ELH Implications of Climate Change

LO: hypothesize consequences of climate change on ELH of marine fish given examples of biological responses to environmental variability

The Greenhouse Effect

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

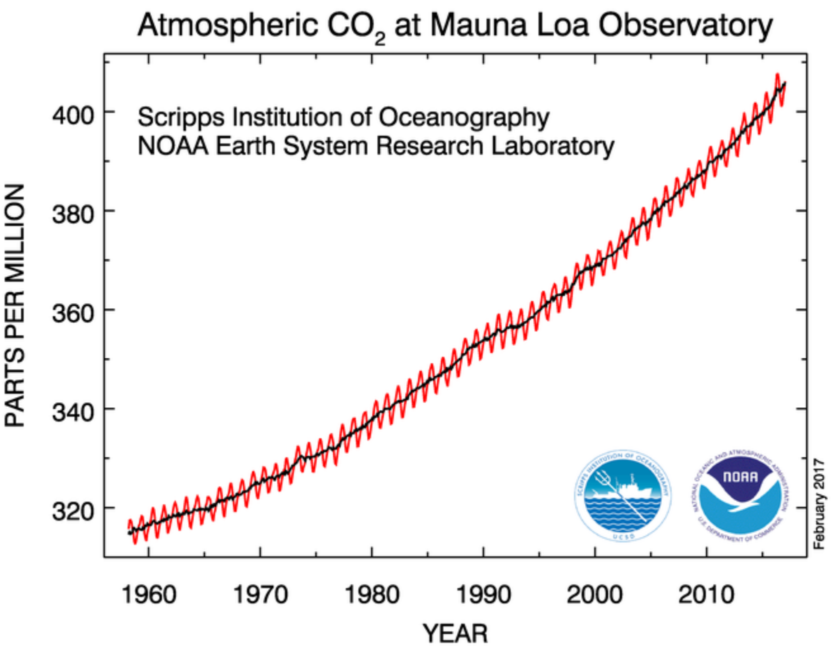
XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground. By* Prof. SVANTE ARRHENIUS *.

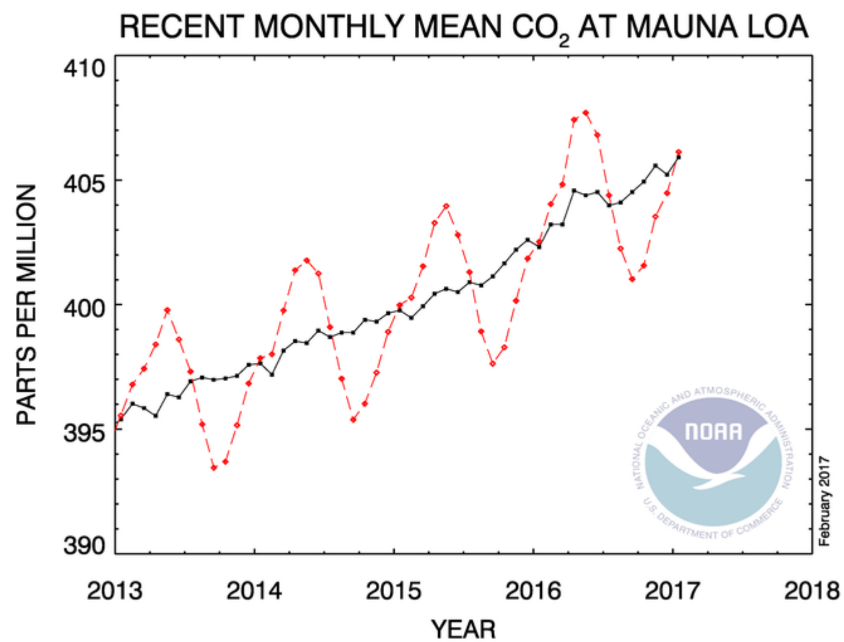
I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this : Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet § ; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to —200° C., if that atmosphere did not possess the quality of selective

