



NOAA
FISHERIES

NEFSC

Multispecies and Ecosystem Models

Sean Lucey, Kiersten Curti, Sarah Gaichas,
Robert Gamble and Michael Fogarty

NEFSC Ecosystem and Climate Science Program Review
Modeling and Analysis Session

June 7, 2016

A spectrum of tools, a spectrum of uses

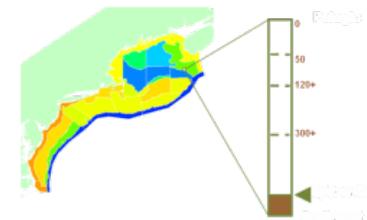
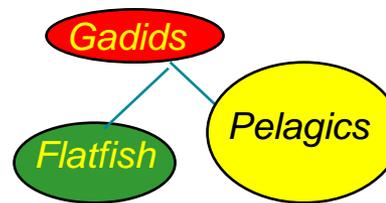
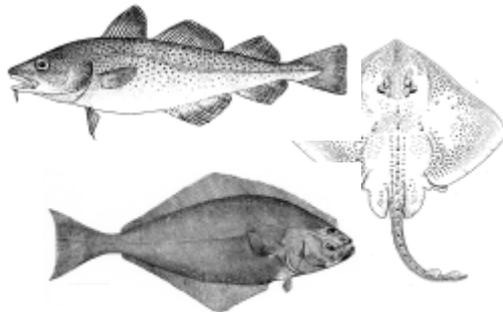


Stock/Single Species

Multi-species

Aggregate Biomass

Ecosystem



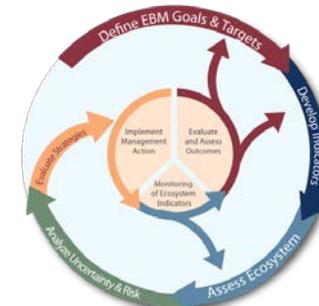
Single stock models

Multi-species assessments

Functional group models

Whole system models

Stock assessments with add-ons:
explicit M2 or habitat or climate considerations



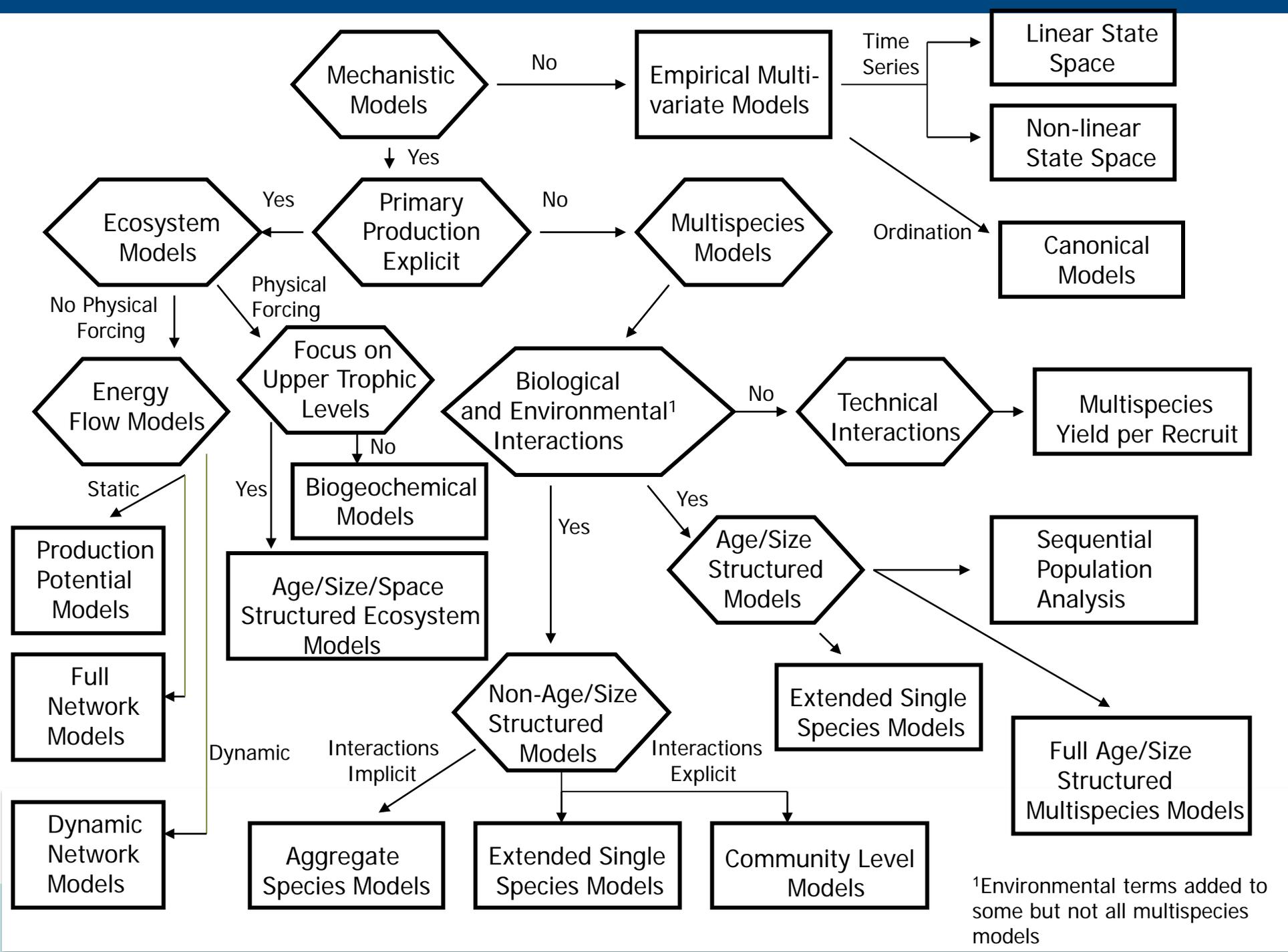
Multiple stock assessments integrated

Economic assessments, social impacts

Integrated ecosystem assessments

Modeling Approach Review

- Center for Independent Experts Review (2011)
- Three main recommendations
 - Broader focus on direct impacts of fishing on non-target species/habitats
 - Further input from the economic and social sciences
 - Use models as operating models in Management Strategy Evaluation (MSE) to explore tradeoffs



Examples of Multispecies/Ecosystem Models

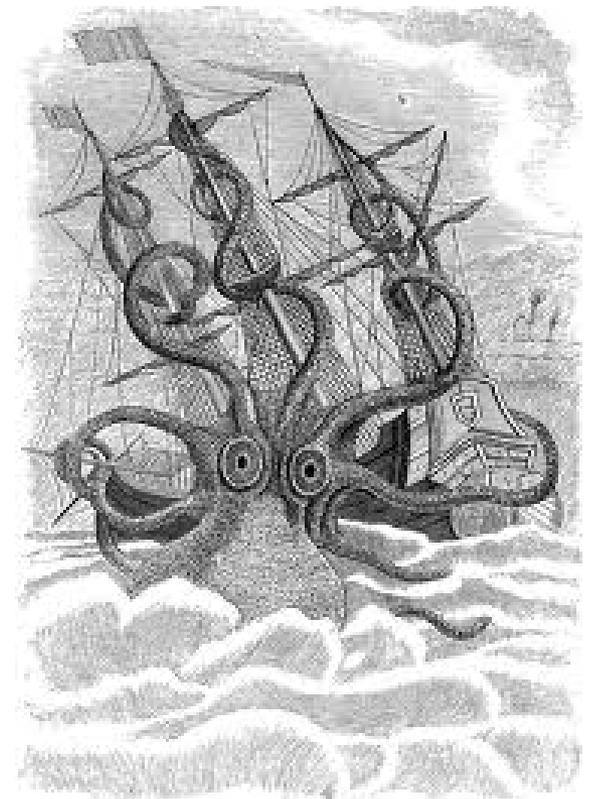
Model name	Reference	Development
MS-PROD	Gamble and Link 2009, Gaichas et al. 2012	Published
Kraken	Gamble et al. In Prep, based on Gamble and Link 2009	Ongoing, Performance testing initiated
MS Delay Difference	In prep	Ongoing, Performance testing initiated
MS Statistical Catch-at-age	Curti et al. 2013	Published
MSVPA-X	Tyrell et al. 2008, Garrison et al. 2010	Published
Qualitative Network Model	In prep	Ongoing
EMAX	Link et al. 2006, 2007, 2008, 2009	Published
Rpath	Lucey et al. In Prep	Ongoing, Parameterizing GB
Hydra	Gaichas et al In Review, based on Hall et al. 2006	Ongoing
Atlantis	Link et al. 2010, 2011	V1.0 published, v1.5 in development

