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Ecosystem Structure and Function

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Ecosystem structure & function

Structure: who, what, where?

Species (taxon) distribution and abundance.

Function: when, how fast?

Transfer rates (feeding, growth, production, mortality).

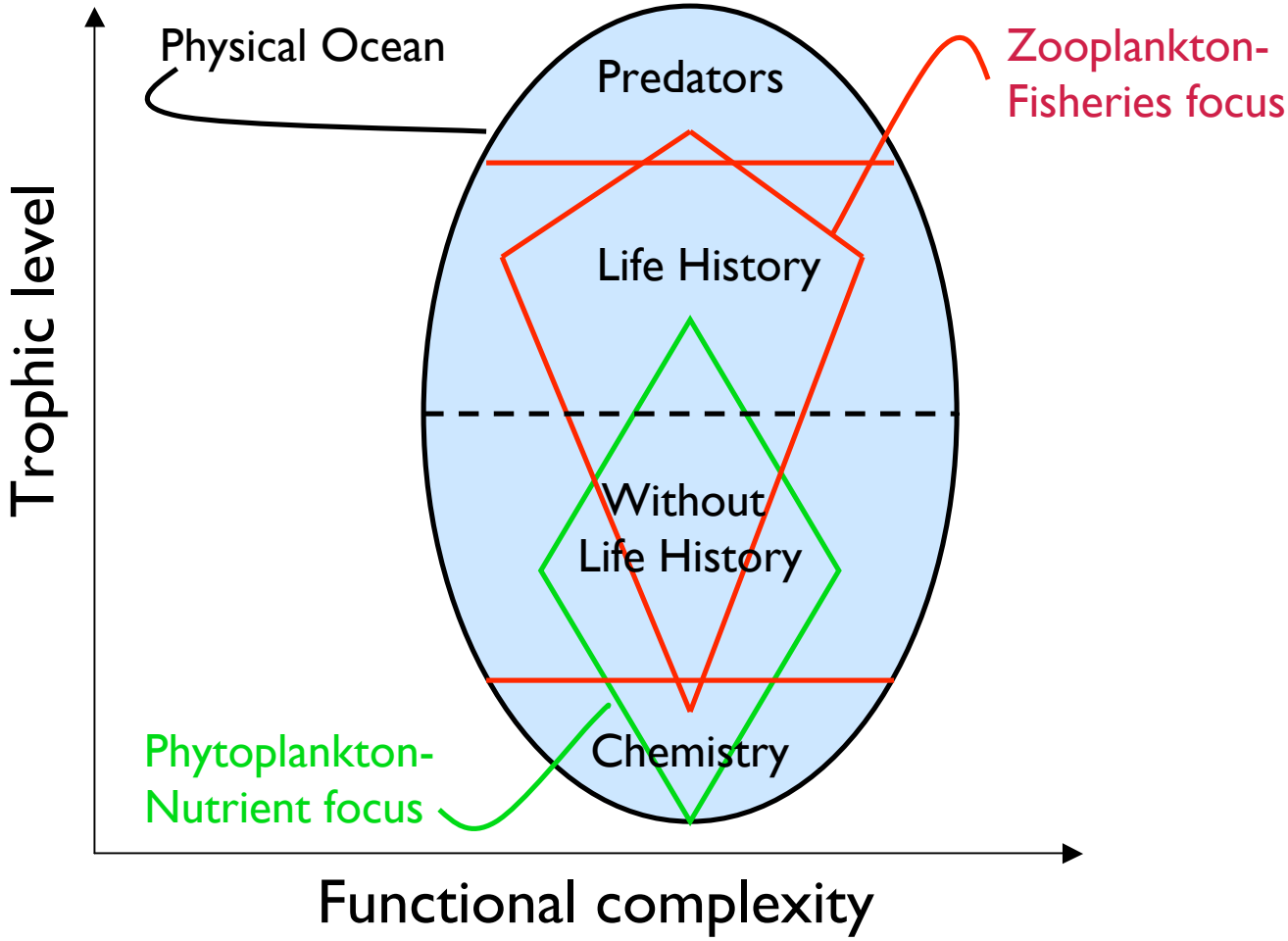
Ecosystem Structure and Function

- What is the role of individual species dynamics in determining ecosystem and food web dynamics?
- How has climate forcing altered ecosystem structure and function across regions?
- What are the characteristics that contribute to the resilience and sensitivity of ecosystems?
- To what extent does the strength of climate effects in systems result from different anthropogenic and/or historical effects?
- How does climate change impact the range and distribution of predators and their impacts on ecosystems?

Species-centric vs. food-web approach

- **Species-centric approach** is directed at understanding population dynamics, interannual variability, and biological-physical coupling in the target species. ⇒GLOBEC
- **Trophic-centric approach** is directed at understanding the entire ecosystem. In the GLOBEC context, this includes the long-term effects of climate forcing, based on the assumption that this forcing is propagated through the food web.
- The two approaches are complementary; the approach used depends on the questions being asked.
- There is no single model that can integrate across trophic levels and provide taxonomic resolution (deYoung et al. 2004. Science 304:1463-1466).

Species-centric v. trophic-centric



Example of the trophic-centric approach

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Balancing end-to-end budgets of the Georges Bank ecosystem

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The Big Question

Q: Is biological production on Georges Bank controlled by bottom-up (i.e., climate) or top-down (i.e., fishing) processes?

