Centre de Recherche Halieutique Méditerranéenne et Tropicale

IRD Institut de recherche pour le développement

Modeling and observations: How do they interact (parameterization to data assimilation)?

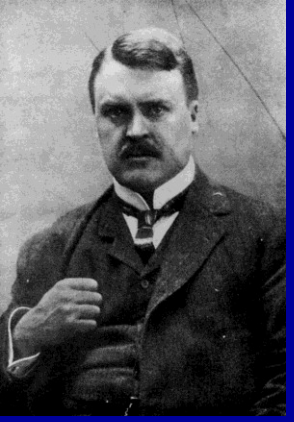
A fisheries perspective

Philippe Cury, Yunne-Jai Shin
Morgane Travers

Workshop on Ocean Biology Observatories

Venice – 16-18 September 2009

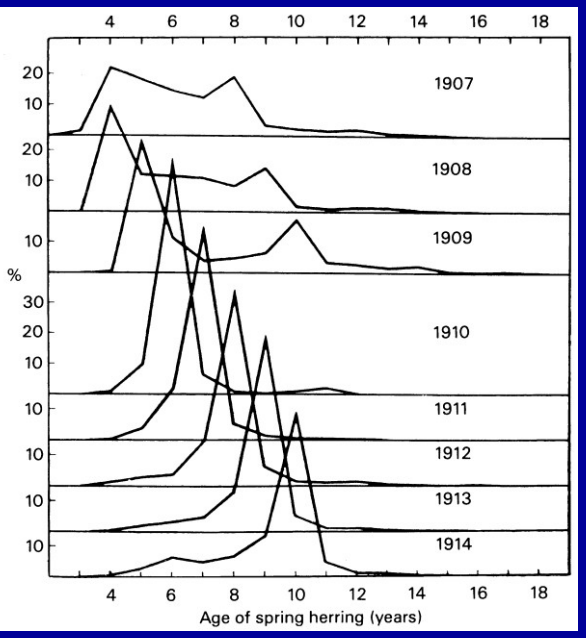
Local Context



‘Fisheries oceanography’

Hjort (1869-1948)

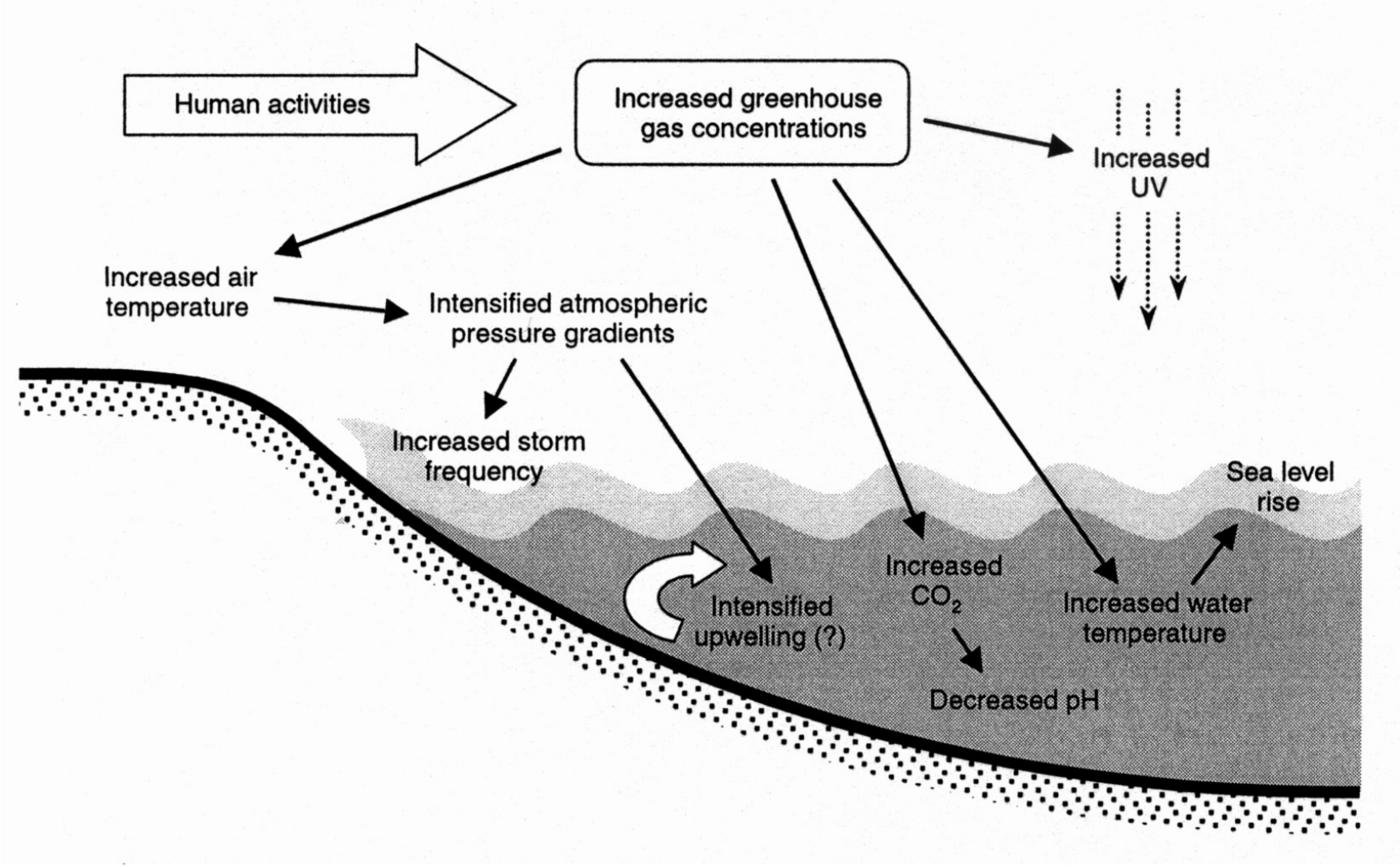
Analysing the very irregular number of young herring and cod fish in the northern Atlantic, Johan Hjort stated in 1914: ‘the renewal of the (fish) stock … must depend upon highly variable natural conditions’



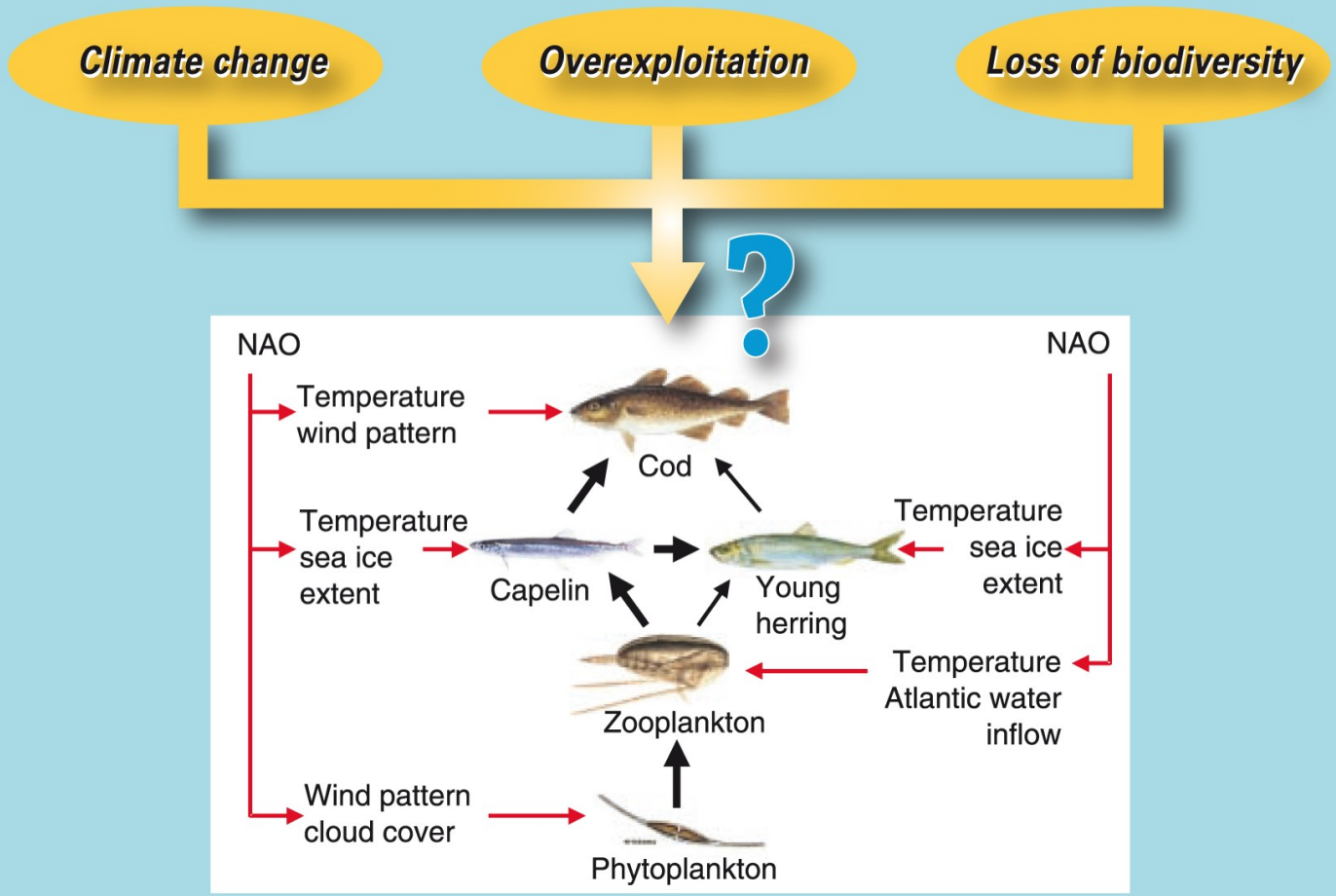
Global Context(s)

Global change & Sea changes

(Harley C. D. et al. 2006)



Global Change & Marine Ecosystems: building scenarios for the future (IPBES)



Towards ‘Ecosystem Oceanography’

Scientific question :

Who is controlling whom, when, and for how long in a context of global changes?

Technical questions :

How to integrate Global Change effects (i.e. climate and fisheries) into models?

How far should we go into complex models?

Which data do we need?

Ecosystems Models & data

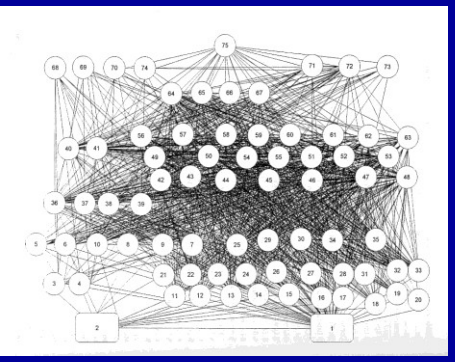
'Process oriented' data ⟷ *Time series*

Multiple TS

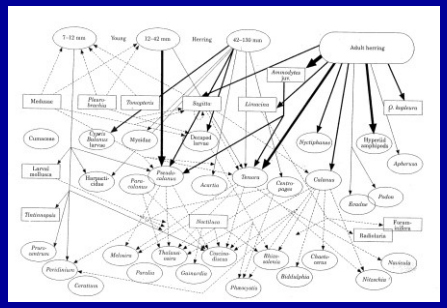
processes ⟷ *patterns*

complexity ⟷ *simplicity*

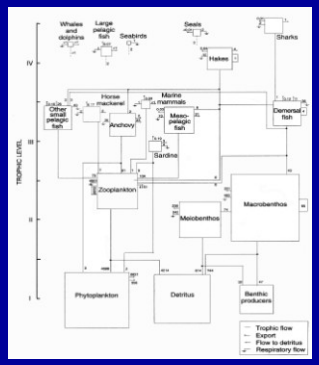
integration ⟷ *aggregation*



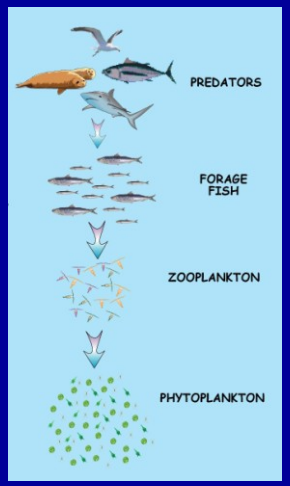
Complex and multiple Interactions



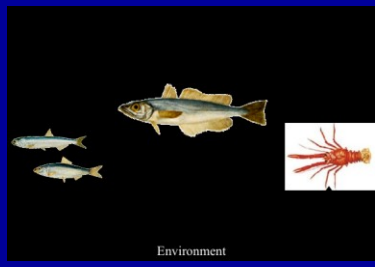
Food-Webs with preferential trophic interactions