Kraken

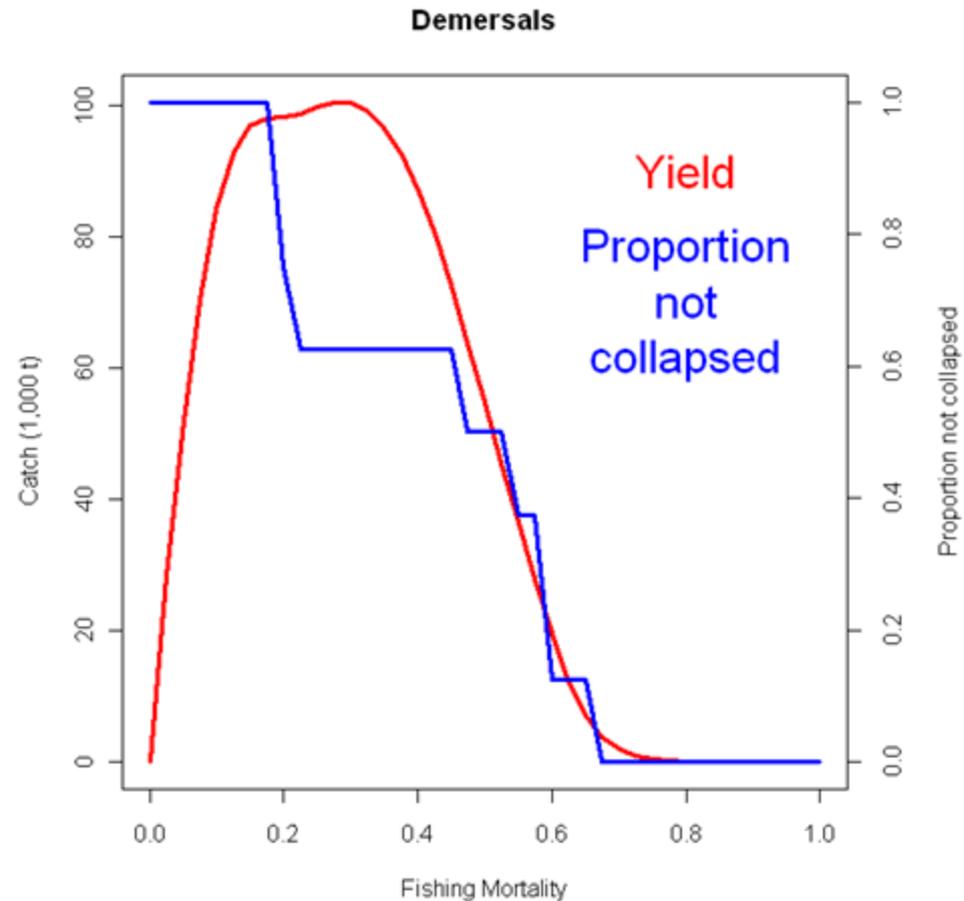
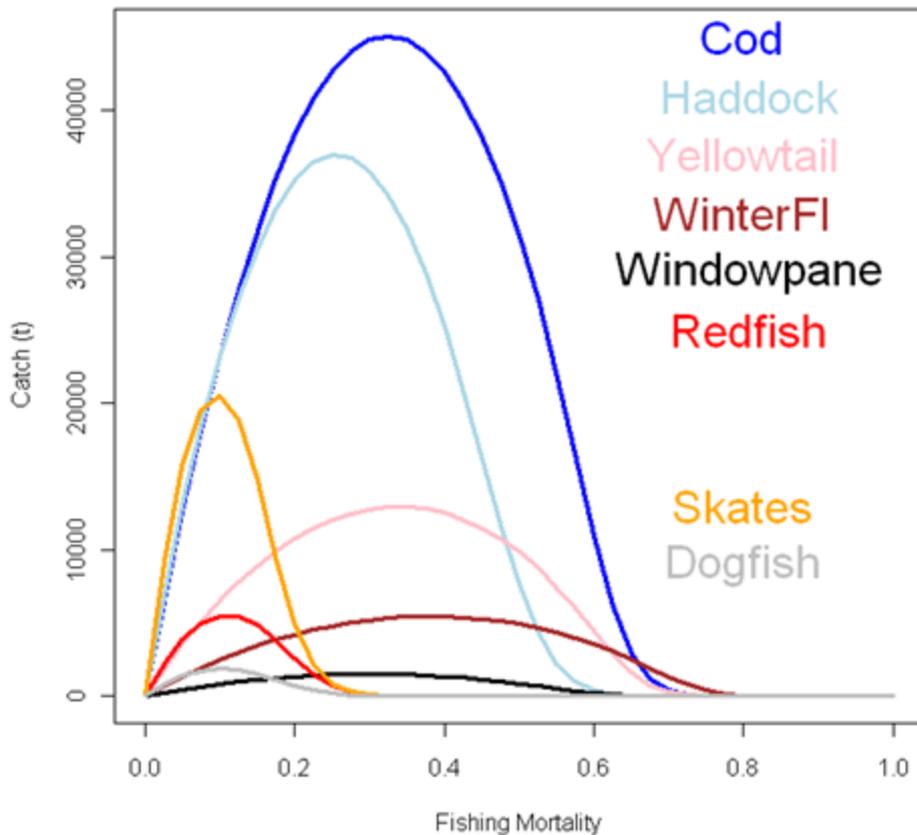
(MS Surplus Production Modeling Framework)

Features

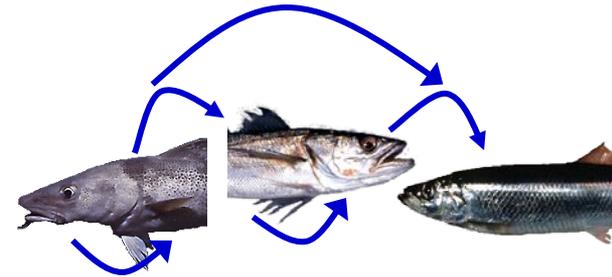
- Flexible framework for creating production models
- Linear and logistic growth functions
- Inter and intra guild competition
- Predation (Type I, II, III)
- Harvest (Catch, effort, fishing mortality)
- Covariates on growth or carrying capacity
- Fitting routines – Genetic Algorithm with Least Squares/Maximum Likelihood in the works
- Estimates predation and competition parameters, survey Q's, covariates, and initial biomass



