Cormoran	0.50	0.60	0.60	0.80
Gulls	0.50	0.60	0.60	0.80
Albatross	0.80	0.60	0.60	0.80
Sleeper Sh	0.50	0.70	0.70	0.60
Salmon Sh	0.50	0.70	0.70	0.80
Dogfish	0.80	0.70	0.70	0.80
W. Polloc	0.80	0.40	0.40	0.10
W. Polloc	0.10	0.40	0.40	0.10
P. Cod Ju	0.80	0.40	0.40	0.10
P. Cod Ad	0.10	0.30	0.30	0.10
Herring J	0.80	0.40	0.40	0.80
Herring A	0.50	0.60	0.60	0.70
Arrowtoot	0.50	0.40	0.40	0.10
Arrowtoot	0.10	0.30	0.30	0.10
P. Halibut	0.50	0.40	0.40	0.10
P. Halibut	0.10	0.30	0.30	0.10
YF. Sole	0.10	0.60	0.60	0.10
FH. Sole	0.80	0.40	0.40	0.10
FH. Sole	0.10	0.30	0.30	0.10

Group	Biomass	Prod/Bio	Cons/Bio	Diet
N. Rock s	0.50	0.60	0.60	0.10
S. Rock sc	0.50	0.60	0.60	0.10
AK Plaice	0.10	0.60	0.60	0.70
Dover Sol	0.50	0.60	0.60	0.30
Rex Sole	0.50	0.60	0.60	0.30
Misc. Flat	0.50	0.60	0.60	0.30
Bathyraja	0.10	0.70	0.70	0.80
Bathyraja	0.50	0.70	0.70	0.80
Bathyraja	0.50	0.70	0.70	0.80
Bathyraja	0.50	0.70	0.70	0.80
Bathyraja	0.10	0.70	0.70	0.80
Raja rhina	0.50	0.70	0.70	0.80
Raja binoc	0.50	0.70	0.70	0.80
Black Skat	0.10	0.70	0.70	0.80
Sablefish	0.80	0.60	0.60	0.60
Sablefish	0.50	0.50	0.80	0.60
Eelpouts	0.80	0.70	0.70	0.80
Giant Gre	0.50	0.70	0.70	0.30
Pacific Gr	0.10	0.70	0.70	0.70
Other Mac	0.50	0.70	0.70	0.70
Prickle sq	0.80	0.70	0.70	0.80
POP Juv	0.50	0.40	0.40	0.10
POP Adu	0.10	0.30	0.30	0.10
Sharpchin	0.80	0.60	0.60	0.30
Northern I	0.10	0.60	0.60	0.30
Dusky Roc	0.50	0.60	0.60	0.30
Shortraker	0.50	0.60	0.60	0.30
Rougheye	0.50	0.60	0.60	0.30
Shortspine	0.80	0.40	0.40	0.30
Shortspine	0.50	0.30	0.30	0.30
Other Seb	0.80	0.60	0.60	0.70
Atka Juv	0.80	0.60	0.60	0.80
Atka Adu	0.50	0.50	0.80	0.70
Greenling	0.10	0.70	0.70	0.70
Bigmouth	0.10	0.70	0.70	0.70
Other scul	0.80	0.70	0.70	0.70
Pricklies S	0.80	0.70	0.70	0.70
Octopi	0.80	0.70	0.70	0.80
Squids	0.80	0.70	0.70	0.80
Salmon re	0.80	0.50	0.80	0.70
Salmon ou	0.80	0.60	0.60	0.80
Bathylagid	0.80	0.70	0.70	0.80
Myctophid	0.80	0.70	0.70	0.80
Capelin	0.80	0.70	0.70	0.80

