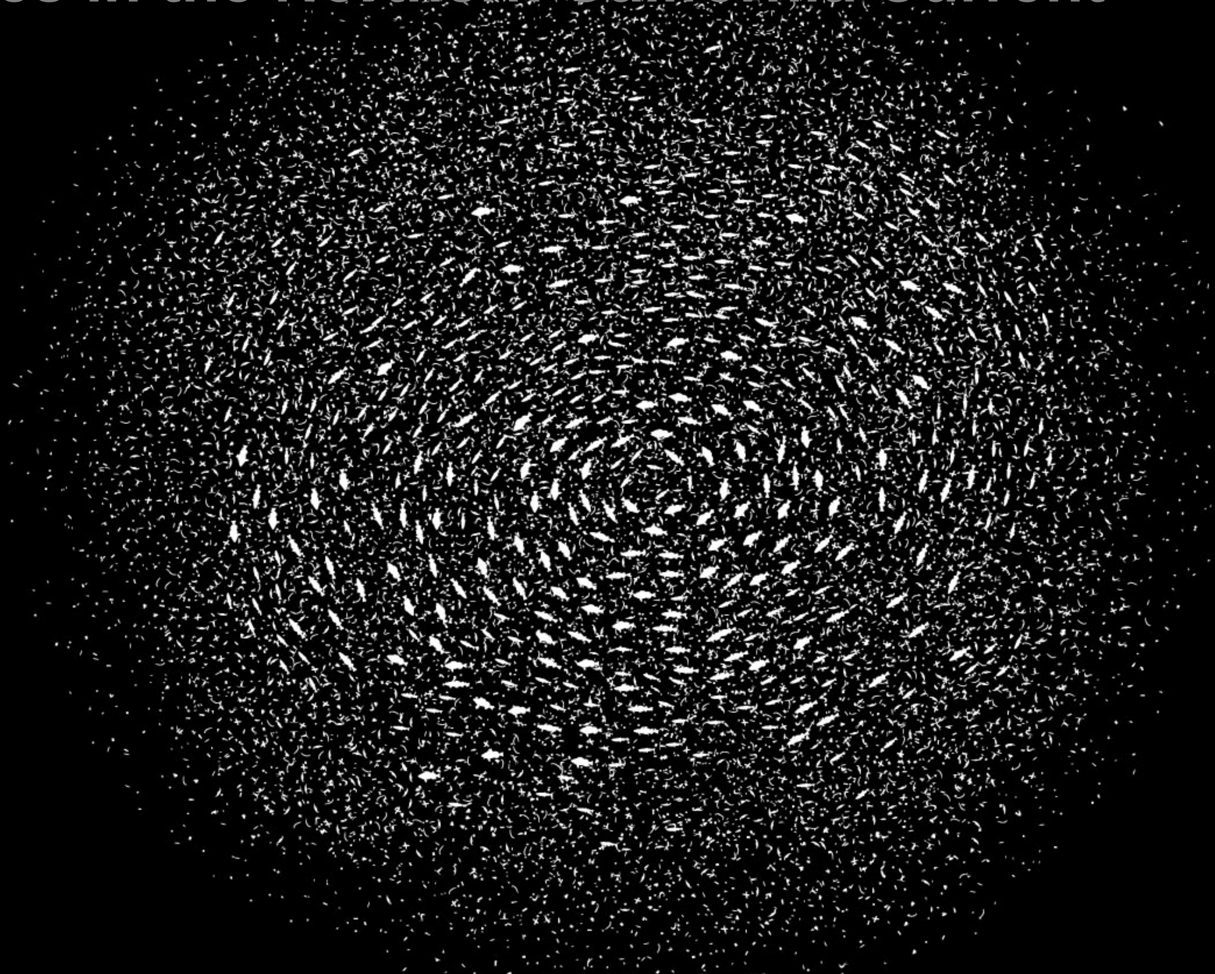
Top down modeling and bottom up dynamics: Linking fisheries-based multispecies models with climate hypotheses in the Northern California Current



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Organization of this talk

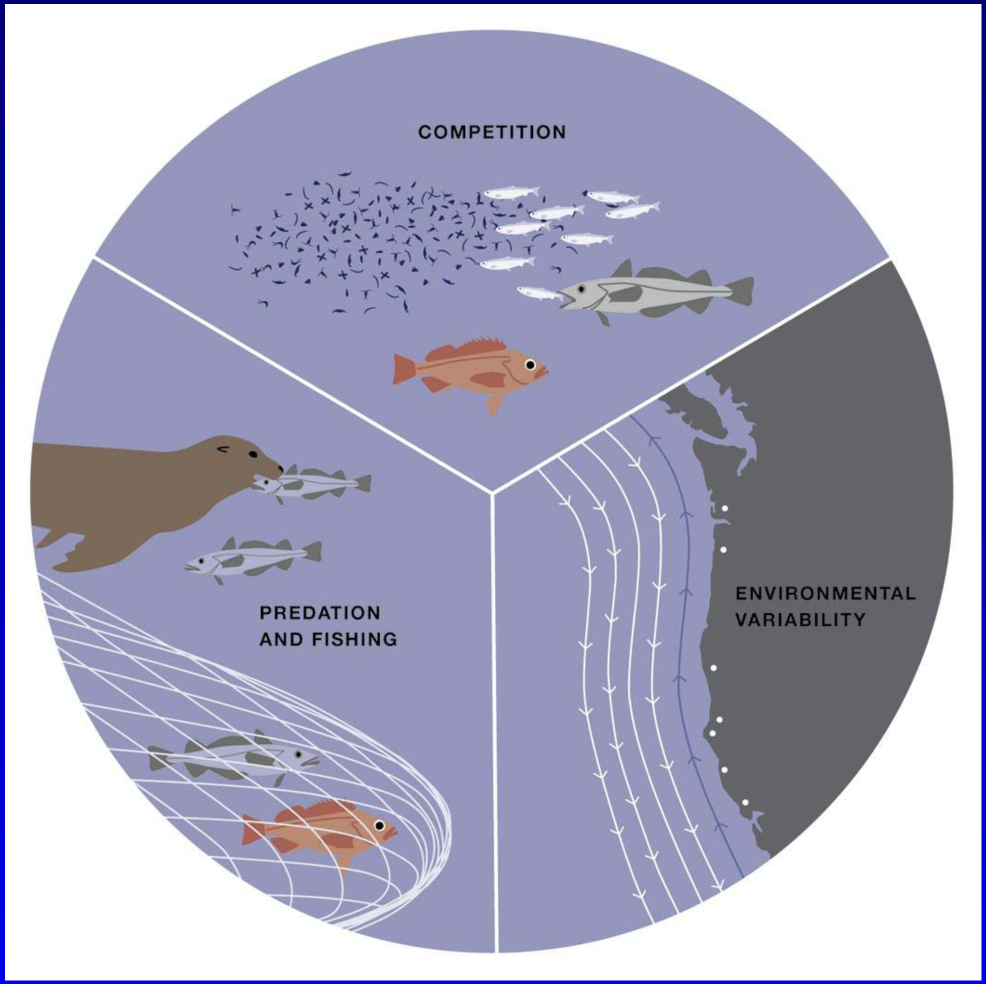
- Brief overview of modelling approach
- Description of the Northern California Current region, model structure and data sources
- Simulations of model behavior with and without climate as as both a bottom-up and top-down forcing mechanism
- One way to measure the relative improvement of model behavior

Why do multi-species or ecosystem models?