MS-PROD: NEUS-LME Simulation



SCAA model details: 3-species example



Estimated parameters

Annual fishing mortality rates

Fishery selectivity

Abundances in 1st year

Annual recruits

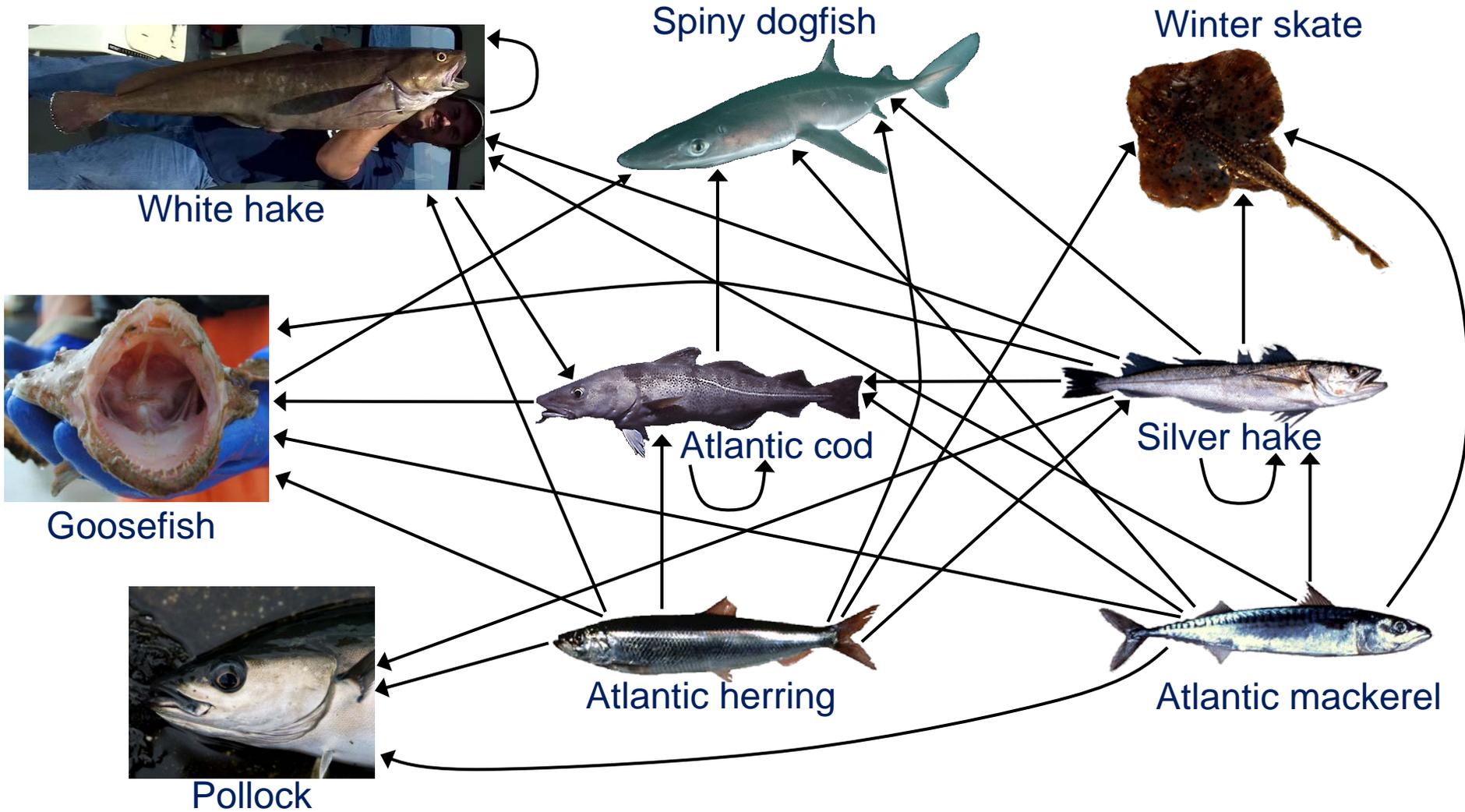
Survey selectivity

Survey catchability

Food selection parameters

Species preference

*Size preference

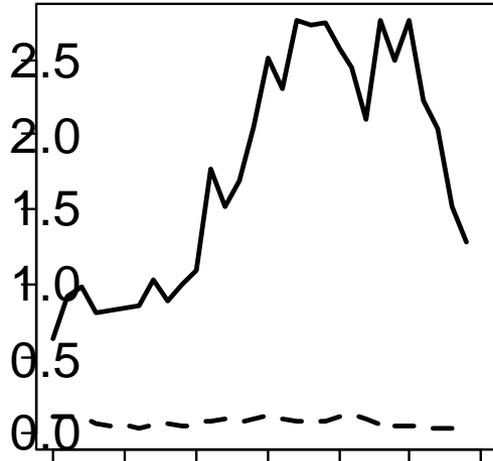


9 species, 27 predator-prey interactions

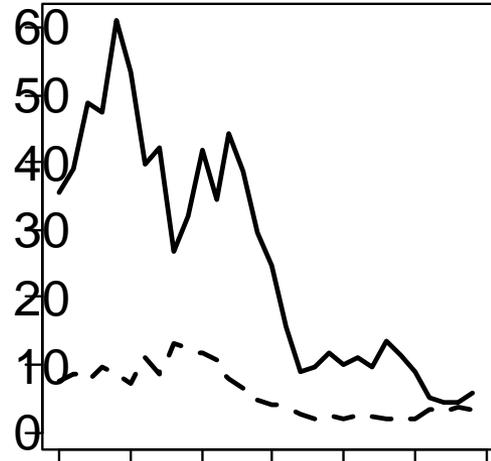
How does predation compare to fishing?