Trophic levels



Food-Chain



Population level

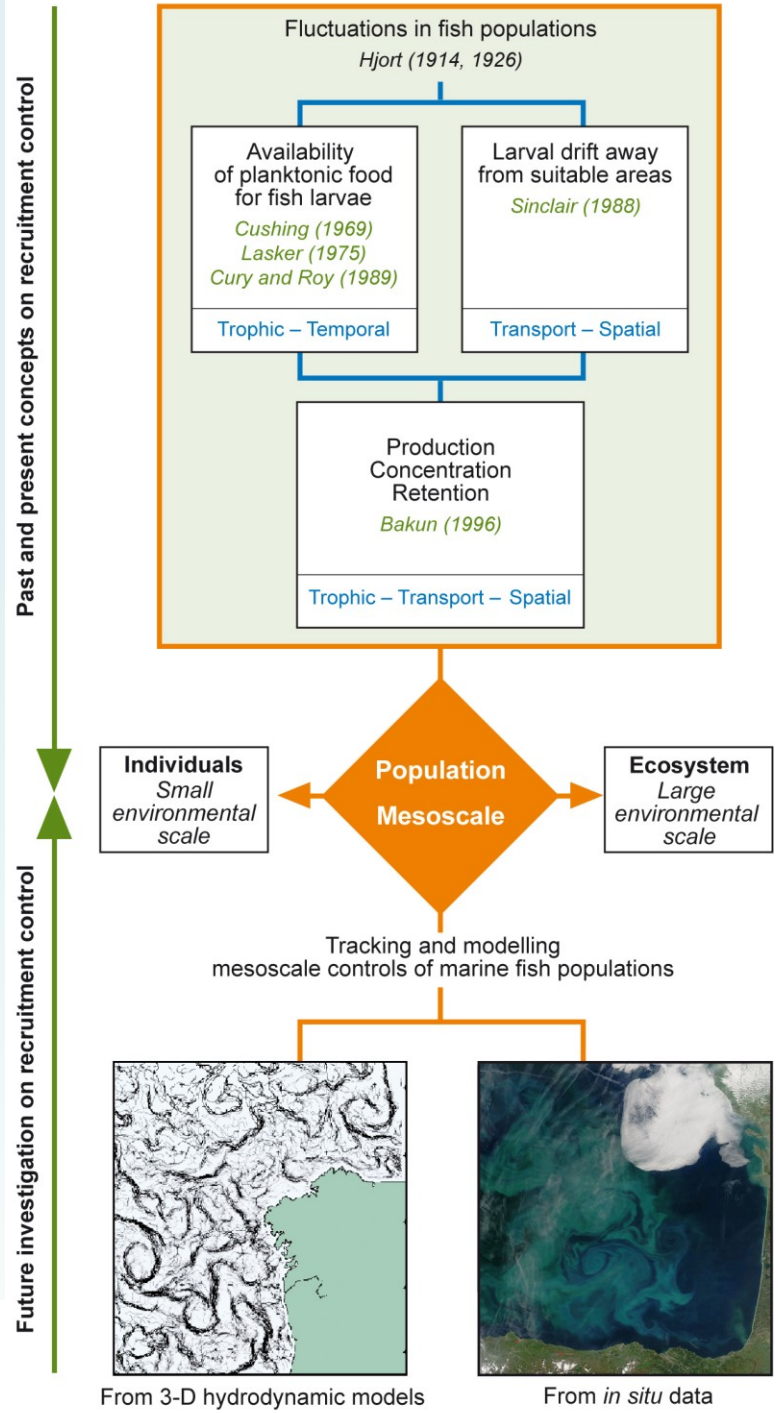
1. Linking Populations to climate changes

Recruitment and environmental control

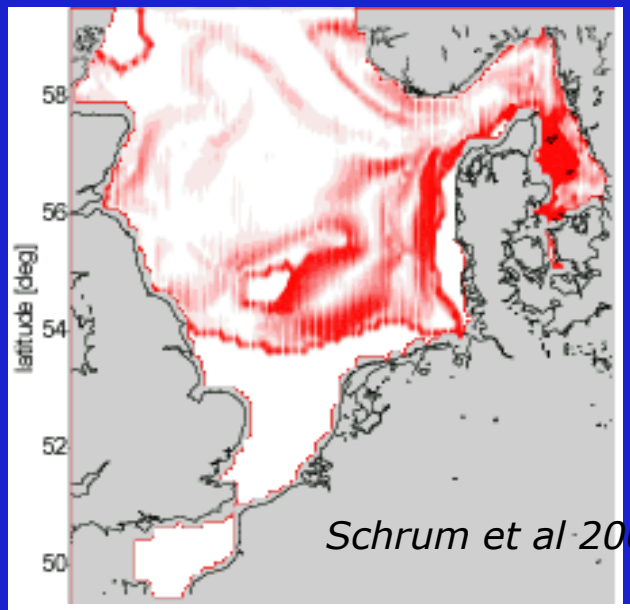
- Hjort "critical period" (1913): The Oceanographic environment affects larvae survival and has an important effect on recruitment success.
- Cushing "match-mismatch" hypothesis (1969): The production of fish larvae matches or mismatches the production of their food.
- Lasker "stability" hypothesis (1975, 1978): A stable environment is needed to allow successful feeding for larvae.
- Parrish *et al."* transport" hypothesis (1981) : Larvae transported by currents offshore are lost for the recruitment.
- Rothschild and Osborn/MacKensie "turbulence" hypothesis (1988): micro turbulences increase the encounter rates between larvae and their food.
- Cury and Roy The OEW hypothesis (1989).
- Sinclair "member/vagrant" hypothesis (1988): constraints imposed by mesoscale oceanographic events on the life cycle.
- Bakun "triad" hypothesis (1993): Retention, Production Concentration processes important to recruitment success…..

Revisit the spatial and temporal dimensions of recruitment-environment studies considering the mesoscale activity

(Planque Fromentin et al. 2007 in Cury et al. 2008)



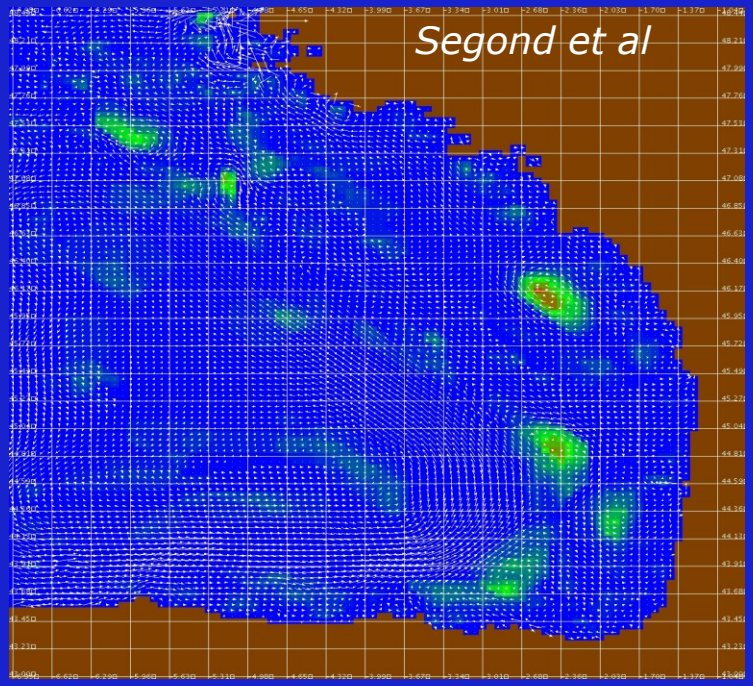
Revisiting the spatial and temporal dimensions of recruitment-environment studies (ICES/Eur-Oceans-wkims & wkamf WGs)



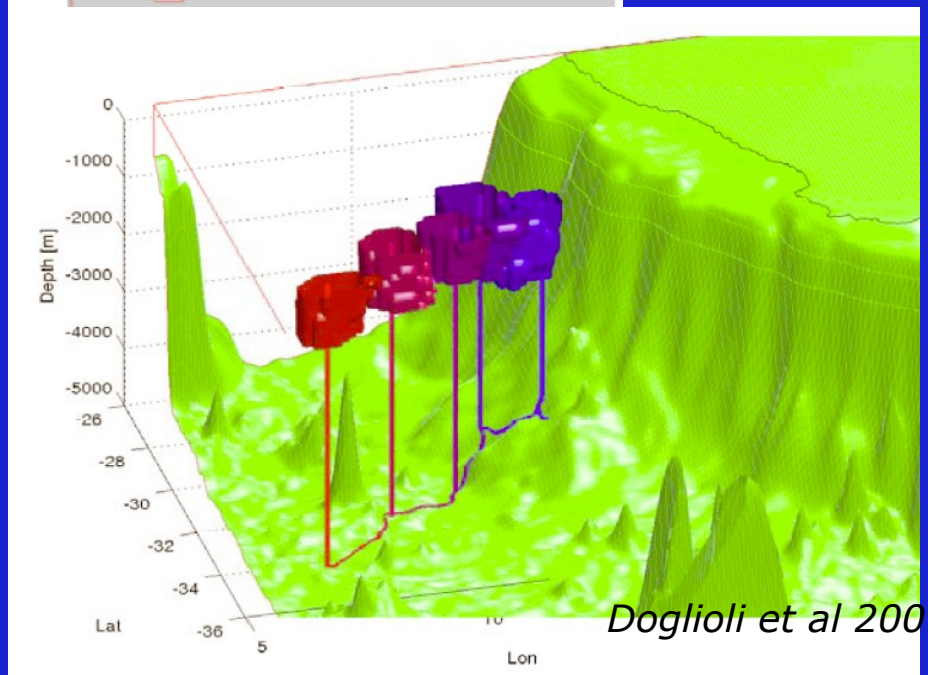
Schrum et al 2006

Mesoscale

Detect, characterise and track mesoscale structures (Satellite, models output, direct obs…



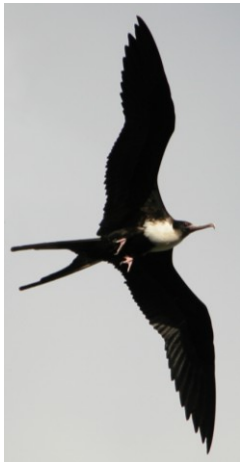
Segond et al



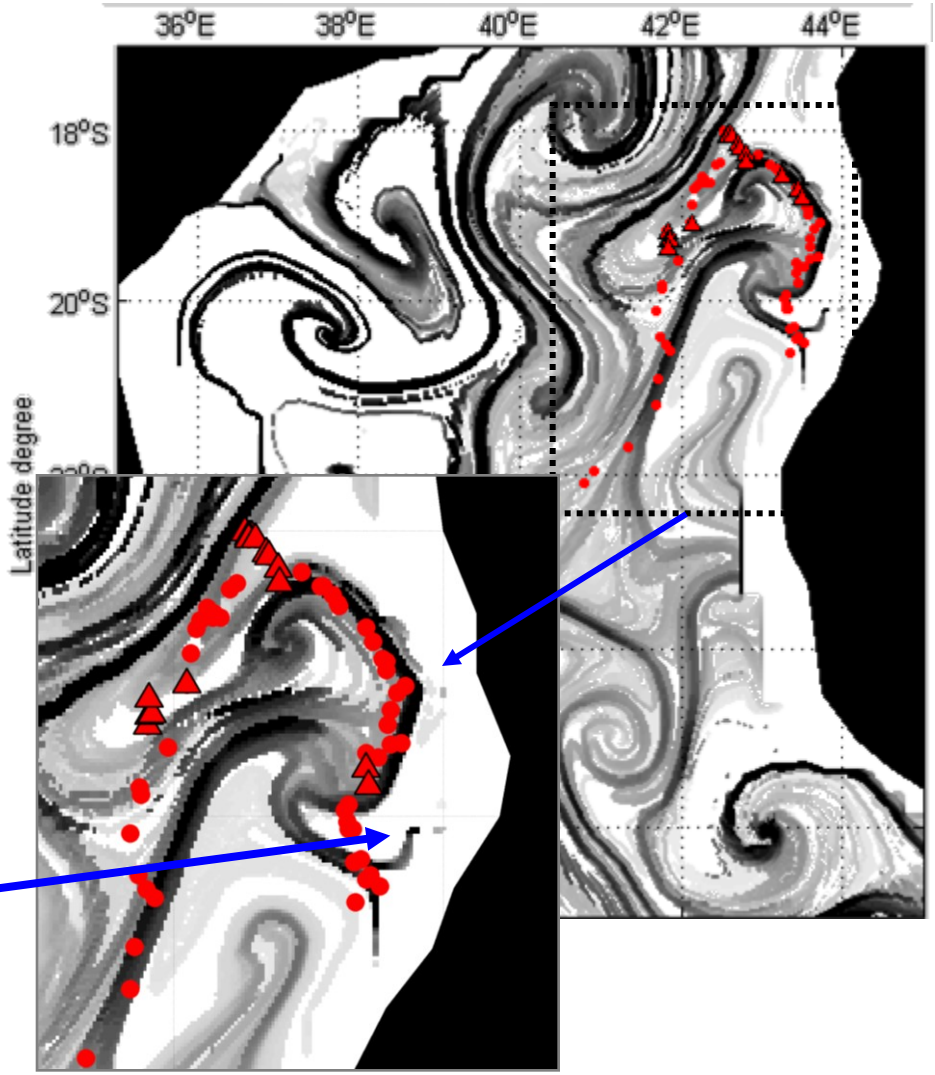
Doglioli et al 2007

Mesoscale activity to characterize trophic behaviour: Great Frigatebirds track Lagrangian Coherent Structures in the Mozambique Channel

