Modeling Southern Ocean Food Webs Approaches and Challenges

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Integrating Climate and Ecosystem Dynamics (ICED) in the Southern Ocean

ICES/PICES 6th Zooplankton Production Symposium
New Challenges in a Changing Ocean

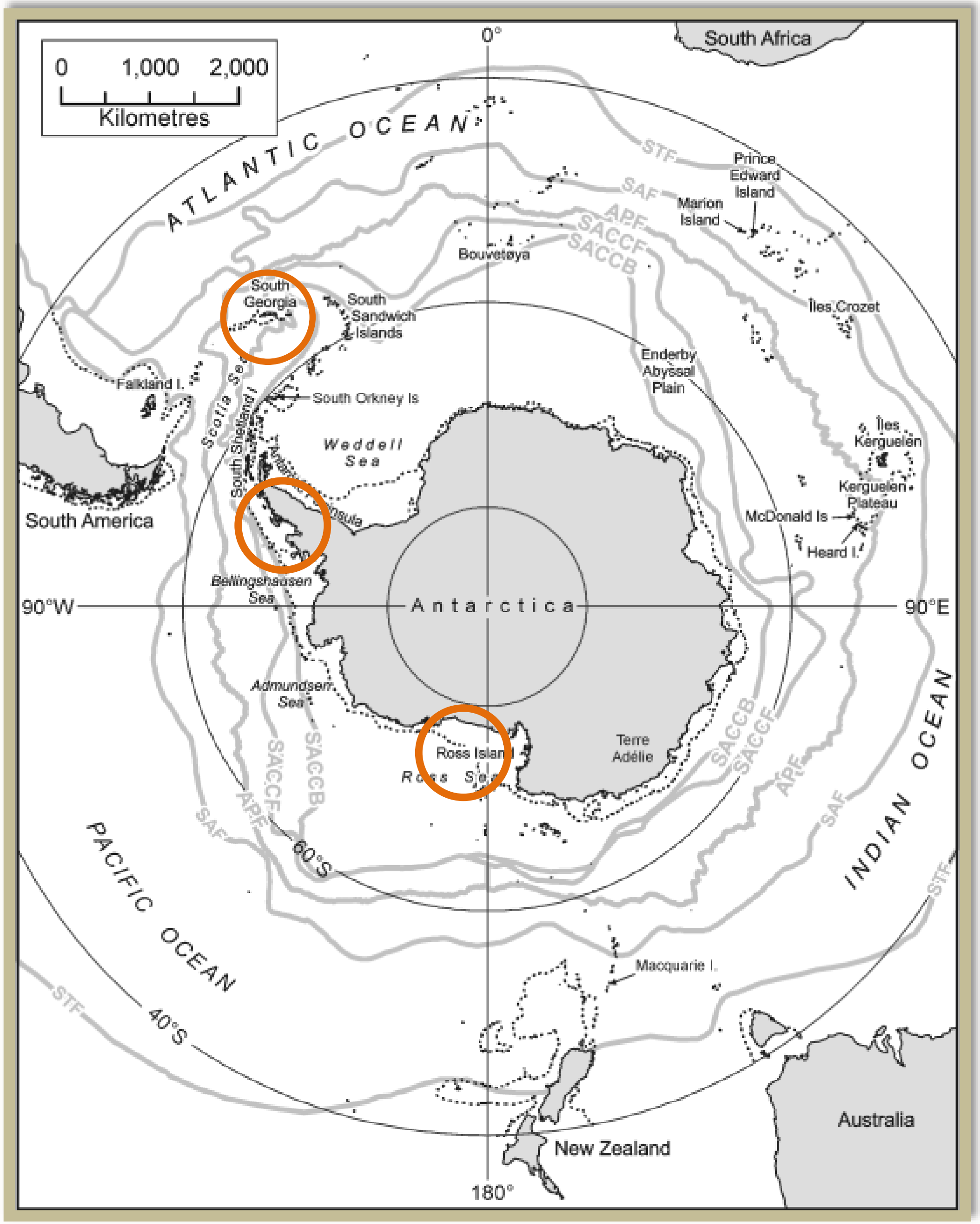
9-13 May 2016
Bergen,Norway

Symposium Focus

- Zooplankton…..
  - Pivotal role in ecosystems and biogeochemical cycles
  - Community dynamics structure ecosystem
  - Target for commercial harvesting
  - Influenced by climate change
  - Role in global ecosystem
- Focus on zooplankton in Southern Ocean food webs and incorporation into modeling frameworks

Presentation Outline

- Southern Ocean food webs
- Consider food webs from South Georgia, west Antarctic Peninsula, and Ross Sea
- Environmental changes and implications for food webs
- Projections of future changes
- Modeling strategies to assess changes in food webs



Southern Ocean Food Webs

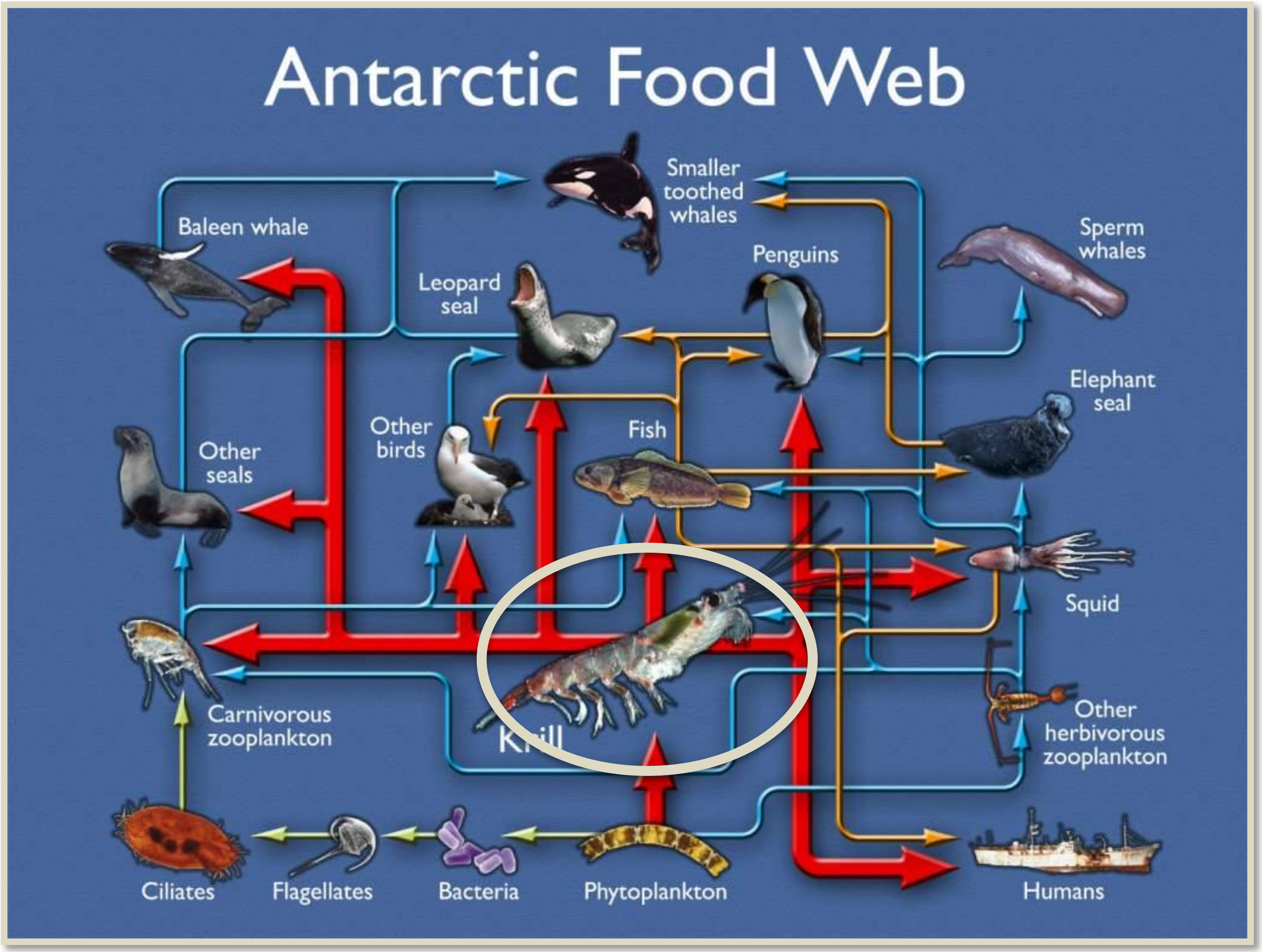
Circumpolar System

Heterogeneity in forcing and habitat structure

Different levels of exploitation

Regional differences in Responses from top down and bottom up effects

What is a Southern Ocean Food Web?