Thousands of metric tons

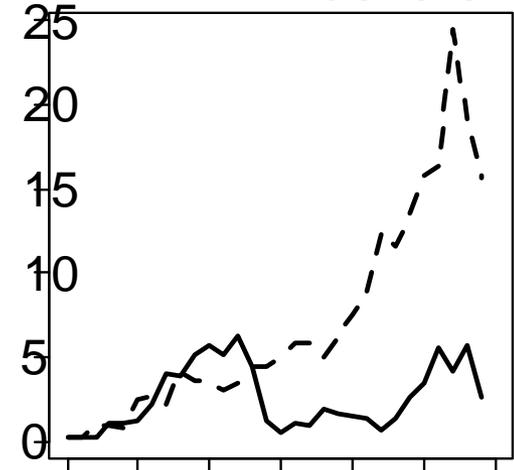
Goosefish



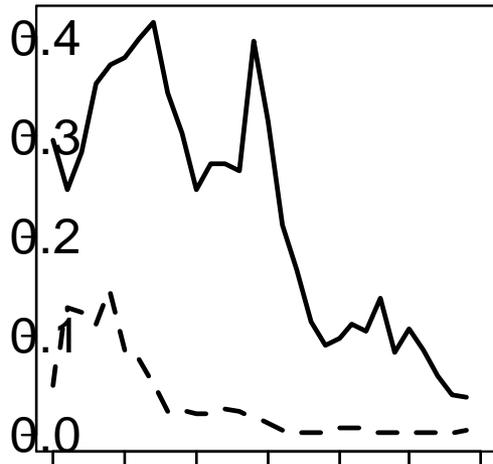
Cod



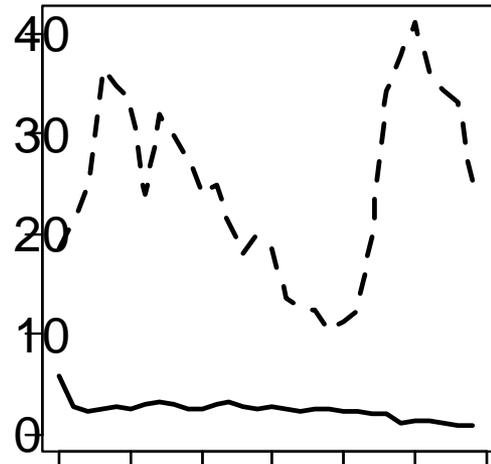
Mackerel



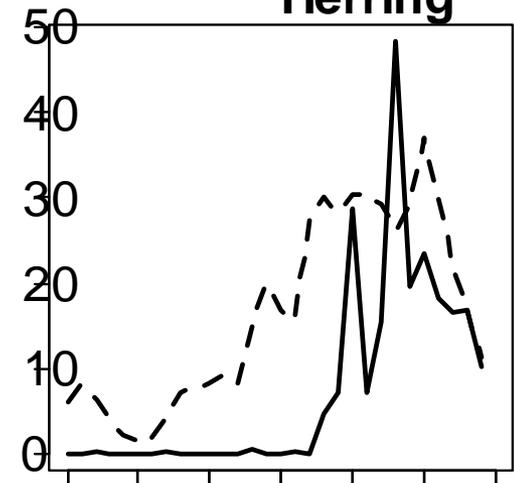
White hake



Silver hake



Herring



1978 1993 2008

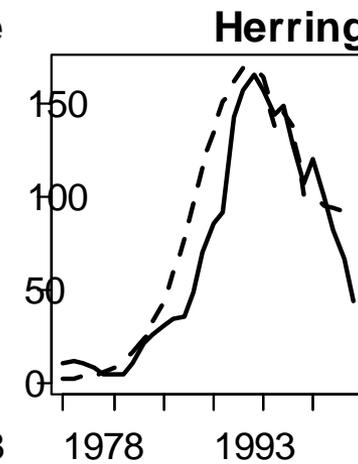
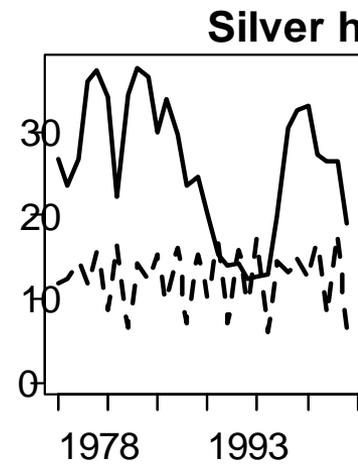
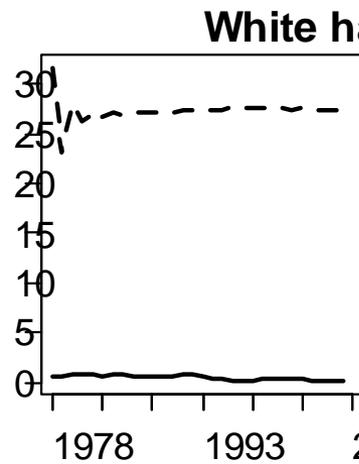
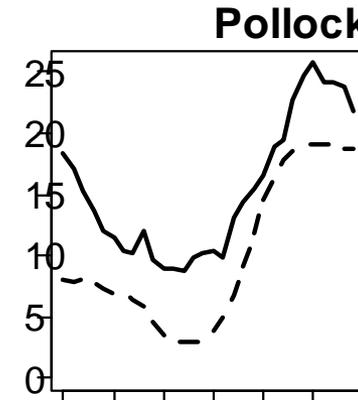
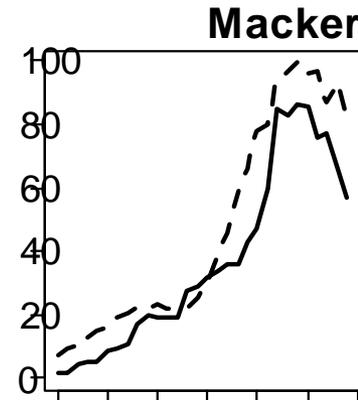
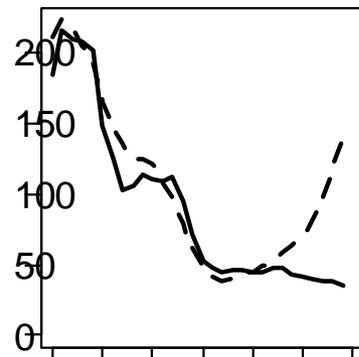
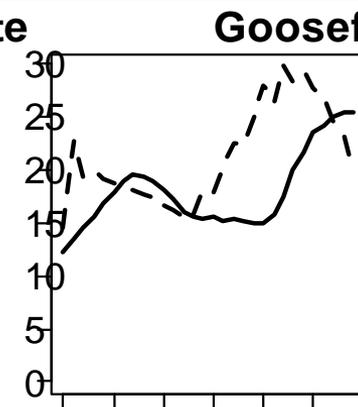
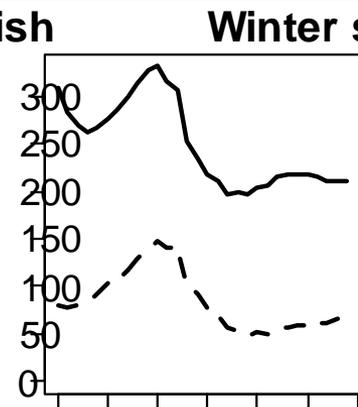
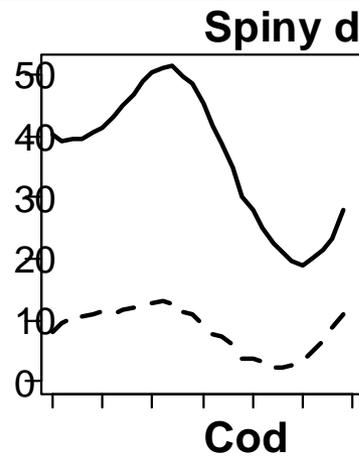
1978 1993 2008