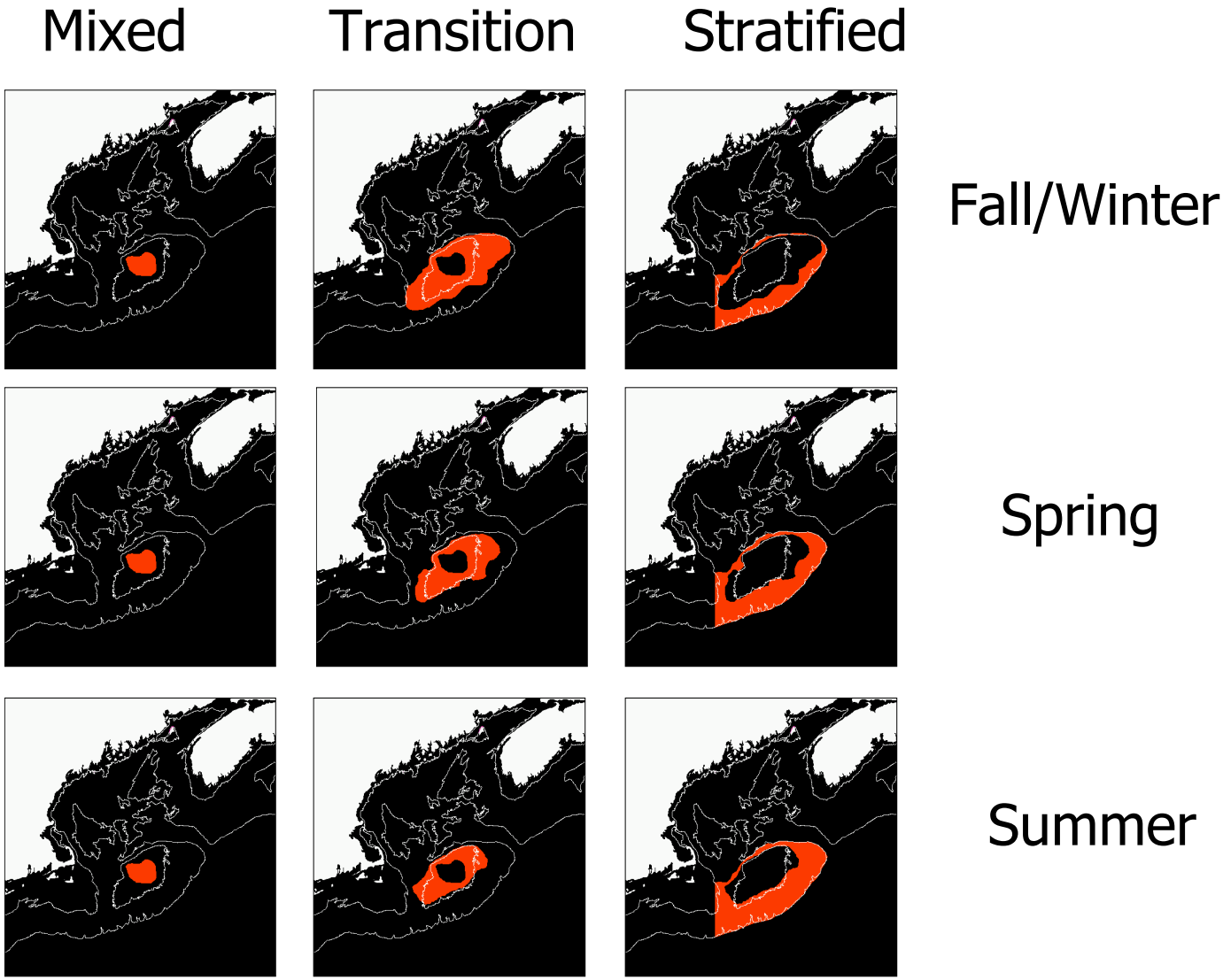
Q can be asked of ***any*** ecosystem, given sufficient data

Time-series data are useful (longer is better)

Georges Bank Data Sources

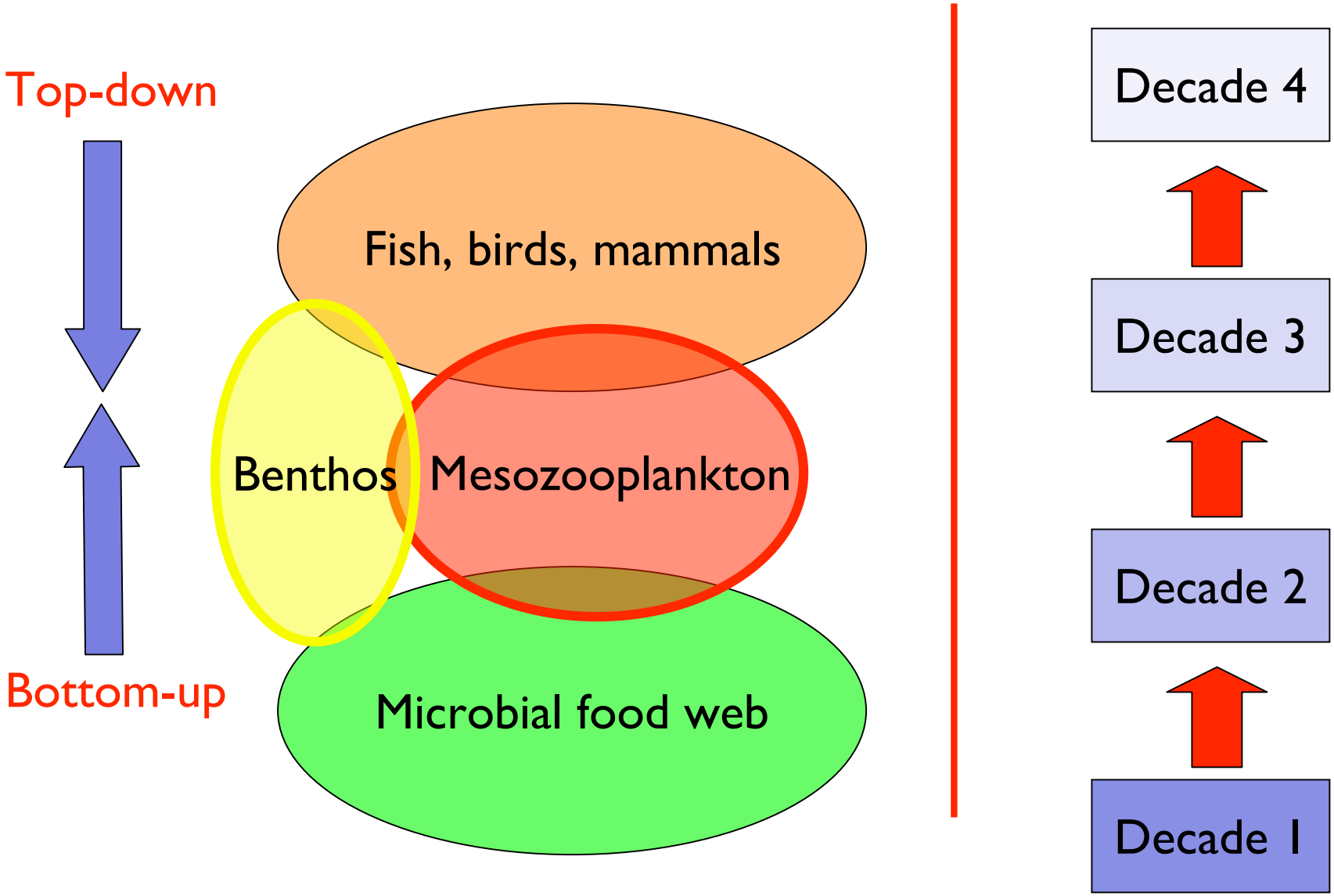
Decade	Physical Regime	Fishery Regime	Fish Community Structure	Data
1964-1972	Cold water temp	High catches distant water fleets	Abundant groundfish	CPR, NMFS Literature
1973-1984	Variable water temp & salinity	Continued high fishing	Groundfish decline Pelagics and elasmobranchs begin to increase	CPR, NMFS, Literature
1985-1994	Average water temperature	Overfishing of principal groundfish	Groundfish @ lowest levels	MARMAP, GLOBEC, NMFS, Literature
1994-2002	Warm water temp Low salinity	Reduced fishing mortality	Groundfish rebuild Max. elasmobranchs & pelagics	GLOBEC, NMFS, Literature