Atmospheric CO_2

rising by approximately 2.7% per year since 1900



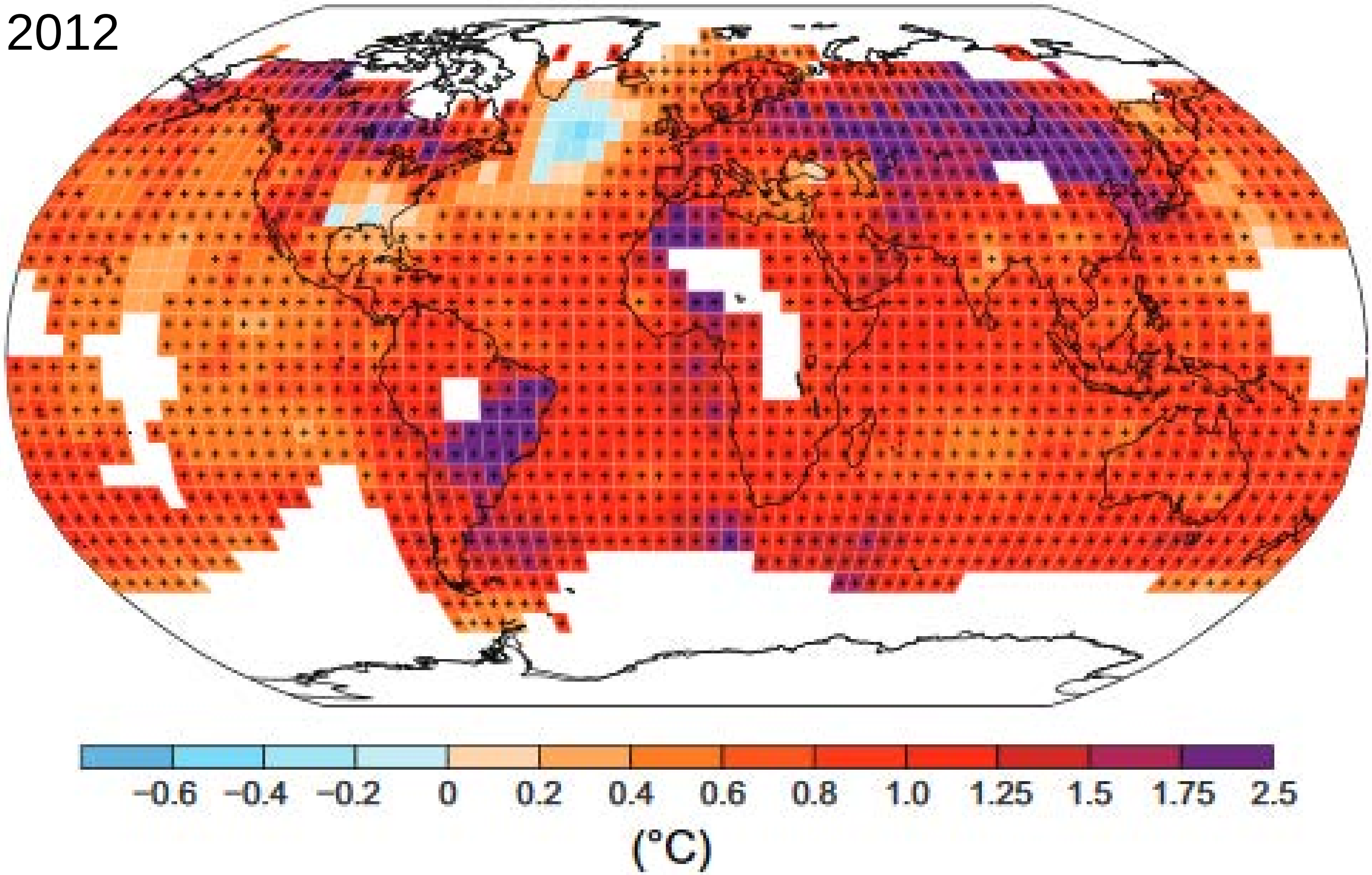


		from:	*to:*
carbon dioxide	(CO_2)	0.028 %	0.038 %
methane	(CH_4)	0.00008 %	0.00017 %
nitrous oxide	(N_2O)	0.000028 %	0.000032 %

http://www.esrl.noaa.gov/gmd/ccgg/trends/

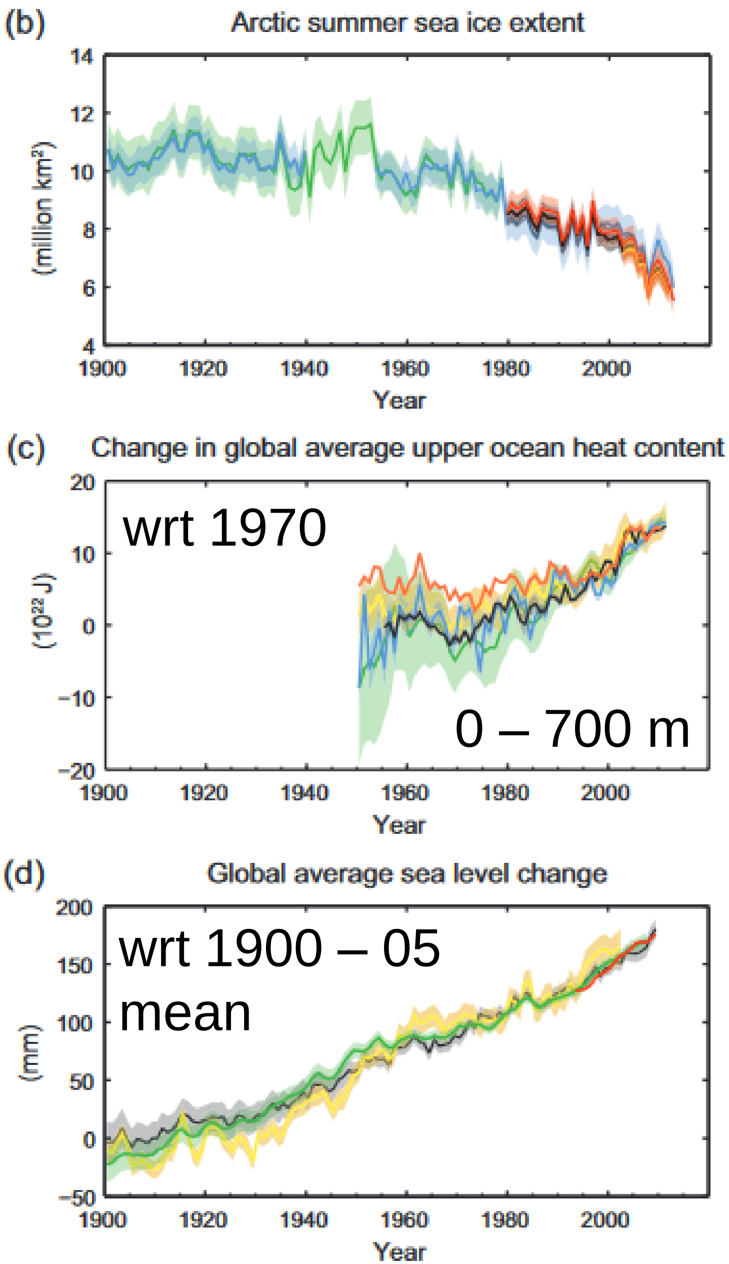
Surface Temperature Anomalies

1901 - 2012



- oceans still warming, except for Northern Atlantic
- takes 2-3 decades before temperature hits half of equilibrium temperature increase

Global Ocean Changes



Jul, Aug, Sept

Upper Ocean Heat Content (ZetaJ=10^{21} J)

- Ocean’s heat capacity is ~1000 times that of the atmosphere’s
- Heat uptake has been 20 times that of the atmosphere since 1960
- >90% of stored energy from 1971-2010 in ocean