Three fundamental processes that structure populations;

- **Competition**
- **Predation and fishing**
- **Environmental variability**

Hollowed et al. (2000)



Ecosystem models give us a framework for addressing some of these interactions, albeit simplistically, that most single species models cannot

Modeling framework: Ecopath with Ecosim

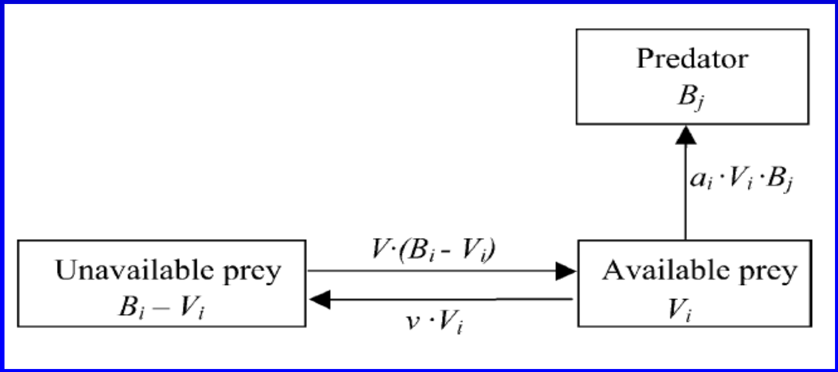
The static, mass balance equation: ecosystem bookkeeping

$$B_i\left(\frac{P}{B}\right)_i EE_i + IM_i + BA_i = \sum_j \left(B_j \frac{Q}{B} DC_{ij}\right)_j + EM_i + C_i$$

Ecopath to Ecosim: dynamic simulation based on population rates, where total mortality (predation, fishing) is key

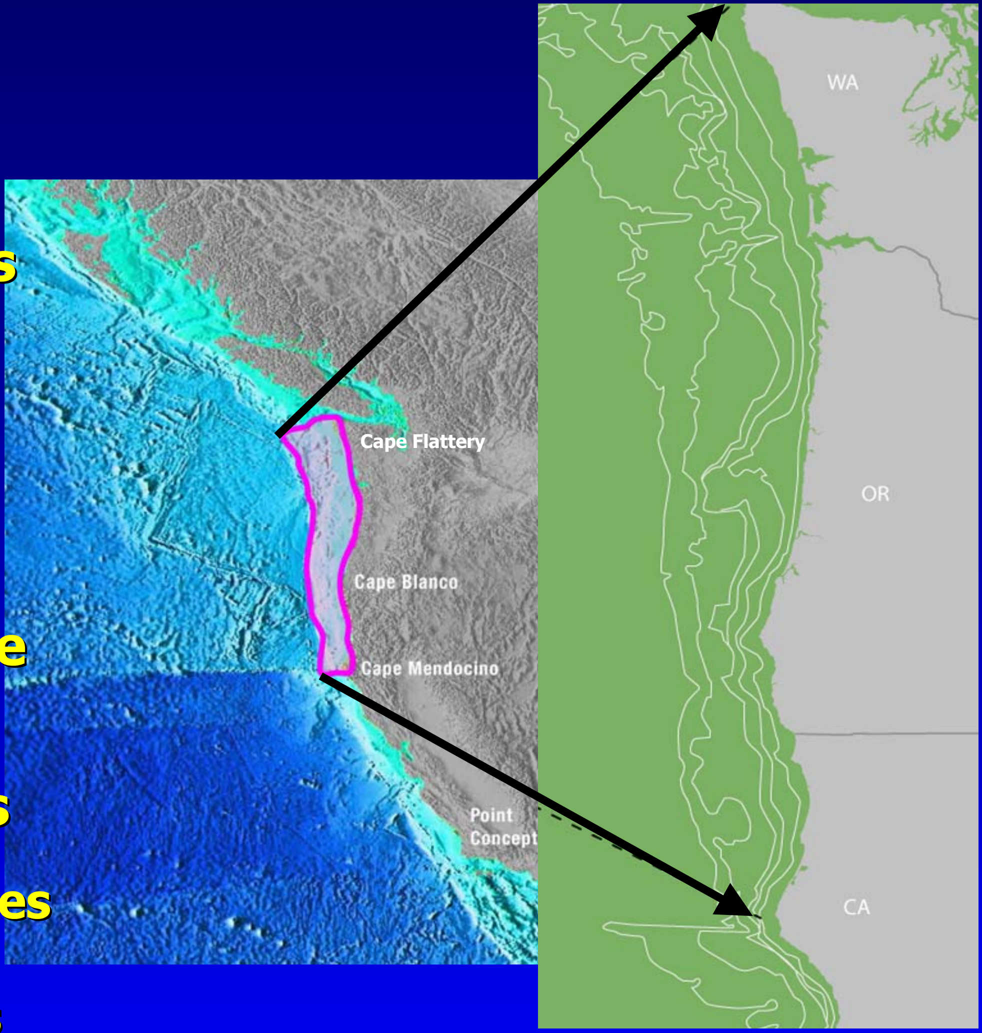
$$\frac{dB_i}{dt} = g_i \sum_j Q_{ji} - \sum_j Q_{ij} + I_i - (M0_i + F_i + e_i)B_i$$