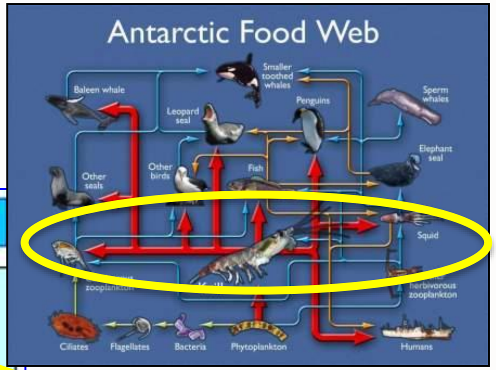


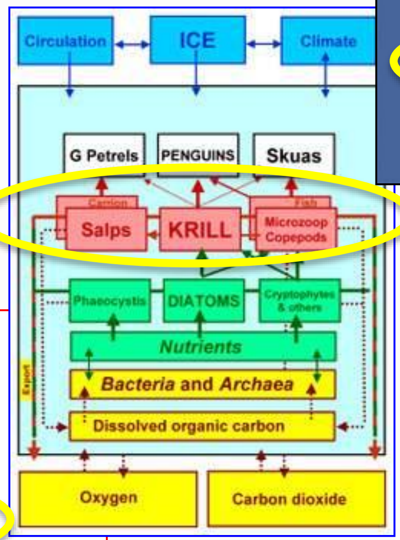
Range of Food Webs

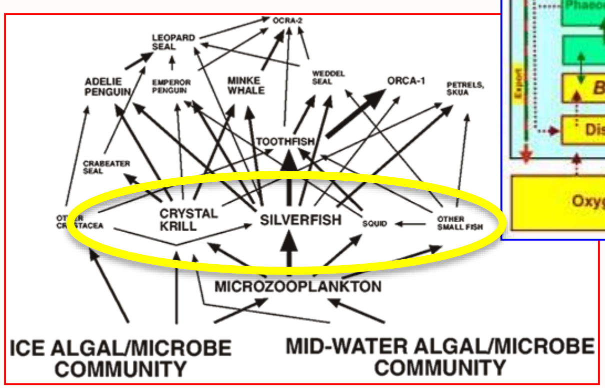
Sub Antarctic

Seasonal length

High Antarctic



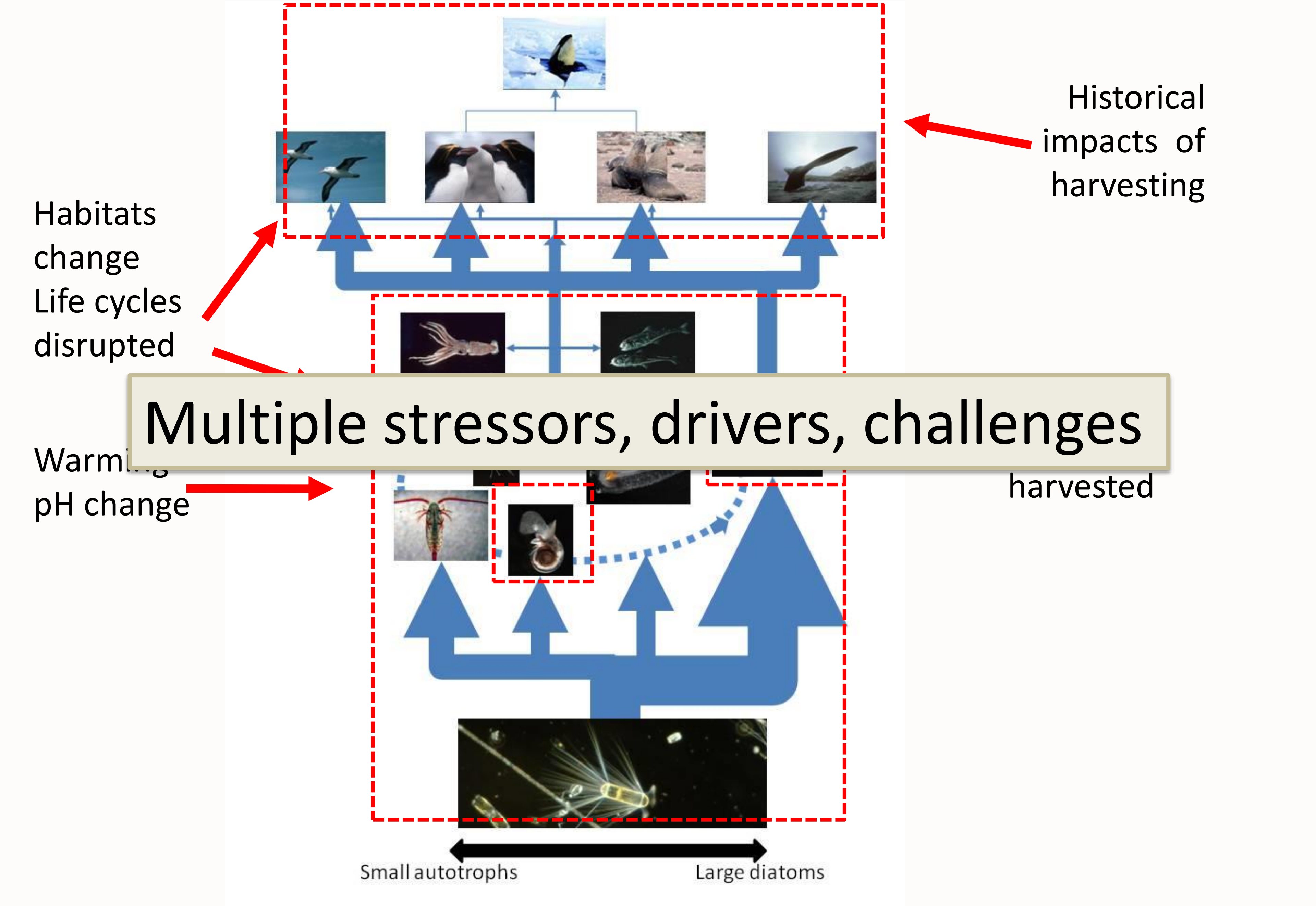




Differences due to
Circulation
Sea-ice
Biogeochemistry
Production
Seasonality

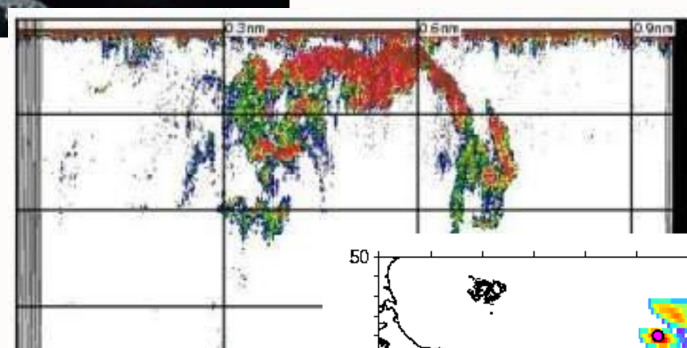
Low Production

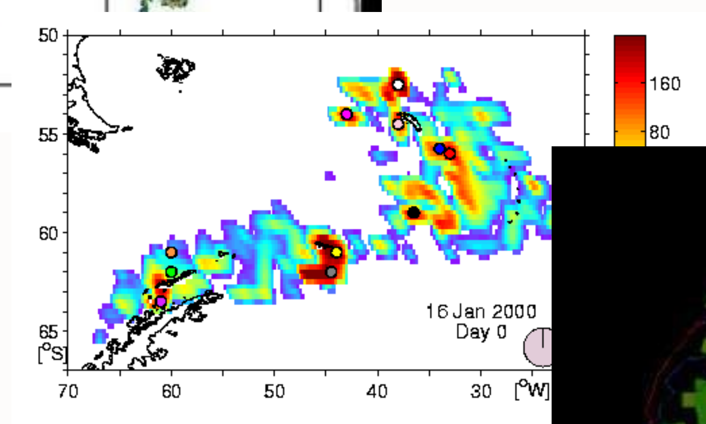
High Production

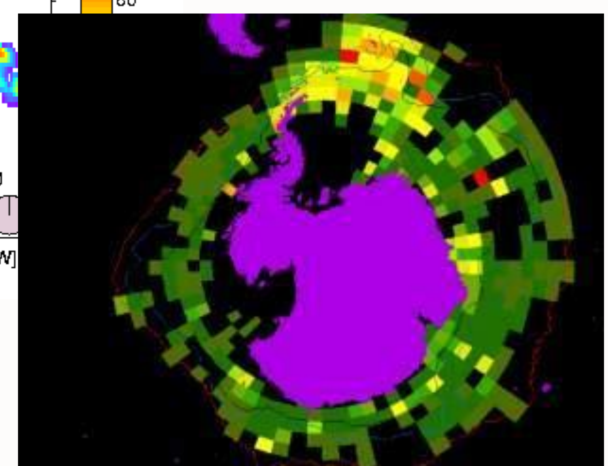

Historical impacts of harvesting
Habitats change
Life cycles disrupted
Warming
pH change
harvested
Small autotrophs
Large diatoms
Multiple stressors, drivers, challenges

Scales of spatial variation

Scale of aggregation depends on view of system

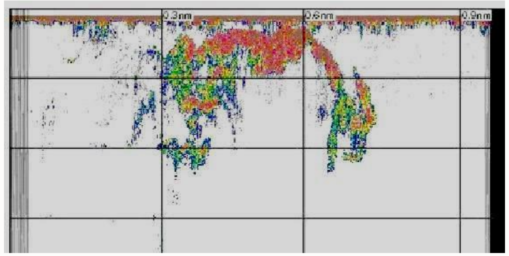


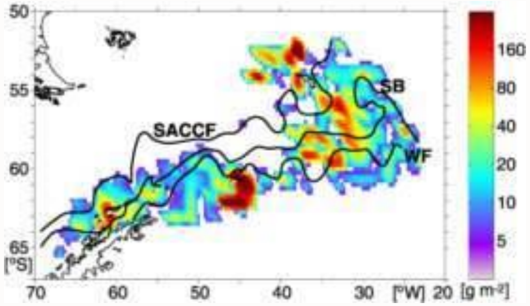




Each scale requires a different model and/or approach

Structure modifies the operation of the ecosystem





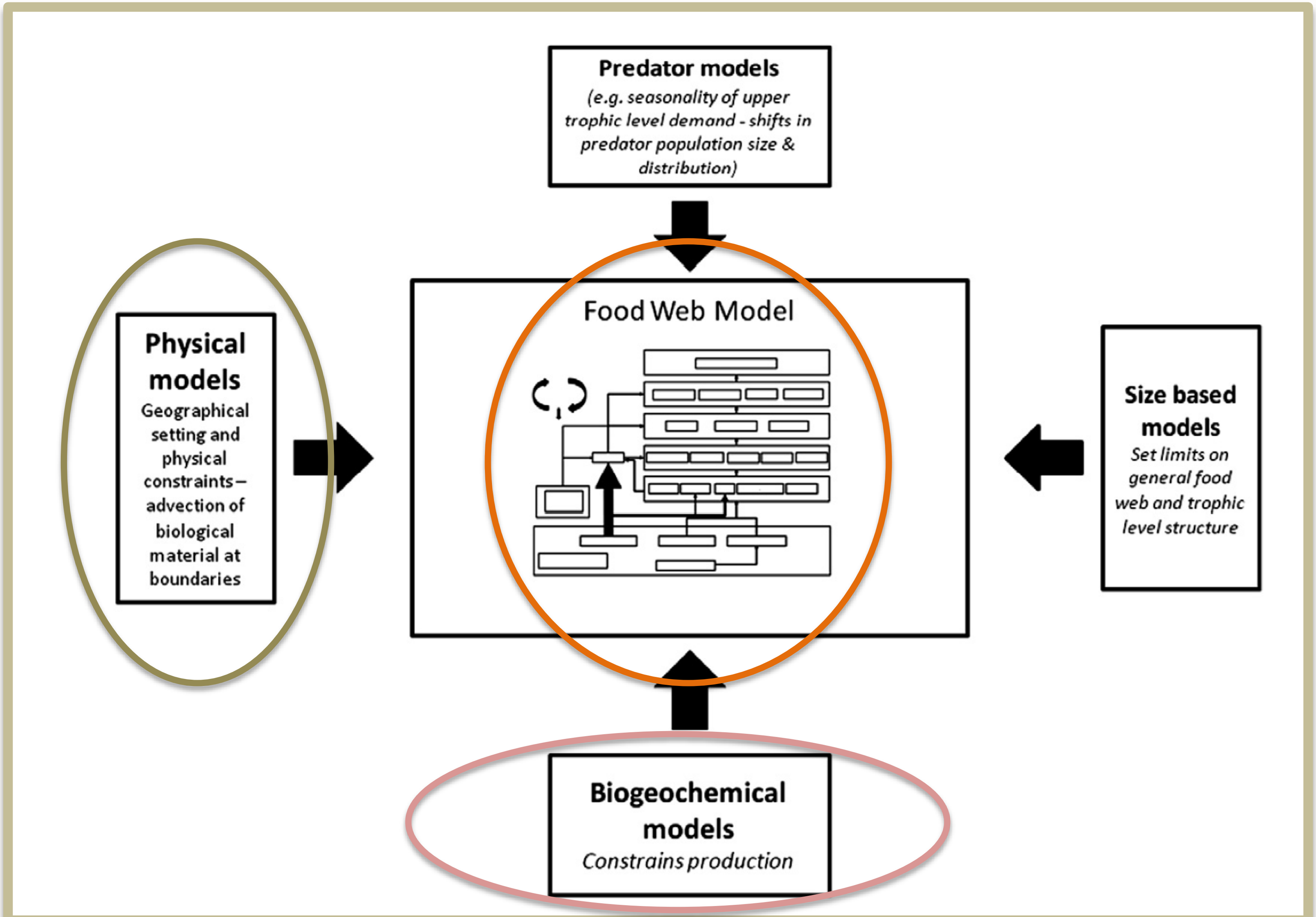
Scale of aggregations - exploited by different predators

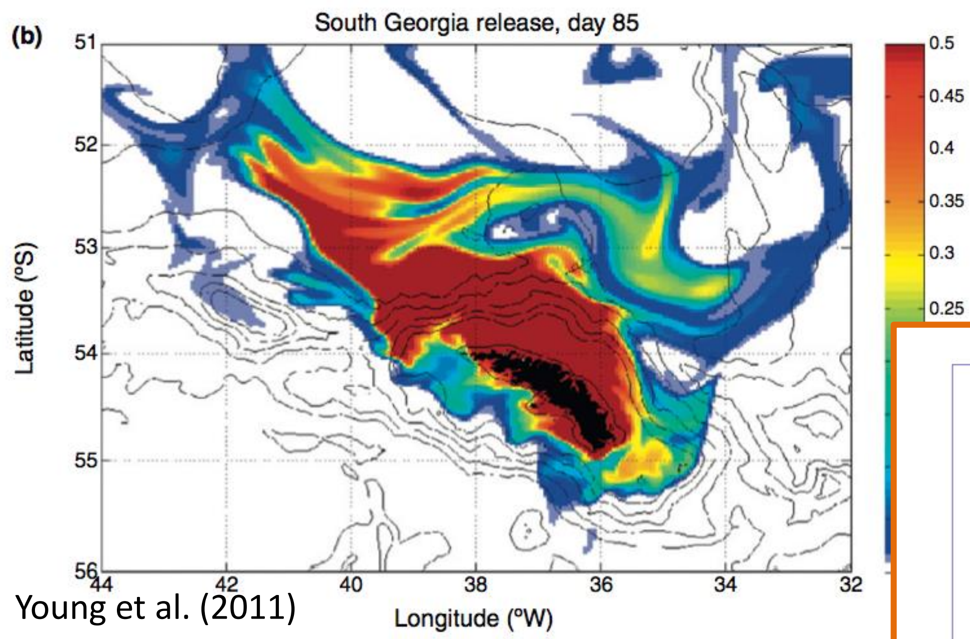
Krill are important to different parts of the food web because of a spatial structure that covers many scales