IPCC WGI 5th Assessment,

Depth-Latitude Temperature Trends

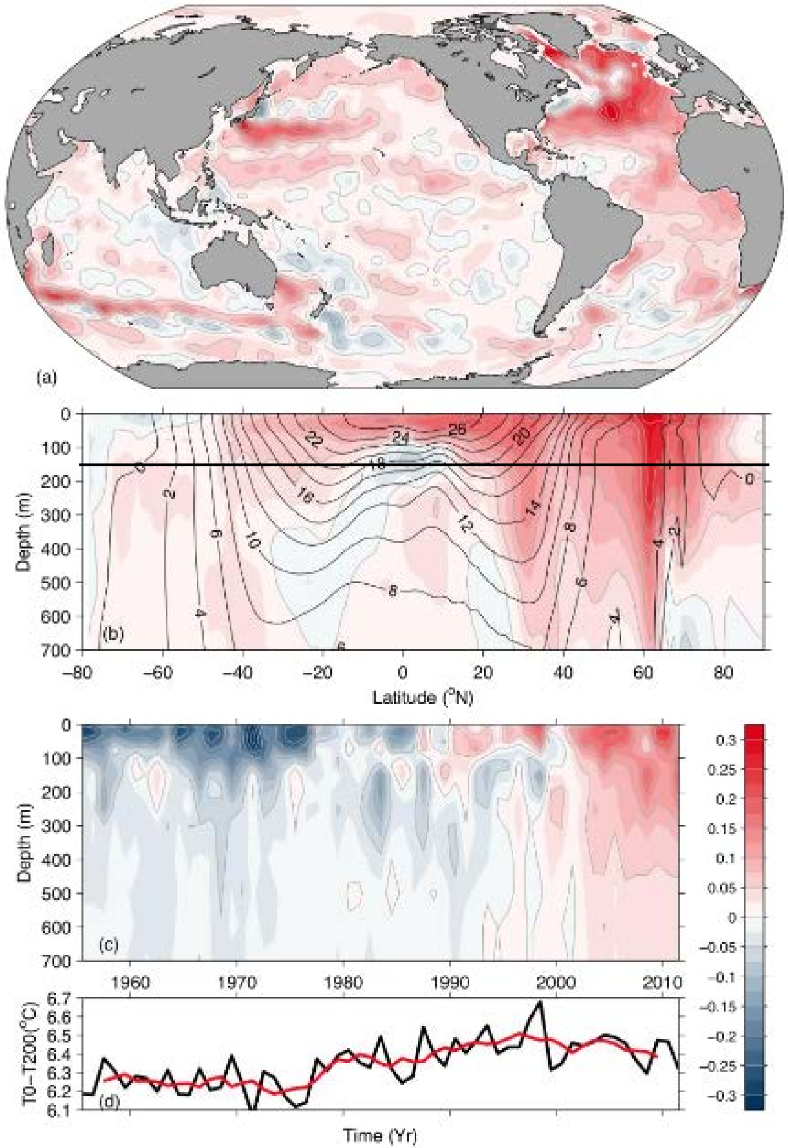
0 – 700 m

Latitude

Temperature anomaly

Δ T 10-200 m

annual, 5 yr



- most warming in upper 150 m

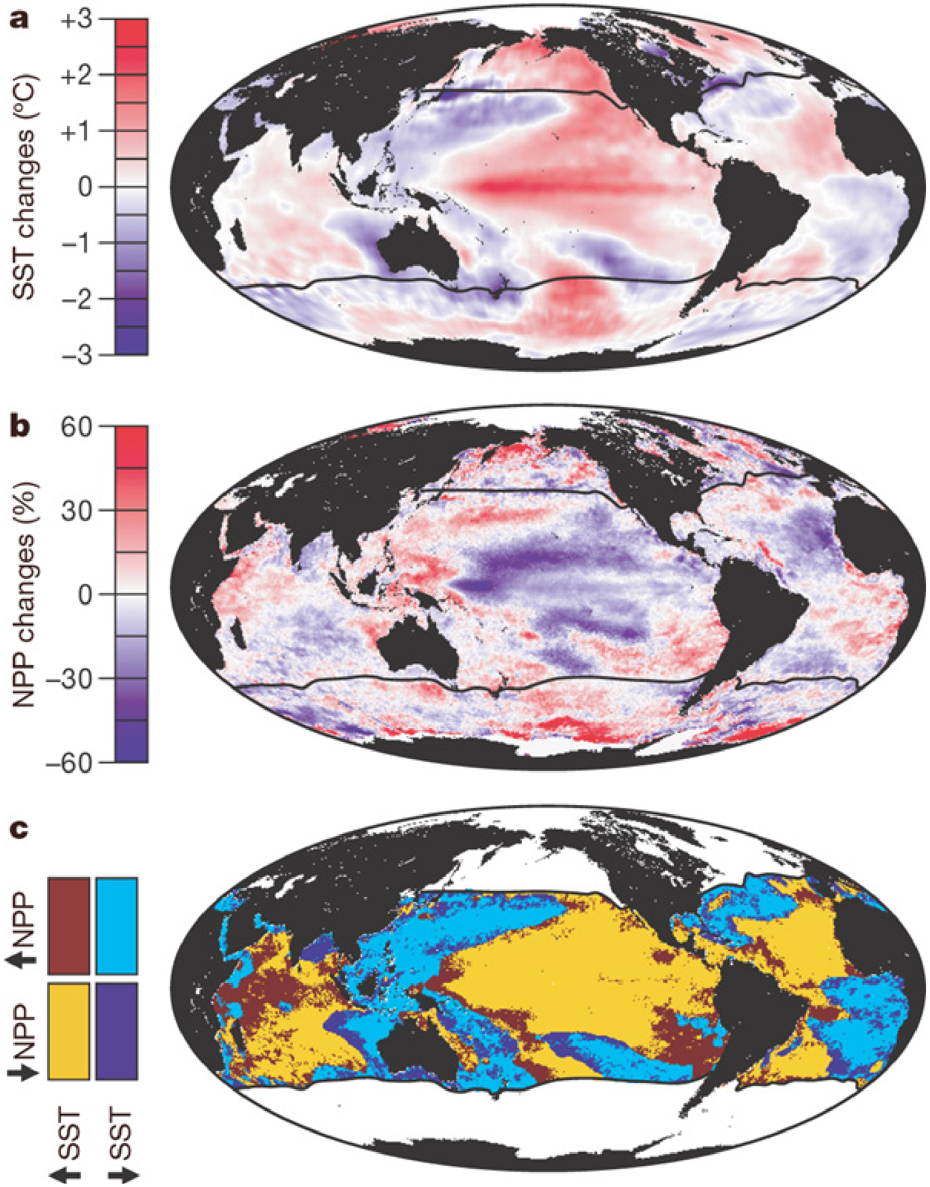
- increased stratification

data from Levitus et al. (2009)