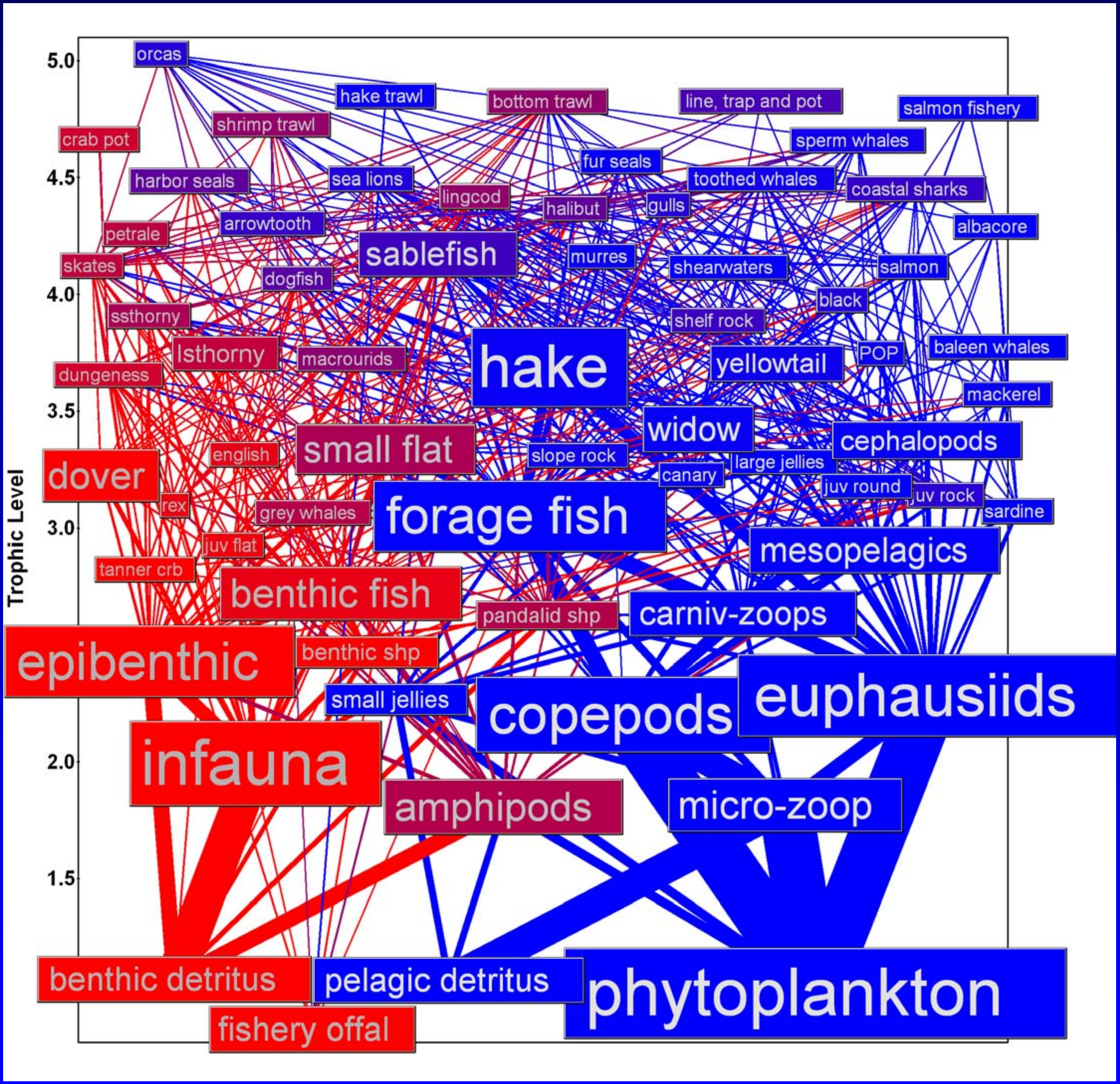
Model is highly sensitive to parameters that define the vulnerability of prey to predation, which in turn determine how top-down or bottom-up the model will behave…



Model Structure

- A “bite-sized” piece of the California Current
- Shelf and slope between Capes Flattery and Mendocino
- Static models created for the 1960s and 1990s
- Transitional, open ecosystem, driven by local and global climate forcing on many scales
- Model includes 62 components
  - 27 commercially important species and functional groups
  - 11 higher trophic level predators
  - 20 functional groups of zooplankton, nekton, benthic fauna
  - 7 commercial fisheries





Trophic Level
5.0
4.5
4.0
3.5
3.0
2.0
1.5
orcas
hake trawl
bottom trawl
line, trap and pot
salmon fishery
crab pot
shrimp trawl
sperm whales
fur seals
harbor seals
sea lions
toothed whales
coastal sharks
lingcod
halibut
gulls
petrale
arrowtooth
albacore
skates
sablefish
murres
shearwaters
salmon
dogfish
black
ssthorny
shelf rock
lsthorny
macrourids
hake
POP
baleen whales
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small flat
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grey whales
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sardine
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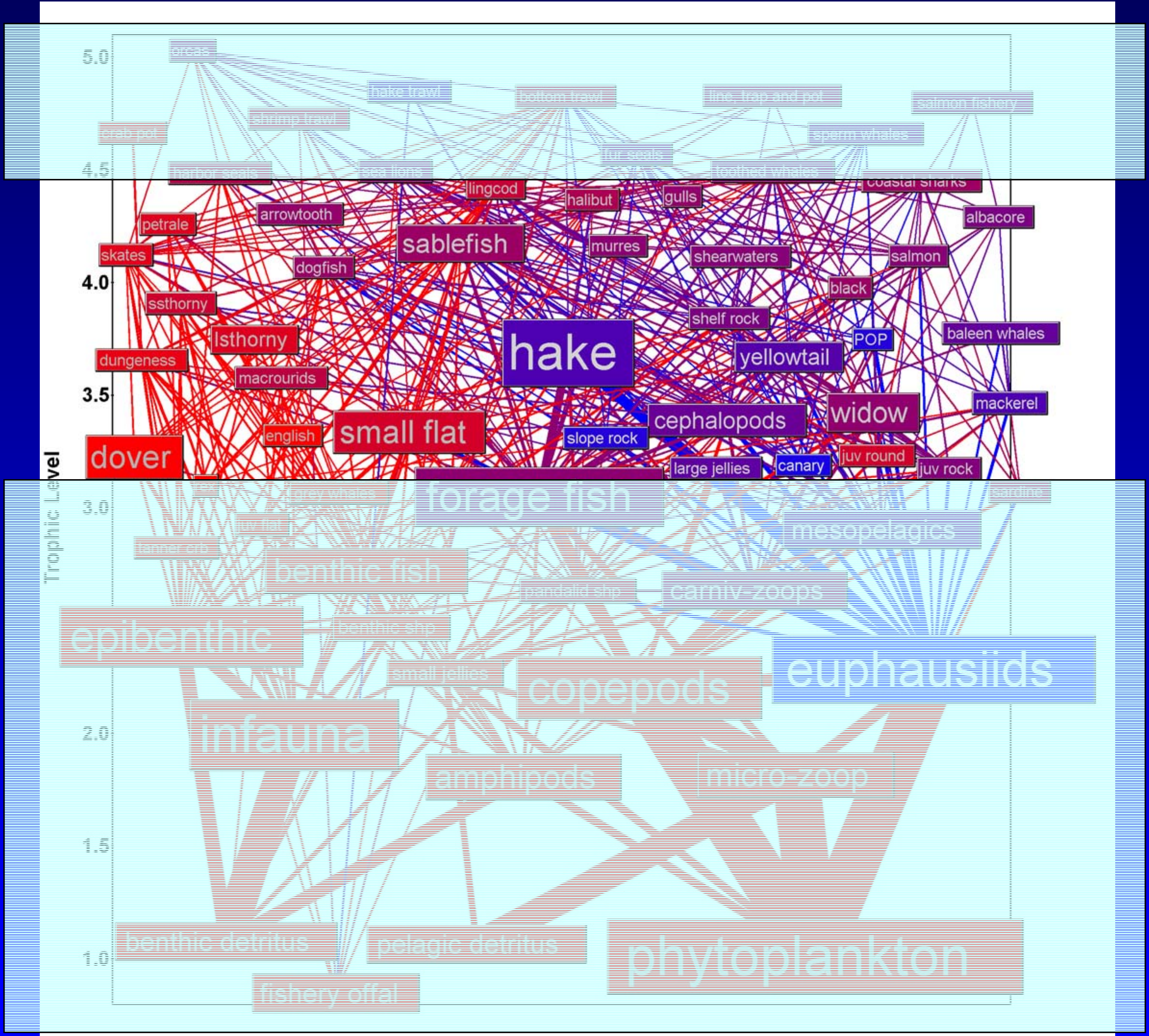
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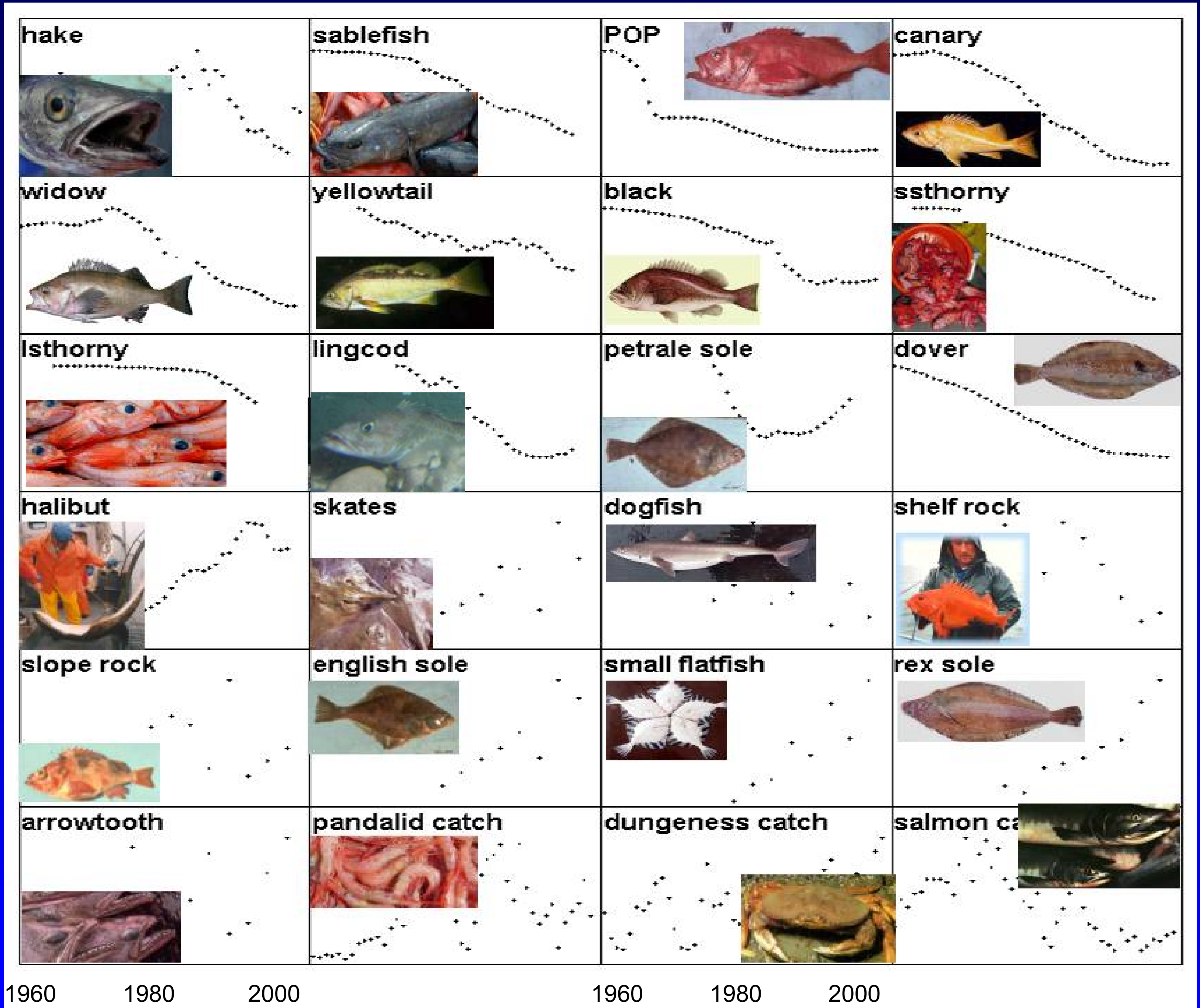