Longevity and overwinter survival allows spatial and temporal transfer

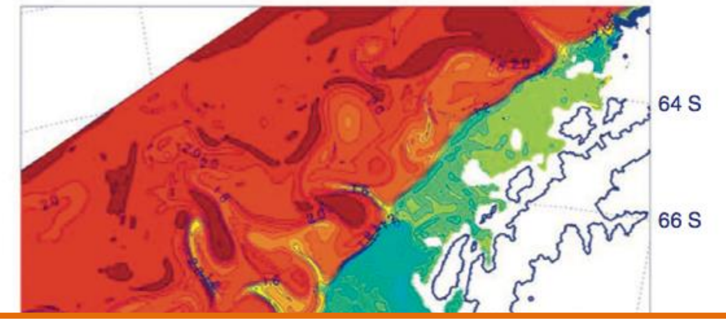
Makes energy available to predators

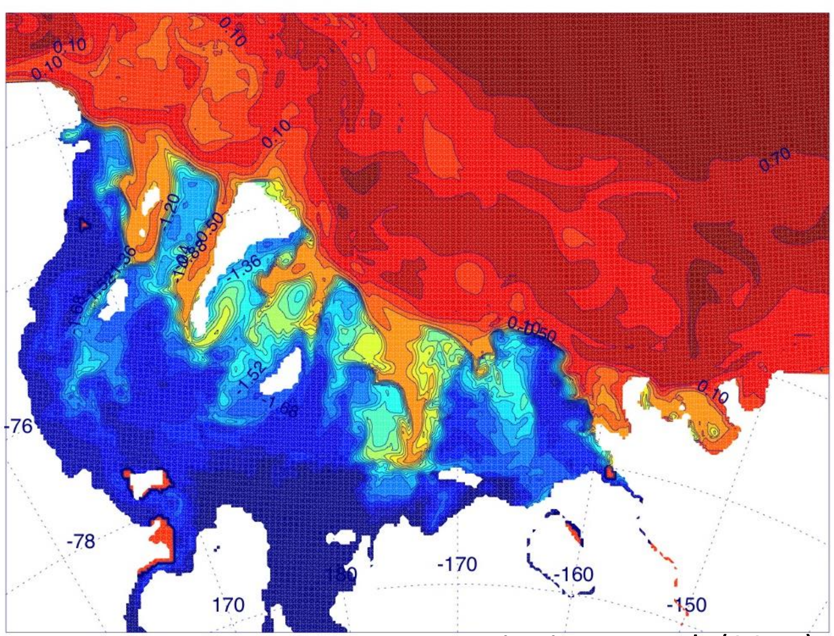
Modeling Southern Ocean Food Webs



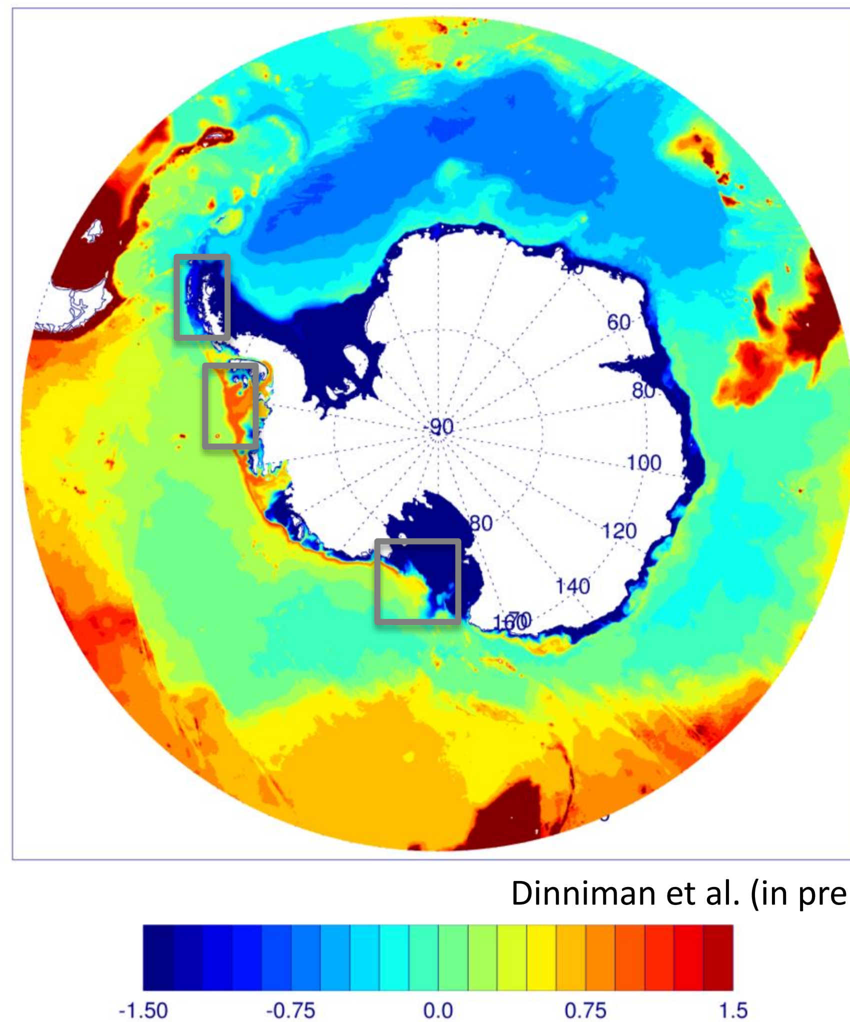


Young et al. (2011)

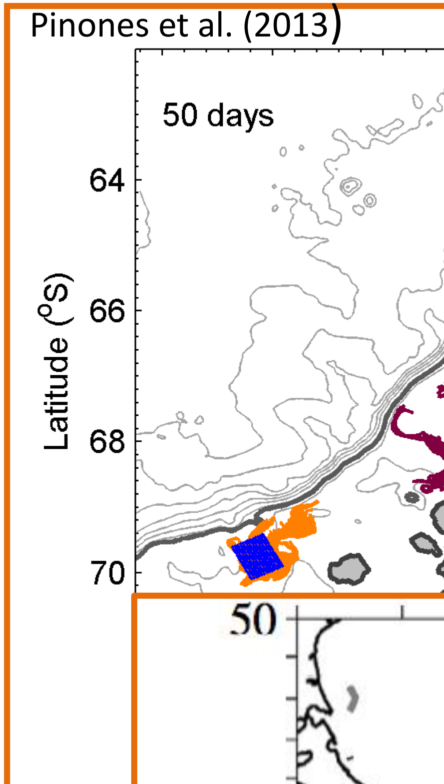




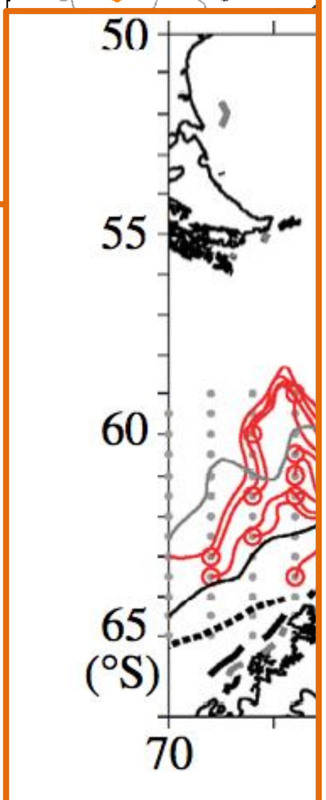
Dinniman et al. (2011)

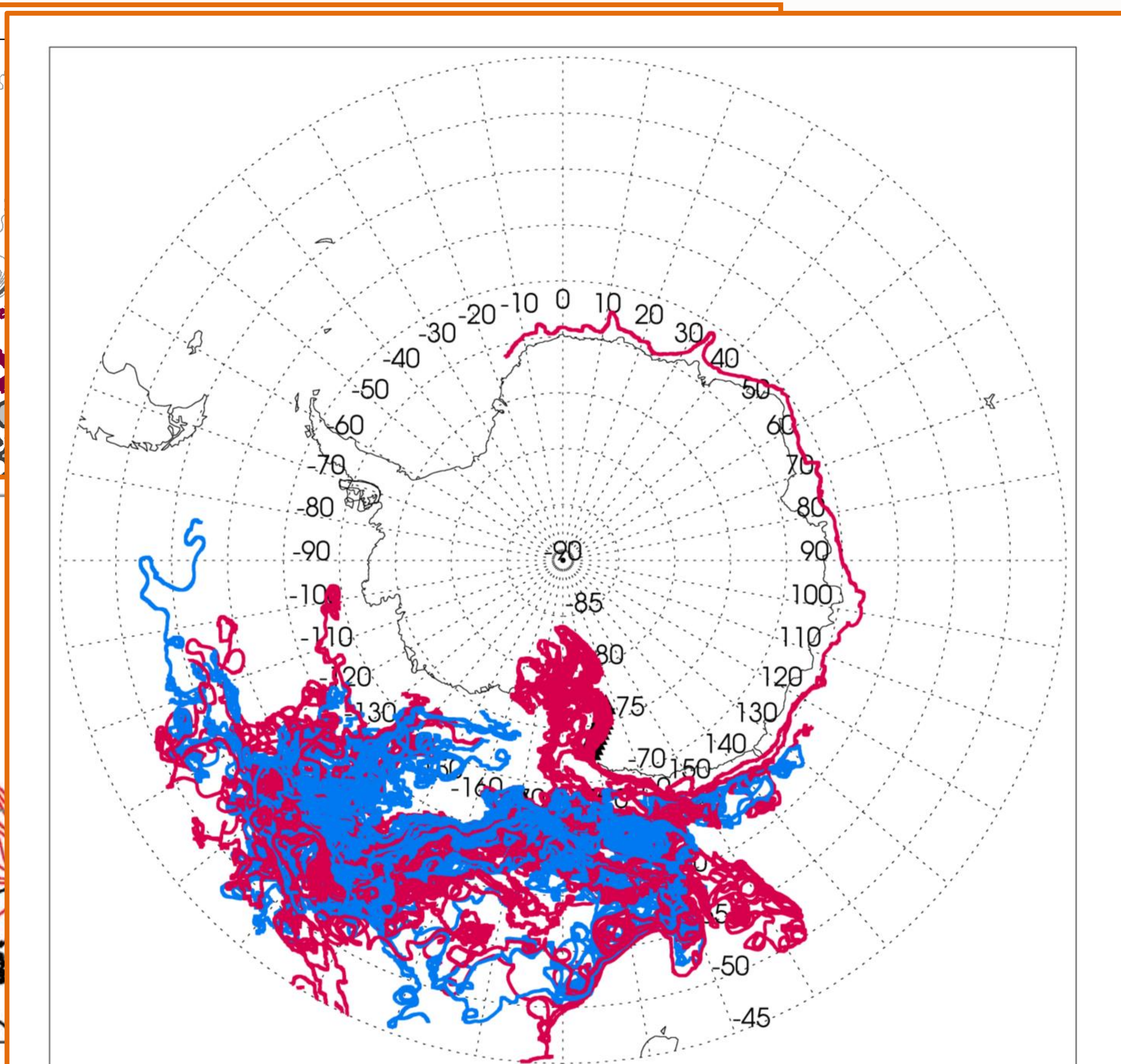


Dinniman et al. (in prep)



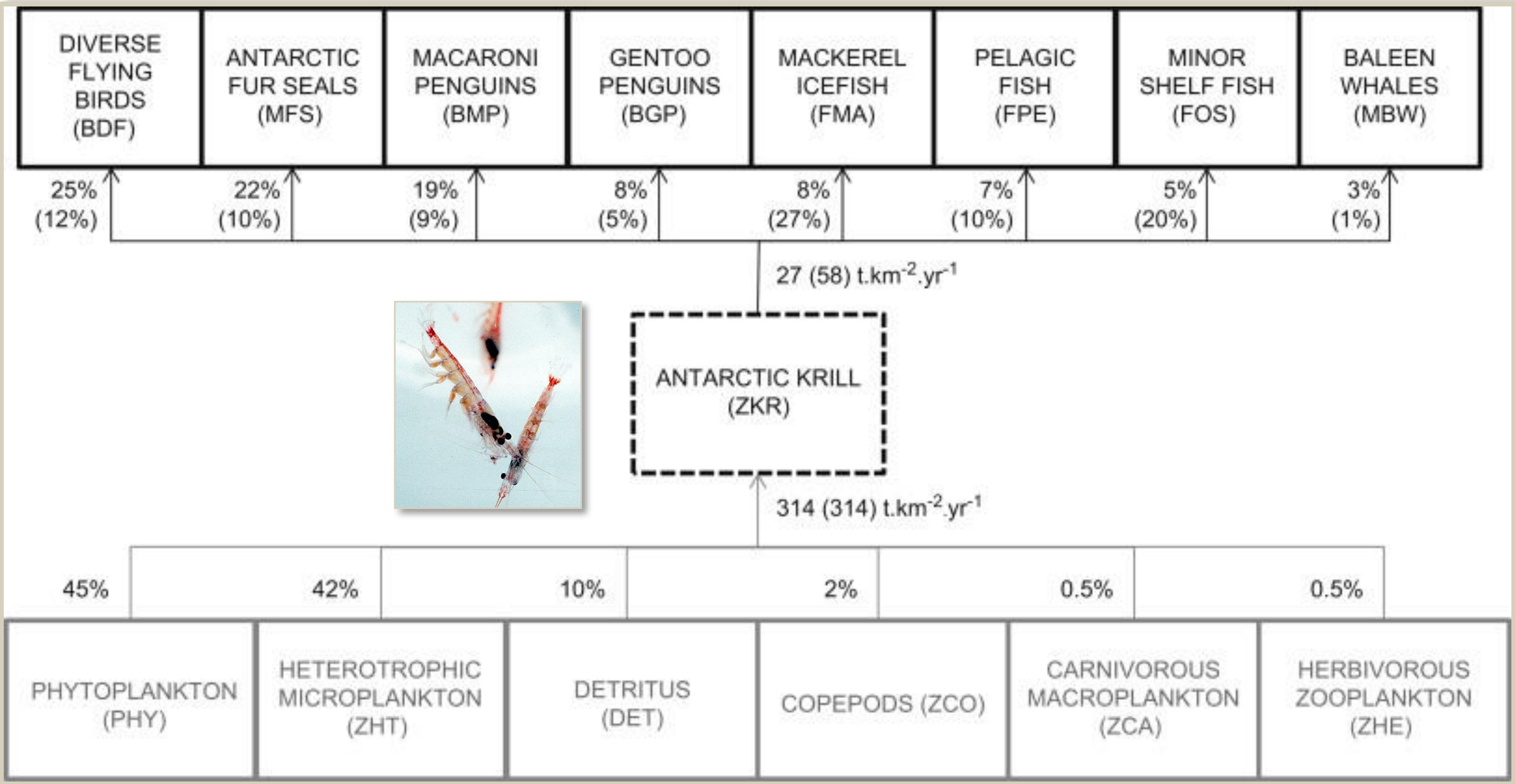
Pinones et al. (2013)