IPCC WGI 5th Assessment, Chapter 3

SST and Net Primary Productivity (NPP)

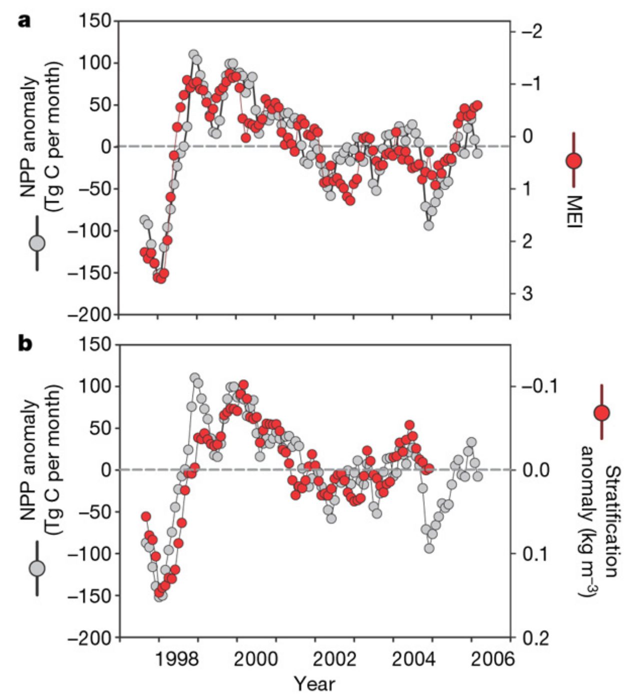
1999-2004



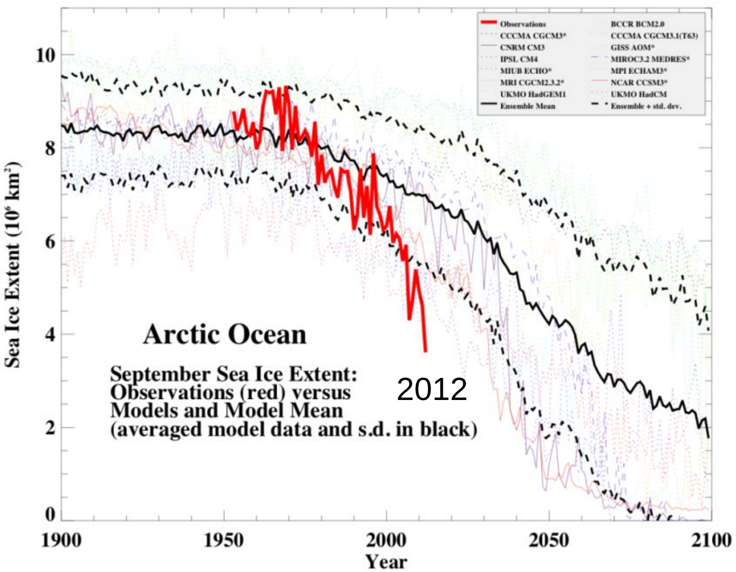
Behrenfeld et al. 2006: Nature

Chlorophyll and NPP anomalies in the stratified oceans are highly correlated with ENSO

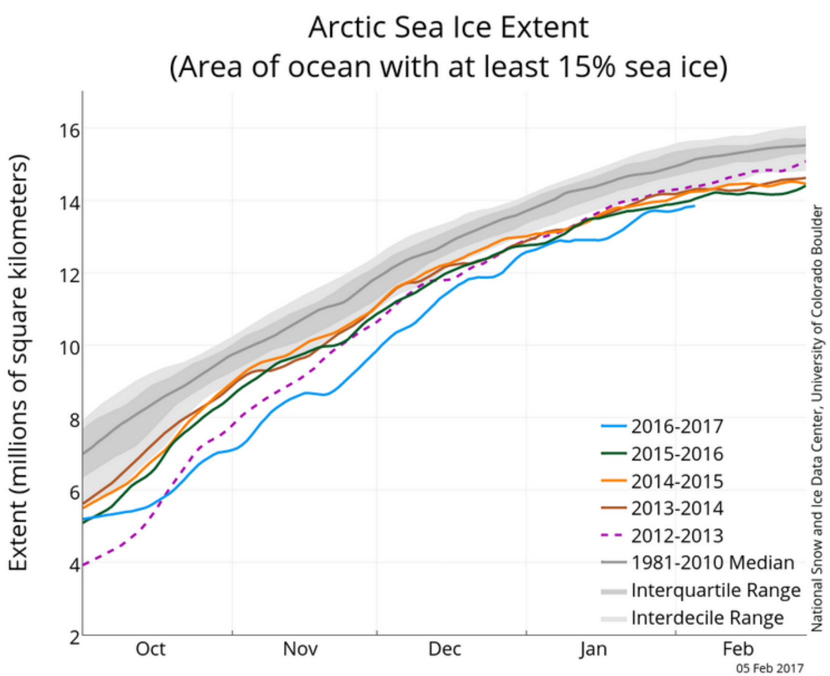
NPP-Multivariate ENSO Index $r^2=0.77$

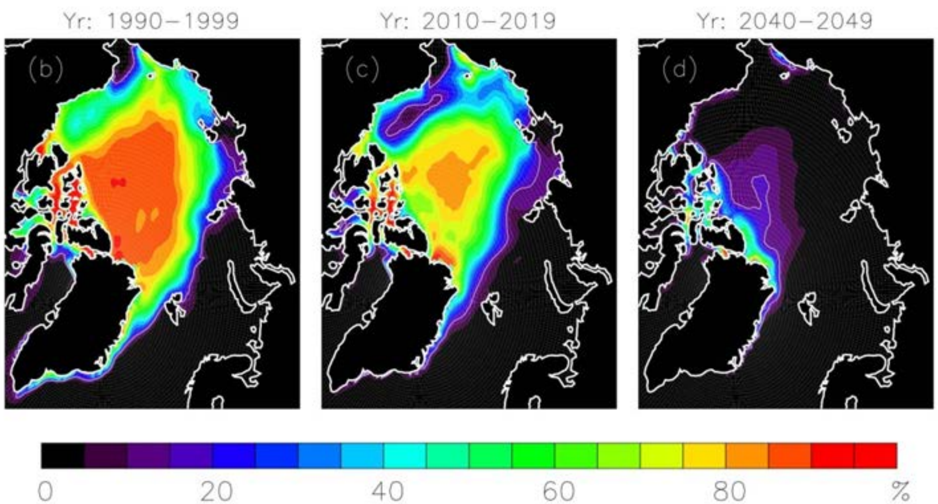


Loss of Sea-Ice



Influences of natural oscillations that alter heat transports to the Arctic + increased greenhouse gases leads to a rapid (near total) loss of summertime Arctic sea ice by 2040 in one of 7 different simulations with the same climate model