Group	Biomass	Prod/Bio	Cons/Bio	Diet
Sandlance	0.80	0.70	0.70	0.80
Eulachon	0.80	0.70	0.70	0.80
Managed F	0.80	0.70	0.70	0.80
Oth pel. sr	0.80	0.70	0.70	0.80
Bairdi	0.80	0.60	0.80	0.80
King Crab	0.50	0.60	0.80	0.80
Opilio	0.10	0.60	0.80	0.80
Pandalidae	0.80	0.50	0.80	0.80
NP shrimp	0.80	0.60	0.60	0.80
Sea Star	0.50	0.60	0.70	0.80
Brittle Sta	0.50	0.60	0.70	0.80
Urchins do	0.50	0.60	0.70	0.80
Snail	0.80	0.60	0.70	0.80
Hermit cra	0.80	0.60	0.70	0.80
Misc crab	0.80	0.60	0.70	0.80
Misc. Cru	0.80	0.60	0.70	0.80
Benth. Am	0.80	0.60	0.70	0.80
Anemones	0.50	0.60	0.70	0.80
Corals	0.10	0.60	0.70	0.80
Benth. Hy	0.80	0.60	0.70	0.80
Benth. Urc	0.50	0.60	0.70	0.80
Sea Pens	0.10	0.60	0.70	0.80
Sponge	0.50	0.60	0.70	0.80
Clam	0.80	0.60	0.70	0.80
Polychaet	0.80	0.60	0.70	0.80
Misc. Wo	0.80	0.60	0.70	0.80
Scypho Je	0.50	0.60	0.60	0.80
Fish Larva	0.80	0.70	0.70	0.80
Chaeteg et	0.80	0.70	0.70	0.80
Euphausiid	0.80	0.60	0.60	0.80
Mysid	0.80	0.70	0.70	0.80
Pel Amph	0.80	0.60	0.60	0.80
Pel. Gel. F	0.80	0.70	0.70	0.80
Pteropod	0.80	0.70	0.70	0.80
Copepod	0.80	0.70	0.60	0.80
Microzoo	0.80	0.70	0.70	0.80
BenthicBa	0.80	0.70	0.70	0.10
Algae	0.80	0.70	0.70	0.00
Lg Phytop	0.80	0.50	0.00	0.00
Sm Phytop	0.80	0.50	0.00	0.00
Outside P	0.80	0.70	0.00	0.00