1978 1993 20

Model comparison: biomass

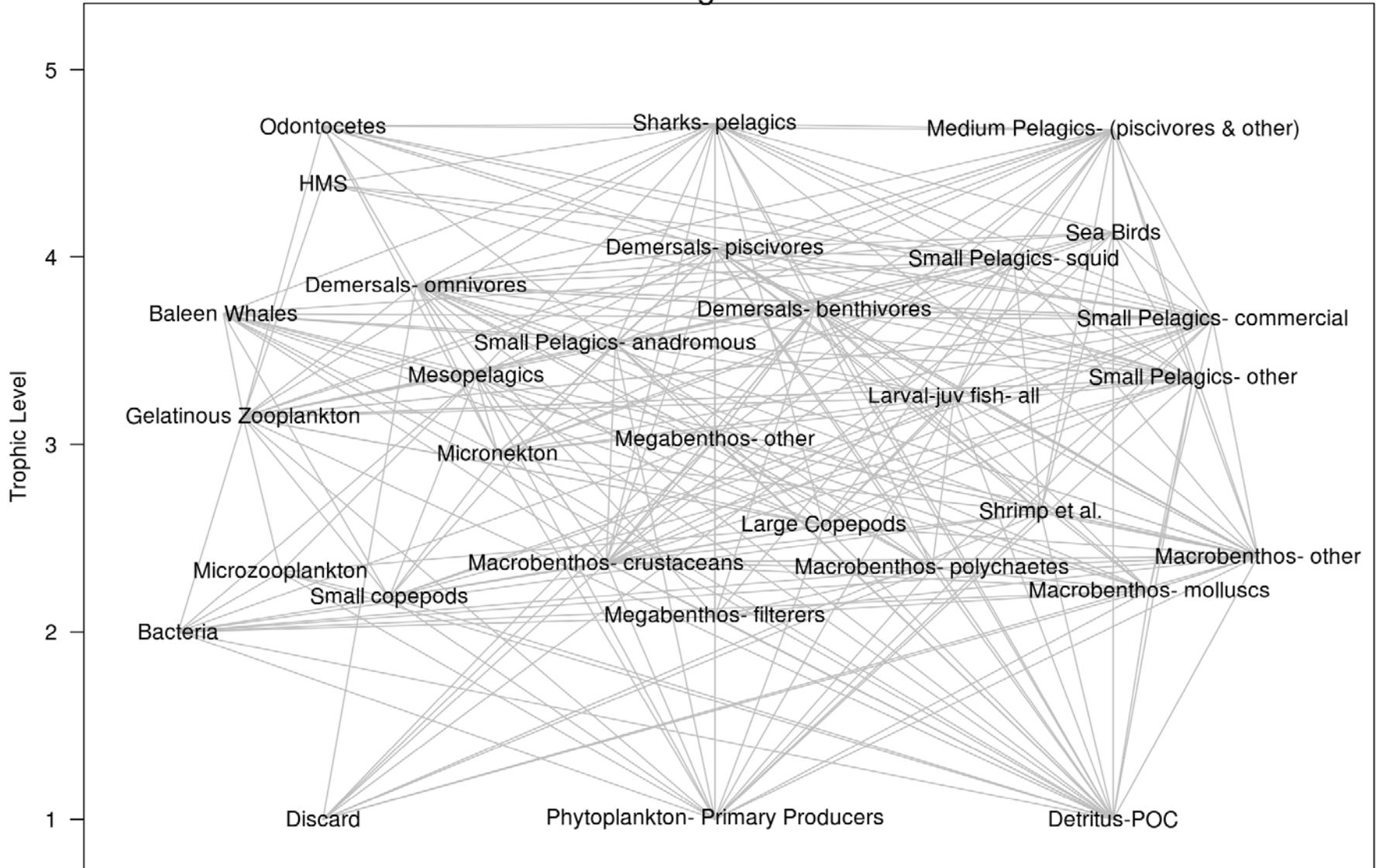
SCAA 
 Production 

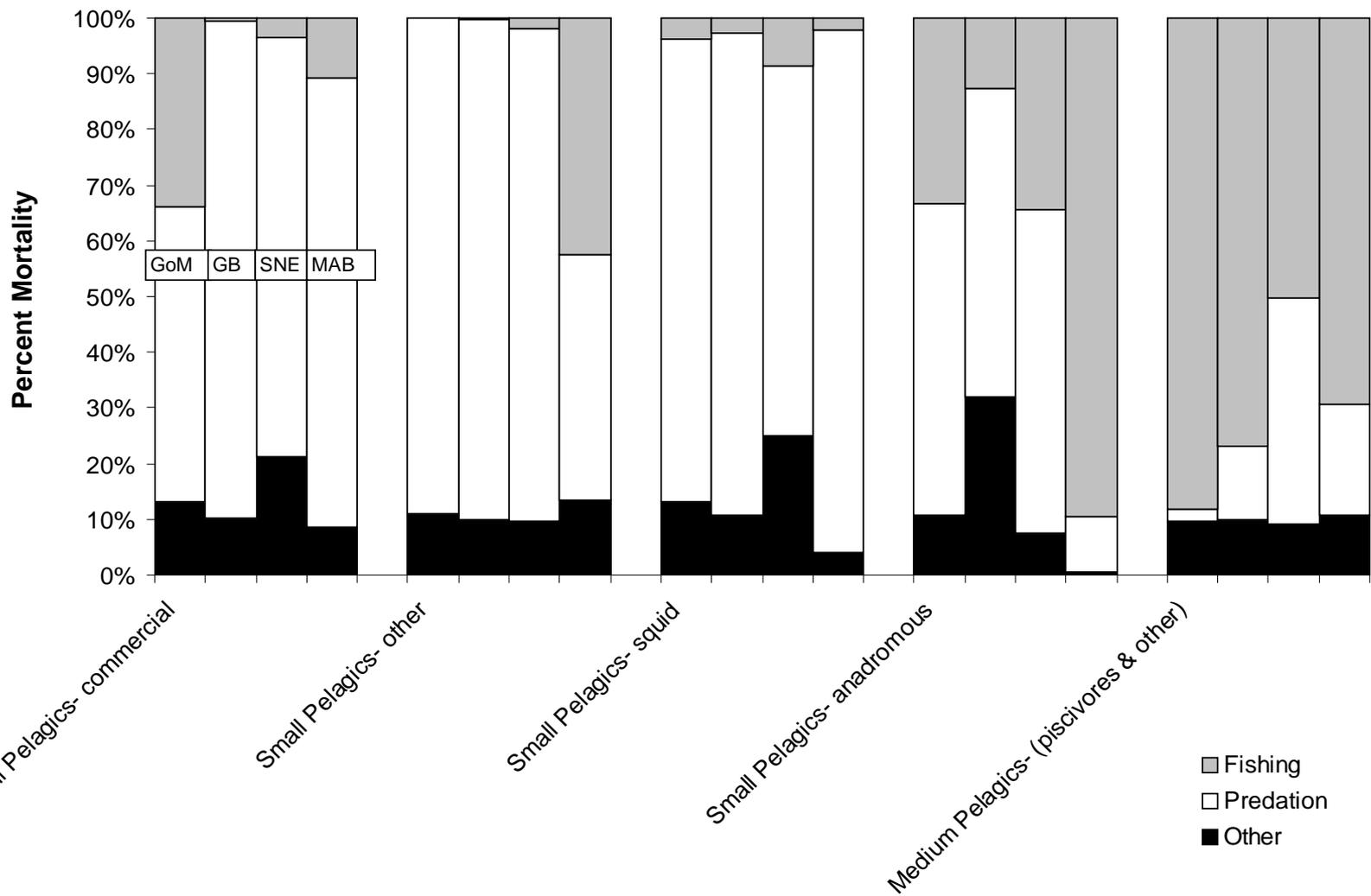
Thousands of metric tons



EMAX

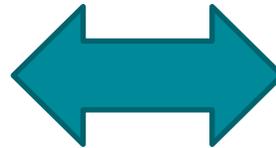
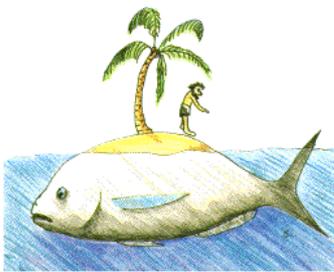
Georges Bank