Tew Kai, E. et al. *PNAS* 2009

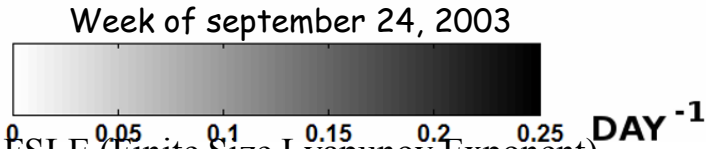


H.Weimerskirch,©CNRS



Sub-mesoscale structures:
Lagrangian coherent structures
(In this case eddy's edge)

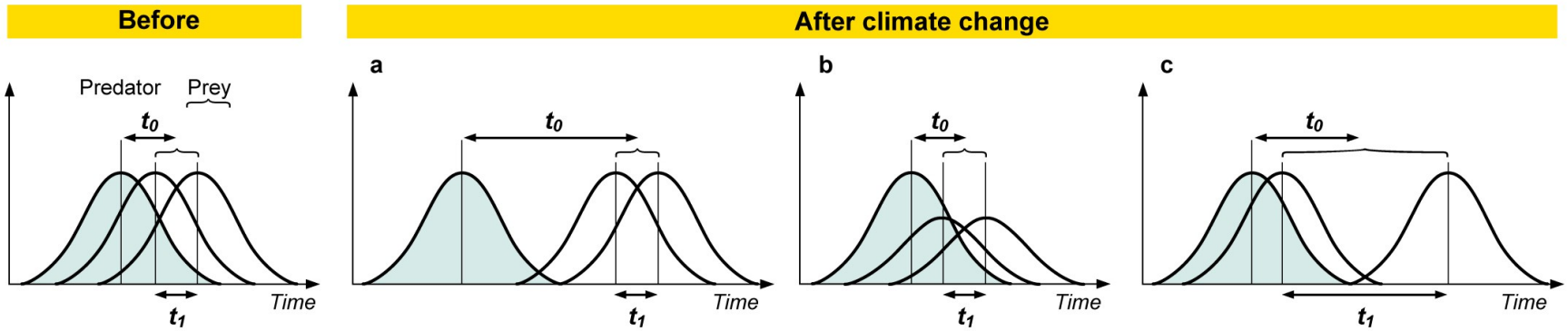
Foraging patch
Seabird trajectory



FSLE (Finite Size Lyapunov Exponent)

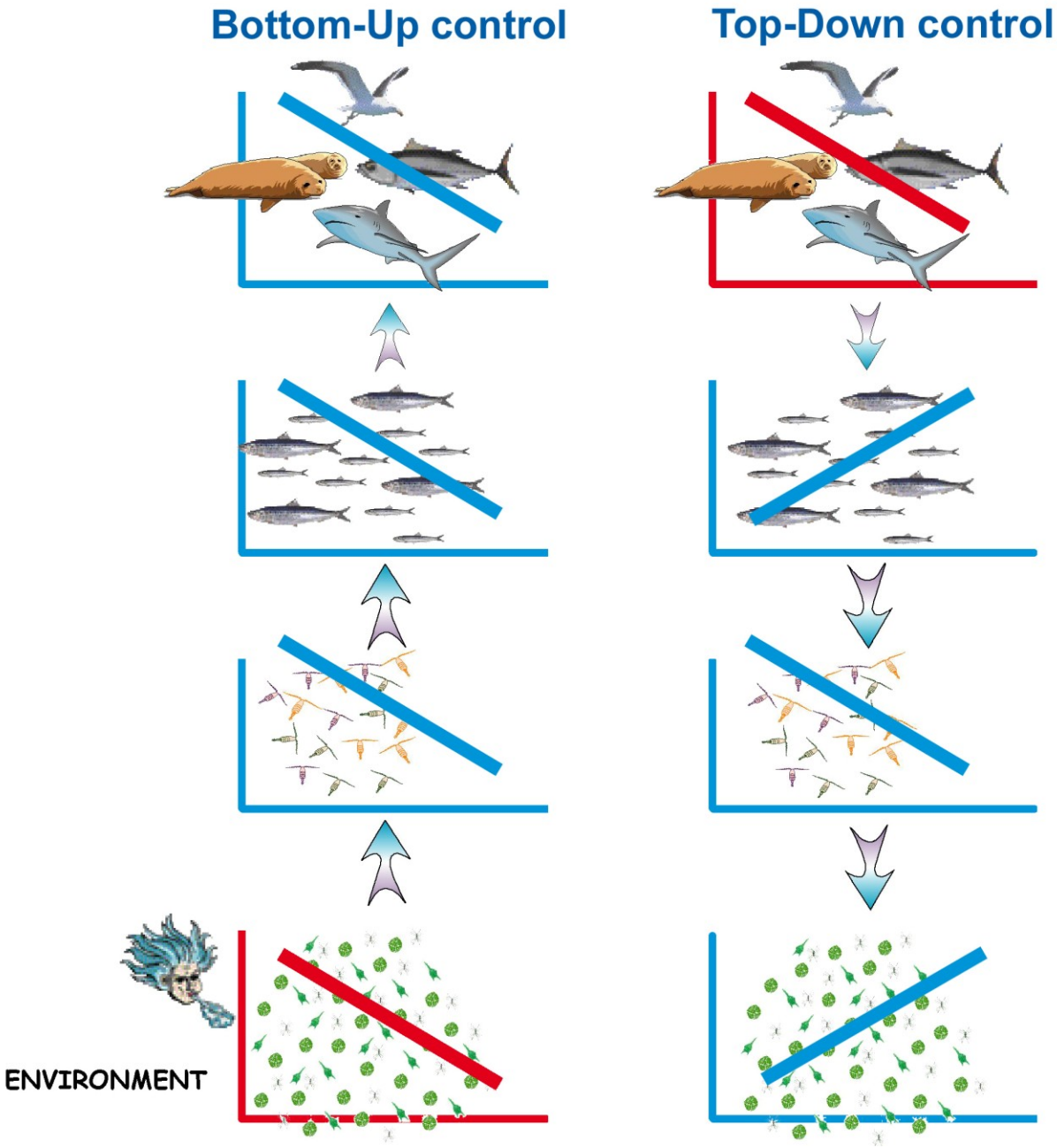
Revisit old concept in the climate change context: example of the match-mismatch

(from J.M. Durant in Cury et al. 2008, Durant et al. 2005, 2007)

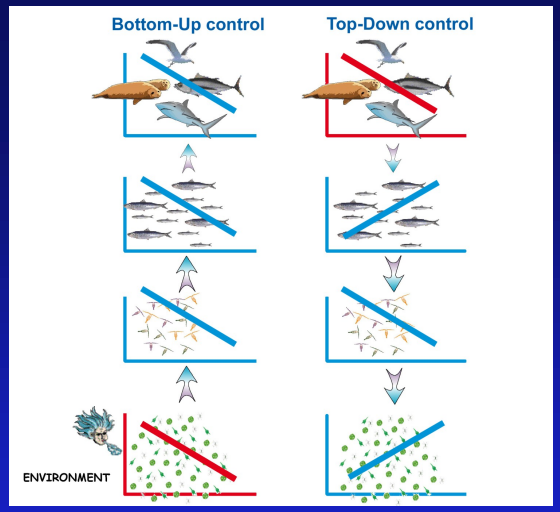


Fine scale spatial distribution is needed to study Match-mismatch between predator and prey under a global change context :

2. Linking food-chains to global change


Bottom-Up control
Top-Down control
ENVIRONMENT

Bottom-up versus Top-down controls in marine ecosystems

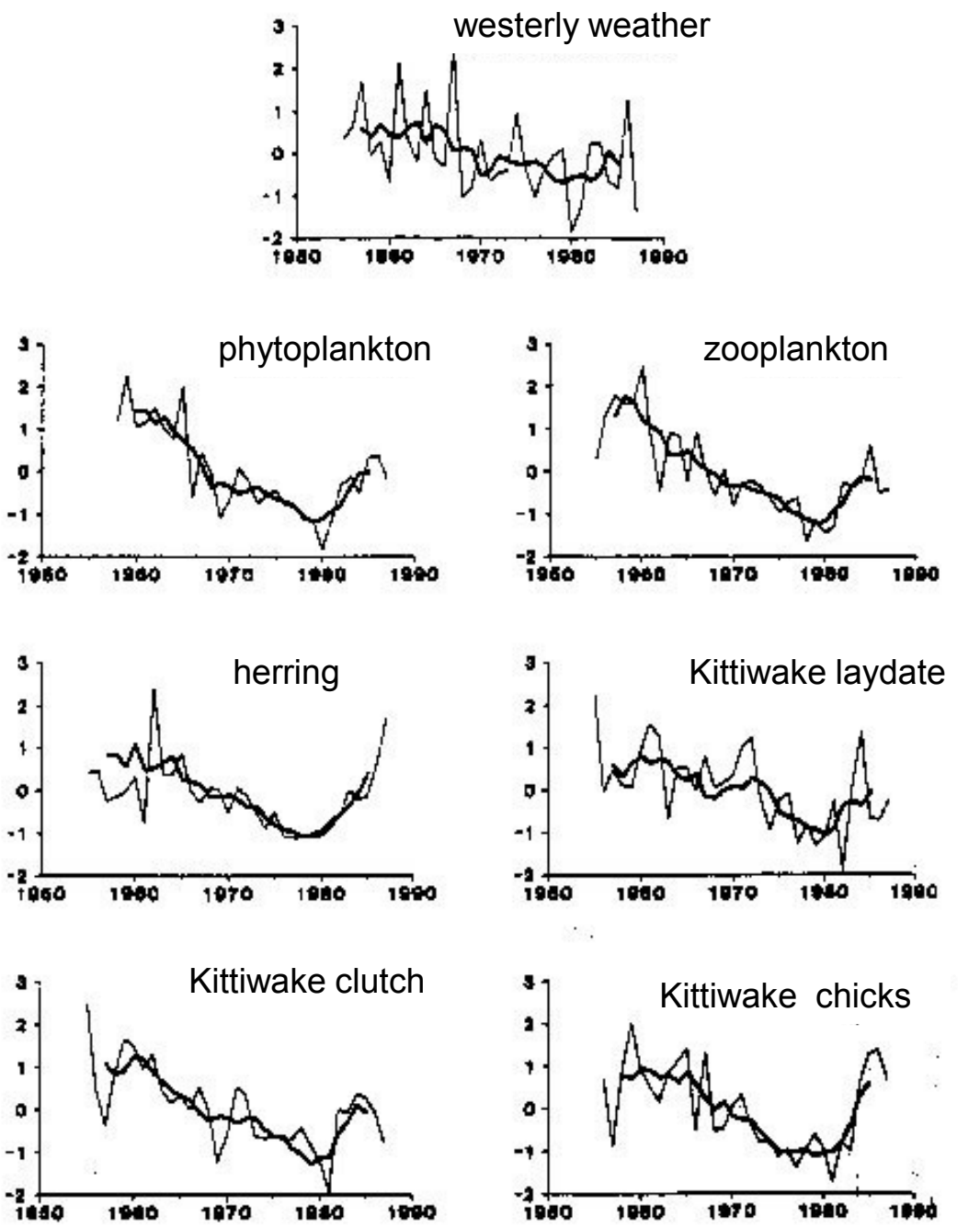


- Bottom-up :
  - Phytoplankton-zooplankton-herring- marine birds - North Sea (*Aebischer et al. Nature 1990*)
  - Chl-a - fish yield - North Pacific (*Ware & Thompson Science 2005*)
  - Shrimp-cod - North Atlantic (*Worm and Myers Science 2003*)
  - Phytoplankton-copepod-zooplankton carnivores - North Atlantic (*Richardson et al. Nature 2004*)
  - Primary production - fish productivity (Chassot et al MEPS 2007, 2009)