Spatial and seasonal domains: Water column structure and fluxes



Scientific approach:

Combine top-down (consumption-based) and bottom-up (production based) approaches to describe Georges Bank food webs over 4 decades



Upper web:

-juvenile fish

-3 fish feeding guilds

-carnivorous ZP

-carnivorous benthos

Lower web:

-nutrients

-2 categories PP

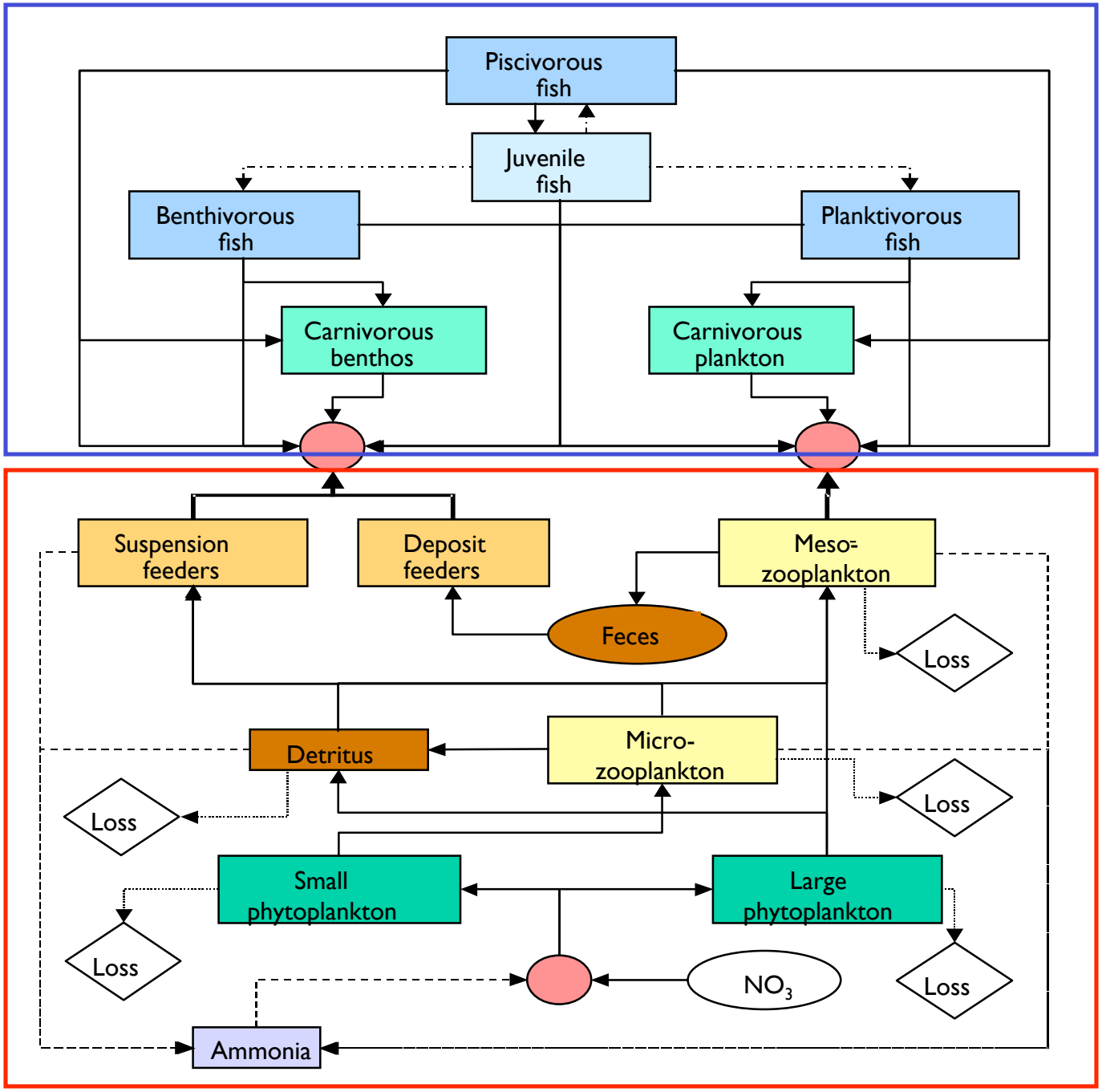
-detritus, feces

-μzp

-mesoZP

-DF+SF benthos

-N recycling



Stepwise calculation of the entire web

For each of 9 space-time scenarios of the lower web, find a value for the fraction of detritus recycled that gives the calculated *f*-ratio for that scenario, with the maximum growth efficiency of mesozooplankton in the range 0.1-0.3.