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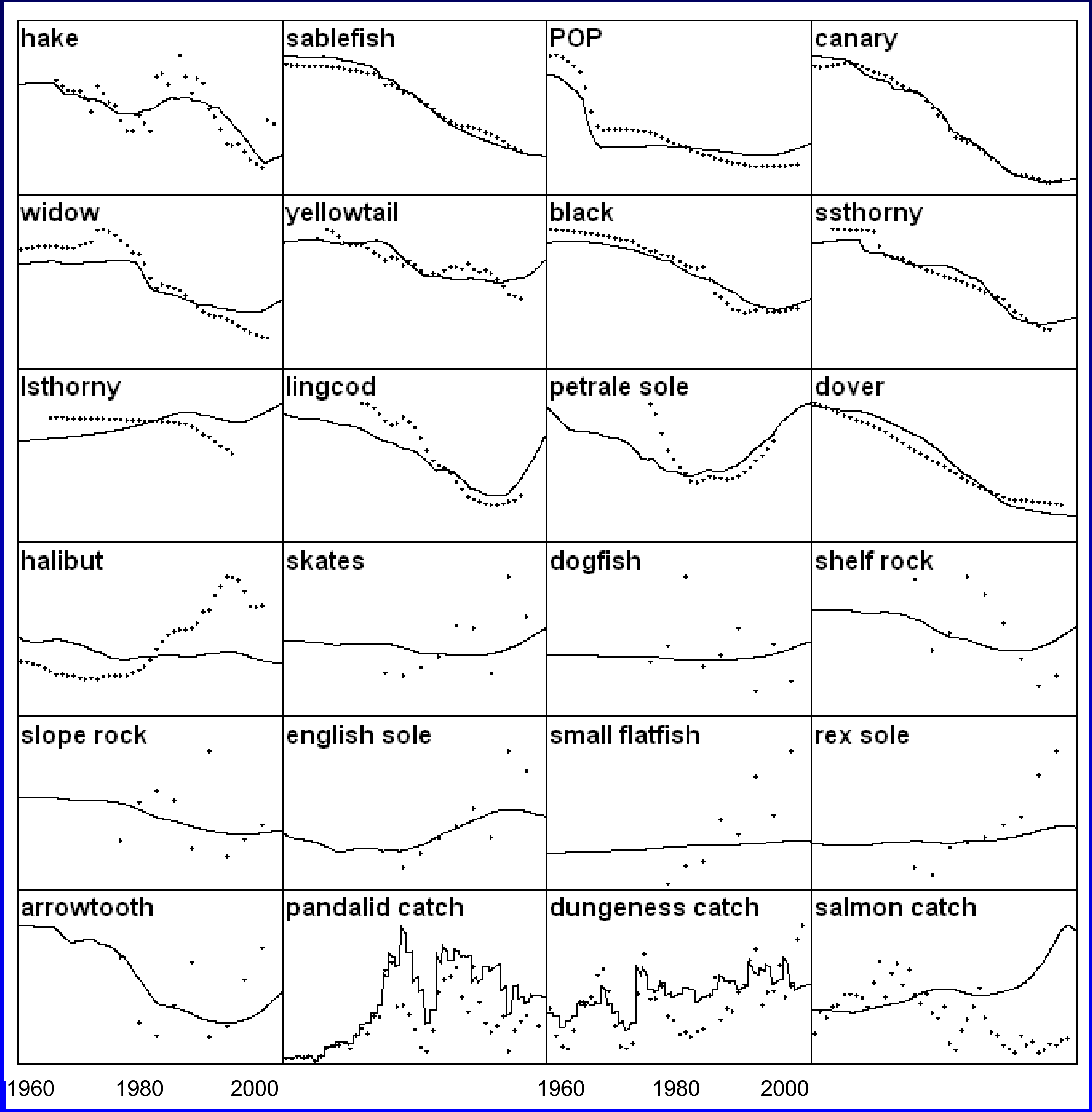


Model driven with fishing mortality rates for assessed species, relative effort indices for unassessed and bycatch species

Neg log like: -352

How to measure improvement in fit when "adding" climate to the model?