Holland et al. 2006

Key Issues for ELH of Marine Fish

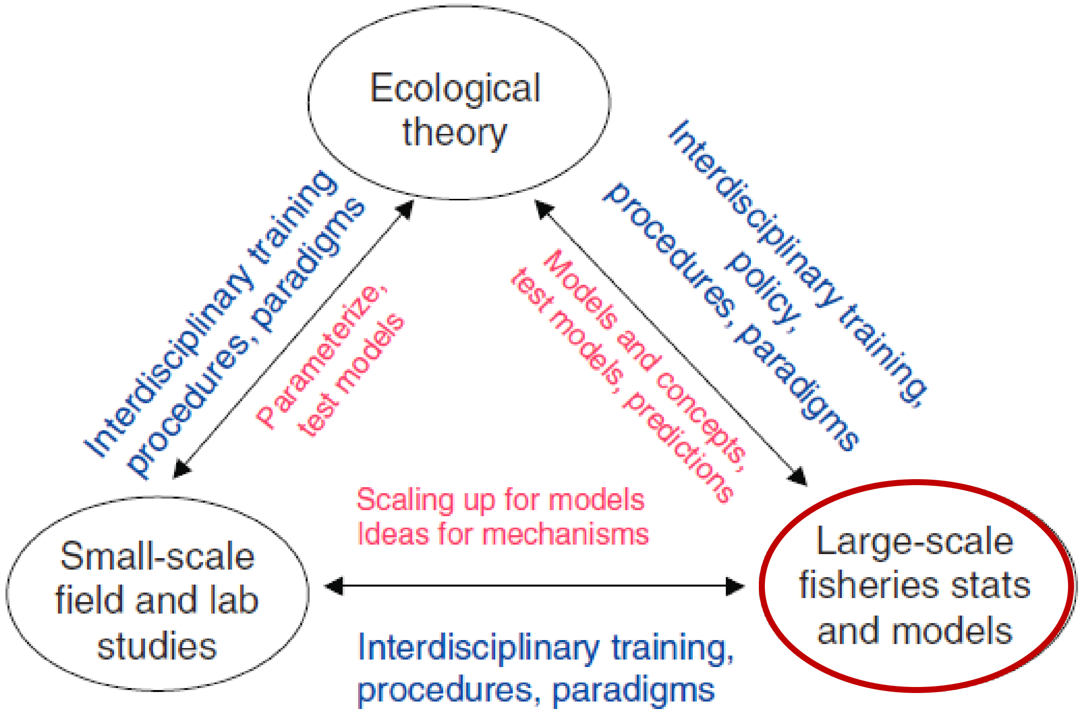
What will be the effect on fish ELH of:

1. future warming and will be concentrated in the upper ocean
2. year-to-year and multiyear regional climate variations due to: winds, ENSO cycles, PDO cycles, Regime Shifts)
3. summertime sea ice declines likely
4. rising sea level likely
5. low-productivity “tropics” expansion with upper ocean warming
6. upper ocean will be become more acidic

US/NOAA Management Directives

1. Magnuson Stevens Fishery Conservation & Management Reauthorization Act
2. Endangered Species Act
3. Marine Mammal Protection Act
4. Marine Sanctuaries Act
5. Coastal Zone Management Act/NERRS
6. Coral Reef Conservation Act & Task Force
7. International Treaties, Bilateral Agreements, Commissions & Councils

NMFS Management Approach



- recognition of scale differences
- can be conducted independently
- catalysts for advances: interdisciplinary training, changes in marine policy, advances in technology and philosophy