Dinniman et al. (in prep.)

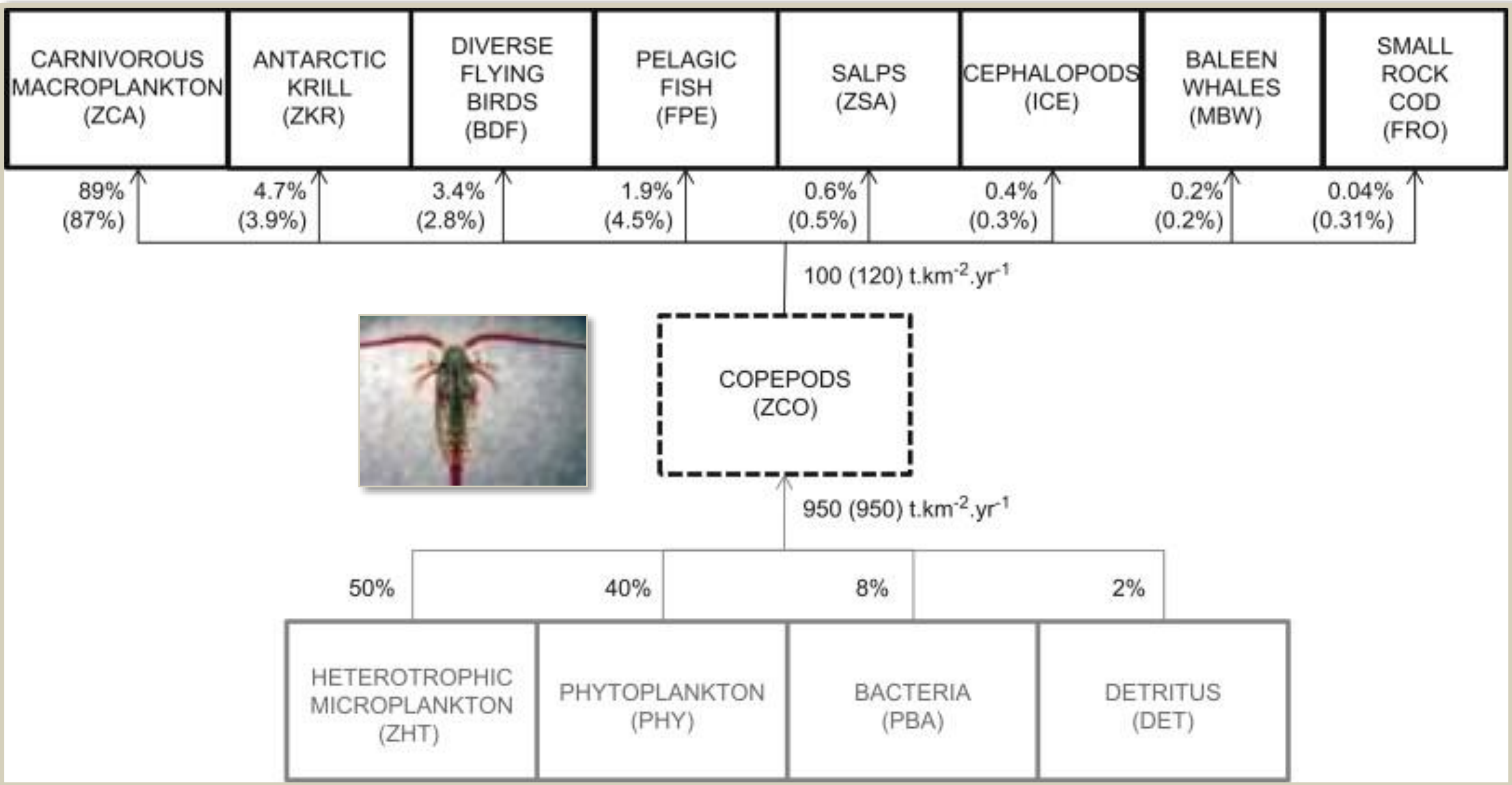
South Georgia Food Web



Hill et al. (2012)

12% from Antarctic krill to upper trophic levels

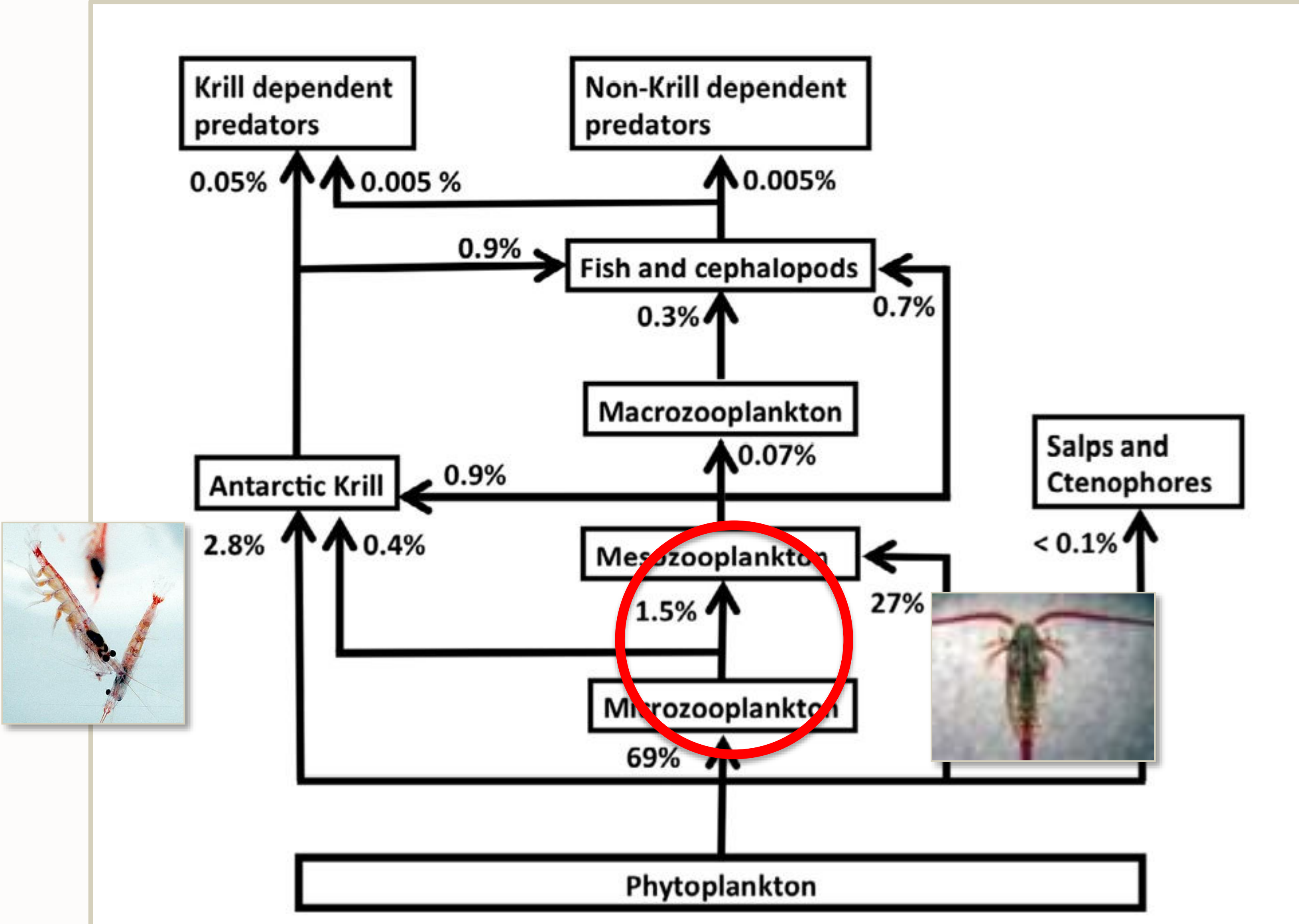
South Georgia Food Web



Hill et al. (2012)

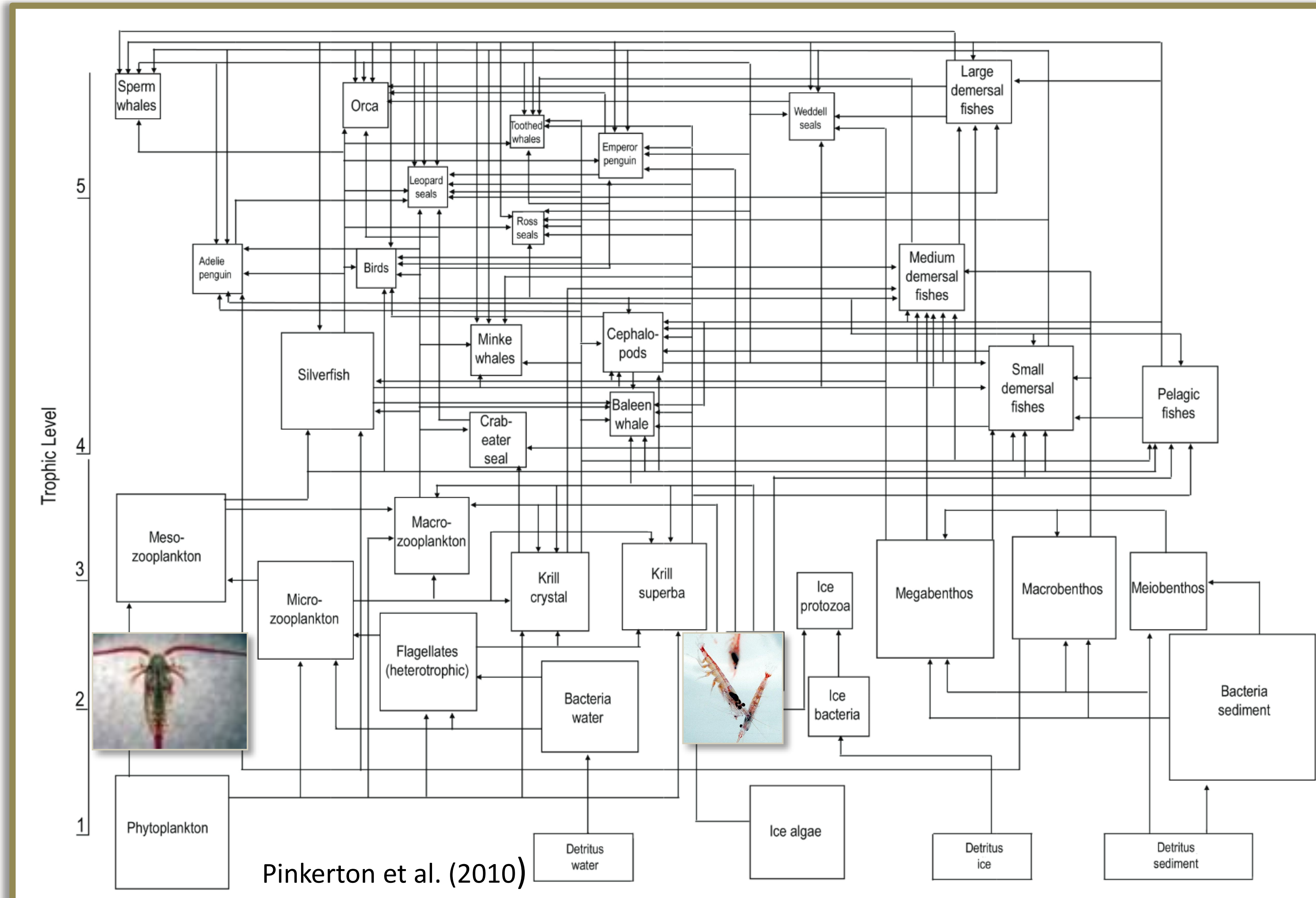
13% from copepods to upper trophic level – different suite of organisms supported