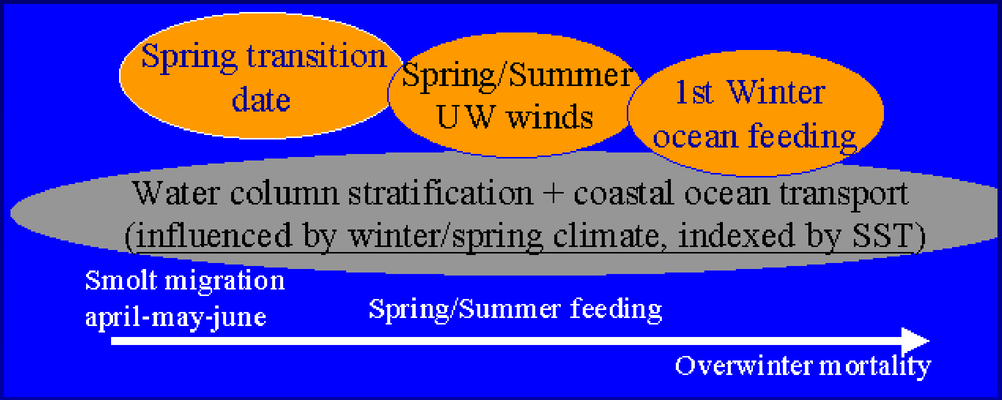
One way: Likelihood ratio test for nested models

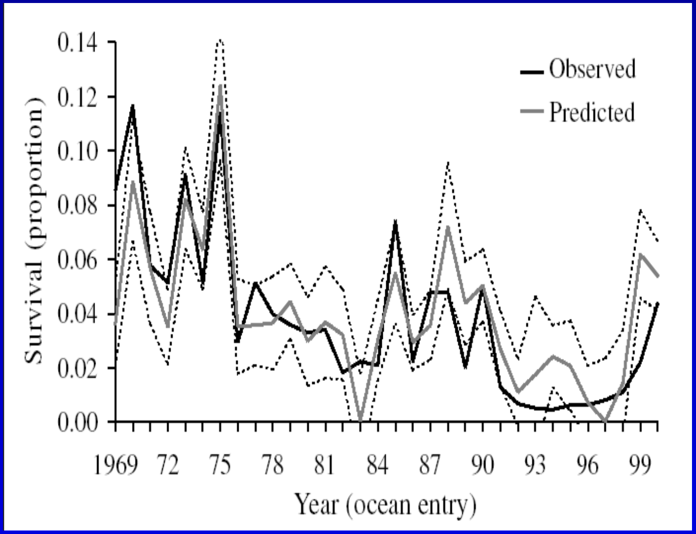
(Hilborn and Mangel 1997)

$$R = 2[\mathbf{L}(Y|M_A) - \mathbf{L}(Y|M_B)]$$

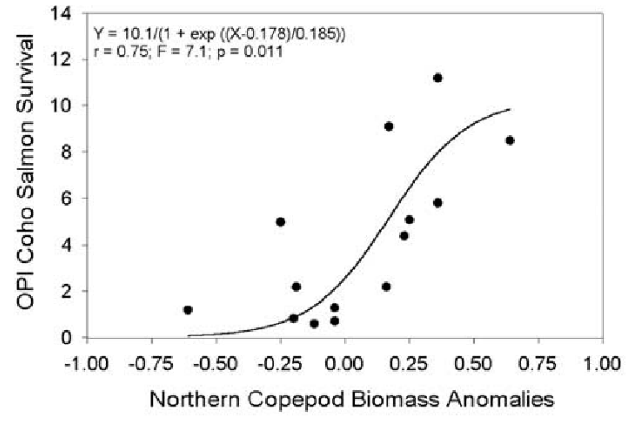
How to add bottom-up forcing into the model?

Logerwell et al. (2003) found that Oregon coastal coho salmon survival was influenced by a series of (mostly) independent physical ocean processes..

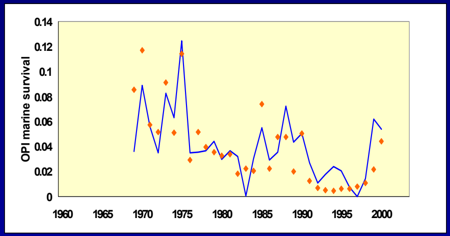




Using a generalized additive model (GAM), they found that they could explain ~75% of the observed variability in coho survival with indices of SST, the timing of the spring transition, and relative sea level.



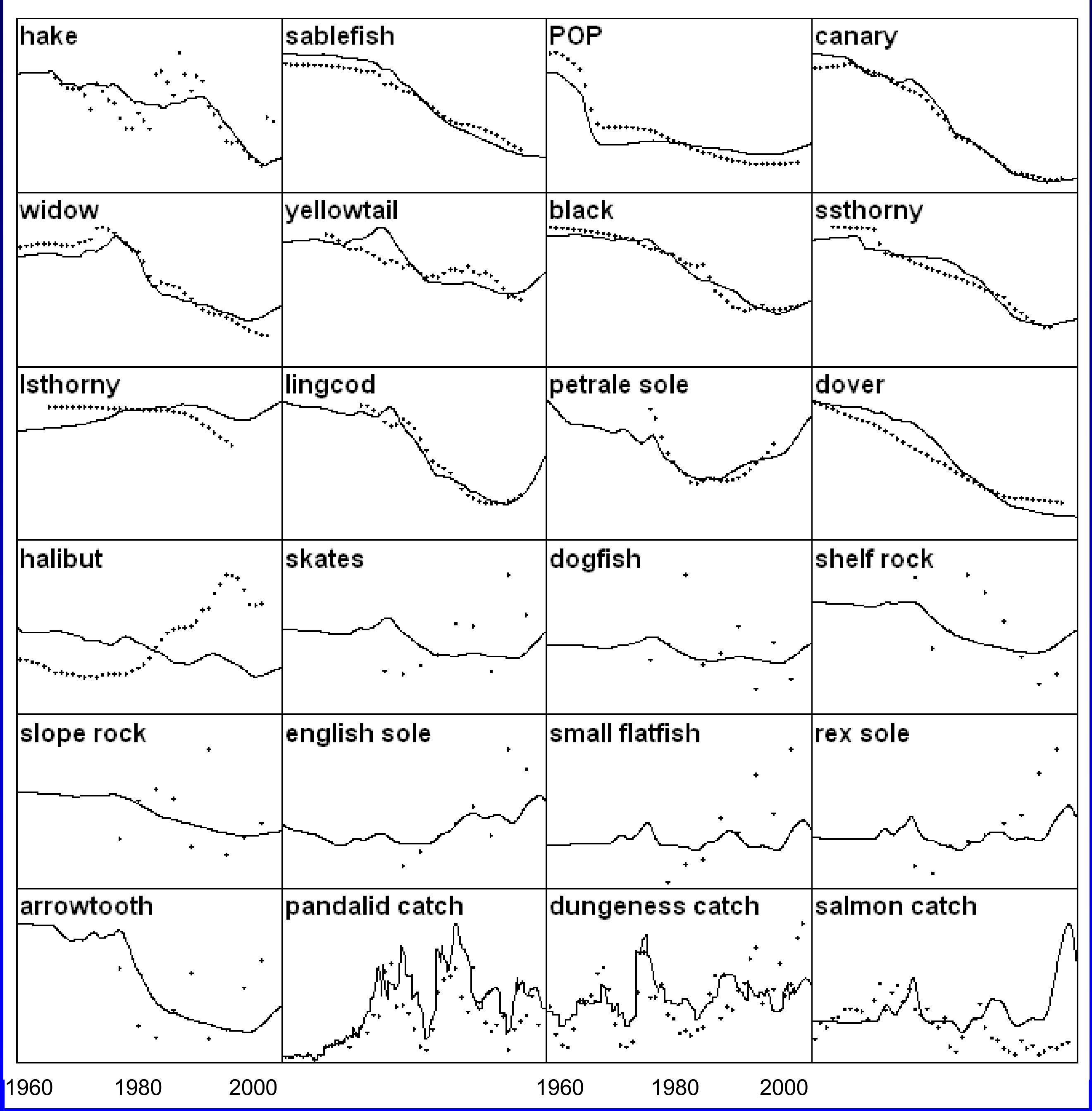
Peterson and Schwing (2003) also found a strong non-linear relationship between survival and the abundance of northern (subarctic) copepods off of Oregon