Integrate the outputs of the microbial web to give annual totals of fluxes of mesozooplankton, benthic suspension feeders and benthic deposit-feeders for the entire Bank.

Use fish biomass and diet data to calculate average annual food requirements of fish from intake of plankton and benthos for each decade.

Estimate the fraction of these intakes that come from fluxes of mesozooplankton, benthos, and invertebrate predators on the plankton and benthos.

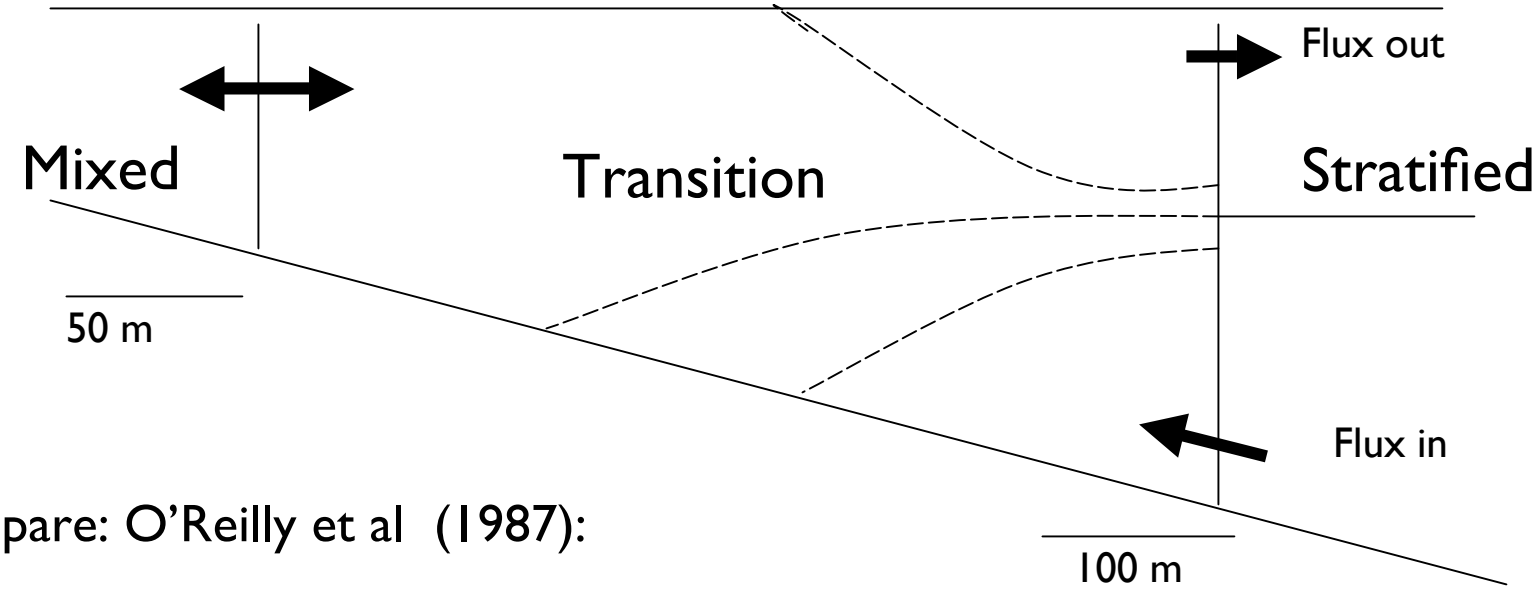
Compare available observations with calculated values of microzooplankton, mesozooplankton, pelagic invertebrate predators and suspension- and deposit-feeding benthos.

Example of results 1:
Most new production occurs in the transitional region

Spring Season

New production ($gC/m^2/yr$)

79 180 91



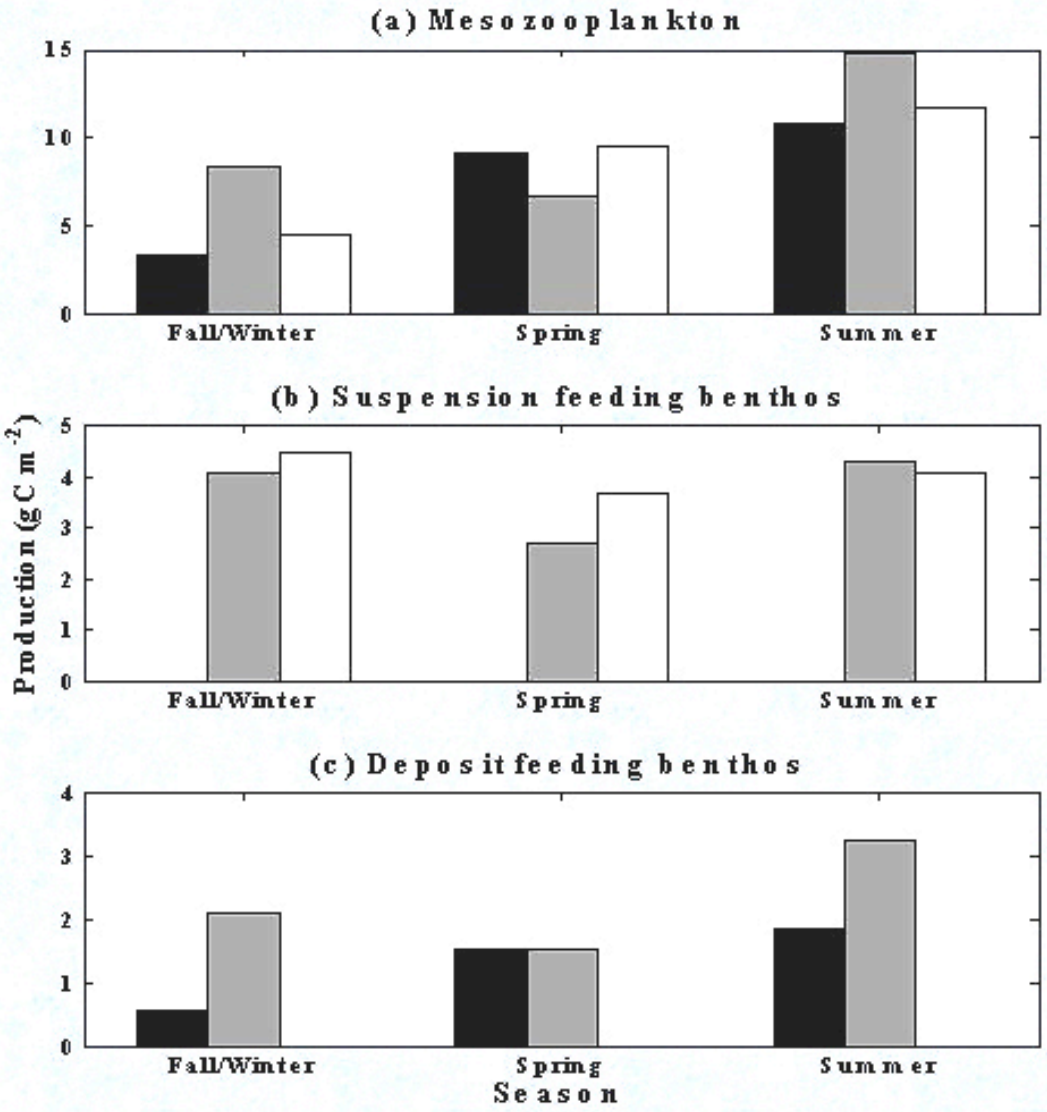
Compare: O'Reilly et al (1987):