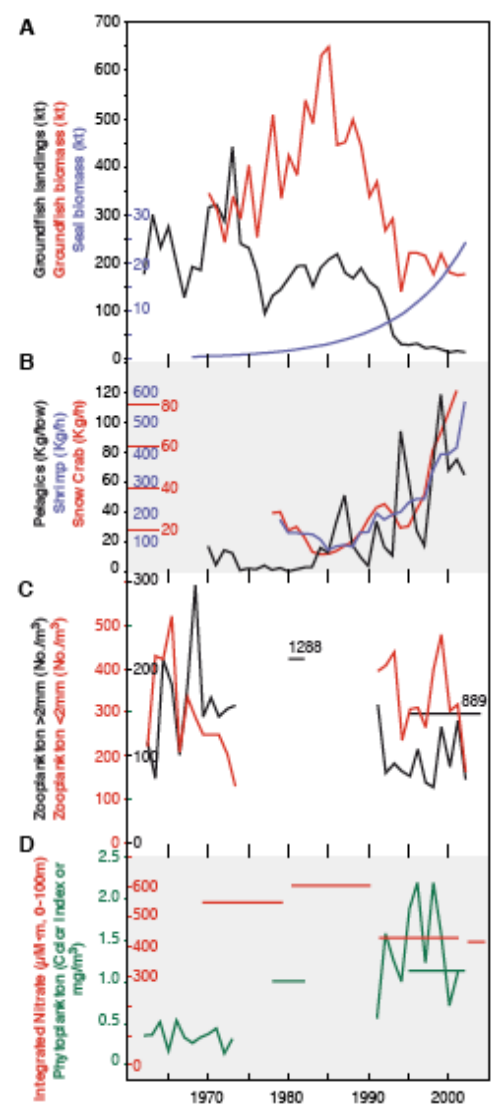
- Top-down :
  - Chl-a - pink salmon - North Pacific (*Shiomato et al. 1997*)
  - killerwhales-otters-urchins-kelp - North Pacific (*Estes et al. Science 1998*)
  - Shrimp-cod - North Atlantic (*Worm and Myers 2003*)
  - Cod-shrimp-snowcrab-pelagic fish-zooplankton-nitrate - North Atlantic (*Frank et al. Science 2005 Ecol. Ltr. 2007*)
  - Sharks-Rays/Skates-bay scallops - North Atlantic (*Myers et al. Science 2007*)
  - Fish predators-pelagic fish-zooplankton-phytoplankton - Black Sea (*Daskalov PNAS 2007*)
  - Cod-sprat-zooplankton-phytoplankton in the Baltic sea (Casini et al. Proc.R. Soc. B.2008)

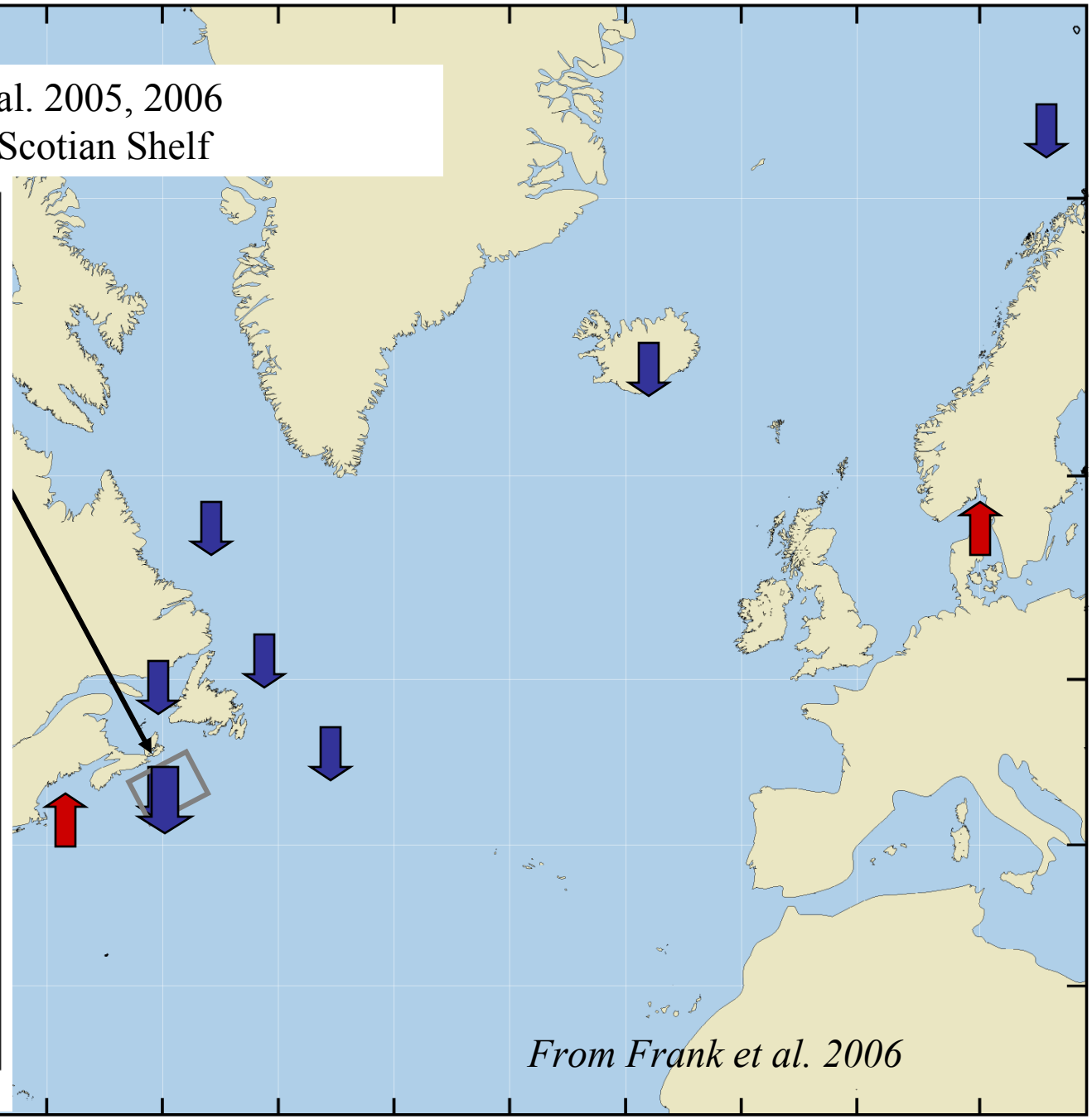
Parallel long term changes for four trophic levels and climate in the North Sea

(from Aebischer et al, Nature 1990)



Frank et al. 2005, 2006
Eastern Scotian Shelf

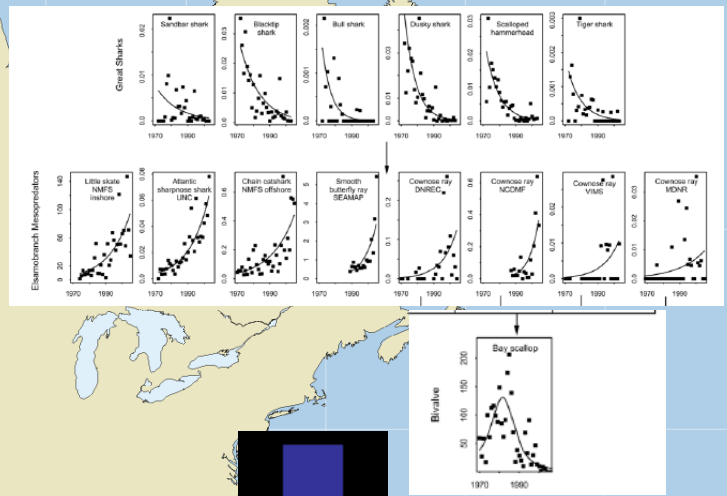


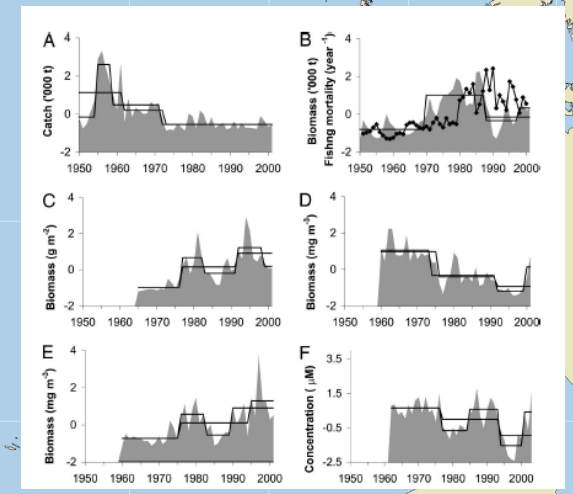


From Frank et al. 2006

Myers et al. Science 2007
Trophic cascade
Sharks-Rays/Skates and bay scallops)

Daskalov et al. PNAS 2007
Trophic cascade
(pelagics, jellyfish, Zoopl. Phyto.)



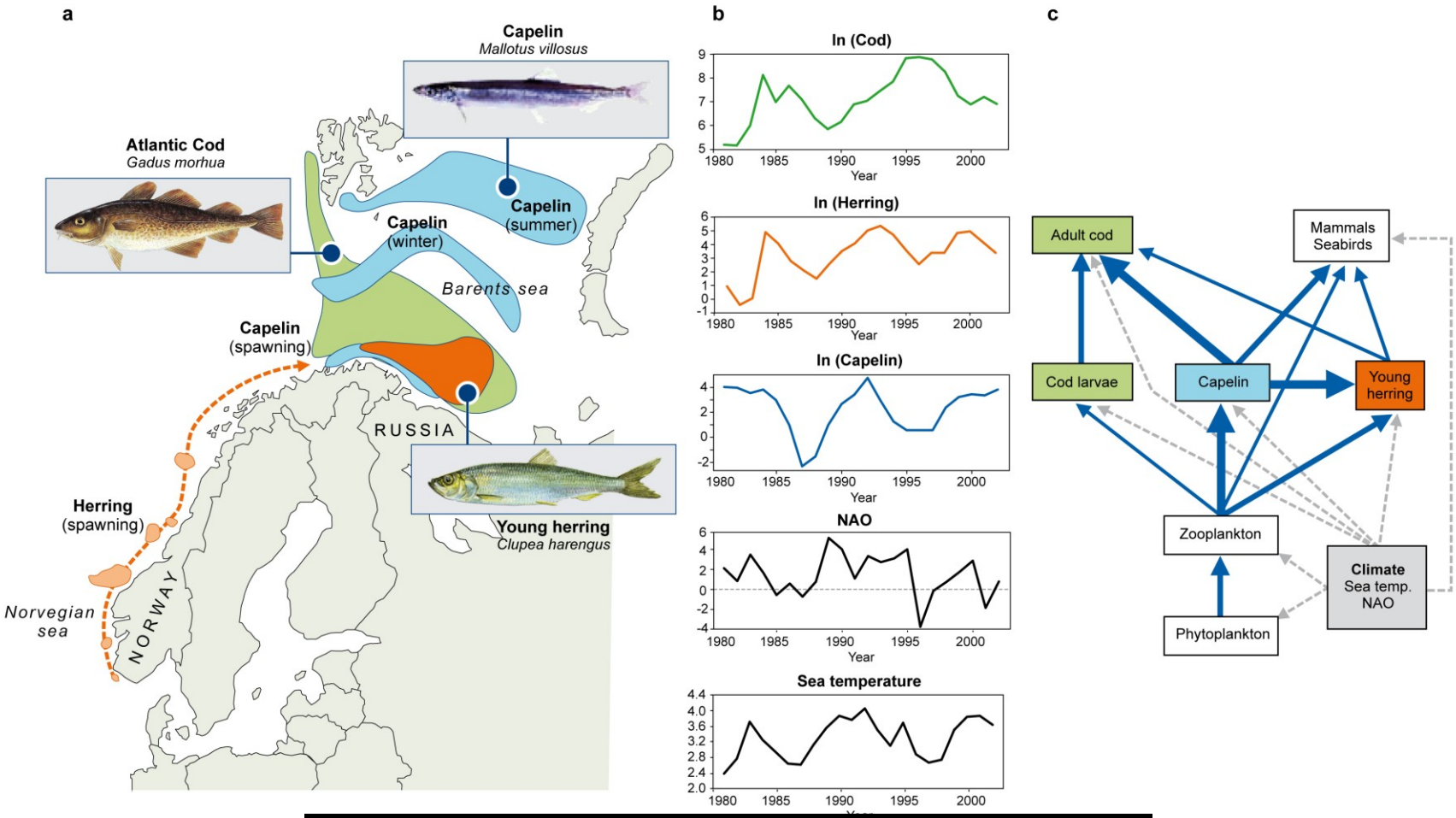


70°N
60°N
40°N
30°N
100°W
80°W
60°W
40°W
20°W
0°
10°E

3. Linking food-webs to global change

Quantifying controls using time series

(Hjermann et al. 2004, Stenseth 2003, 2004)