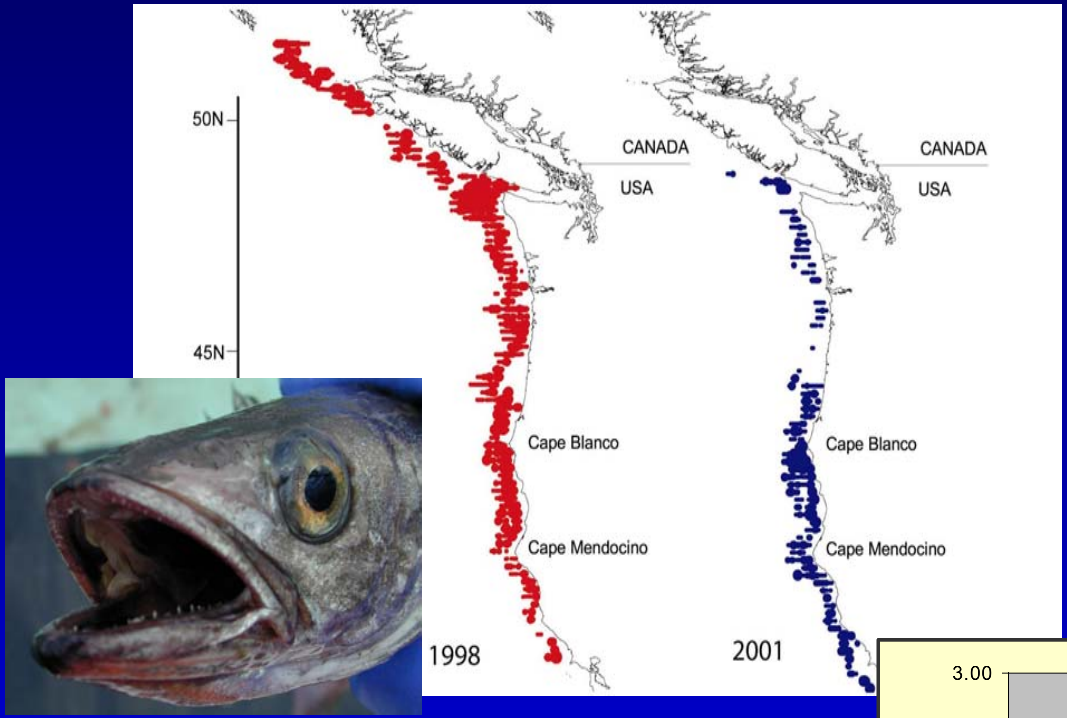
Model fitted to assessment, survey and catch data with coho survival index as bottom-up (primary production) forcing

Neg log like: -389

(no climate: -352)



Another way- “top-down”’ climate forcing

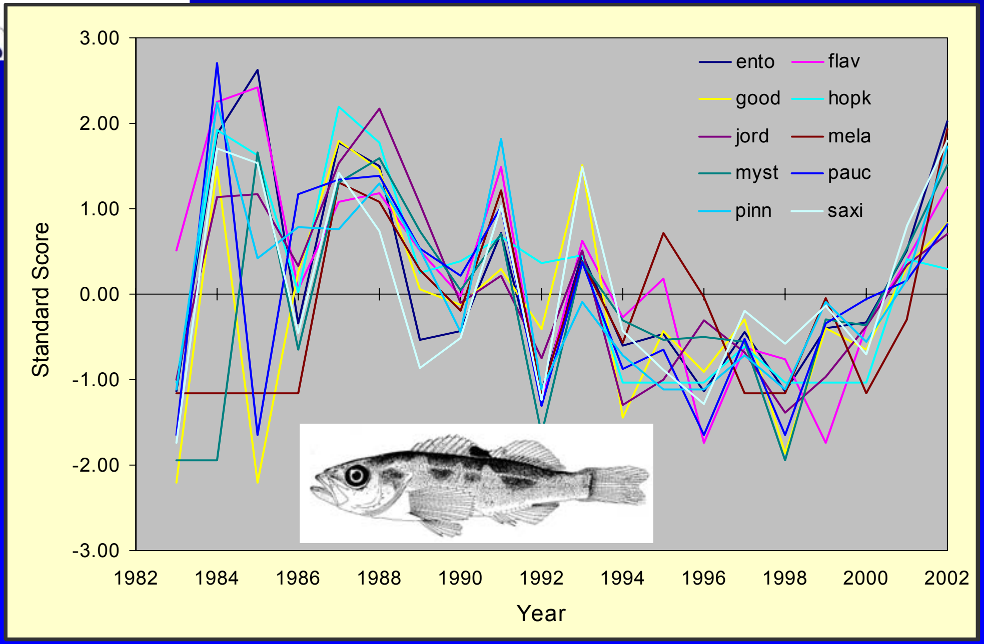


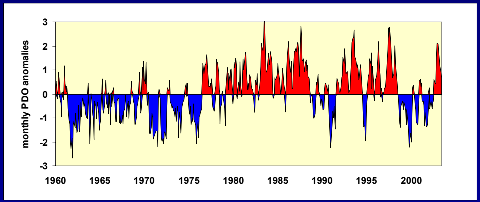
During positive PDO and/or low transport periods coastal pelagics (hake, sardine and mackerel) have more northerly distribution, while halibut and some small flatfish seem to have greater recruitment

Figure from V. Agostini

During negative phase of the PDO and/or higher transport periods salmon, rockfish and some other groundfish seem to have higher productivity (survival and recruitment)