Net production from ^{14}C

455 310 265

f = *0.17* *0.58* *0.34*

Example of results II: Regional + seasonal cycles of mesozooplankton + benthos production

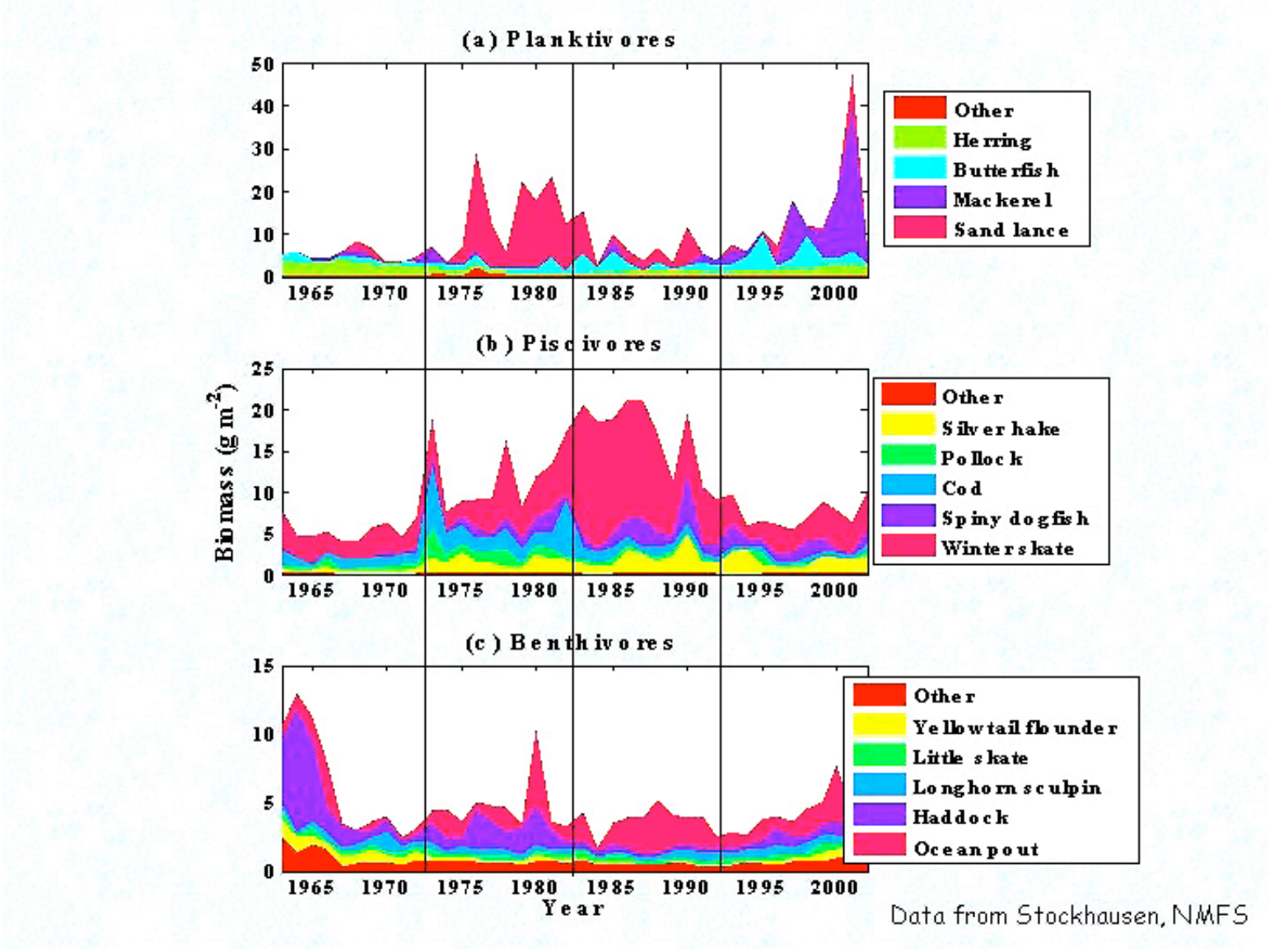


Spatial zones

- Stratified
- Transition
- Mixed

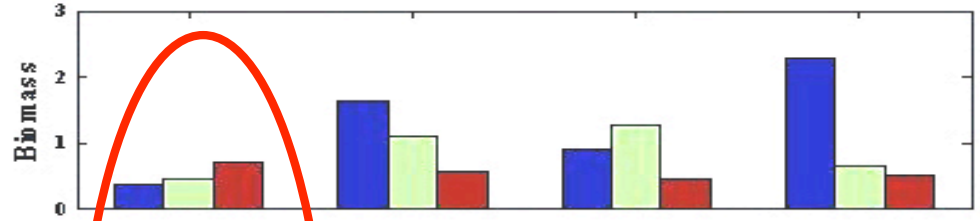
Integrated production ($gC\ m^{-2}\ yr^{-1}$)	
Zooplankton	27.0
Benthos	10.5

Example of results III: Fish biomass on Georges Bank is distributed among different trophic guilds and species over 4 decades. Recent shift to planktivores.



