Modeling Southern Ocean Food Webs: Approaches and Challenges

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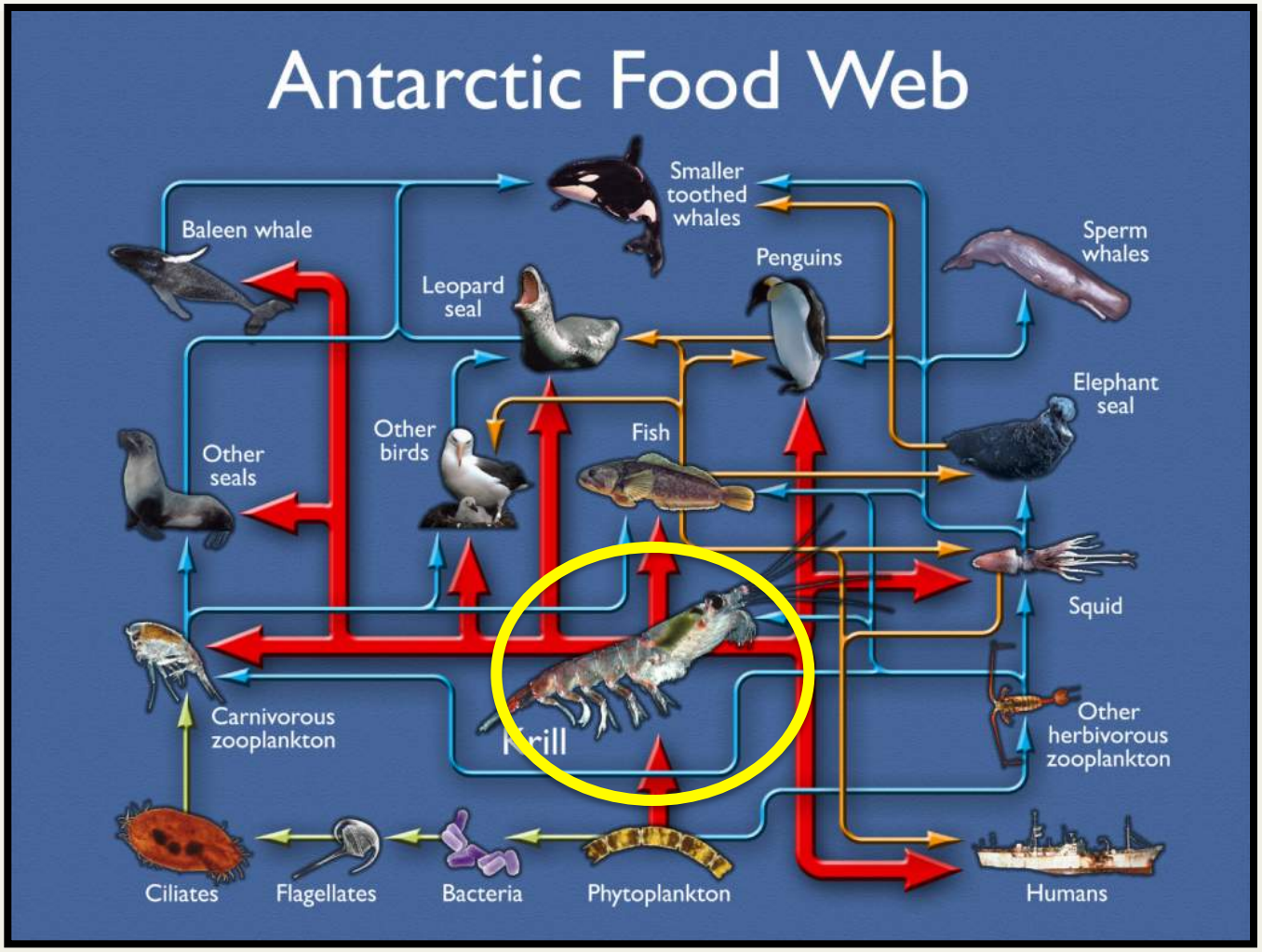
Presentation Outline

- Southern Ocean food webs
- Connectivity between food webs
- Potential effects of climate change on food webs
- Challenges for modeling food webs

What is a Southern Ocean Food Web?