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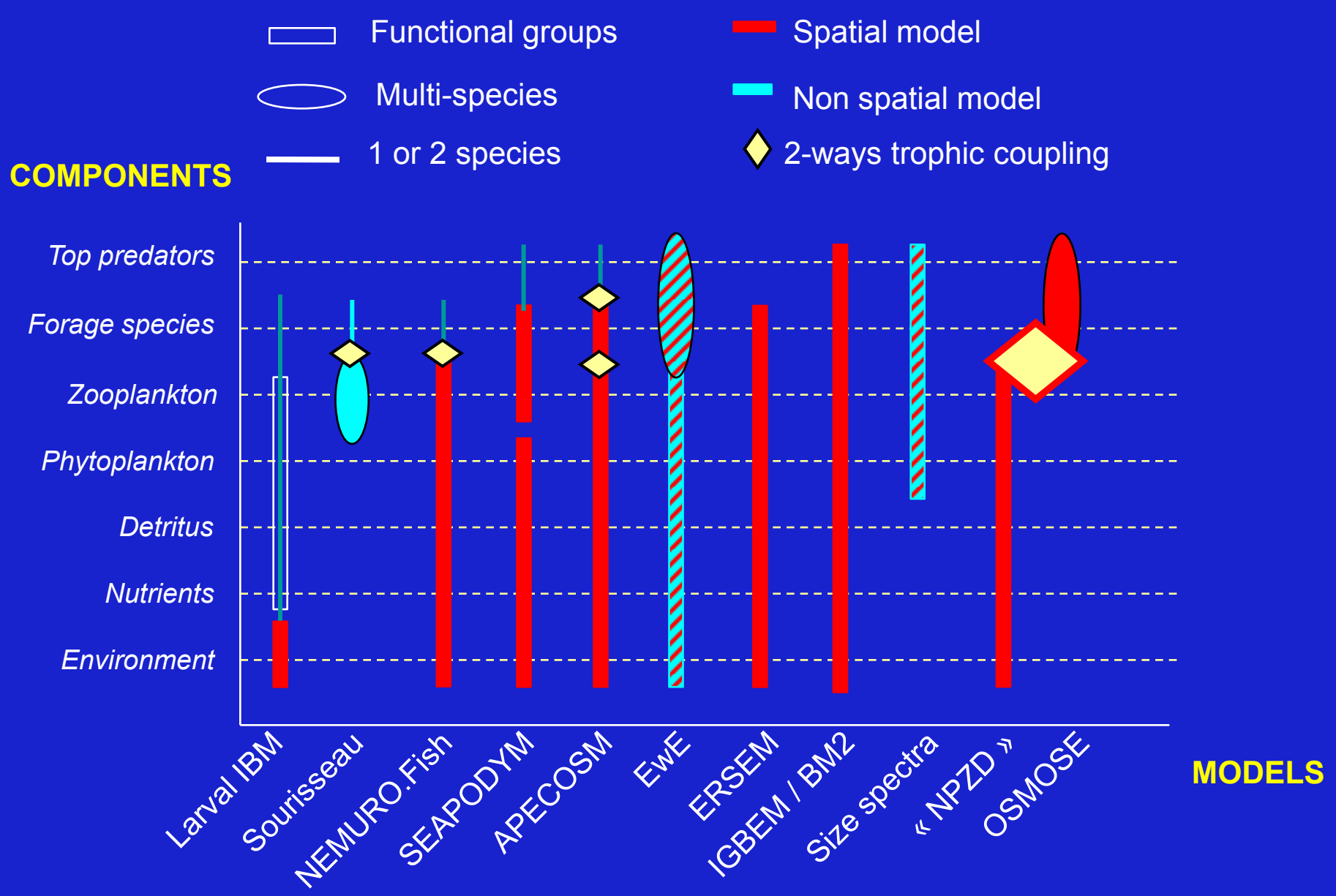
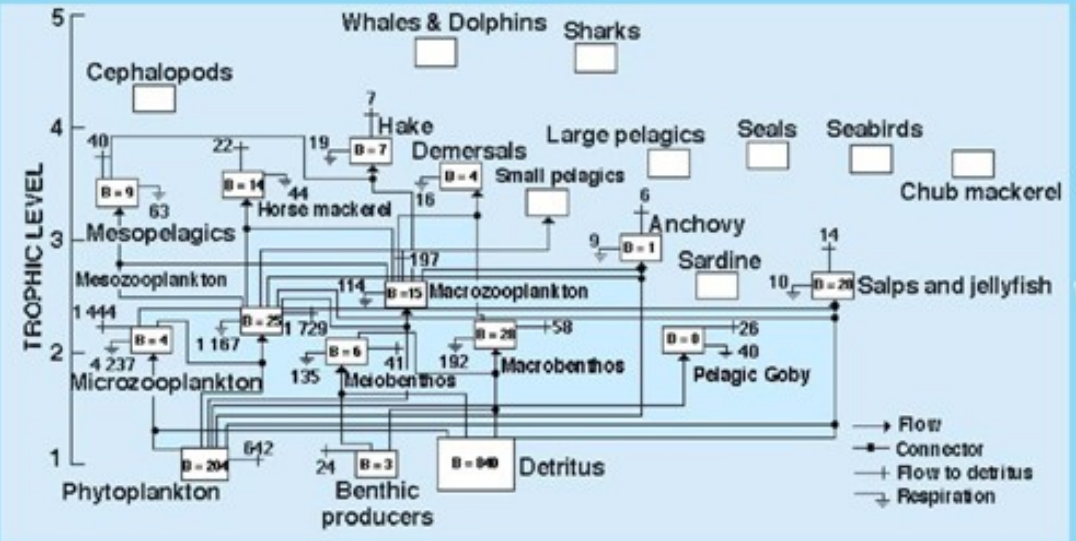
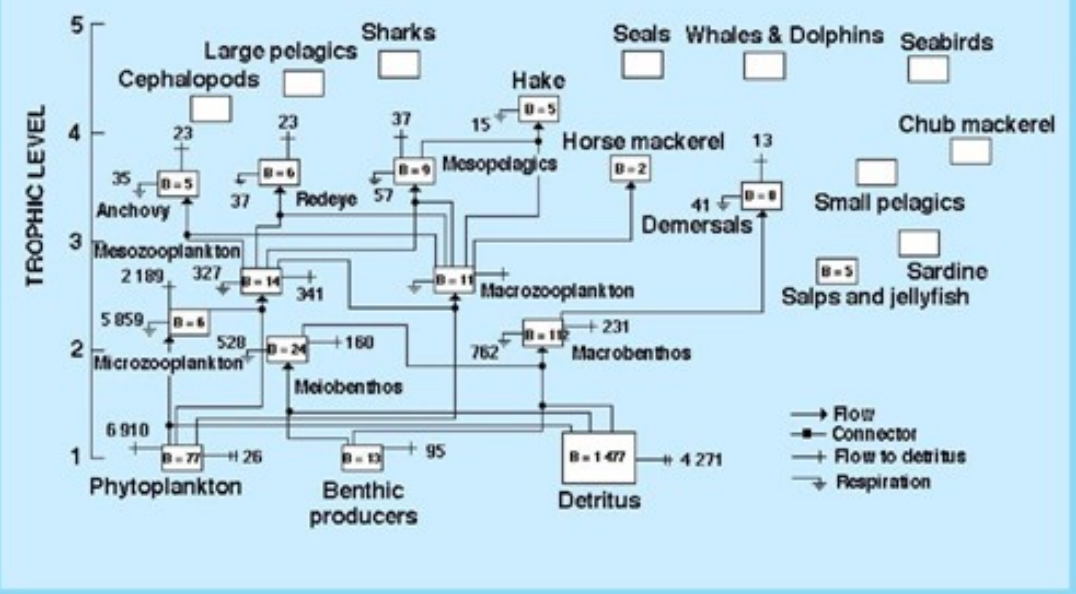
4. Linking ecosystem models to environmental changes

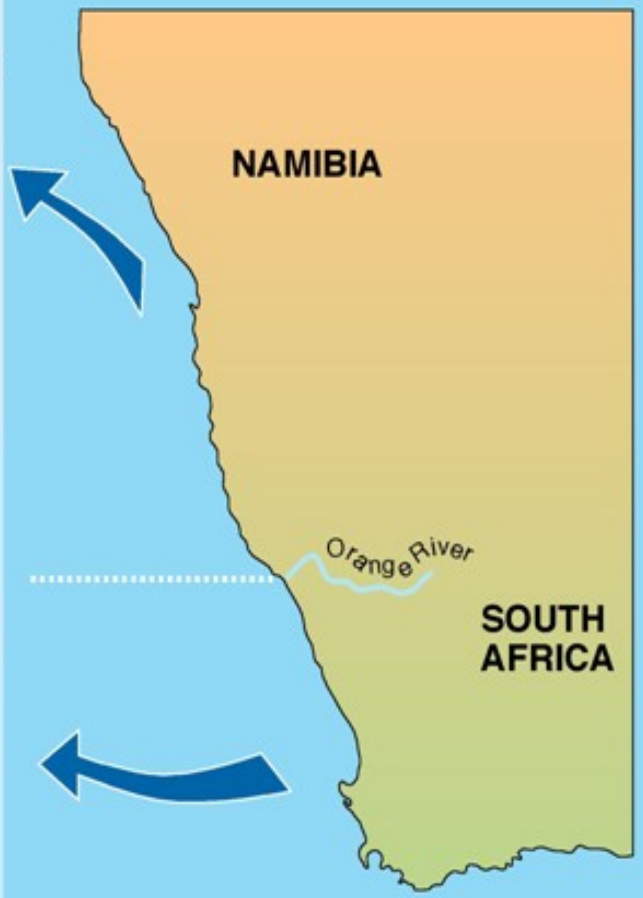
E2E models: review (Travers et al. 2007)