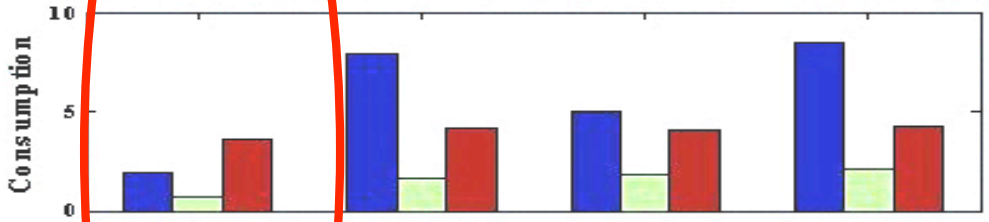
Example of results IV: Where does material & energy go?
The decade 1963-1972 is different.

Food requirements of recruited fish guilds



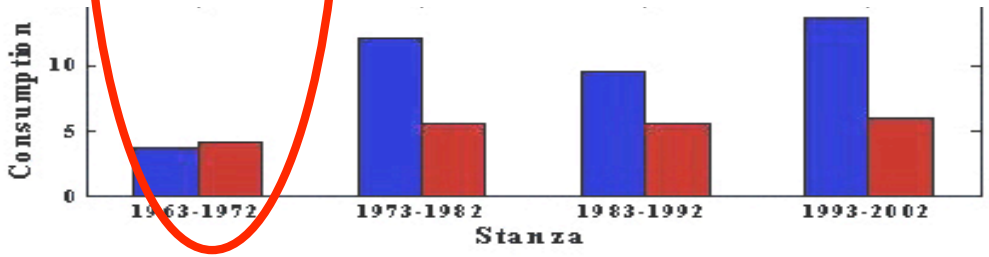
Planktivores
Piscivores
Benthivores

Total consumption by fish guilds



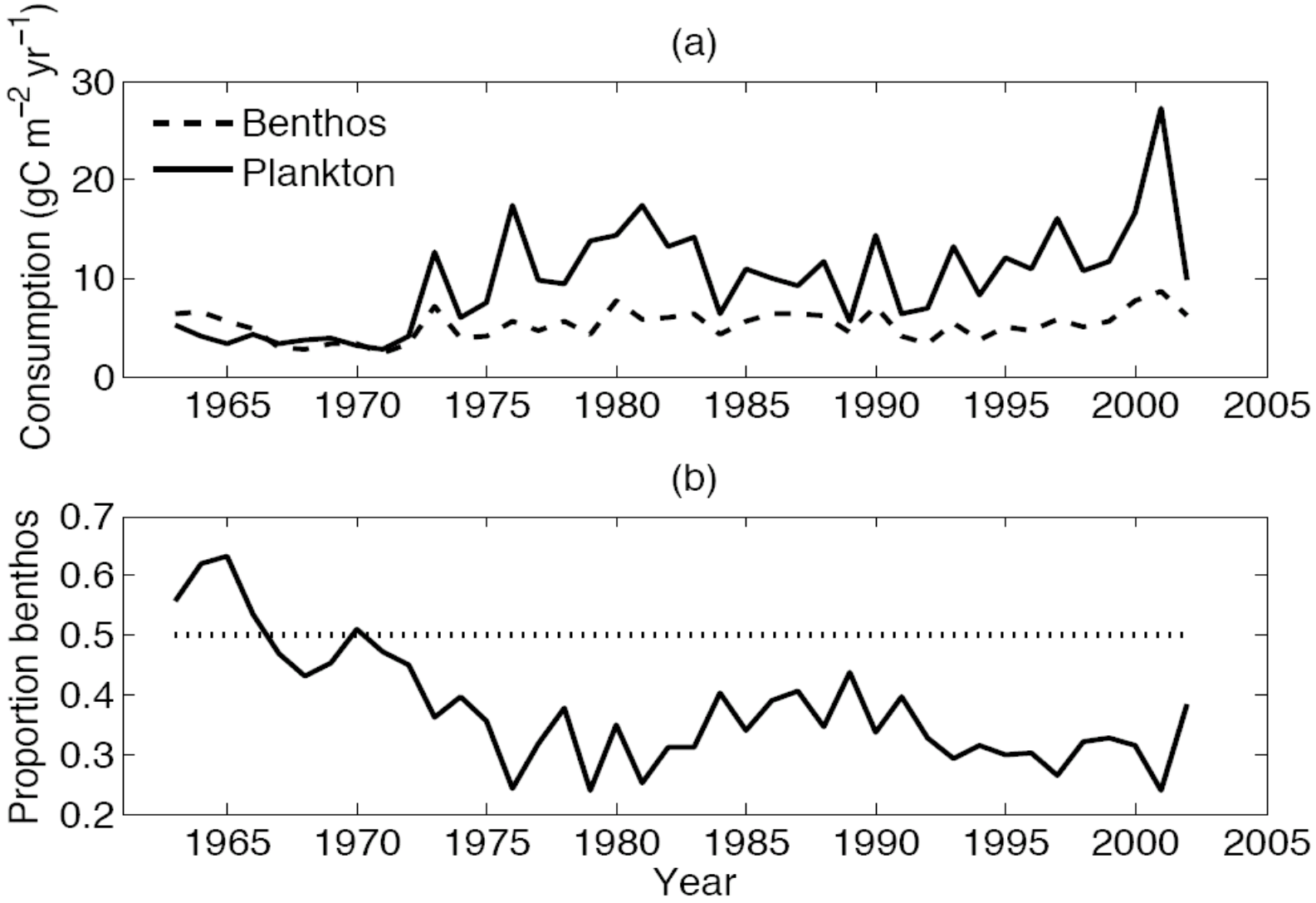
Plankton
Fish
Benthos