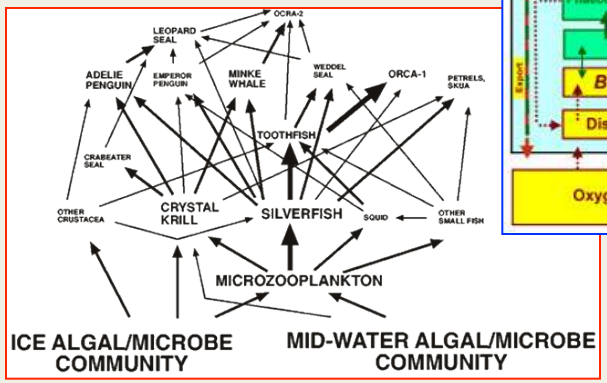


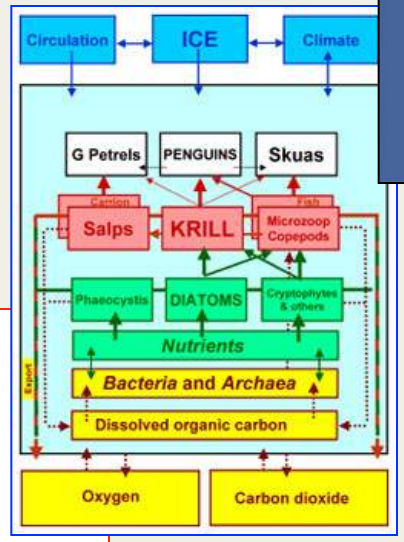
Range of Food Webs

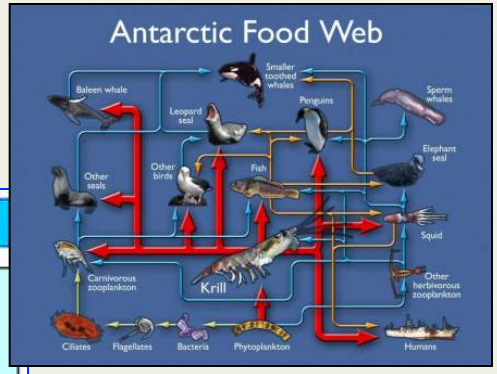
Sub Antarctic

Seasonal length

High Antarctic



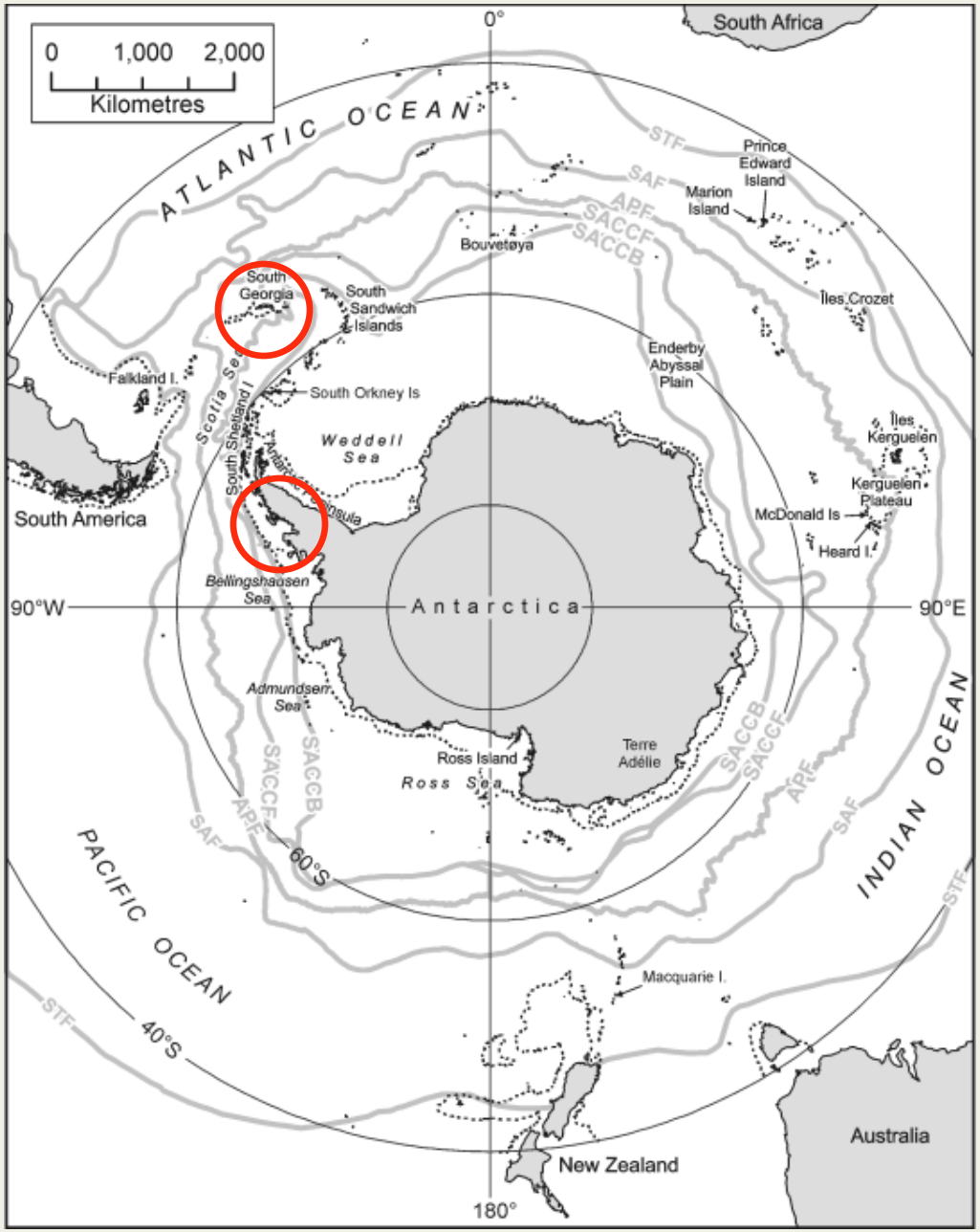




Differences due to
Circulation
Sea-ice
Biogeochemistry
Production
Seasonality

Low Production

High Production



Southern Ocean Food Webs