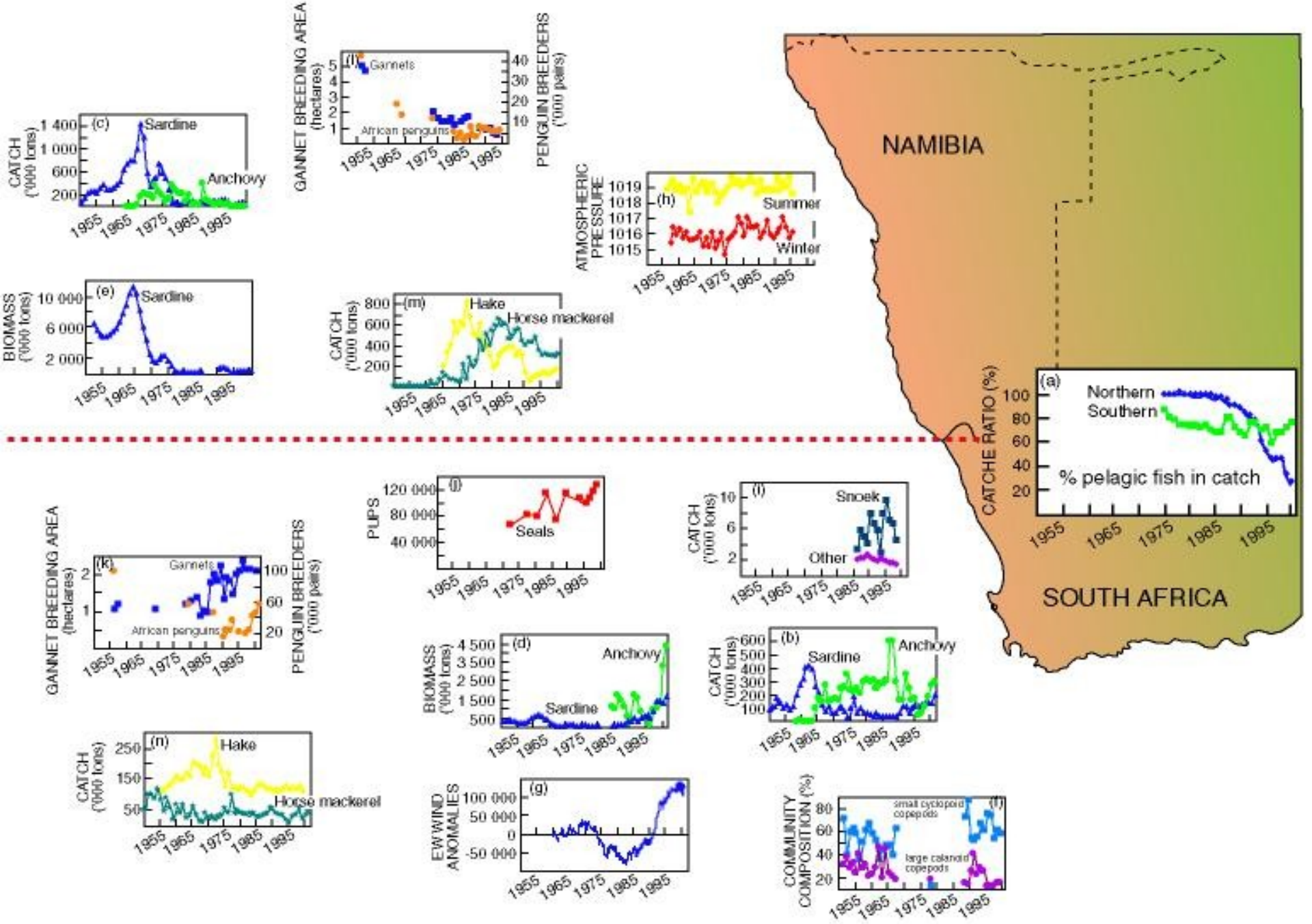


EwE models: trophic interactions
Food Webs in the northern and southern Benguela








NAMIBIA
SOUTH AFRICA
(a)
Northern
Southern
% pelagic fish in catch
CATCHE RATIO (%)
(b)
Sardine
Anchovy
CATCH ('000 tons)
(c)
Sardine
Anchovy
CATCH ('000 tons)
(d)
Anchovy
Sardine
BIOMASS ('000 tons)
(e)
Sardine
BIOMASS ('000 tons)
(f)
small cyclopoid copepods
large calanoid copepods
COMMUNITY COMPOSITION (%)
(g)
EW WIND ANOMALIES
(h)
Summer
Winter
ATMOSPHERIC PRESSURE
(i)
Garnets
African penguins
GANNET BREEDING AREA (hectares)
PENGUIN BREEDERS ('000 pairs)
(j)
Seals
PUPS
(k)
Garnets
African penguins
GANNET BREEDING AREA (hectares)
PENGUIN BREEDERS ('000 pairs)
(l)
Snoek
Other
CATCH ('000 tons)
(m)
Hake
Horse mackerel
CATCH ('000 tons)
(n)
Hake
Horse mackerel
CATCH ('000 tons)
1955
1965
1975
1985
1995

End-to-end modelling (E2E)

Definition in Travers Shin Jennings & Cury, Progress in Oceanography 2007

- aims to represent the entire food web and the associated abiotic environment
- requires the integration of physical and biological processes at different scales
- implements two-way interaction between ecosystem components
- accounts for the dynamic forcing effect of climate and human impacts at multiple trophic levels

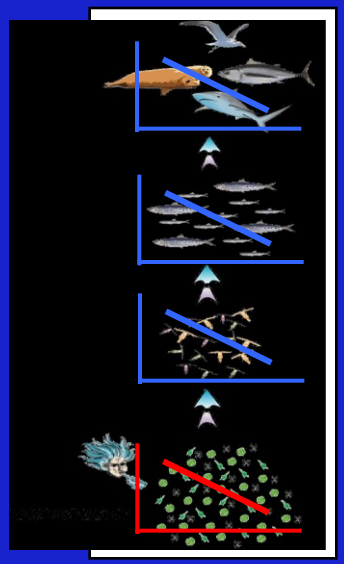
E2E models for EBFM

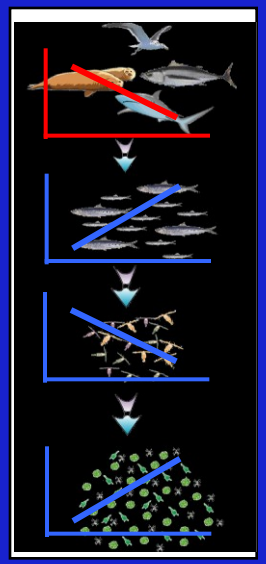
(Shin et al. 2008 Progress in Oceanography
Cury et al. 2008 TREE)

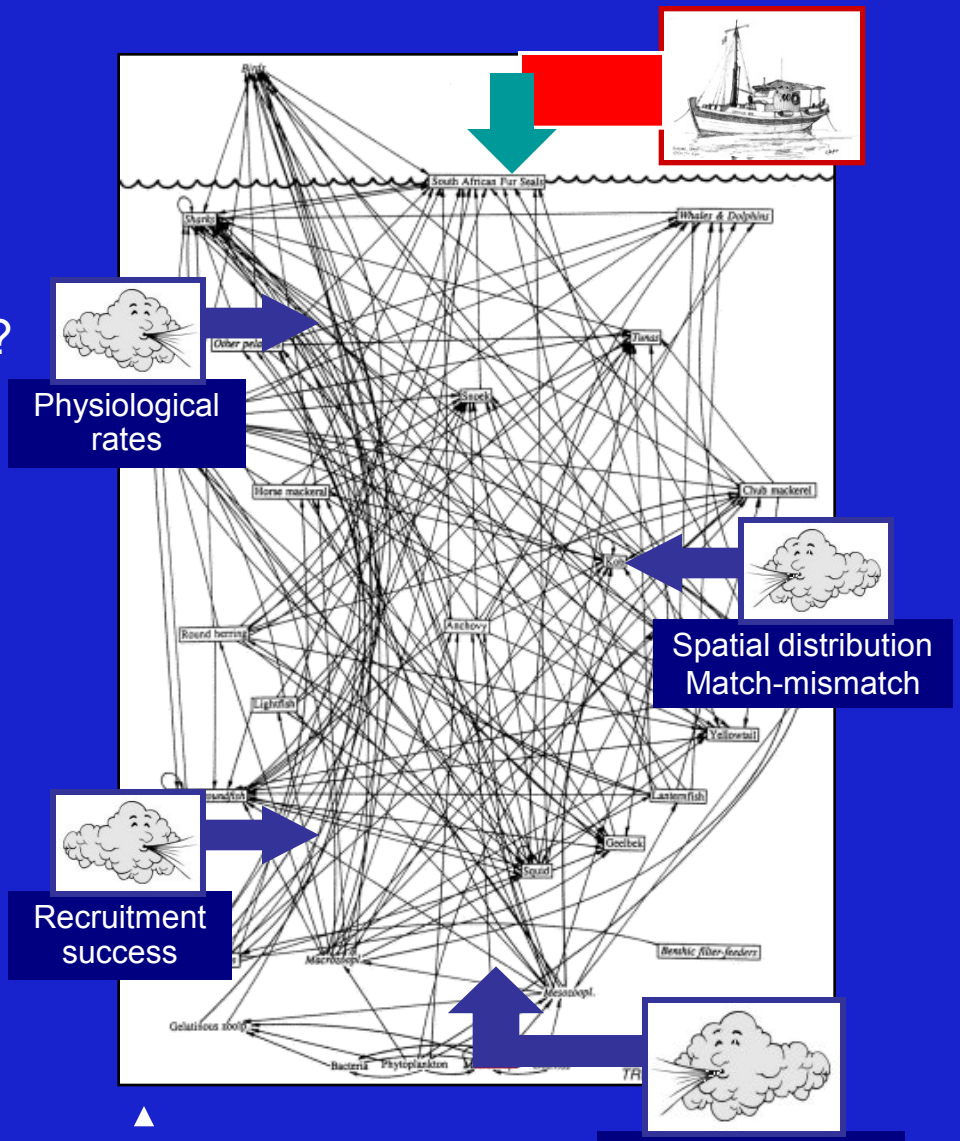
What for ?

- How fishing and climate (F & C) effects affecting various levels of organisation <u>propagate down and up</u> marine foodwebs?

- What are the <u>combined effects</u> of F & C on target and non-target species?







Food web for the Benguela ecosystem (Field et al. 1991)

Structure of E2E models

(Shin et al. 2008. Progress in Oceanography
Cury et al. 2008. TREE)

How?

- Vertical integration

Coupling of LTL and HTL models

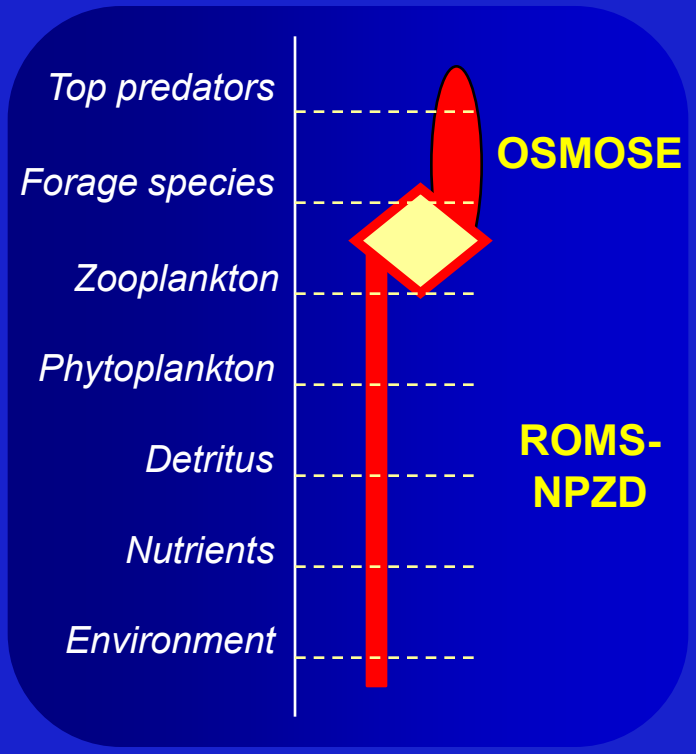
- needs integration of multi-disciplinary knowledge
- relies on pre-existing models
- ensures that processes addressed at appropriate scales at each TL

- Horizontal integration

Biodiversity integration / simplification

(How can we select the key components to be explicitly modelled?)

Osmose-Npzd-Roms



✓ Representation of fishing (Osmose) and climate (Roms-NPZD) drivers

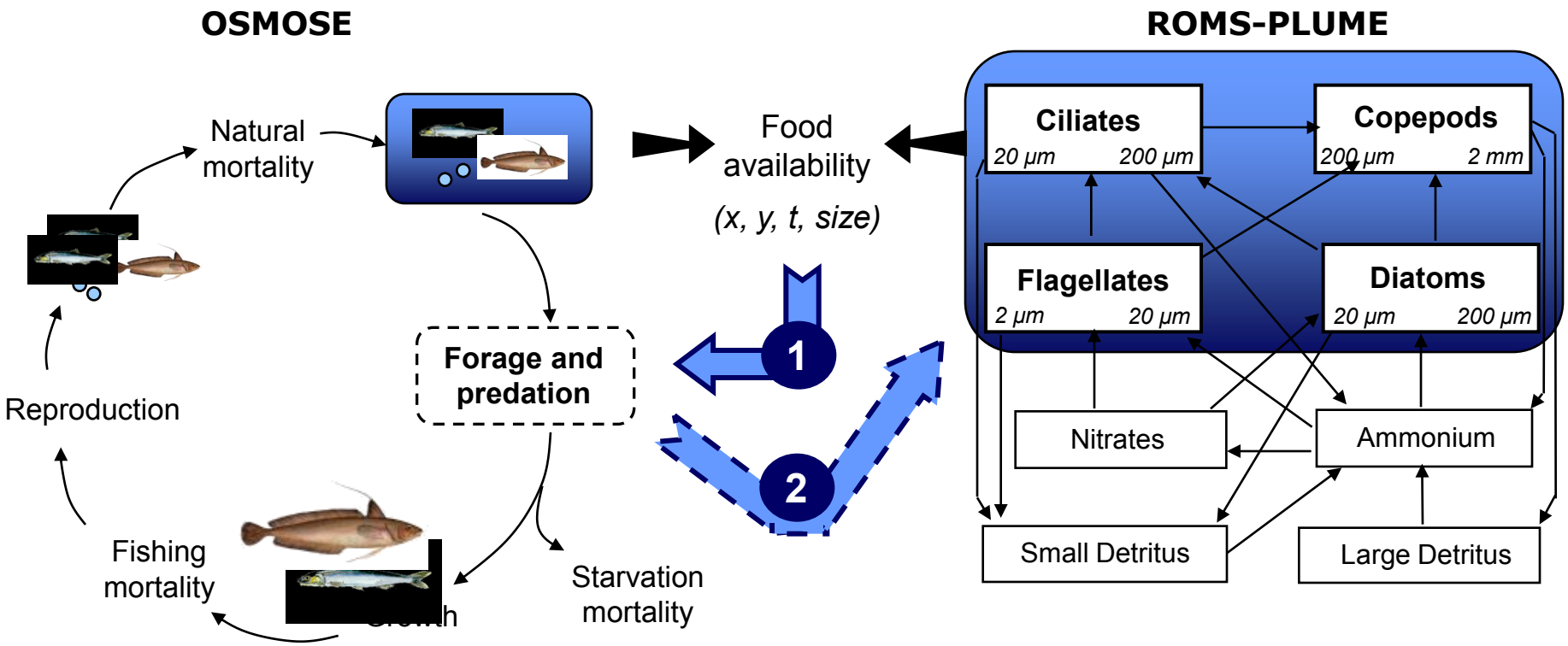
✓ <u>Vertical integration</u>

Predation as the coupling process: propagation of C & F effects via trophic interactions