Food requirements of all fish in plankton and benthos equivalents

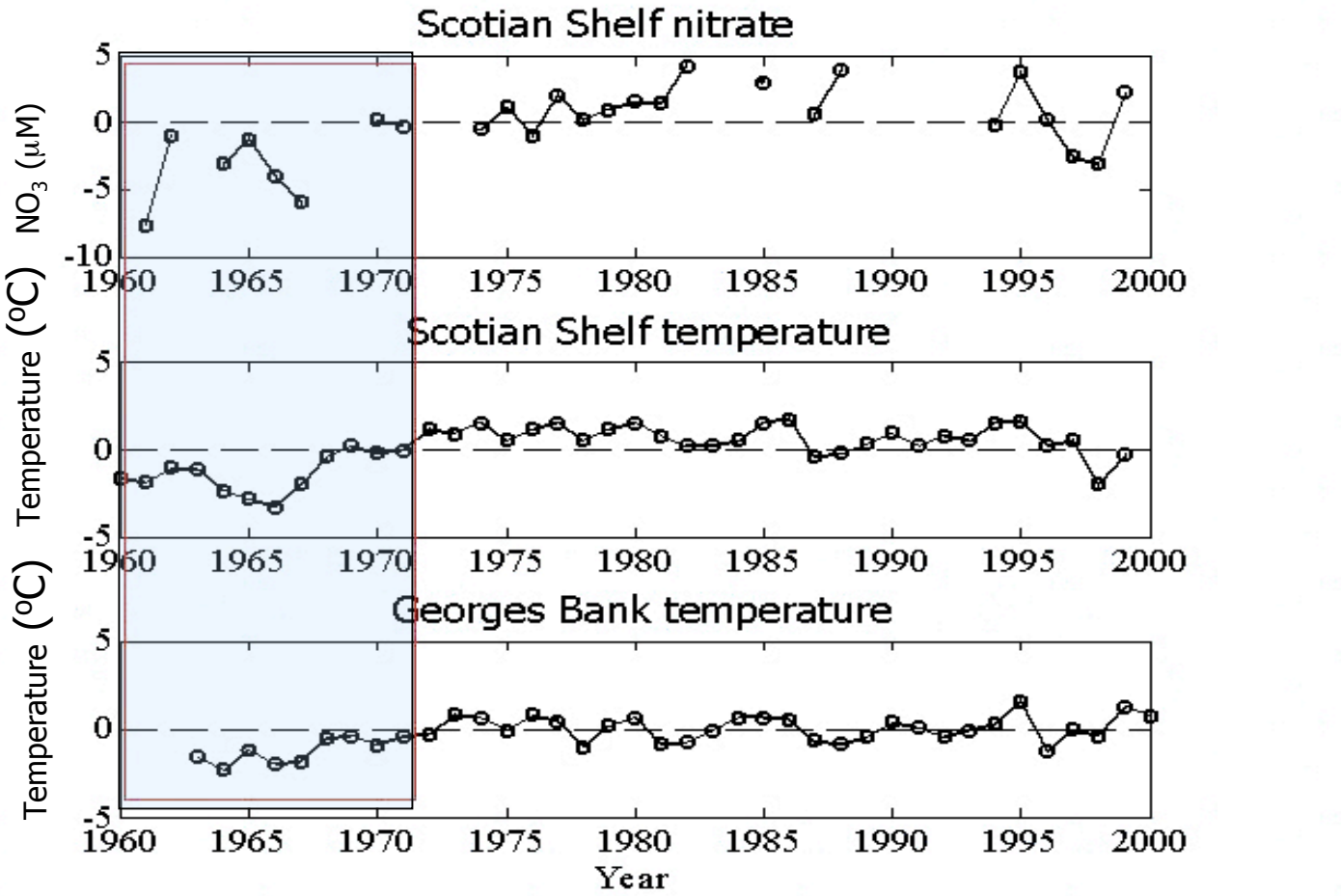


Plankton
Benthos

Example of results V: The ratio of plankton consumed relative to benthos has increased since 1970

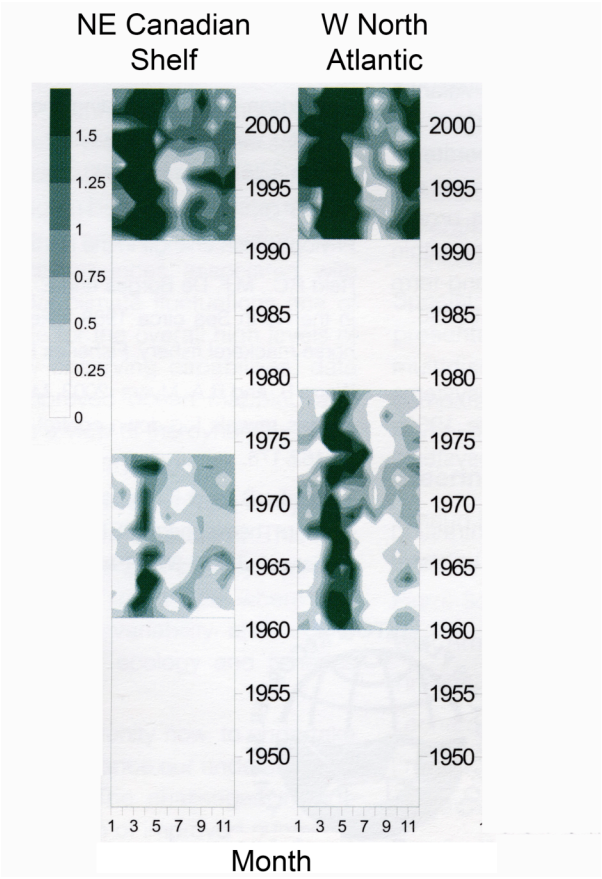


Upstream forcing was different during the first decade

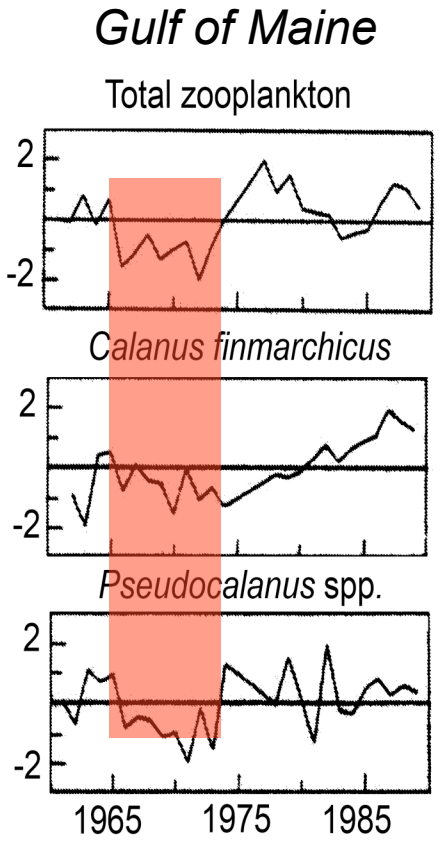


from Petrie and Yeats (1997)