Food Web Southern west Antarctic Peninsula



Two size fractions – large and small

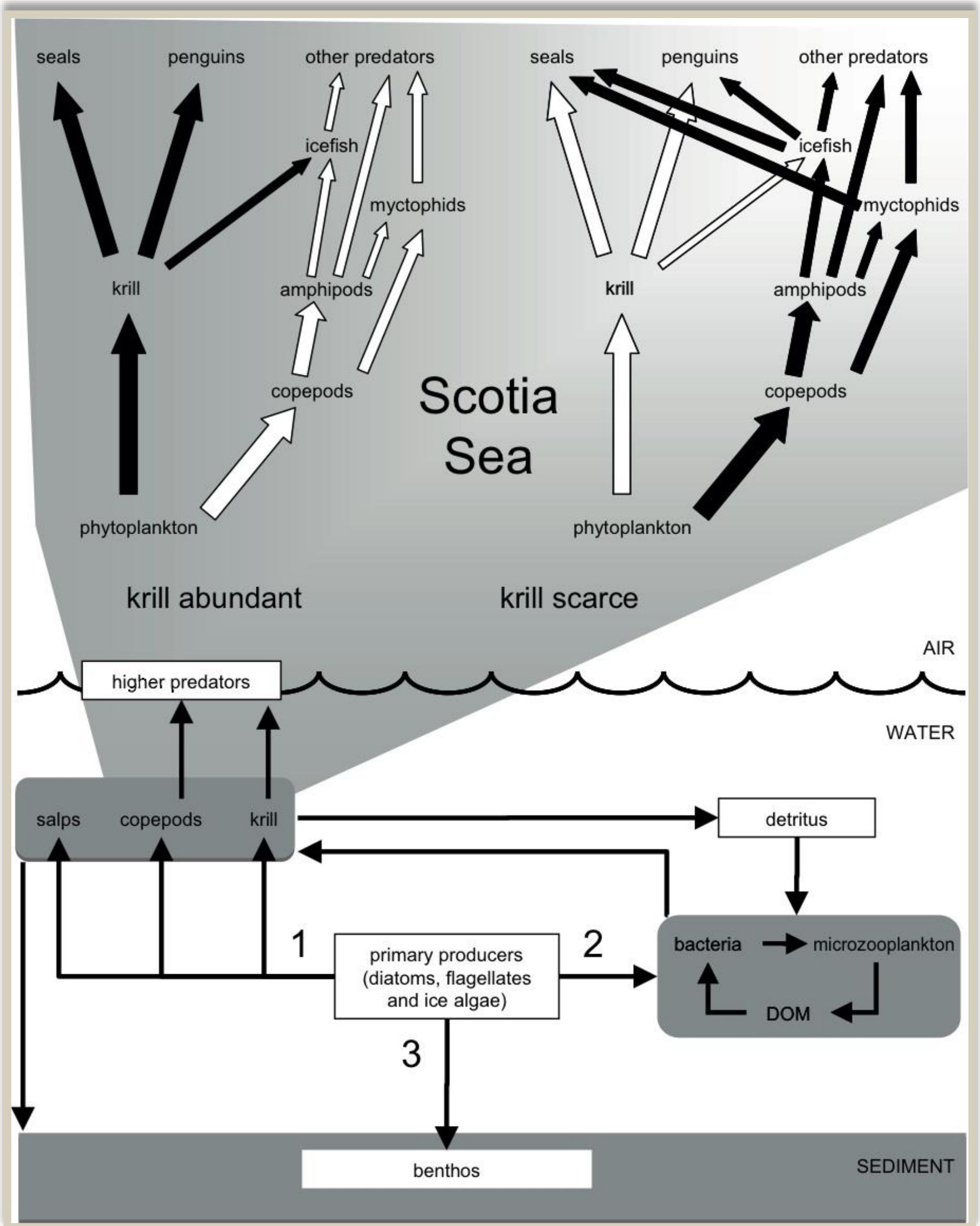
Ballerini et al. 2013



Pinkerton et al. (2010)

Copepods – 53% algal production

Krill – 2% algal production



Adapted from Murphy et al. (2007)

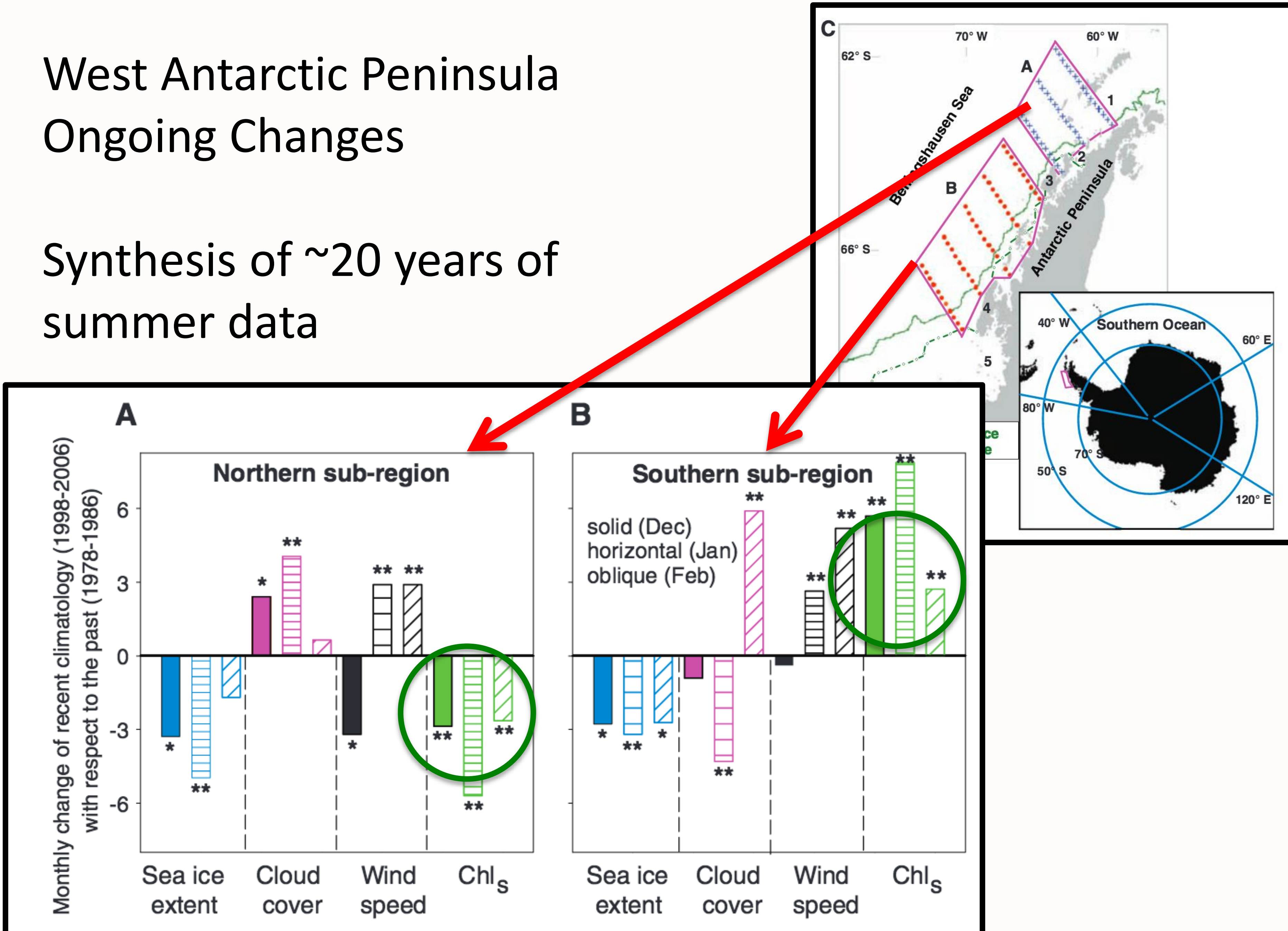
Food Web
simple pathways embedded in more complex network

Modeling Strategy
resolve food webs and individual key species (Krill)

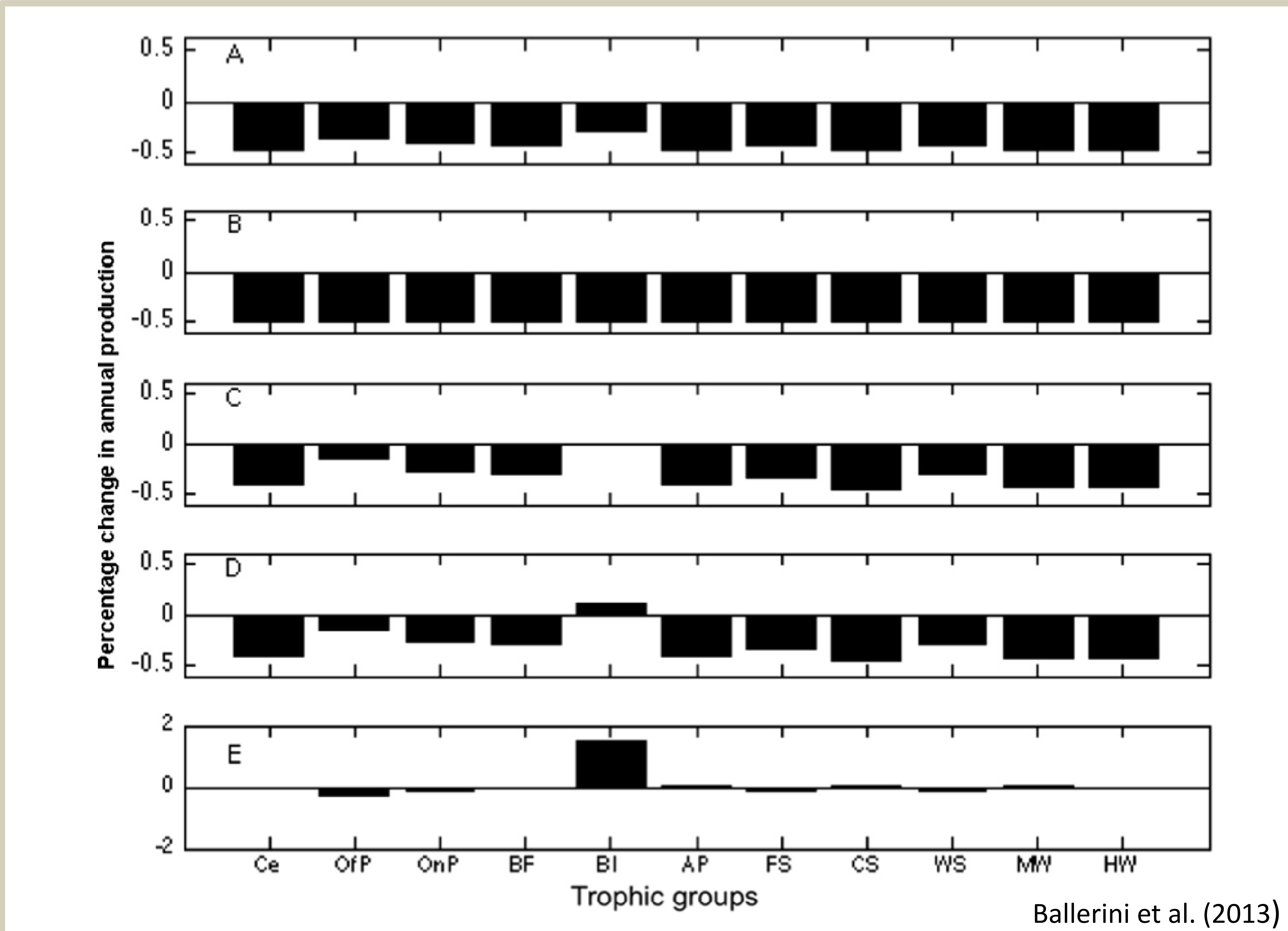
Understand
causes of change, key processes, and consequences