Hollowed & Bailey 2009

Main Sources of Uncertainty

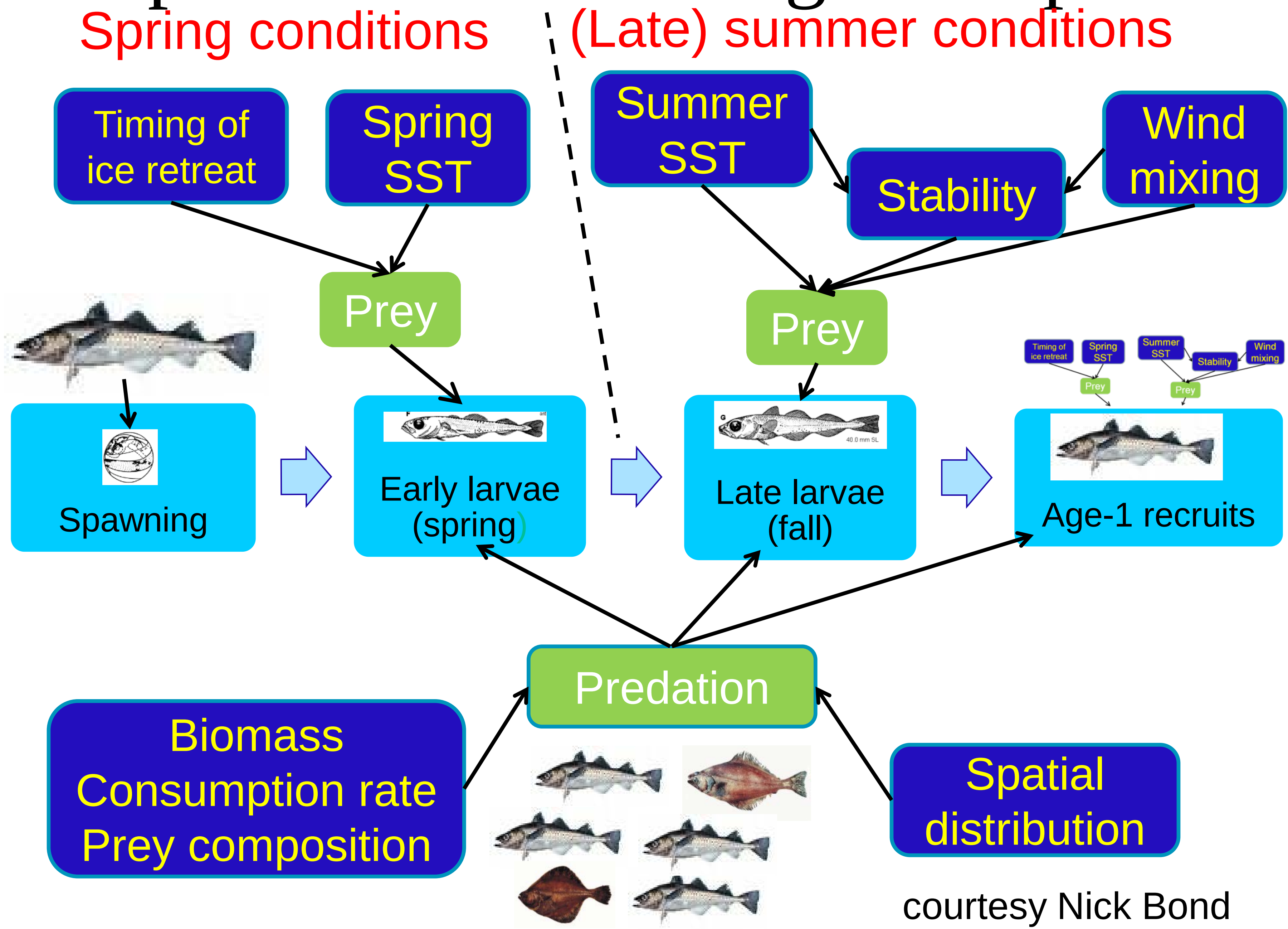
1. Future emissions of greenhouse gases
    - Can't predict how key factors (demographic, social, political, economic, technological, and environmental) will unfold in the future, so use scenarios.
2. Climate sensitivity
    - Imperfect knowledge on how climate functions leads to uncertainty in responses to any change in greenhouse gas changes, so climate models with different parameter values are used to test climate sensitivity

Potential Modeling Approaches

- Empirical downscaling: Ecosystem indicators for stock projection models are projected from IPCC global climate model simulations.
- Dynamical downscaling: IPCC simulations form the boundary conditions for regional bio-physical numerical models with higher trophic level feedbacks.
- Fully coupled bio-physical models that operate at time and space scales relevant to regional domains (impractical at present).