Other evidence for climatic differences during the 1960s



P.C. Reid, *SAHFOS Newsletter*, October 2005



J.W. Jossi & J.R. Goulet, *ICES Journal of Marine Science*, 50: 303-313, 1993

Conclusions from the food webs

- The lower food web accounts for recycling, spatial and seasonal differences, and advective losses
- Commercially-important species have been replaced with non-commercial species
- Consumption of plankton by fish has increased relative to consumption of benthos
- There is evidence of bottom-up control of fish production in the 1960s
- Outputs from the lower food web limit fish production
- Therefore, recovery of the commercial fish species requires reductions in non-commercial species

Some other kinds of questions we are able to ask:

Q: What happens to cod (or any target species) if we alter the food web?

Q: How do altered nutrient inputs impact the upper web?

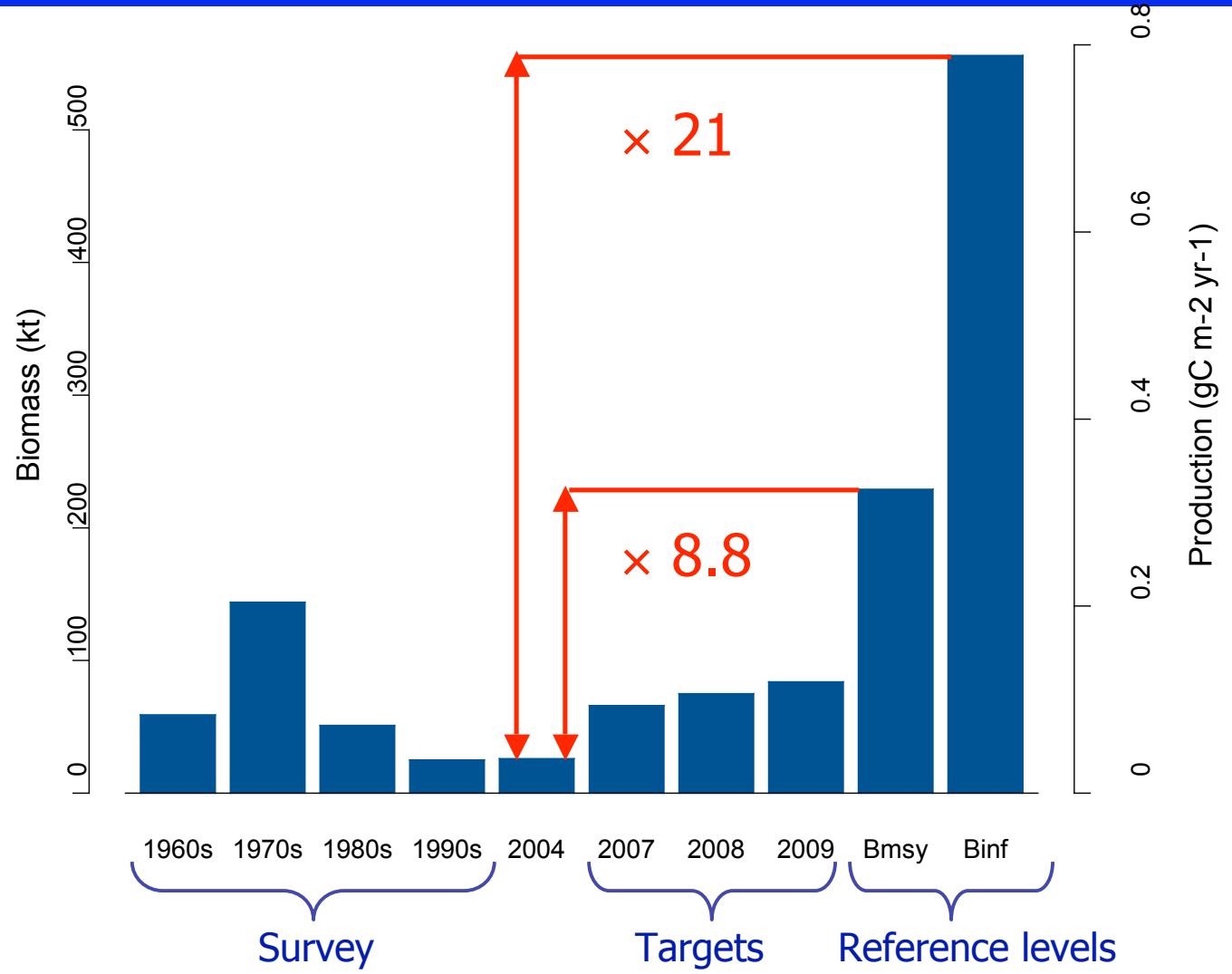
Q: What happens if carnivorous ZP (jellies) are eliminated?

Q: What happens if microzooplankton are reduced or increased?

Q: Does reducing the flux of PP to the benthos affect the upper web?

Etc……..

Q: Is there enough food on GB to support a recovered cod stock?



What does it take to construct end-to-end energy budgets for GLOBEC study regions?

- Interdisciplinary expertise
- Time series of biota, chemistry, physics, climate: the longer the better
- Standing stocks of all trophic levels, not just target species
- Rate measurements and transfer functions for all trophic levels, not just target species
- Knowledge of physics and fluxes
- $$$$$

Thank you