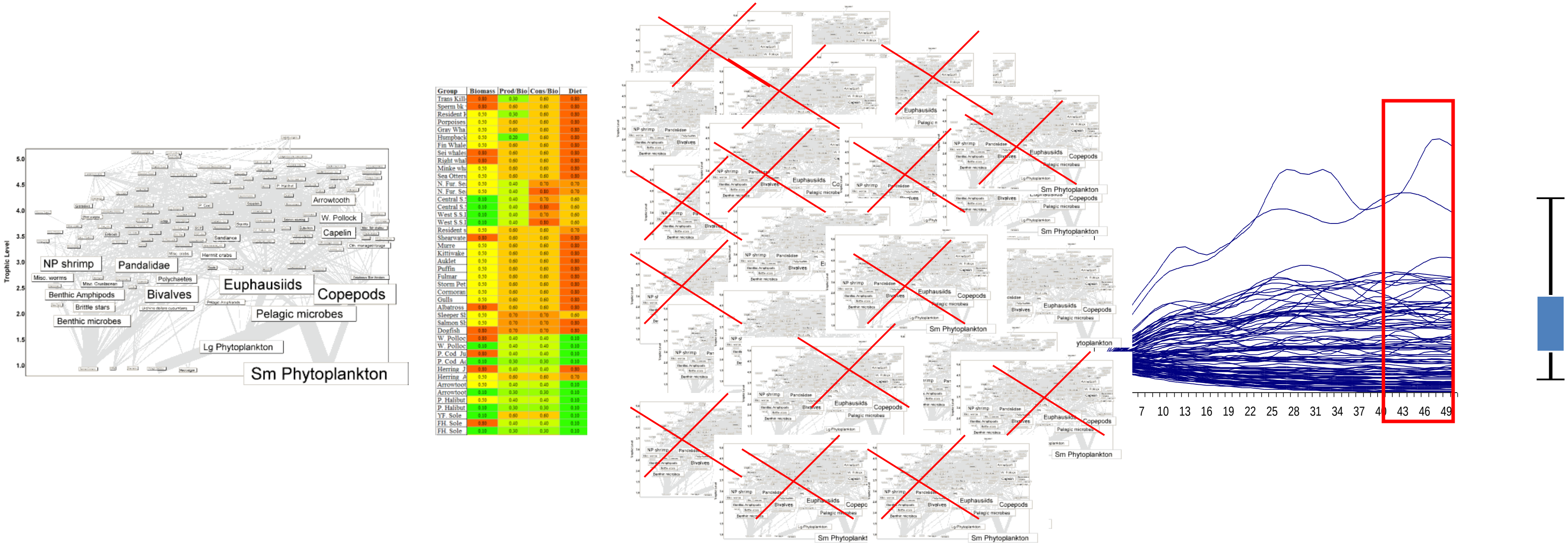
Good

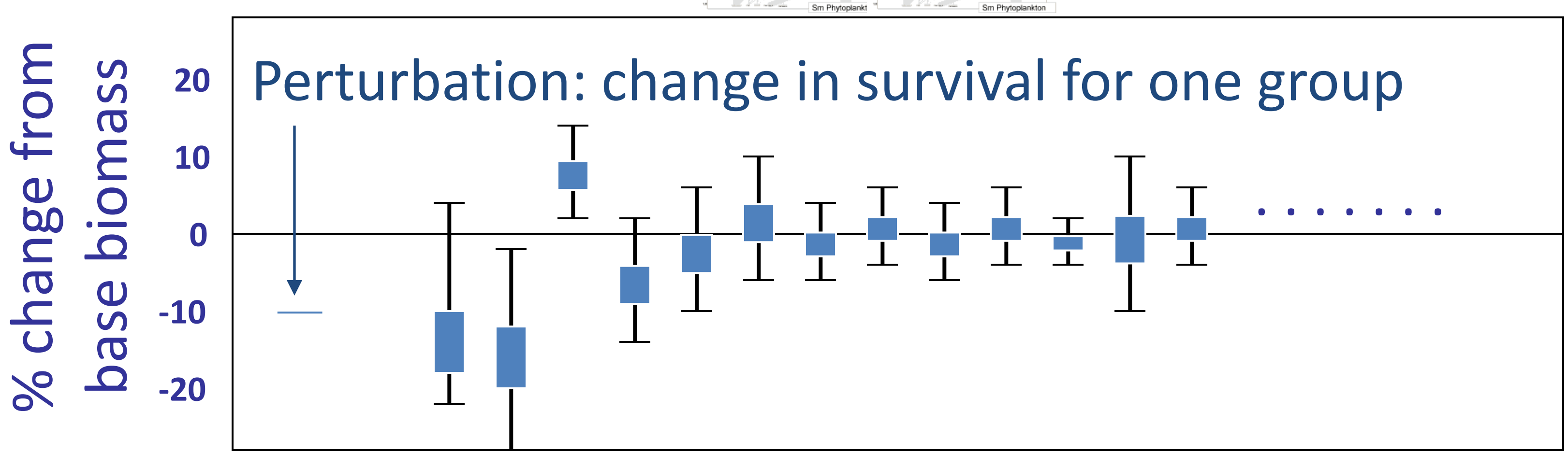
OK

Bad

Ugly

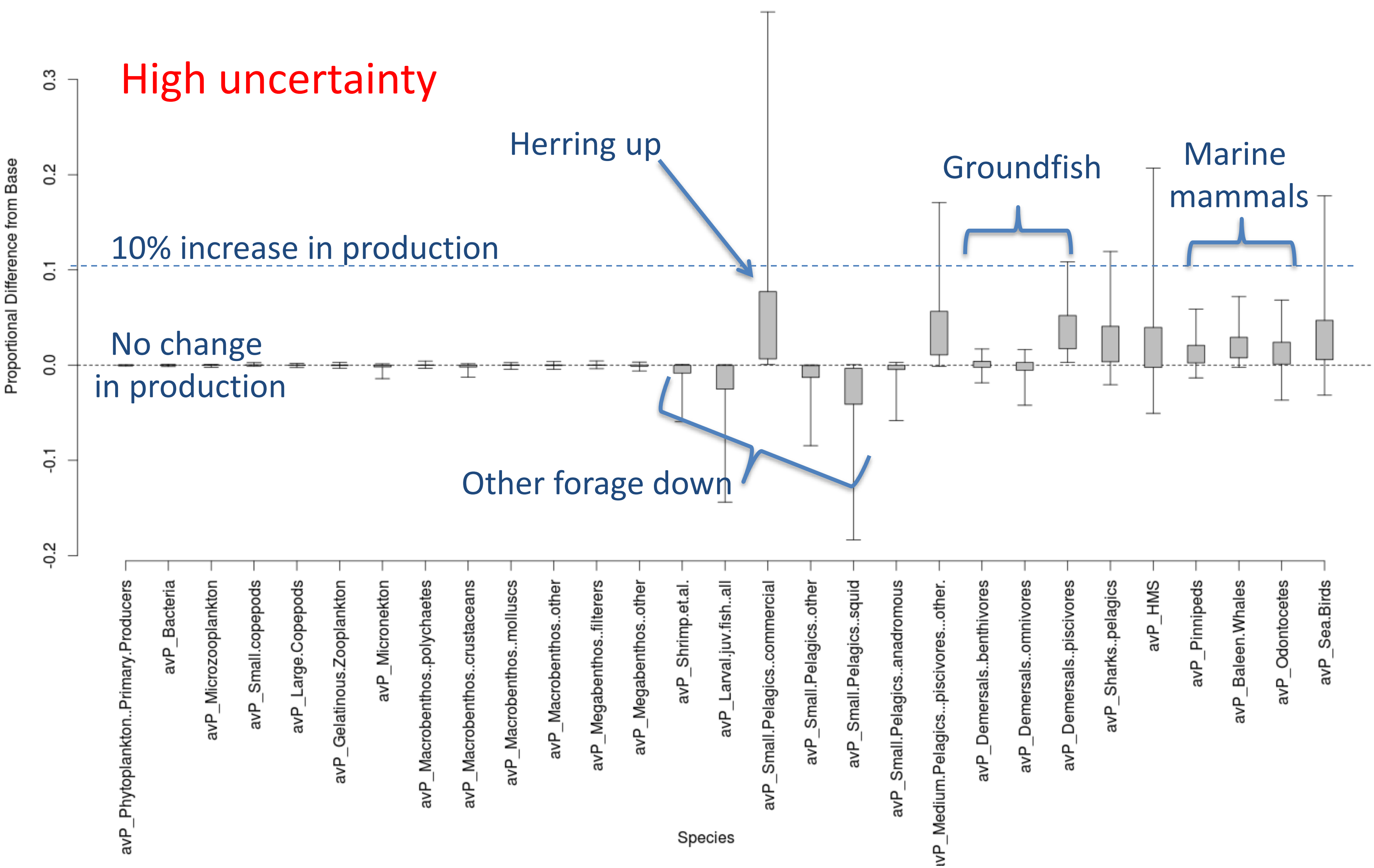
Incorporating uncertainty



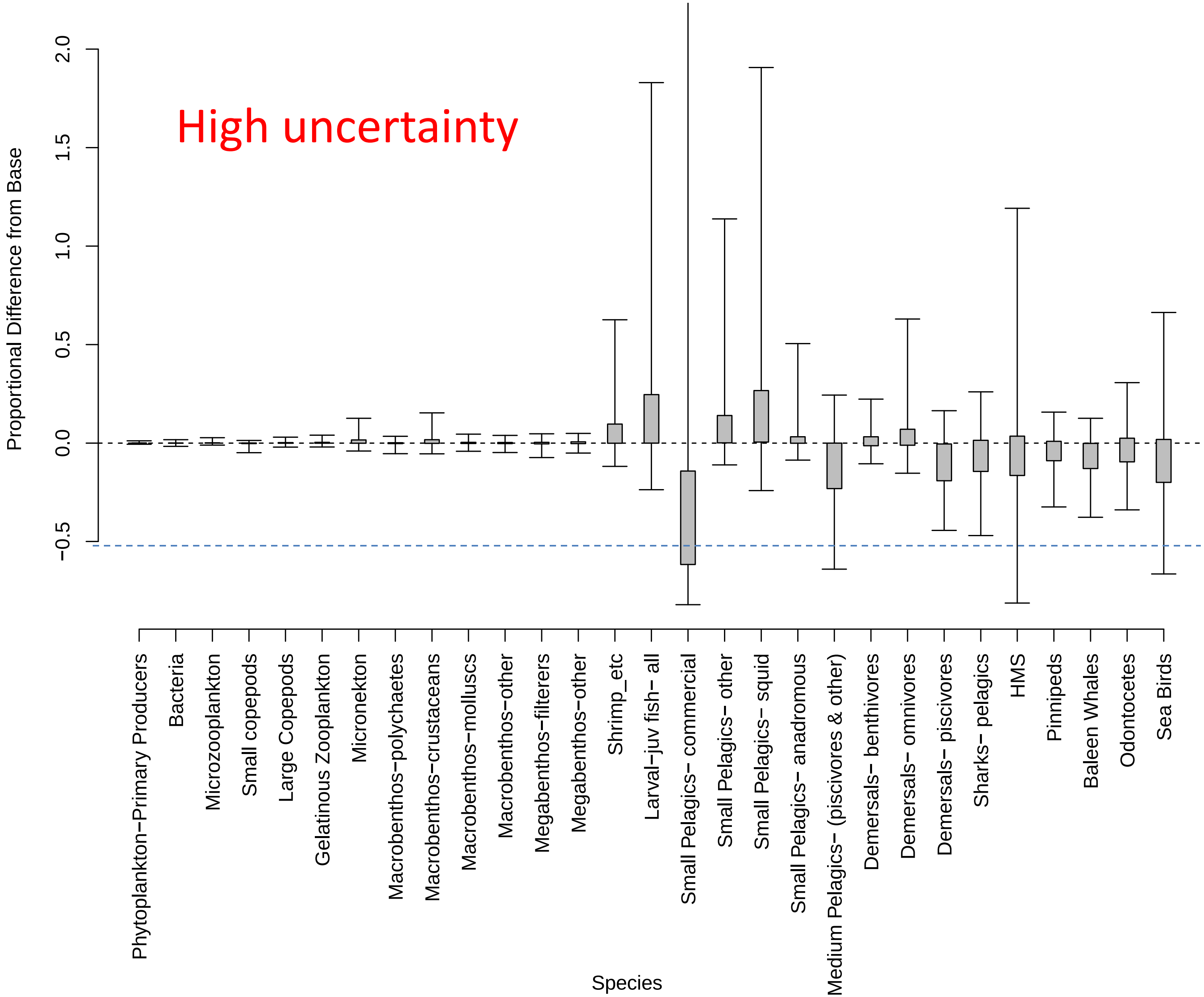


Effects on each group in the food web

Increase GOM herring survival 10%

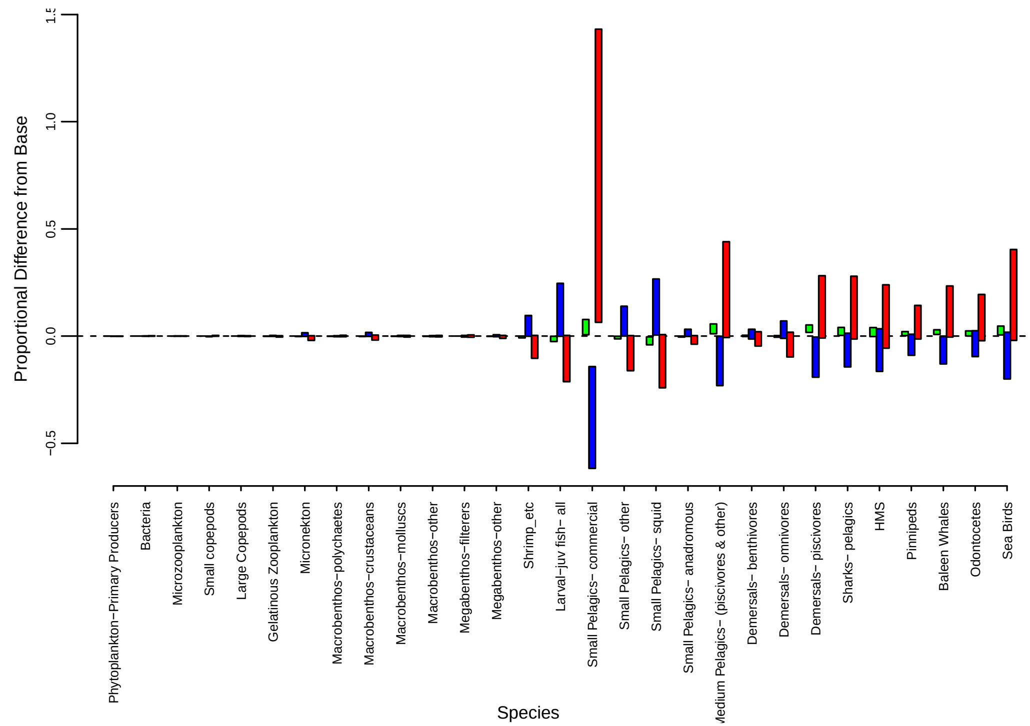


Decrease GOM herring biomass 50%



Food web modeling

- **Showed tradeoffs that single species analyses could not**
- Recent improvements allow closed loop simulation (Lucey et al)
- Need to improve protected species in these models
  - Abundance
  - Life history



Herring biomass increase 50%

Herring biomass decrease 50%

Herring production increase 10%

Given more time and money

New England Fishery Management Council

FOR IMMEDIATE RELEASE | **PRESS CONTACT: Janice Plante**
October 1, 2018 | (607) 592-4817, jplante@nefmc.org

Atlantic Herring: Council Approves Amendment 8 With New ABC Control Rule, Buffer Zone; Asks NMFS to Set 2019 Specs

- But how can we include marine mammals?
  - Needed **time series** here and in other applications