✓ <u>Horizontal integration</u>

Multi-species and multi-compartment coupled model: possible alternative foodchains

COUPLING of Osmose and $N_2P_2Z_2D_2$: 2-WAYS INTERACTIONS (Travers et al. 2008)



1 **FORCING** : Plankton as a prey field for fish

2 **FEEDBACK** : Resulting predation mortality applied on plankton

OSMOSE

Object-oriented Simulator of Marine ecOSystems Exploitation

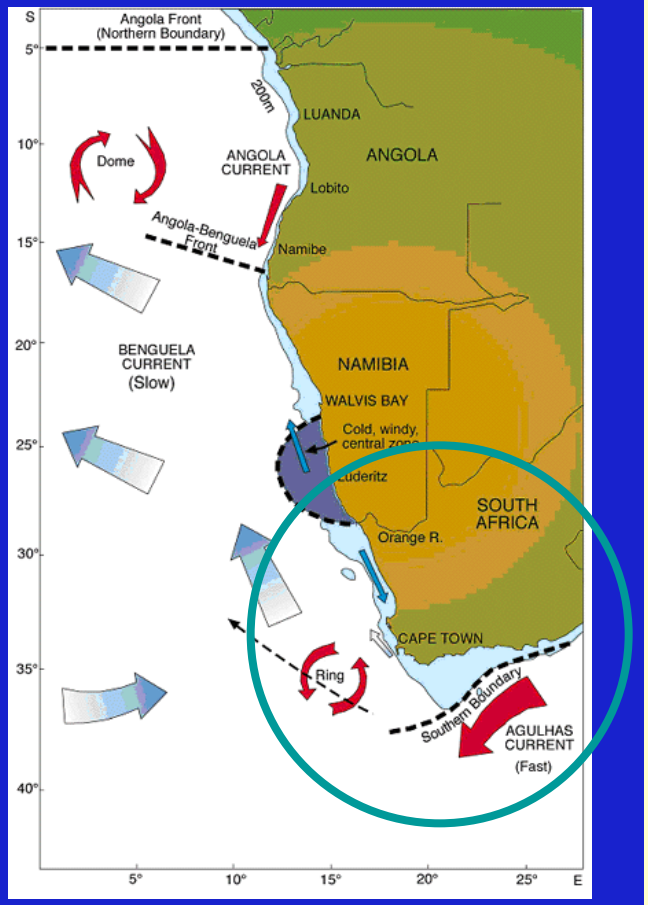
Shin & Cury 2001, 2004

Patterns in fish diets

- Variability in time and space of fish diets
- Cannibalism
- Omnivory

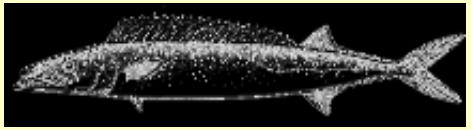
Application southern Benguela

- 12 fish species modelled: 76% total fish biomass, 94% total catch



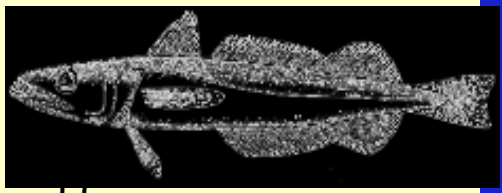
Kingklip

Snoek

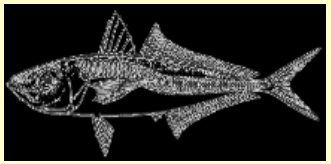


Shallow water hake

Deep water

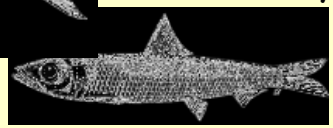


Horse



Chub mackerel

Redey



Anchovy

Lanternfish

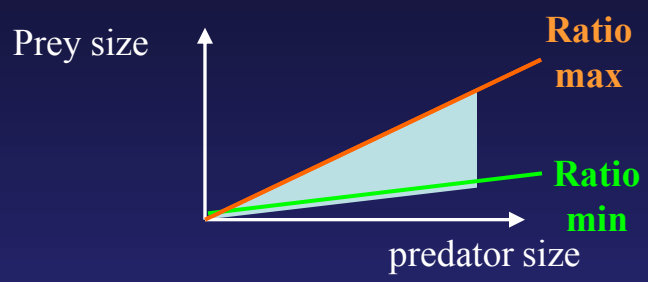
Lightfish

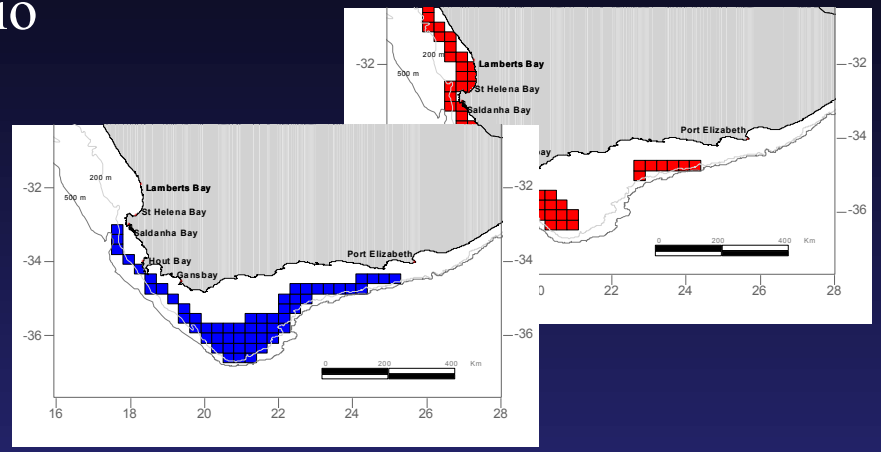
Sardine

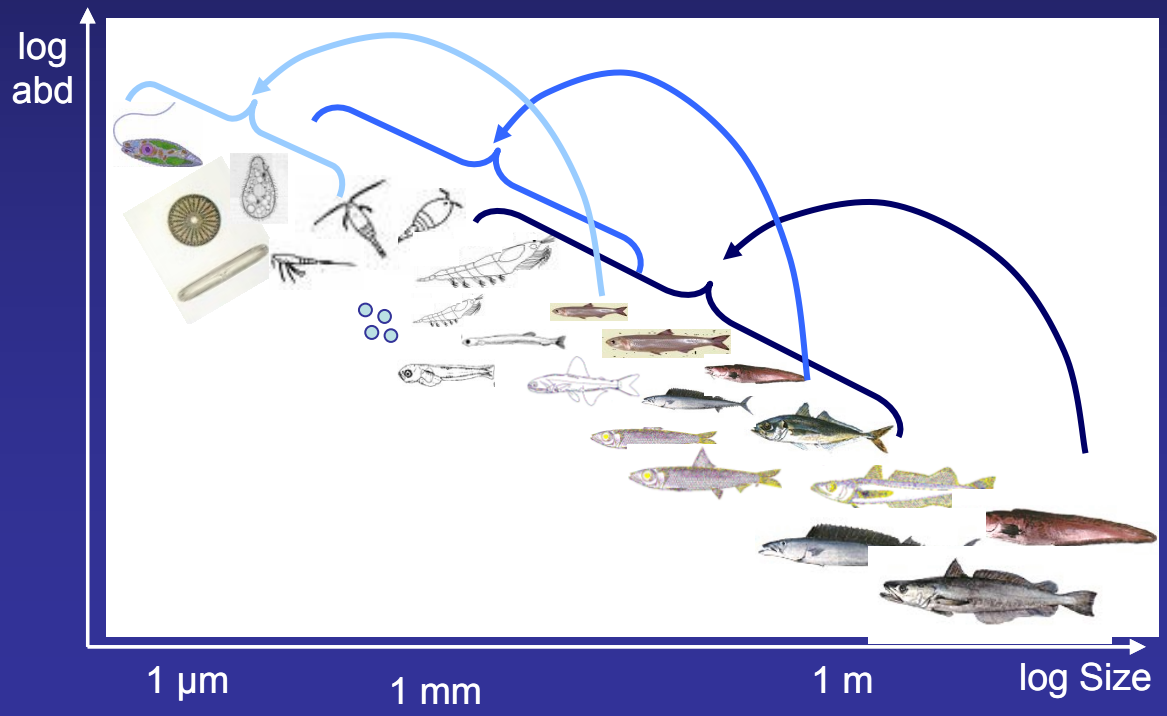
Size-based predation

1- Thresholds for predator/prey size ratio

2- Spatio-temporal co-occurrence







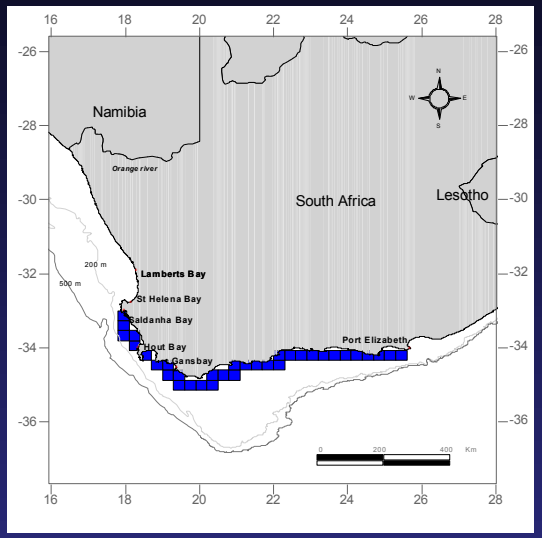
- Modelled food webs are variable in structure
- Opportunistic predation: dampening role on the foodweb

Spatial distributions

Shallow water hake

Southern Benguela

Age 0

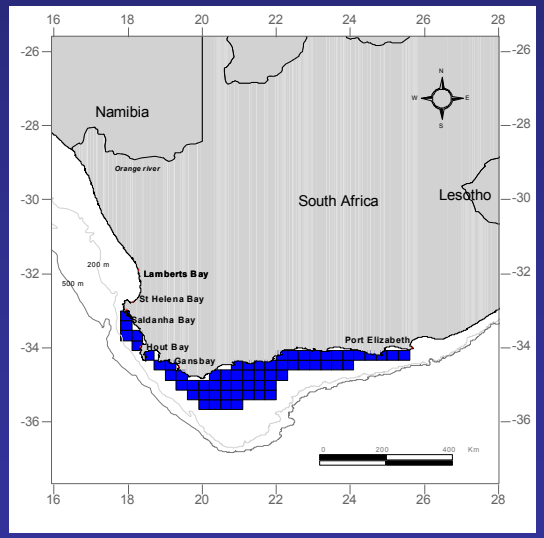


REFERENCES

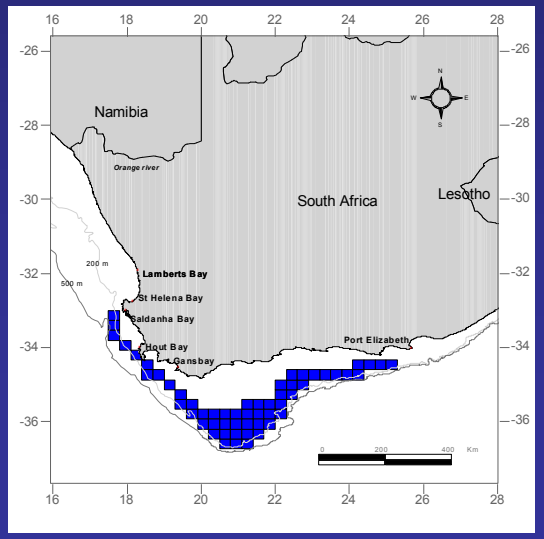
Maps
- Badenhorst and Smale 1991
- Payne, 1989
- Punt 1994
- Punt et al. 1992