Figure from S. Ralston

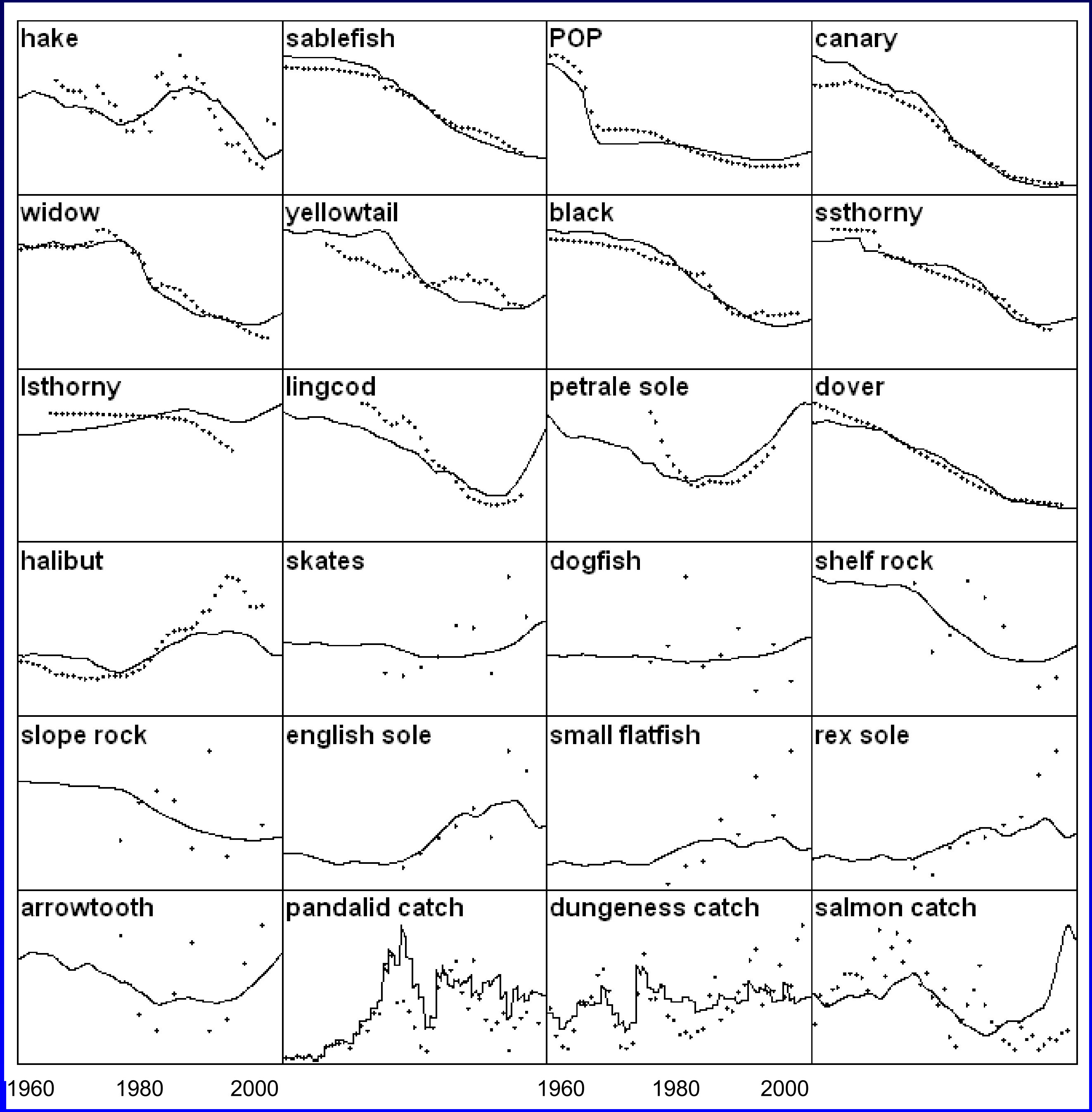


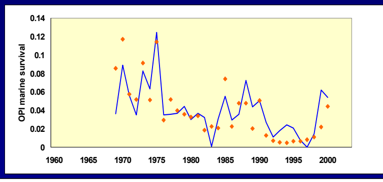


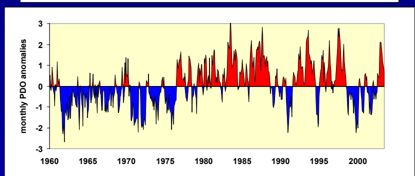
Model fitted to stock assessment, survey and catch data (1960-2002) with PDO index as “top-down” forcer of the vulnerability of prey to higher trophic level predators

Neg log like: -391

(no climate: -352)