West Antarctic Peninsula Ongoing Changes

Synthesis of ~20 years of summer data



Montes-Hugo et al. (2009)

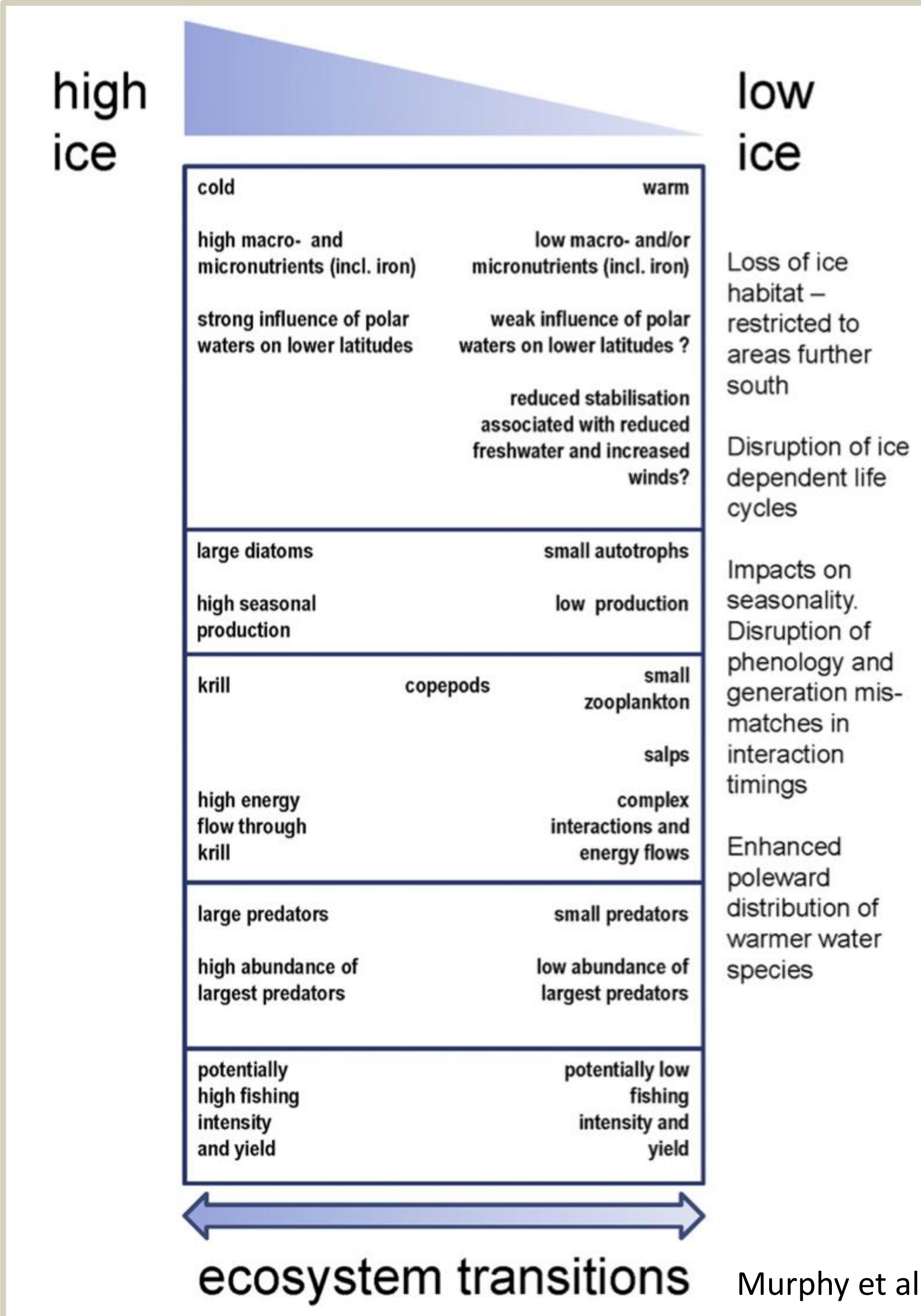


Redirection of phytoplankton food
Different apportioning of large and small phytoplankton

Capacity for Change

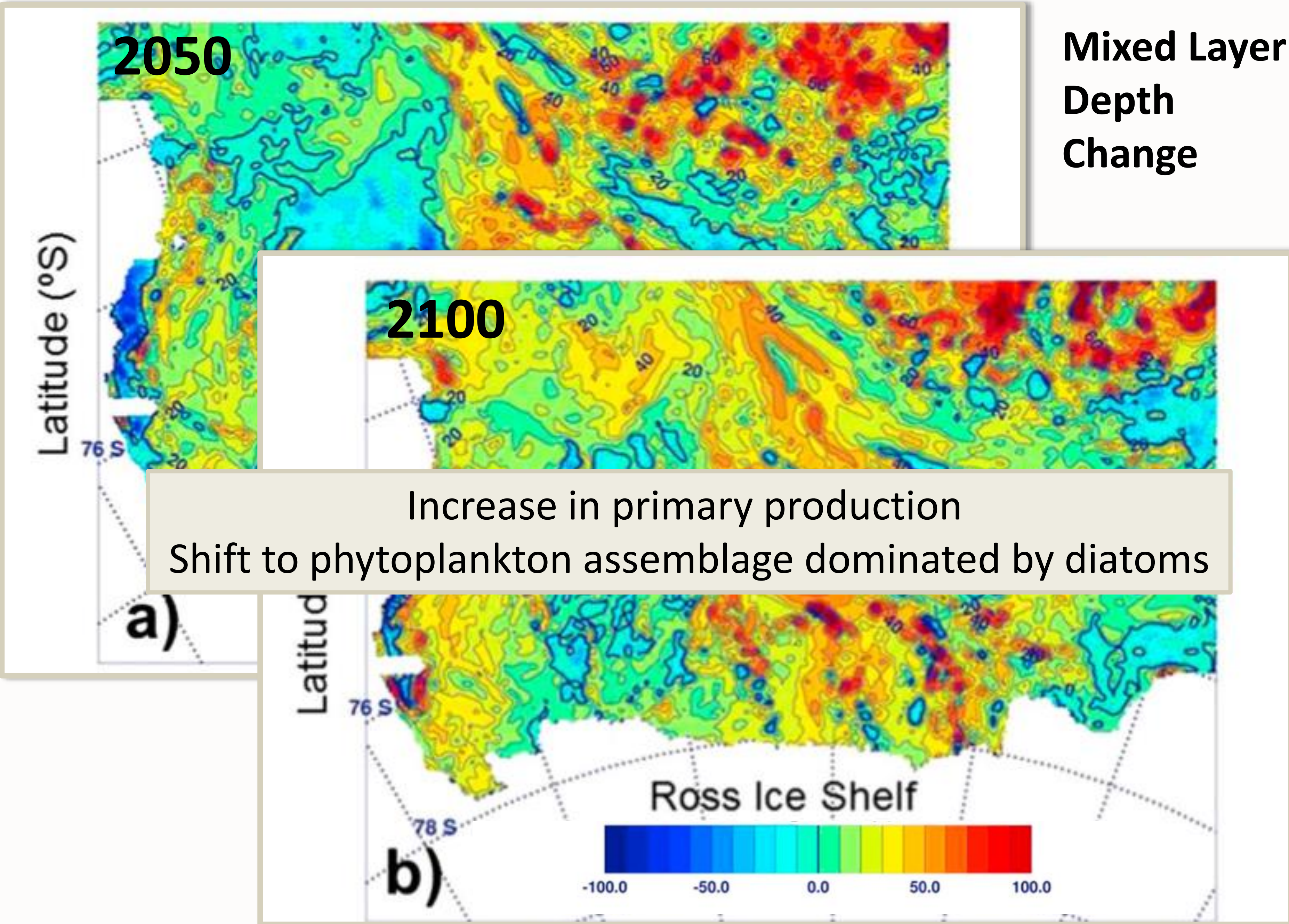
Projected Changes

Scenarios



Murphy et al. (2013)

Mixed Layer Depth Change



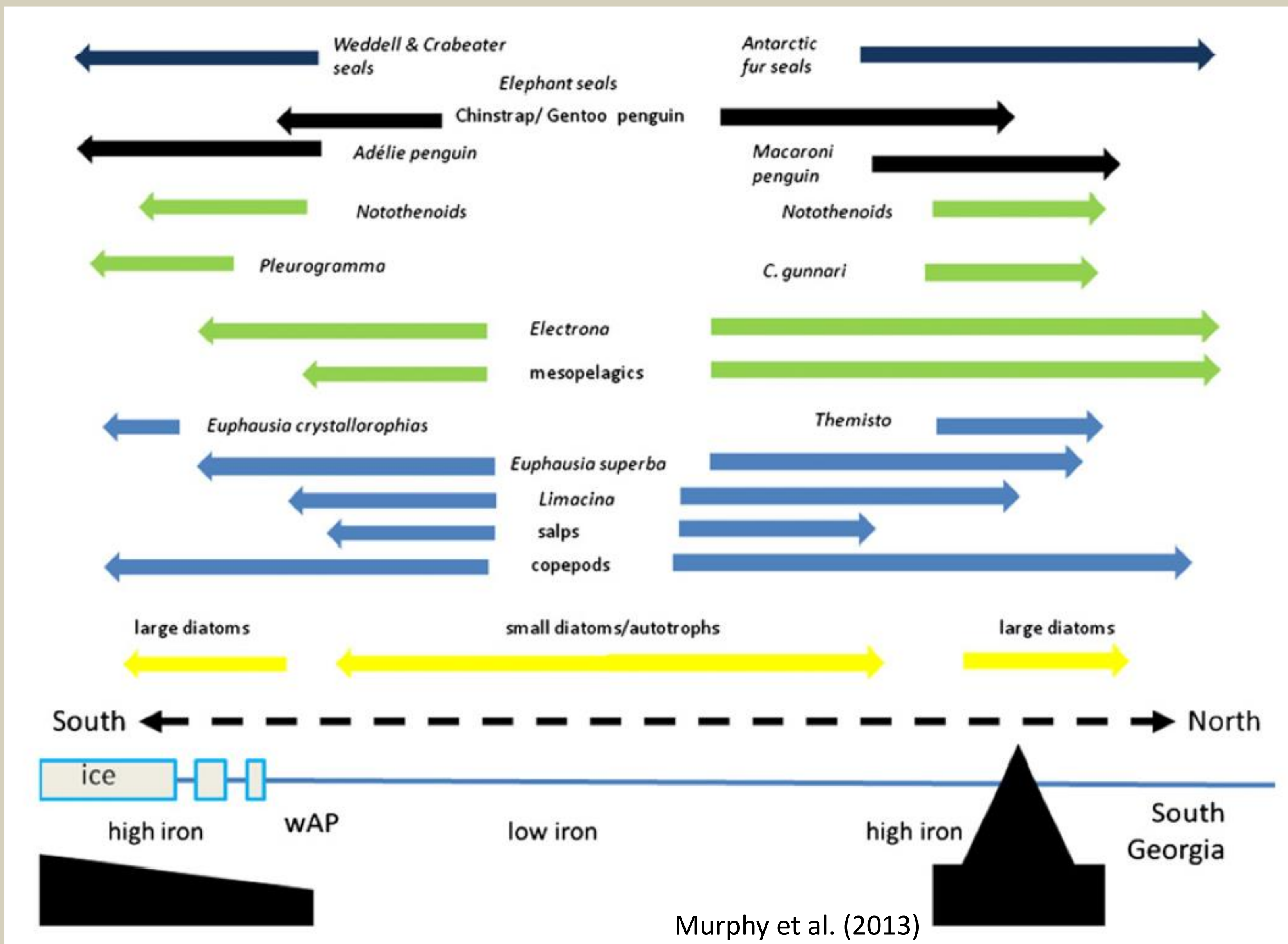
Increase in primary production

Shift to phytoplankton assemblage dominated by diatoms

Smith et al. (2014)

General food web structure stays same
Species exit/replaced

Changes across contrasting habitats
Reorganization of food webs



Murphy et al. (2013)