Circumpolar System

Heterogeneity in forcing and habitat structure

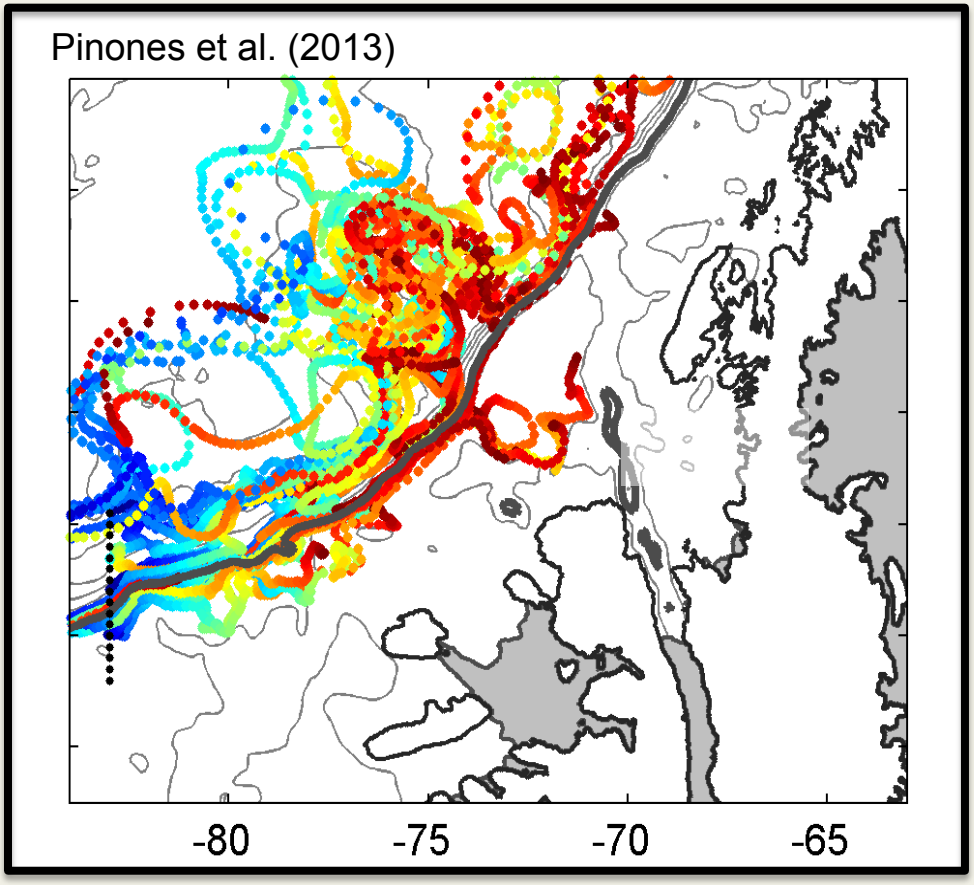
Different levels of exploitation

Regional differences in responses – top down and bottom up effects

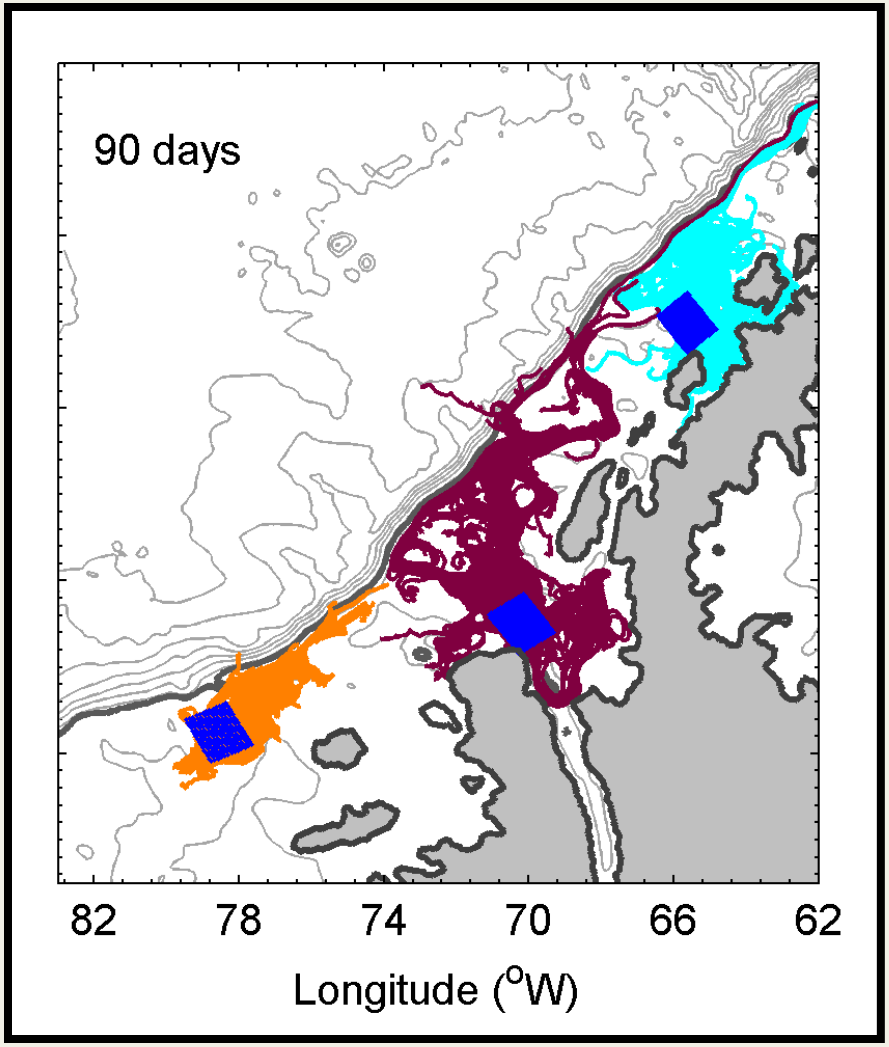
West Antarctic Peninsula and South Georgia

- Support large populations of predators
- Dependent on Antarctic krill
- Differences
    - winter - light, sea ice presence, extent, length
    - controls - CDW/Southern ACC boundary versus Southern ACC Front
    - advective influences - closed versus open system
    - self sustaining krill population versus non-local inputs of krill
    - high productivity - natural iron fertilization through different mechanisms
- Systems are connected by Antarctic krill