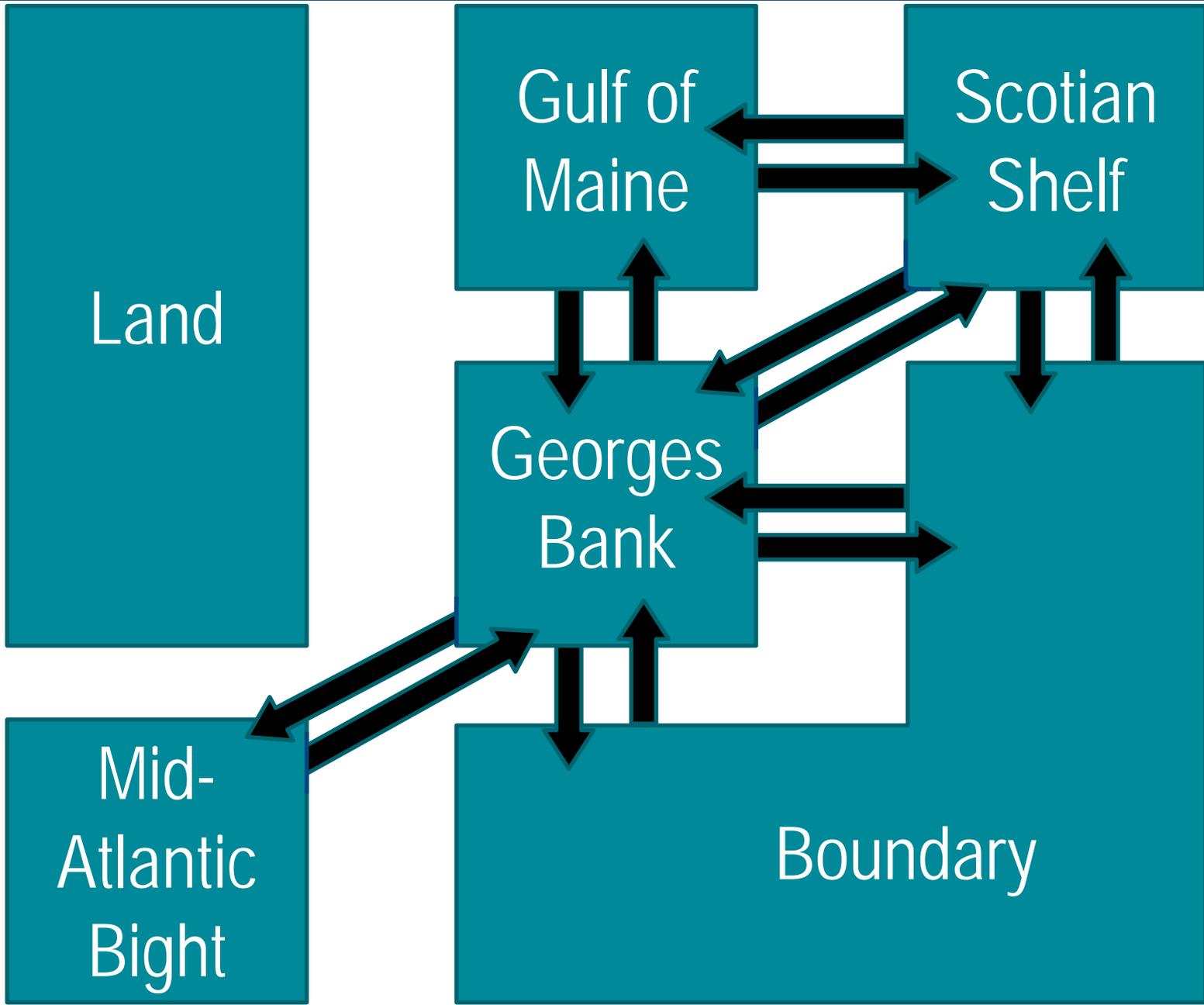




New implementation of EwE - Rpath

- Complement and expand the open source possibilities of Ecopath with Ecosim
- Use a platform widely used by ecologists, R
- Utilize the built-in statistical and graphical capabilities of R





Hydra multispecies model



Multispecies: fish and commercial invertebrates

- 10 fish species: 2 elasmobranchs, 2 pelagics, 4 groundfish, 2 flatfish

Size structured

- 5 variable width size categories for each species

Estimates predation mortality

- Size specific predation mortality

Environmental covariates on growth, maturity, fecundity

- 2 growth forms, exponential and von Bertalanffy
- Temperature covariate on both growth forms

Multiple recruitment functions

- 3 recruitment forms: Ricker, Beverton-Holt, Gamma (3 parameter)

Multiple fishing fleets

- 3 fleets: bottom & pelagic trawls, fixed gear

Likelihood (or Bayesian) parameter estimation in ADMB

- Simulation mode only, operating model

Spatial

- 1 area, "Georges Bank"



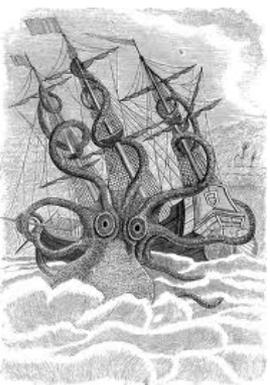
Hydra: ADMB Size structured, 10 species, 3 fleet operating model

True biomass, catch

"Survey" biomass, catch

Year	Species	Biomass	Catch
1	1	2276.38	134.7
1	2	2623.43	2090.03
1	3	2294.81	2512.90
1	4	1836.27	1381.3
1	5	1832.75	1476.03
1	6	2285.96	1912.2
1	7	2323.89	1848.32
1	8	2513.62	1415.3
1	9	1846.24	1423.7
1	10	1832.48	117.3
1	11	1973.51	1794.22
1	12	1826.32	1122.12
1	13	1833.65	1461.9
1	14	1837.87	1708.12
1	15	1833.56	1866.2
1	16	1833.56	1866.2
1	17	1833.56	1866.2
1	18	1833.56	1866.2
1	19	1833.56	1866.2
1	20	1833.56	1866.2
1	21	1833.56	1866.2
1	22	1833.56	1866.2
1	23	1833.56	1866.2
1	24	1833.56	1866.2
1	25	1833.56	1866.2
1	26	1833.56	1866.2
1	27	1833.56	1866.2
1	28	1833.56	1866.2
1	29	1833.56	1866.2
1	30	1833.56	1866.2
1	31	1833.56	1866.2
1	32	1833.56	1866.2
1	33	1833.56	1866.2
1	34	1833.56	1866.2
1	35	1833.56	1866.2
1	36	1833.56	1866.2
1	37	1833.56	1866.2
1	38	1833.56	1866.2
1	39	1833.56	1866.2
1	40	1833.56	1866.2
1	41	1833.56	1866.2
1	42	1833.56	1866.2
1	43	1833.56	1866.2
1	44	1833.56	1866.2
1	45	1833.56	1866.2
1	46	1833.56	1866.2
1	47	1833.56	1866.2
1	48	1833.56	1866.2
1	49	1833.56	1866.2
1	50	1833.56	1866.2

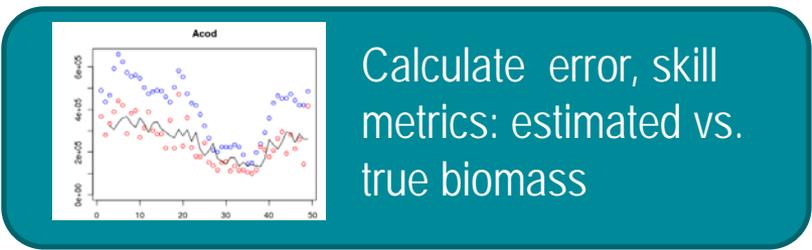
Kraken: C++ Production model, Genetic Algorithm estimation



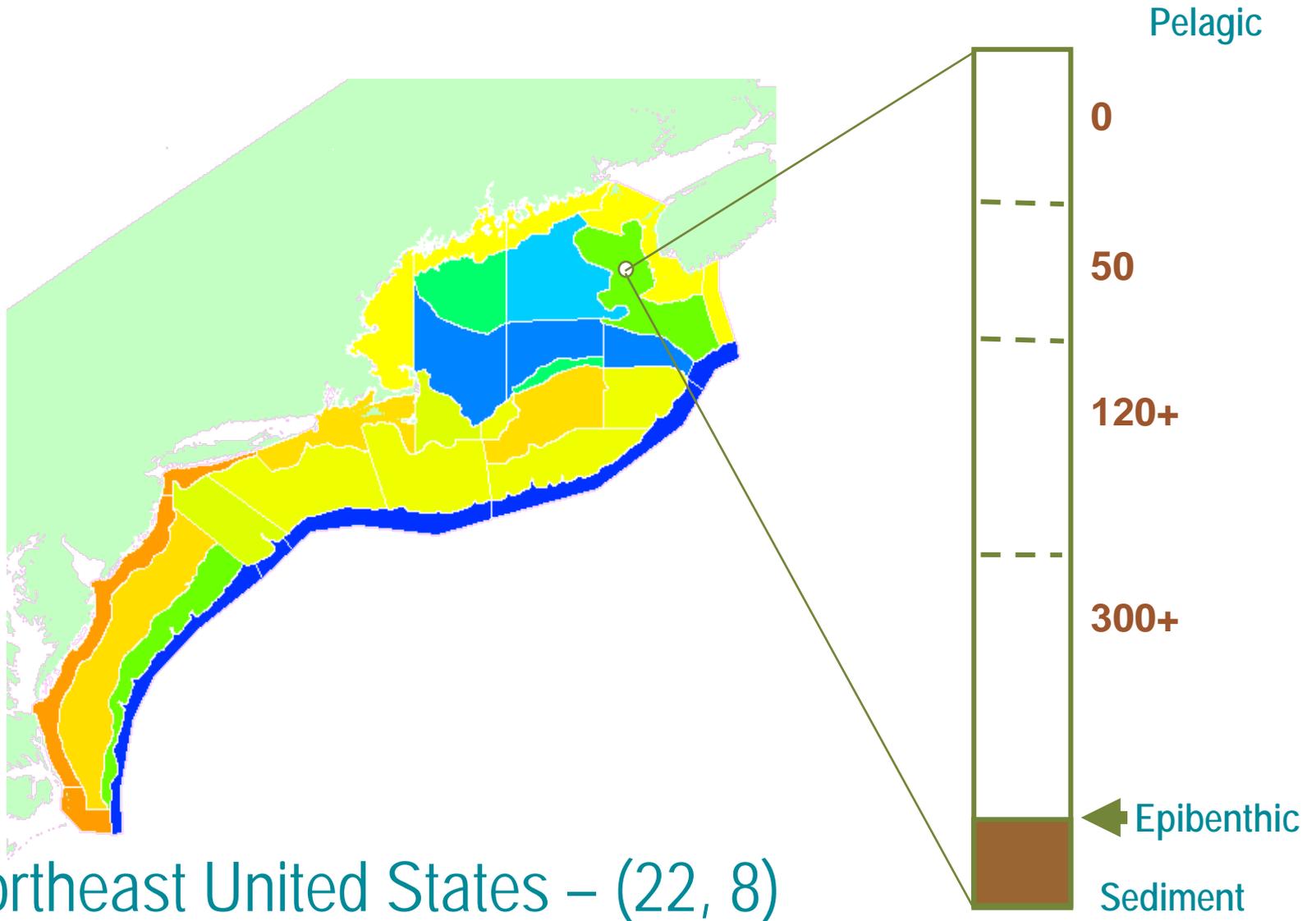
SAS LV: Production model, FIML estimation