courtesy Nick Bond

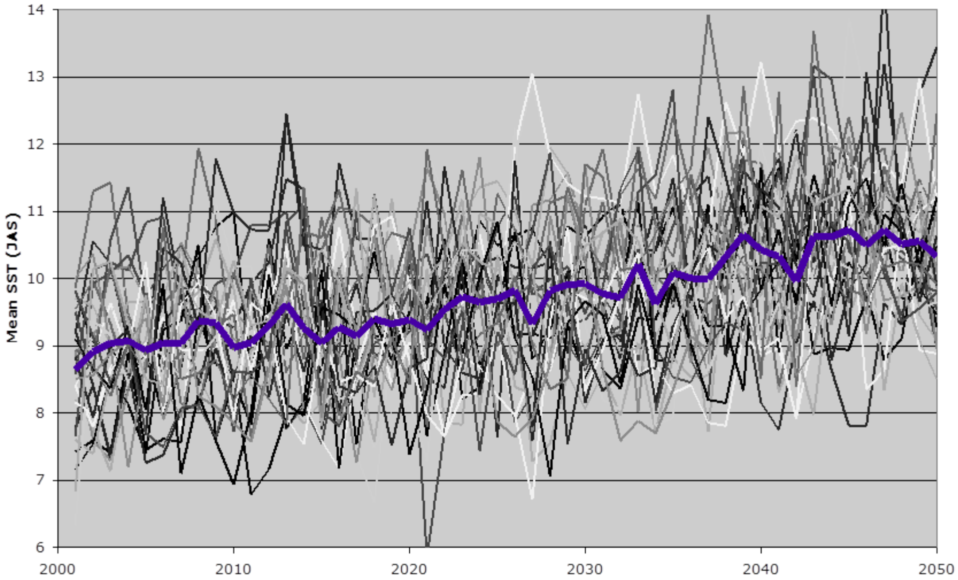
Empirical Downscaling Example



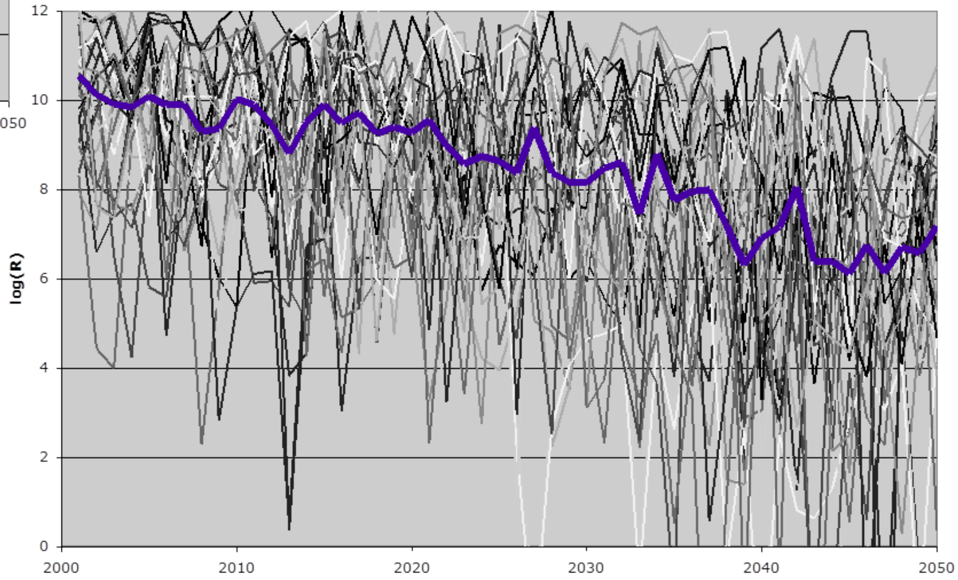
courtesy Nick Bond

Indices derived from Climate Models

Bering Sea SST



Pollock Recruitment



A1B IPCC scenario

courtesy Nick Bond

Quasi-quantitative Assessment of Global Climate Model Capabilities

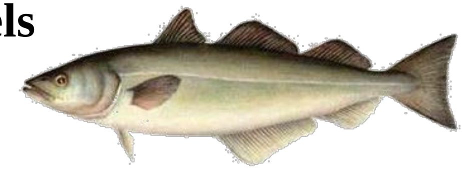
Parameter	Rationale	Reliability
Large-scale mean pressure/wind patterns	Upper ocean advection; Surface forcing for ROMS	Very Good
Large-scale upper ocean T/S and currents	Direct estimates; Lateral BCs for ROMS	Good
Sea ice (Winter/Spring)	Cold pool extent; Nature of spring bloom	Good
Spring bloom timing	LTL Community; Pollock recruitment?	Fair/Poor
Summer SST	Stratification; Mixed layer depth	Fair
Summer wind mixing	Stratification; Nutrient re-supply	Good

courtesy Nick Bond

Dynamical Downscaling Example

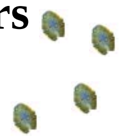
FEAST: Forage and Euphausiid Abundance in Space and Time

Higher trophic levels
(Pollock etc.)



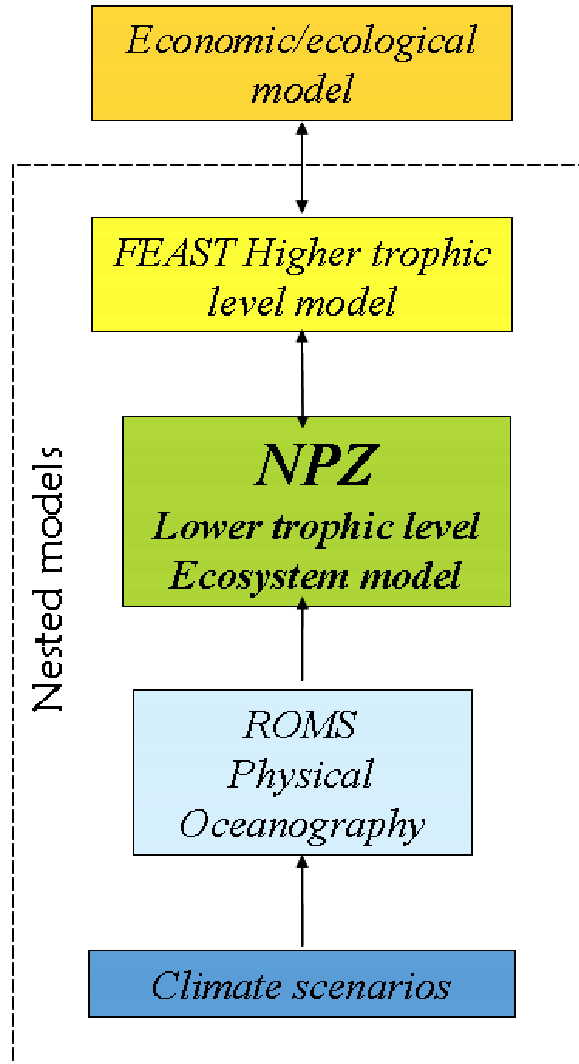
Secondary Producers
(Zooplankton)

Primary Producers
(Phytoplankton)