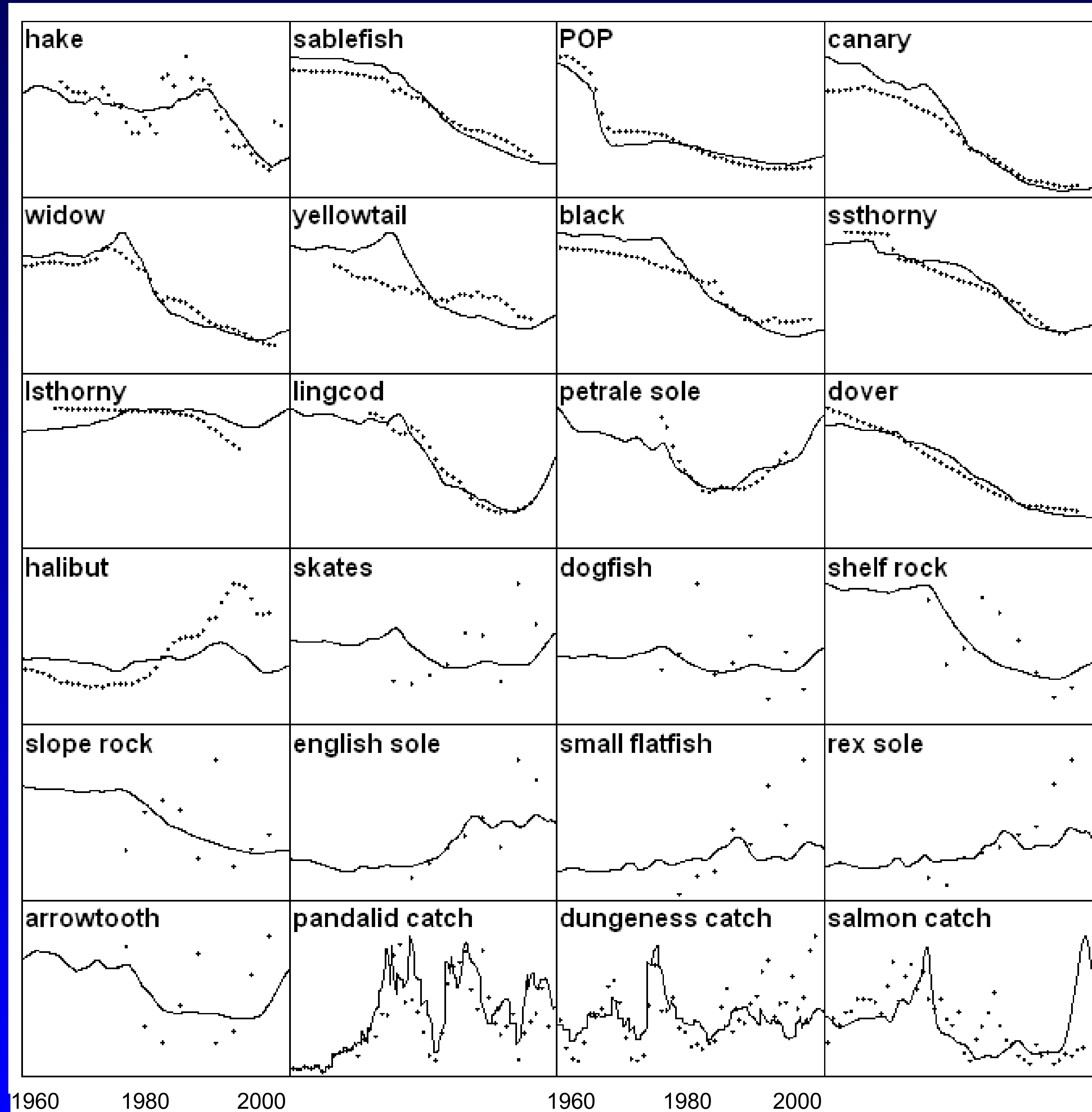




Model fitted to assessment, survey and catch data (1960-2002) with both the survival index (bottom-up) and PDO (top-down) forcing

Neg log like: -379

(no climate: -352)



Is there a significant improvement in fit when "adding" climate to the model?

Likelihood ratio test for nested models

$$R = 2[\mathbf{L}(Y|M_A) - \mathbf{L}(Y|M_B)]$$

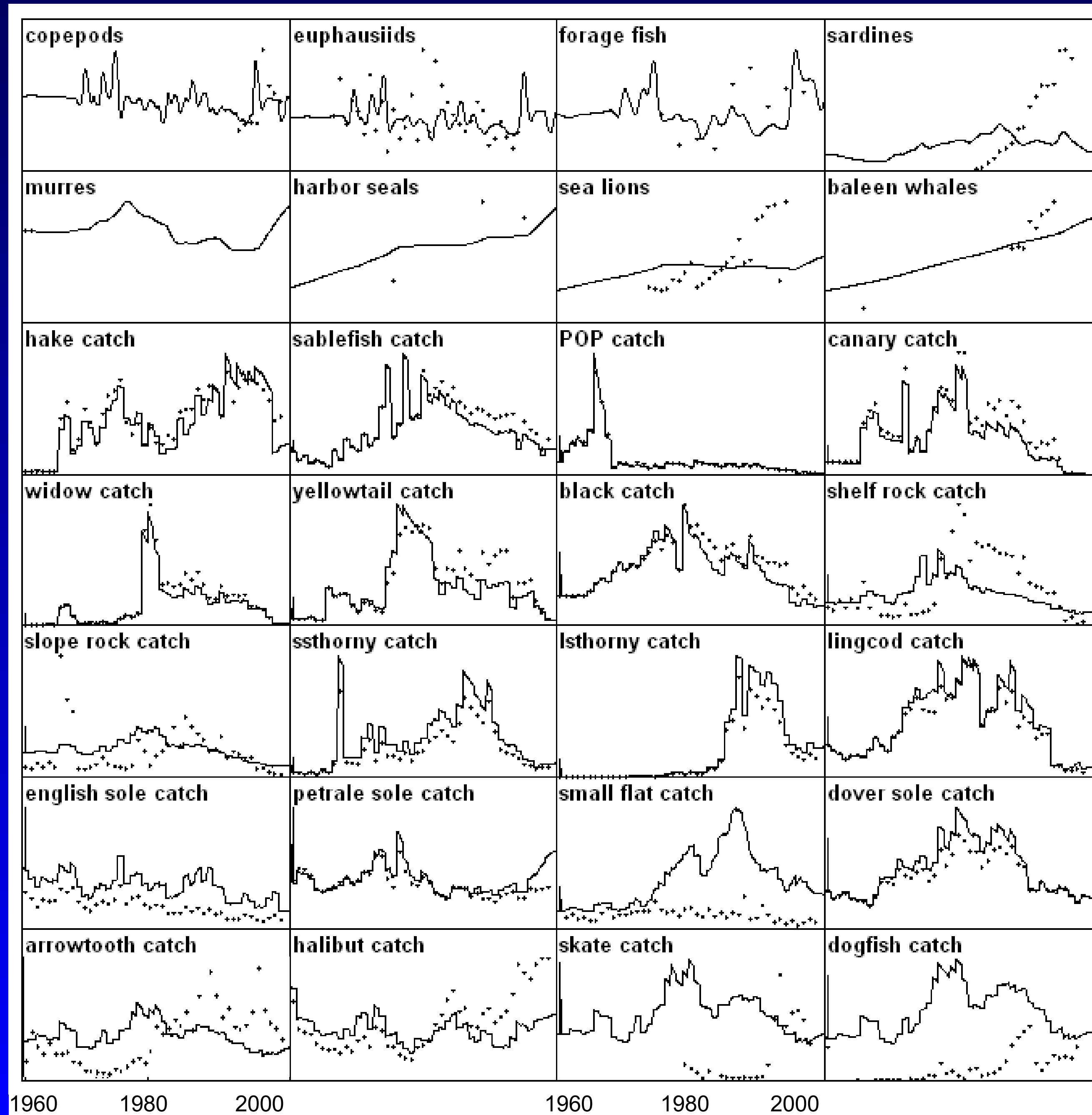
	no climate	Survival index	PDO	Survival and PDO
total negative log likelihood	-352	-389	-391	-379
likelihood ratio (relative to no climate)		73	78	53
d.f. (number climate years)		33	45	78
Chi square		0.0001	0.0017	0.9856

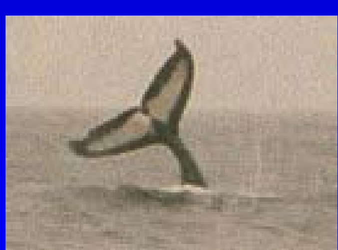
Results were also consistent over a range of baseline vulnerabilities

		no climate	survival index	PDO	survival and PDO
v=0.1	(bottom-up)	-166	-285	-301	-307
v=0.3	(mixed)	-352	-389	-391	-379
v=0.5	(top-down)	-313	-339	-397	-354

What are other components of the model doing?

(Various relative indices and catches shown for scale only, not included in likelihood)





Summary

- Climate is obviously important, and equally complex- effects can work through bottom-up and top-down processes. However for most resident groundfish, fishing is the key driver over the past 40 years

- What data we have suggest that there are relatively few major, direct trophic interactions amongst commercially exploited species in this ecosystem- exceptions include high predation on shrimp and small flatfish, and strong interactions between sablefish and thornyheads!

- Both larger scale (entire CCS, age/stage structure for hake, others) and smaller scale (specific to continental shelf/slope) models may be more appropriate for addressing more specific interactions

- Despite their limitations, models such as this can serve as a stimulus for initiating dialogues and contemplating ecosystem dynamics associated with changing ocean conditions and trophic structure