SAS DD: Delay-difference model, FIML estimation



ATLANTIS - Spatial



ATLANTIS – Biological Groups and Fleets

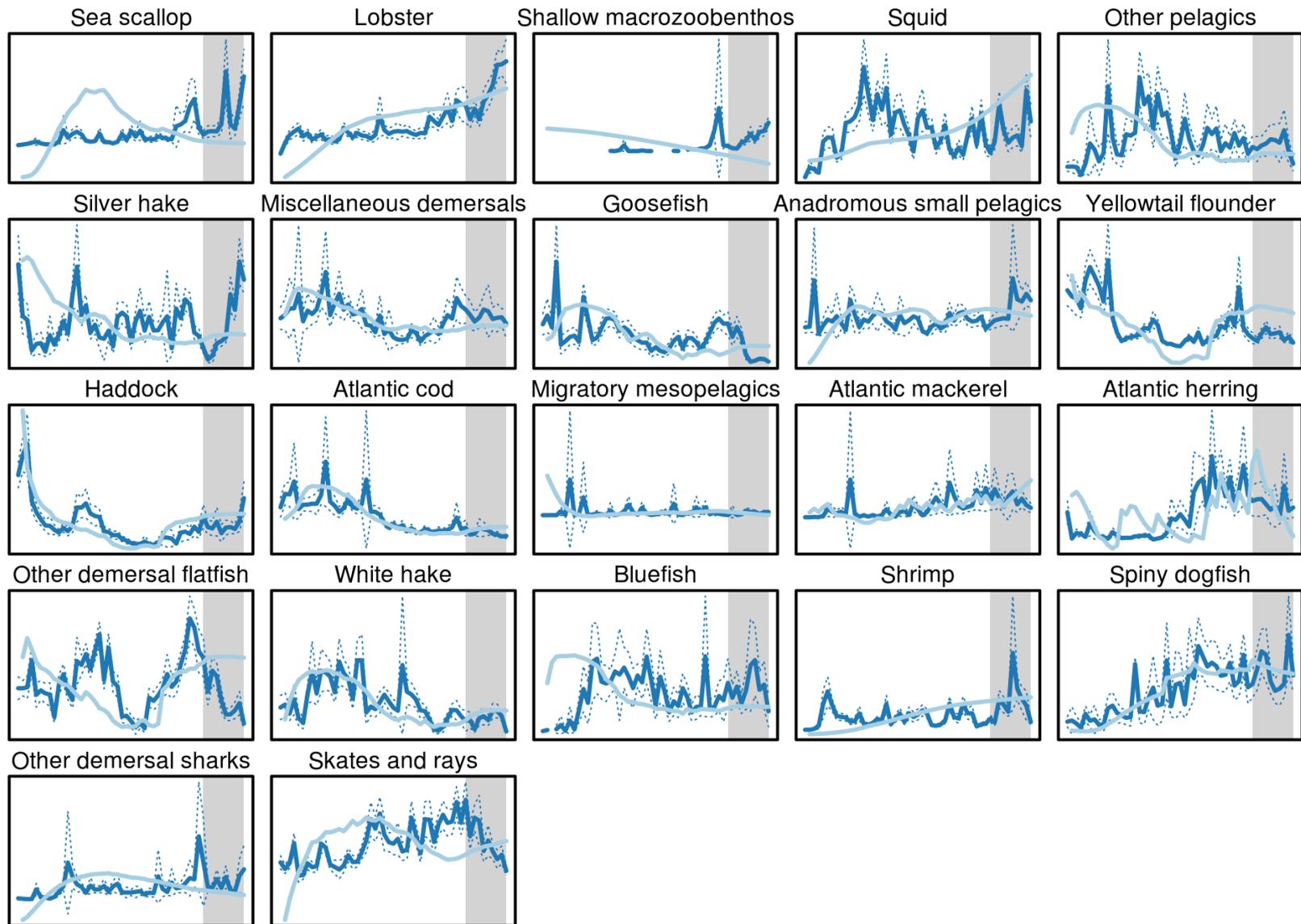
45 Functional Groups



18 Fishing fleets

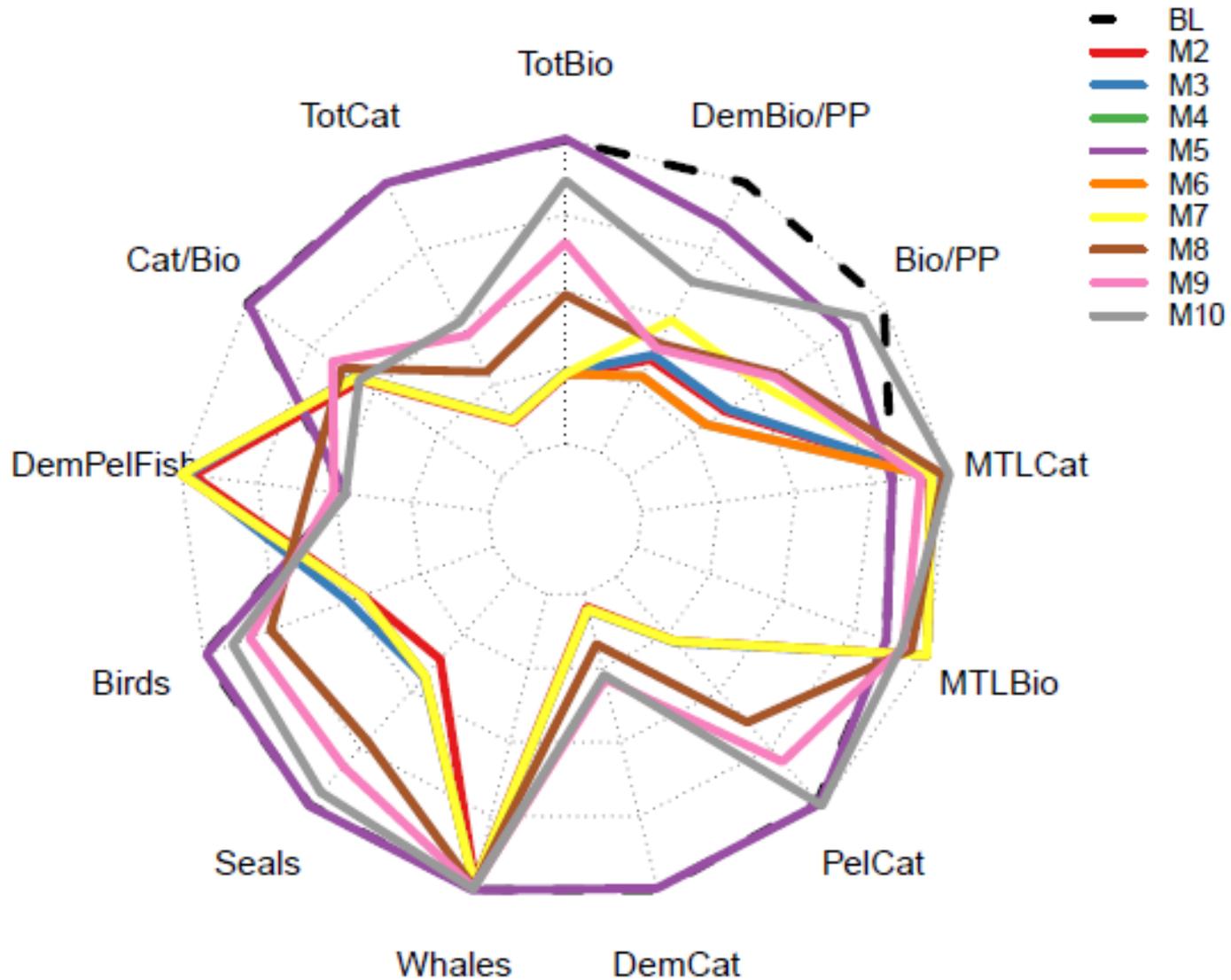


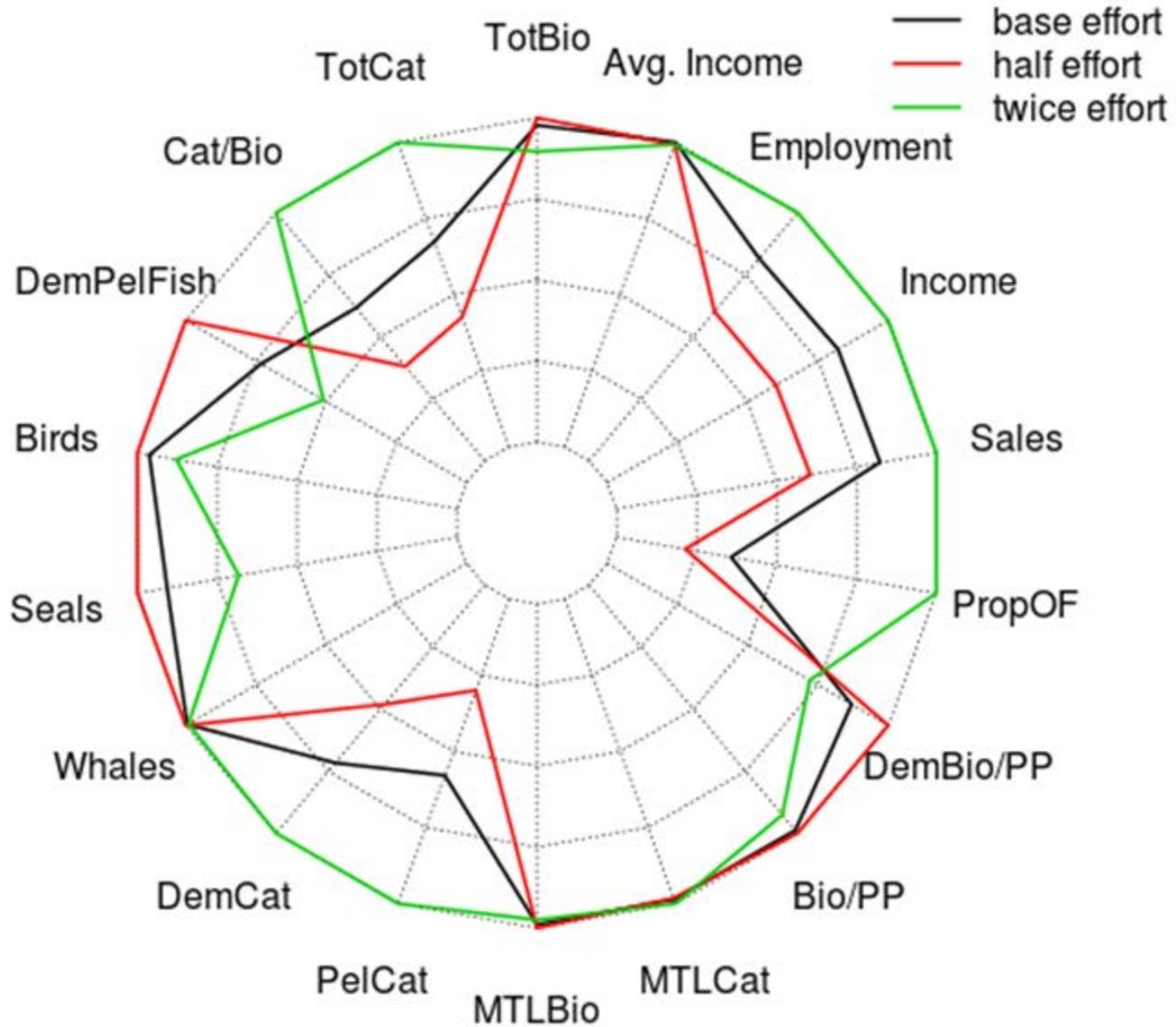
Biomass



Year

Atlantis – Ocean acidification





Successes and Challenges

- Rich history of model development
- Many 'flavors' of MS and ecosystem models
 - Assessment models for deriving biological reference points
 - Operating models for MSE
- Develop multi-model inferences for ecosystem reference points
- Need more dedicated resources for development

Questions?

References

- Curti et al., 2013. Evaluating the performance of a multispecies statistical catch-at-age model. *Can. J. Fish. Aquat. Sci.* 70: 470–484.
- Gaichas et al. In review. Combining stock, multispecies, and ecosystem level fishery objectives within an operational management procedure: simulations to start the conversation. *ICES J. Mar. Sci.*
- Gaichas et al. 2012. Assembly Rules for Aggregate-Species Production Models: Simulations in Support of Management Strategy Evaluation. *Mar. Ecol. Prog. Ser.* 459: 275–292.
- Gamble and Link. 2009. Analyzing the tradeoffs among ecological and fishing effects on an example fish community: a multispecies (fisheries) production model. *Ecol Model* 220: 2570–2582.
- Garrison et al., 2010. An Expansion of the MSVPA Approach for Quantifying Predator-Prey Interactions In Exploited Fish Communities. *ICES J. Mar. Sci.* 67, 856–870.