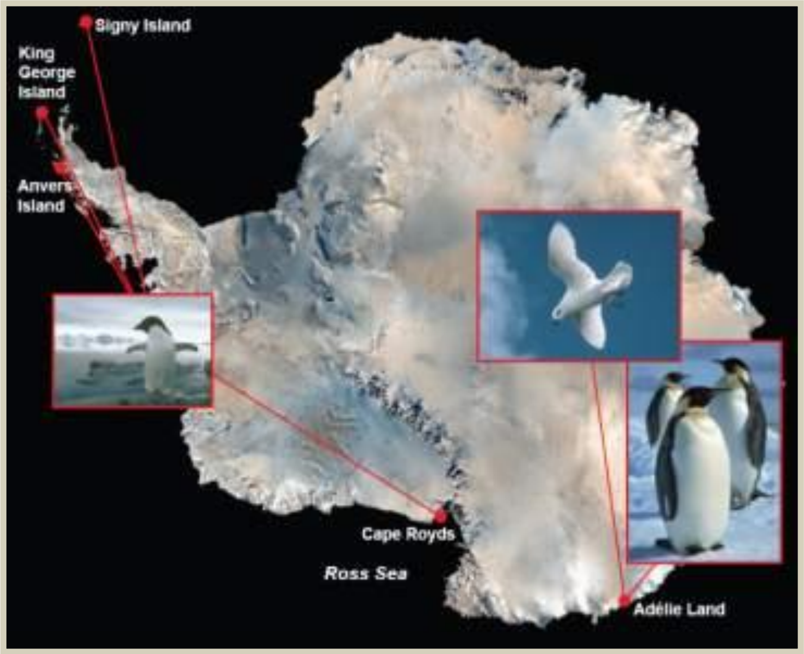
Complexity of Responses

- Local/regional nature of responses, mechanisms & changes

- Direct/indirect impacts
  - Ice, snow
  - Food webs – prey
  - Fishing - mortalities

- Physiological/Life histories
  - Flexibility
  - Sea-ice, timing , seasonality- phenology
  - -> Population reductions/increases

- Interaction effects
  - Competition, predator-prey, food web structure

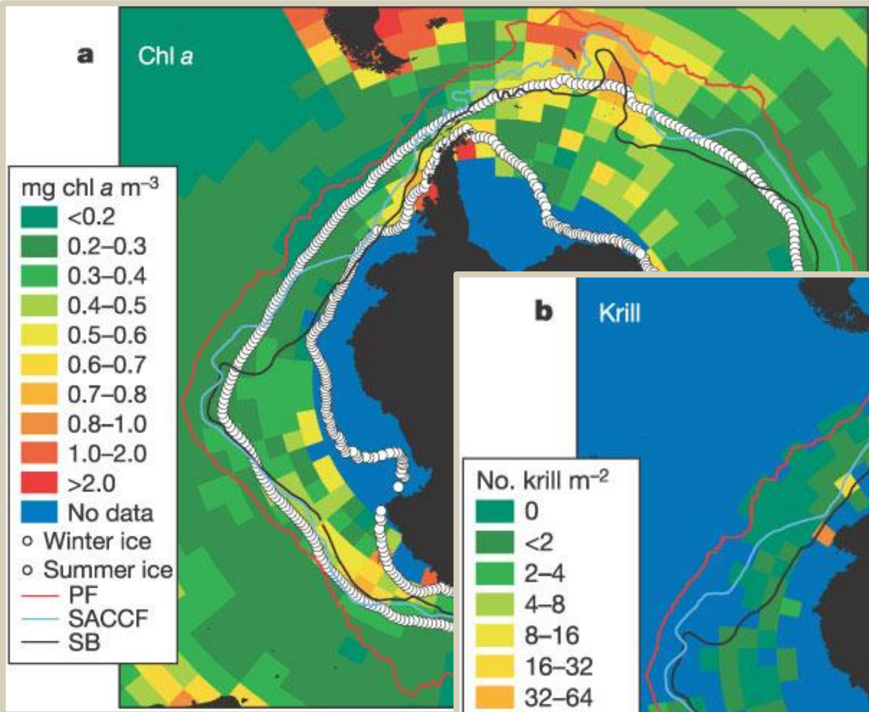


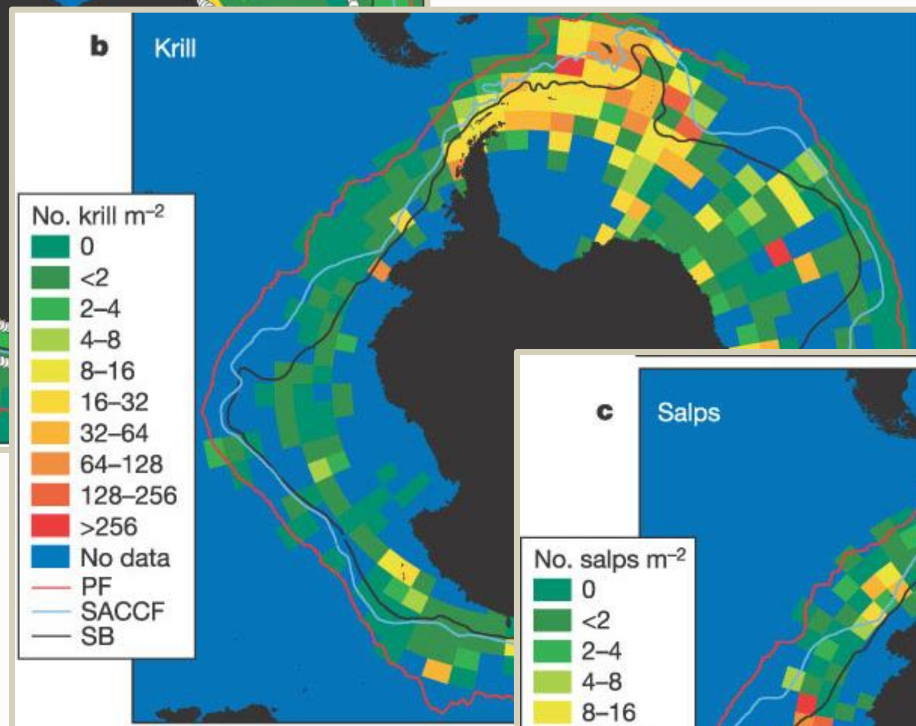
Circumpolar Distributions

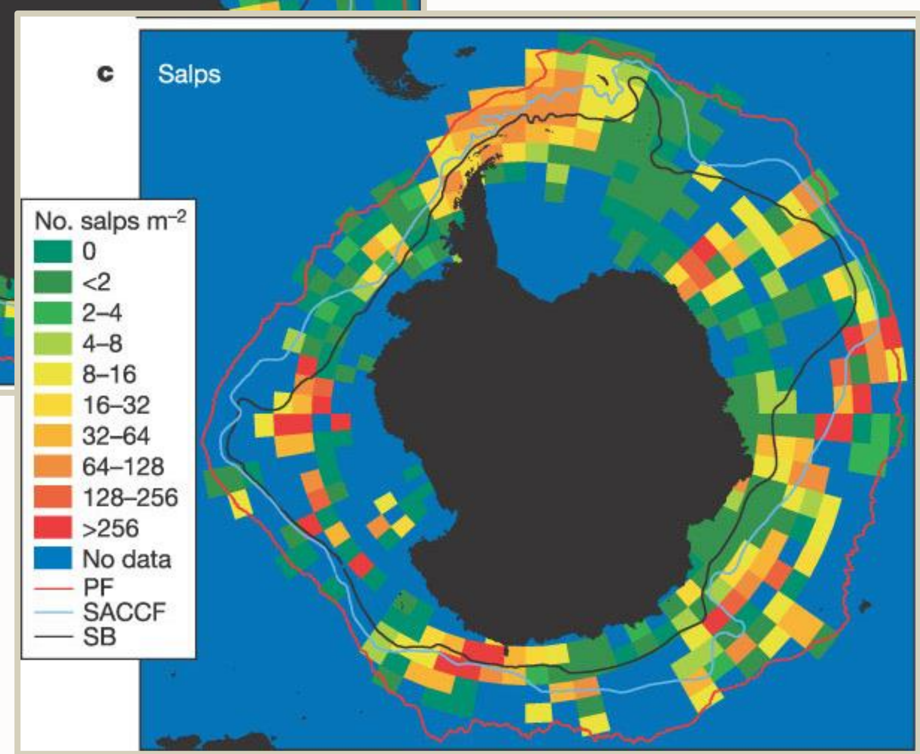
Chlorophyll

Antarctic Krill

Salps







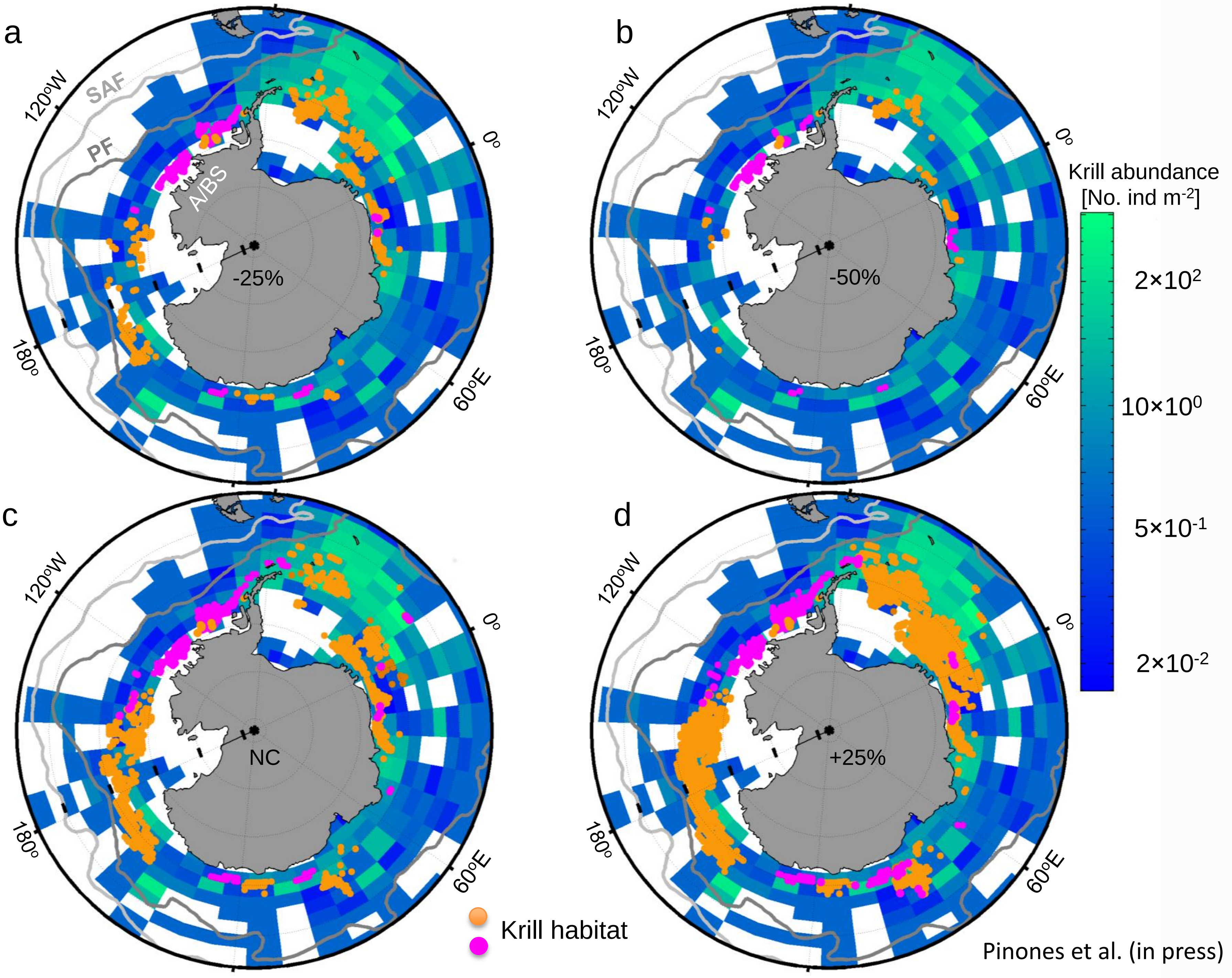
Identification of habitat characteristics