Text
- Badenhorst and Smale 1991
- Payne, 1989
- Punt et al. 1992

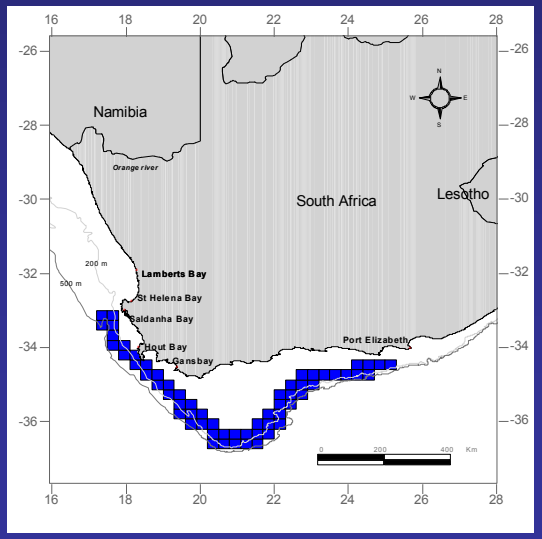
Ages 1-2



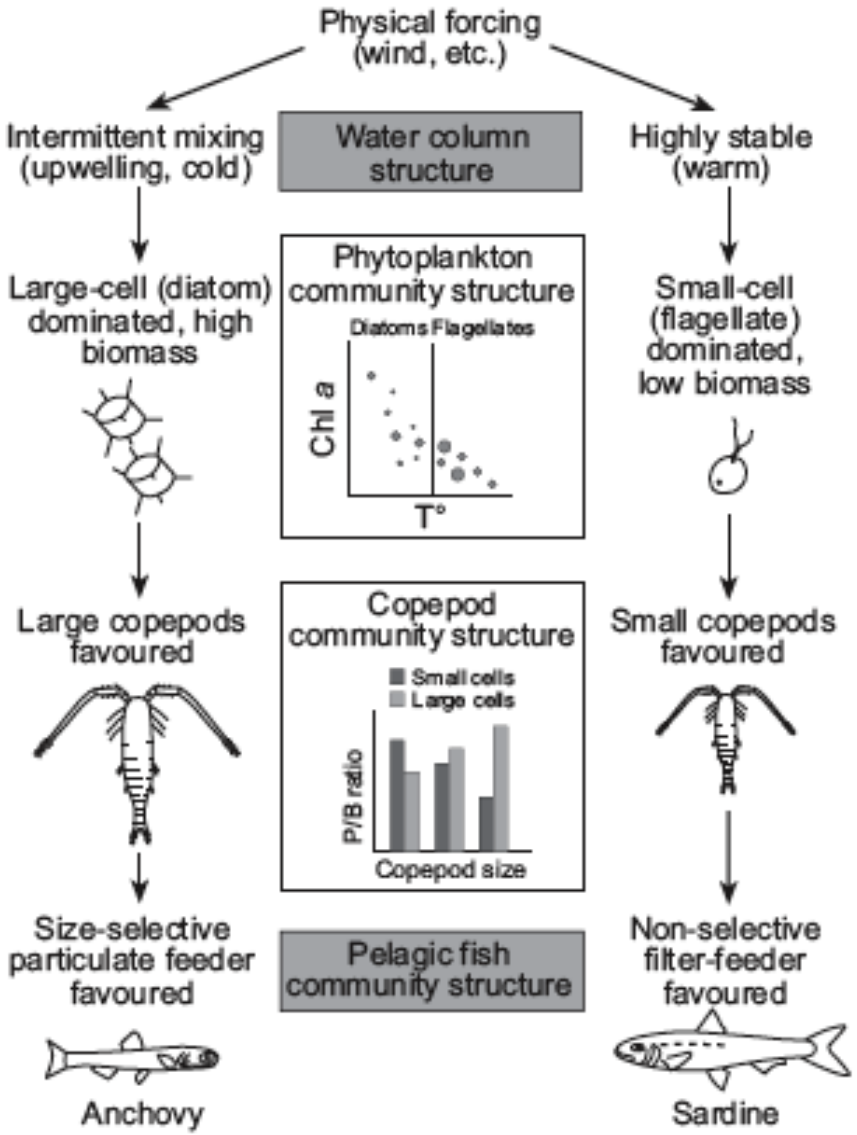
Ages 3-4-5



Ages 6+

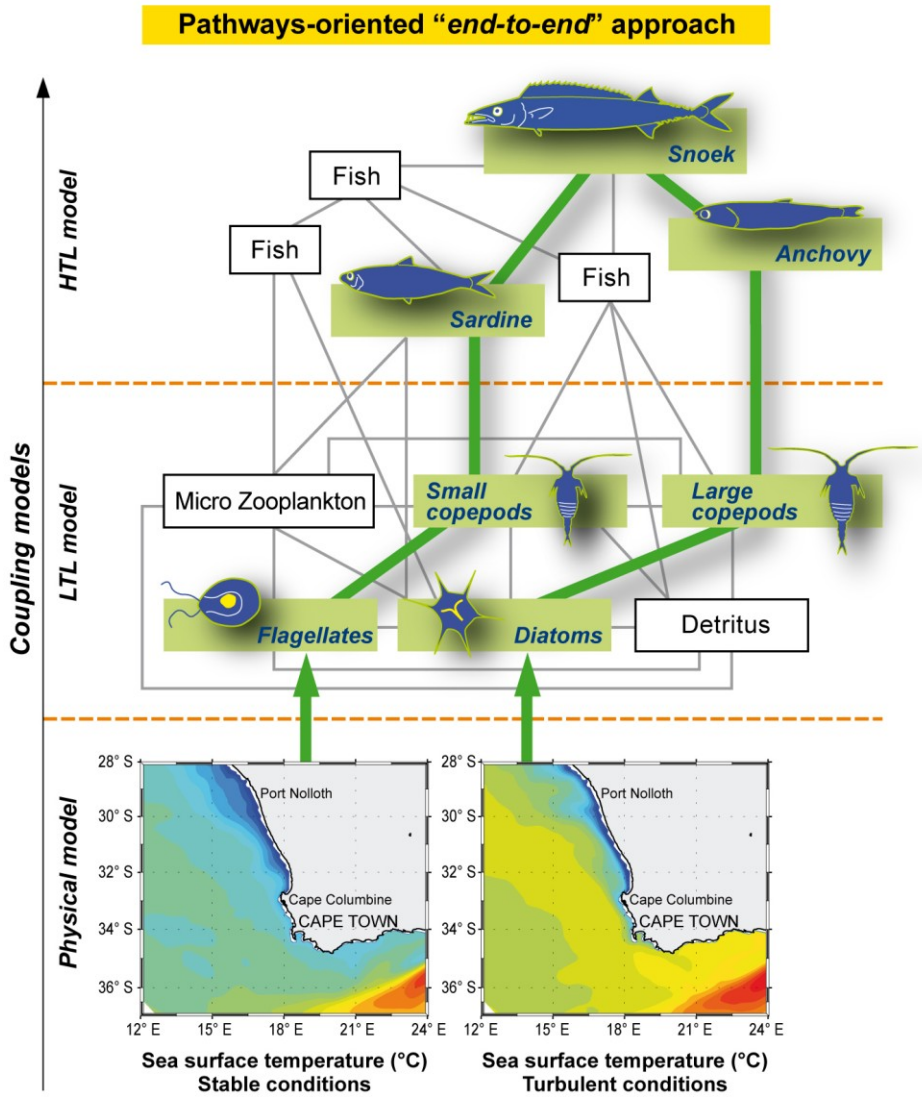


Alternative foodchains – *Carl van der Lingen 2006*



Pathway oriented approach

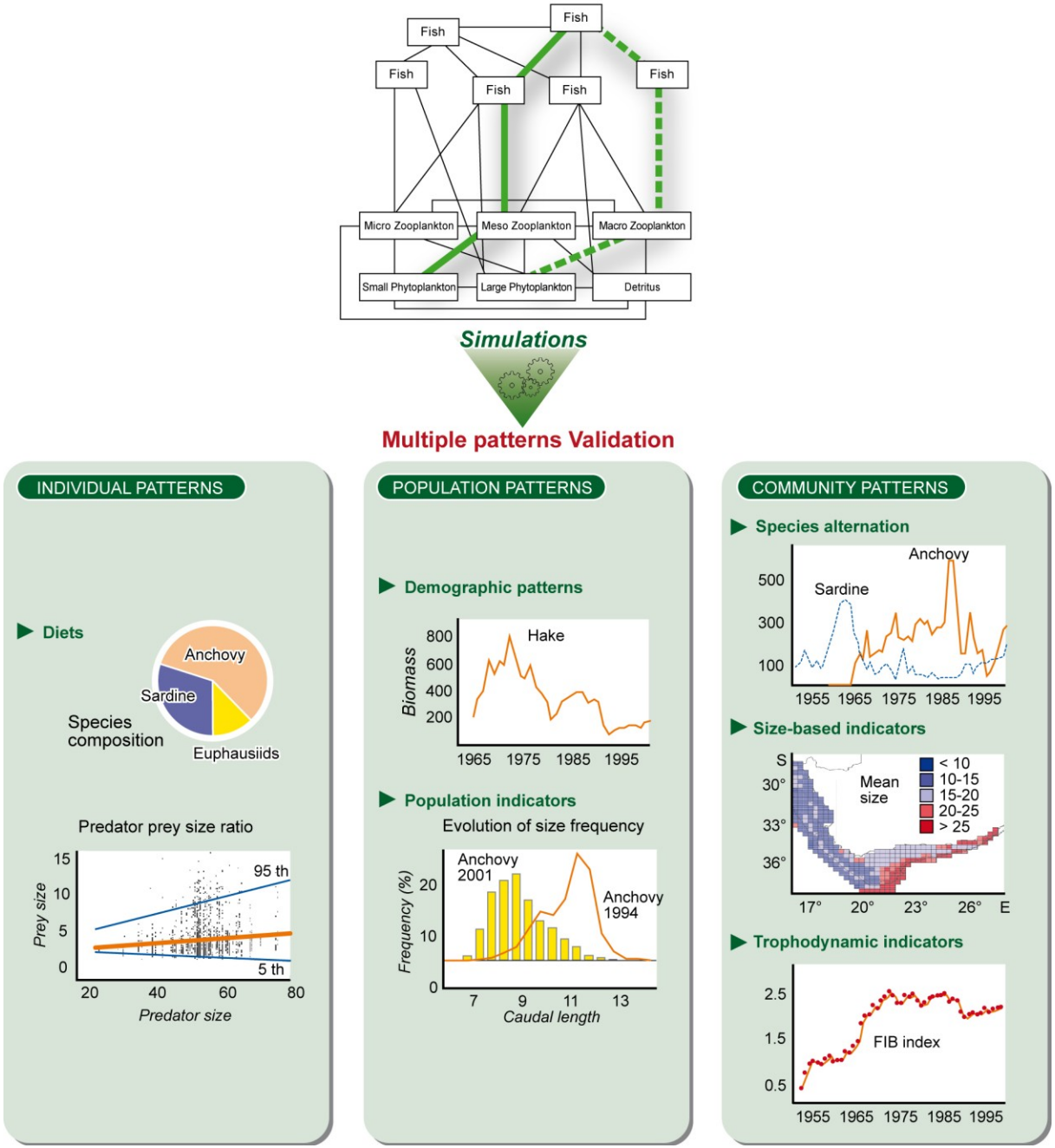
(Shin et al. 2007)



POM approach & Ecosystem validation

(Grimm, Travers et al. 2007
Cury et al. 2008)

Validation at multiple scales & levels



Moving towards Ecosystem Oceanography : models & data for EAF

- Develop robust models that are ecologically-based and issues/data-oriented (*i.e.* pathway oriented approach & POM approach) to better understand ecosystem changes & regime shifts
- Dedicated Times series (abundance/biomass or numbers) from plankton to top predators (e.g. marine birds, seals, predatory species and key indicators species (jelly fish, forage/prey species…)
- Spatial data (e.g. to study prey/predator trophic interaction/match-mismatch, behavior of top predators, the effect of MPAs) (from surveys, tagging experiments, VMS…)
- Downscaling ecological issues: focus on meso-scale dynamics and its dependence on large scale when addressing the recruitment of marine populations
- Diversity & Trophic data: Diversity of zooplankton and link to predators are missing (mesopelagic, ichtyoplancton, myctophids, meso – macro-plankton)
- We also need 'Ecoscope' to integrate our fragmented knowledge on marine ecosystems, particularly through data base (fishbase, sealifebase, encyclopedia of life, census of marine life….)

Thank you!