- Hall et al. 2006. A length-based multispecies model for evaluating community responses to fishing. *Can. J. Fish. Aquat. Sci.* 63(6): 1344–1359.
- Link et al. editors. 2006. Documentation fo the Energy Modeling and Analysis eXercise (EMAX). US Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc. 06-15, Woods Hole, MA.
- Link et al. 2007. Energy flow on Georges Bank revisited: the energy modeling and analysis eXercise (EMAX) in historical context. *J. Northw. Atl. Fish. Sci.*, 39: 83–101.
- Link et al. 2008. The Northeast U.S. continental shelf Energy Modeling and Analysis exercise (EMAX): Ecological network model development and basic ecosystem metrics. *Journal of Marine Systems* 74:453-474.
- Link et al. 2009. Response of balanced network models to large-scale perturbation: Implications for evaluating the role of small pelagics in the Gulf of Maine. *Ecological Modelling* 220:351–369.
- Link et al. 2010. The northeast US application of ATLANTIS: a full system model exploring marine ecosystem dynamics in a living marine resource management context. *Progress in Oceanography*, 87(1), 214–234.
- Link et al. 2011. NEUS – Atlantis: Construction, Calibration, and Application of an Ecosystem Model with Ecological Interactions, Physiographic Conditions, and Fleet Behavior. NOAA Tech Memo NMFS NE-218 247 p.
- Tyrrell et al. 2008. Evaluating the effect of predation mortality on forage species population dynamics in the Northeast US continental shelf ecosystem: an application using multispecies virtual population analysis. *ICES J. Mar. Sci.* 65, 1689–1700.