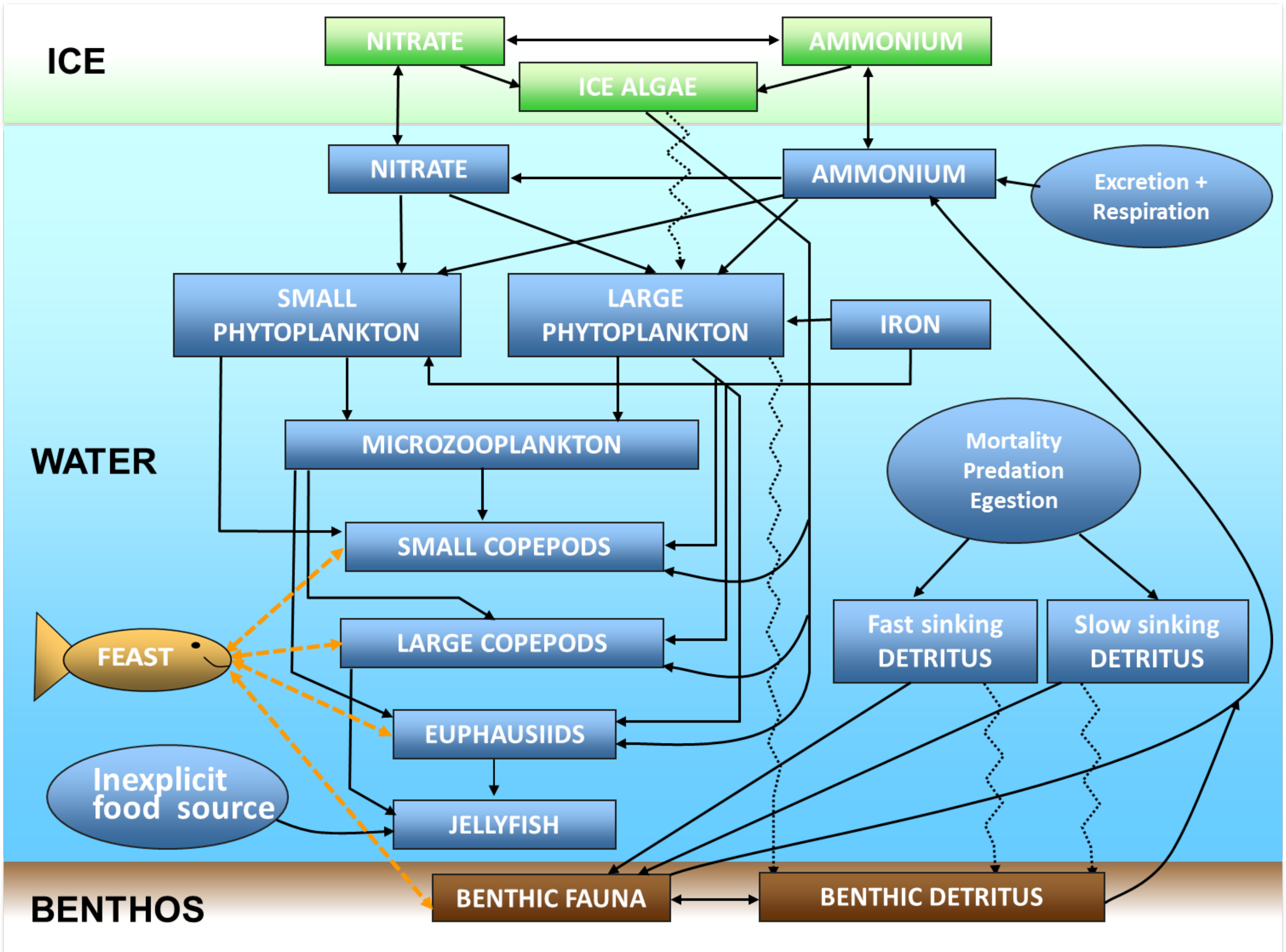


Nutrients
NO_3, NH_4…

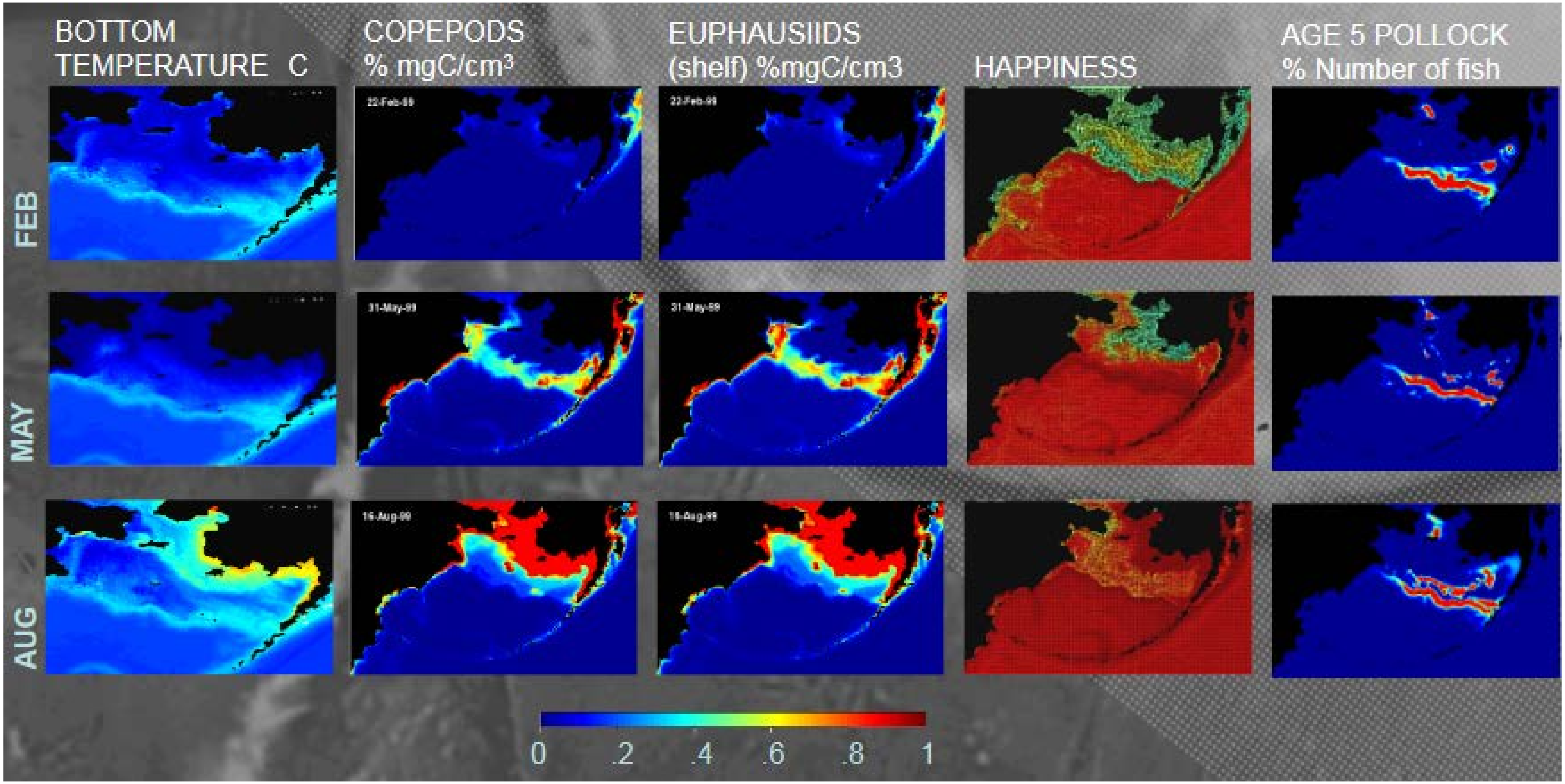
Physical Forcing
(Wind, temp, sun)



FEAST Model Components



FEAST Model Output



Empirical vs Dynamical Downscaling Models

	Empirical	Dynamical
Advantages	interpretable results, computationally cheap, easy to modify, uncertainty quantifiable, scenario driven	interaction-based, include emergent properties, explore processes
Constraints	no extrapolation, relationships data-dependent, no emergent properties	modeling expertise, interpretation difficult, computationally expensive, mechanistic understanding limited (non-linear)
Discrepancy Sources	dependent on empirical indices	dependent on initial conditions and forcing, sensitive to assumptions