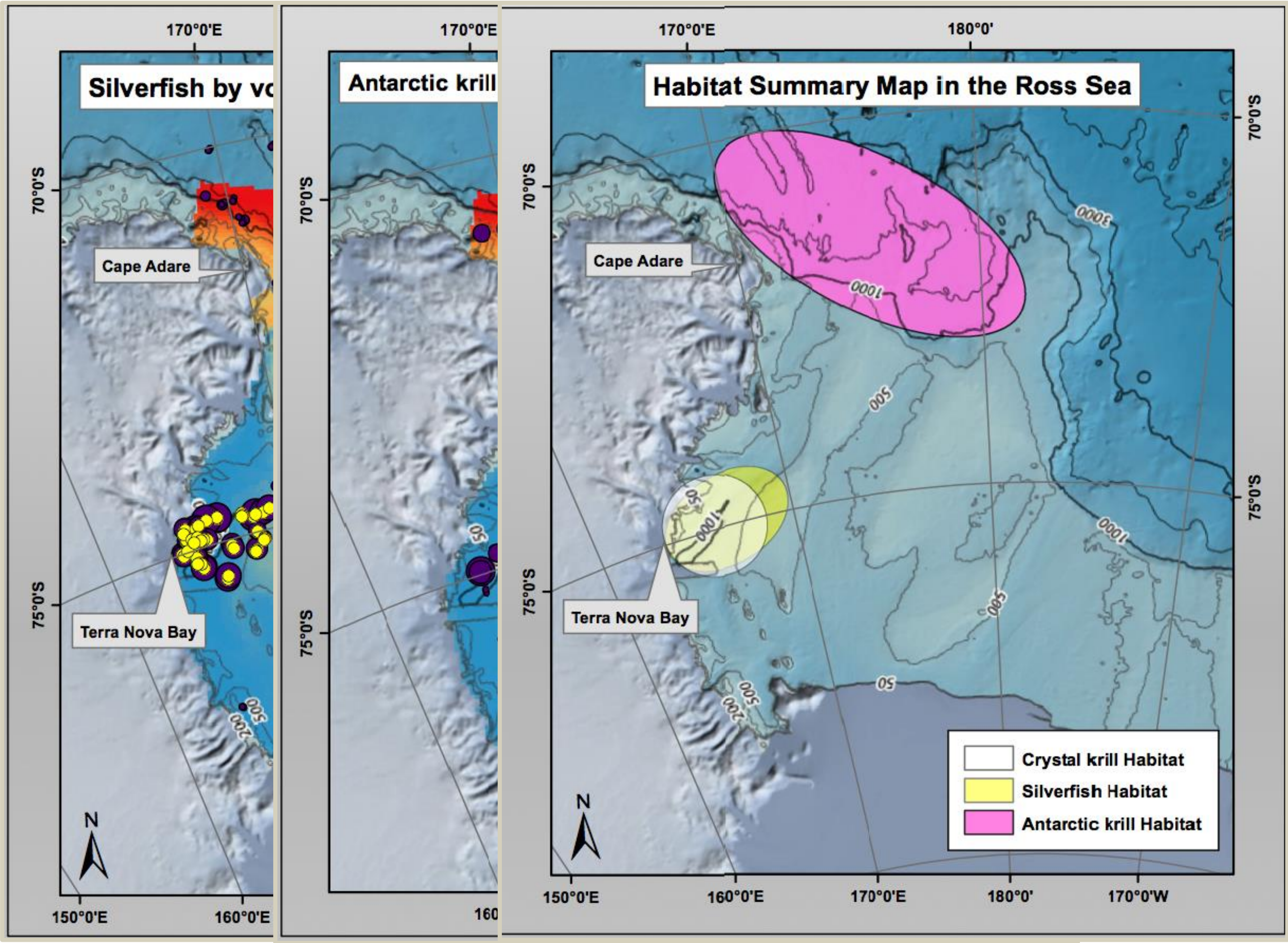
Understand key zooplankton species

Effects on food webs

Projections of ocean warming

Atkinson et al. (2004)

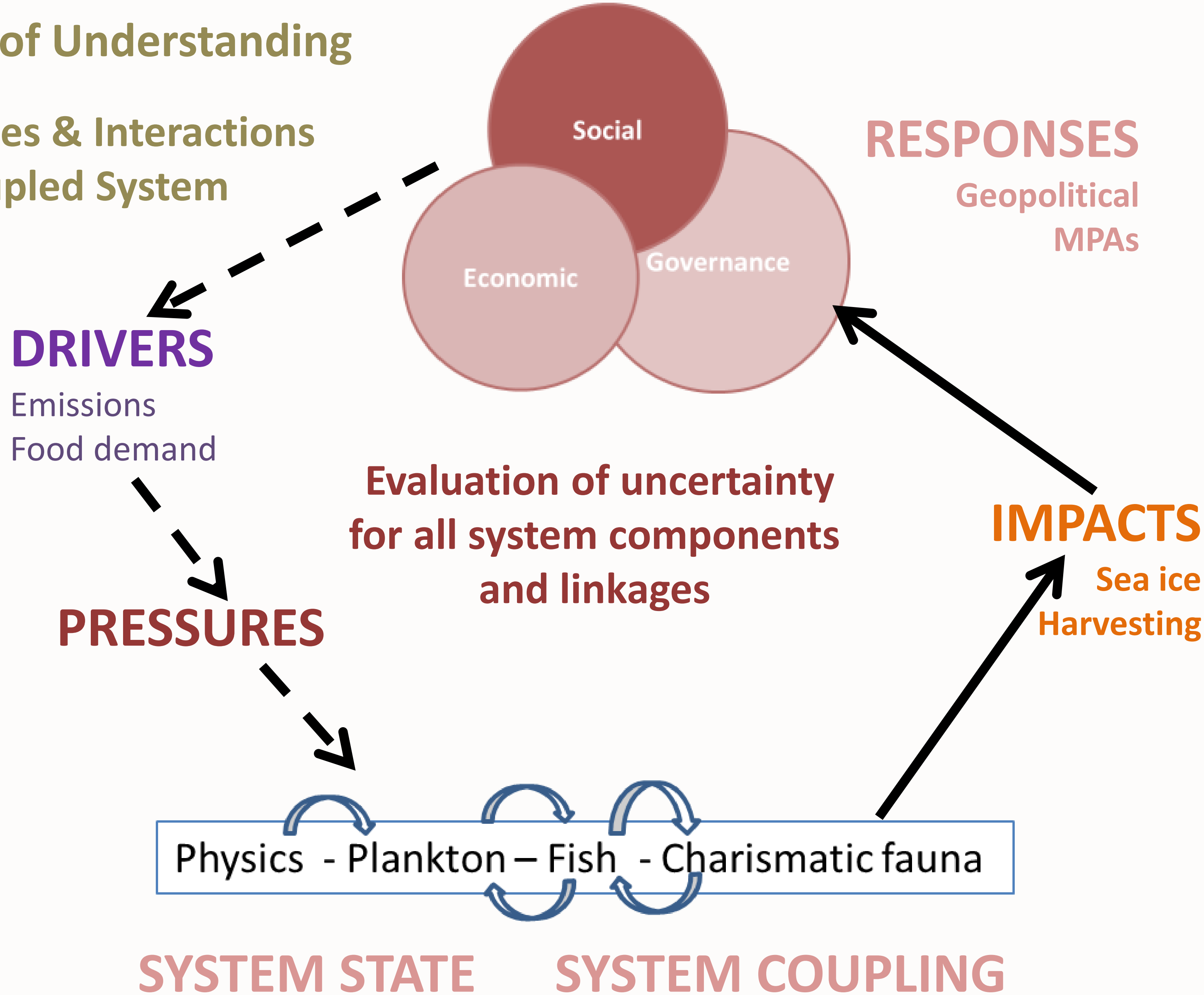

a
b
c
d
SAF
PF
A/BS
120°W
0°
180°
60°E
-25%
-50%
NC
+25%
Krill abundance
[No. ind m-2]
2×10^2
10×10^0
5×10^-1
2×10^-2
Krill habitat
Pinones et al. (in press)



Davis et al. (in prep.)

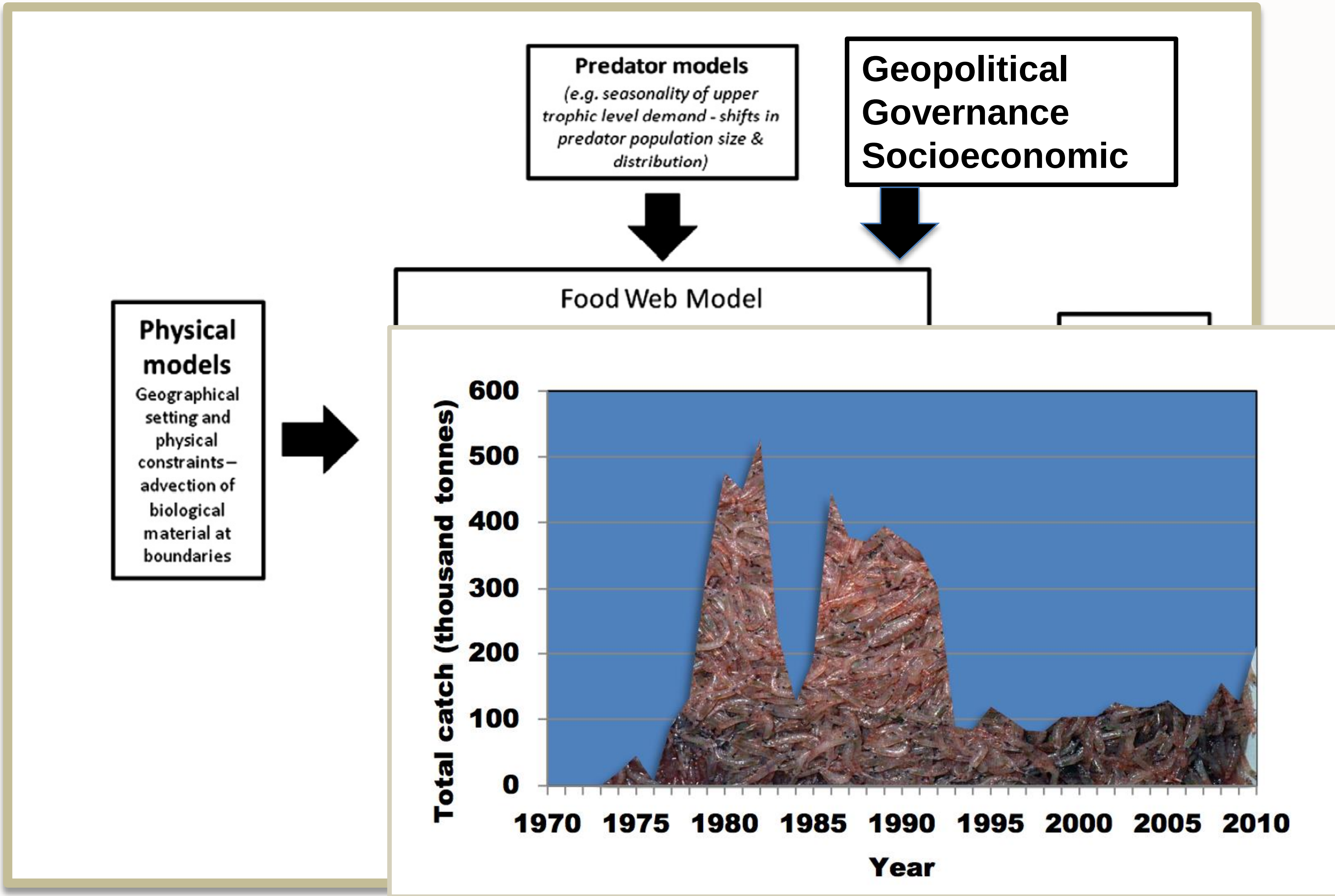
State of Understanding

Linkages & Interactions of Coupled System



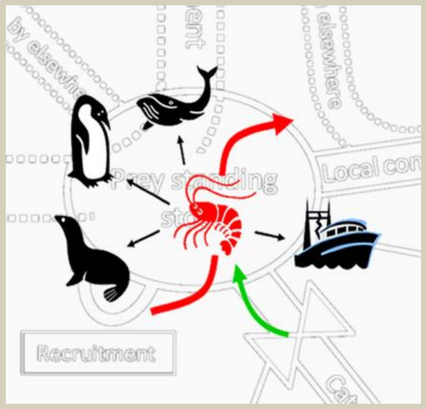
Adapted from Allen, IMBIZO, 2015

Southern Ocean Food Webs
Management Strategy Evaluation



Approaches & Challenges

- Retrospective analyses
  - Past harvesting effects
- Scenario Development
  - Projections of change
- Challenges - Food webs
  - Neglected trophic links
  - Linking to key species
- Challenges – beyond food webs
  - Inclusion of new data/technology
  - Links to new science sectors
  - Human impacts & needs
  - Impact & attribution
  - Adaptation pathways
- Management Strategy Evaluation
  - Network of models
  - Strategy for combining models and identifying transfers between models



Final Remarks

- Circulation models
  - High-resolution regional and circumpolar models with skill
  - Implement and compare
- Mechanistic understanding
  - Incorporate into food web and biogeochemical models
- Projections
  - Input to climate models so that useful for biological studies
  - Develop community-based scenarios (ICED)
- Comparative studies
  - Expand analyses
  - Use model structures that can be compared across systems

- Combine in larger context to consider questions of the central role of zooplankton in a changing ocean

Tusen Takk!

Photos
D. Costa