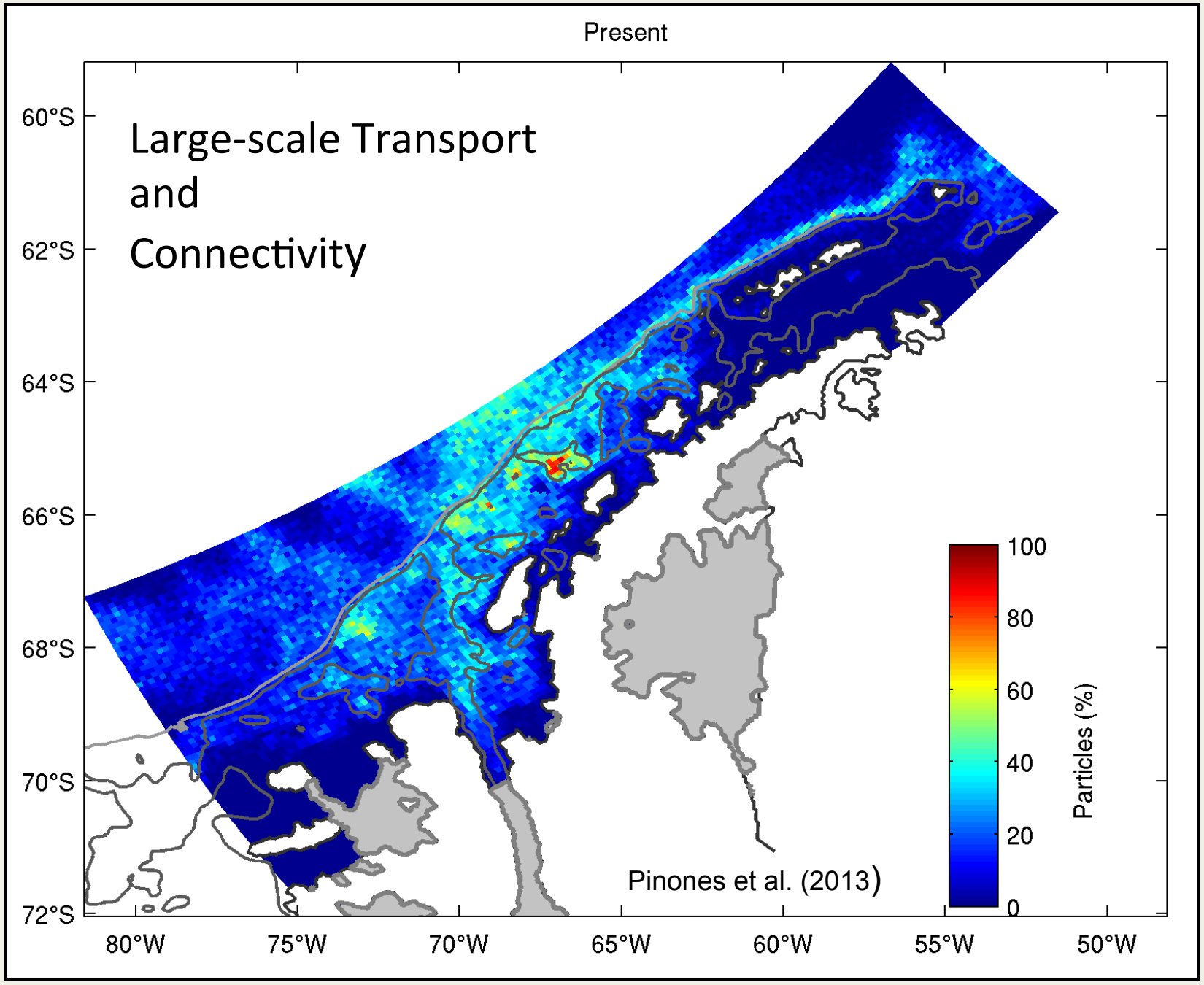
Connectivity – WAP

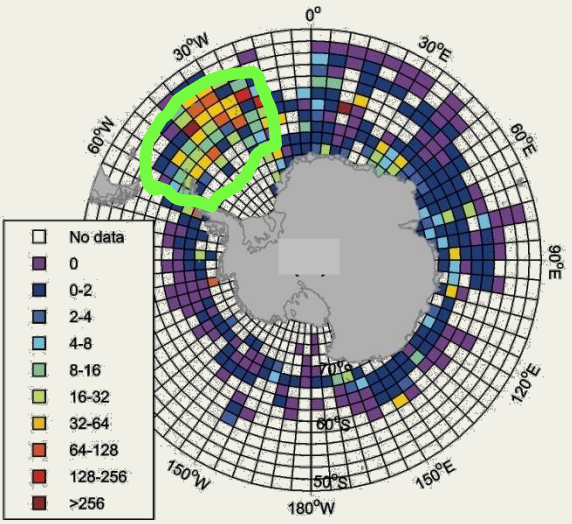


Upstream Inputs



Local Inputs and Retention


Present
Large-scale Transport
and
Connectivity
60°S
62°S
64°S
66°S
68°S
70°S
72°S
80°W
75°W
70°W
65°W
60°W
55°W
50°W
100
80
60
40
20
0
Particles (%)
Pinones et al. (2013)

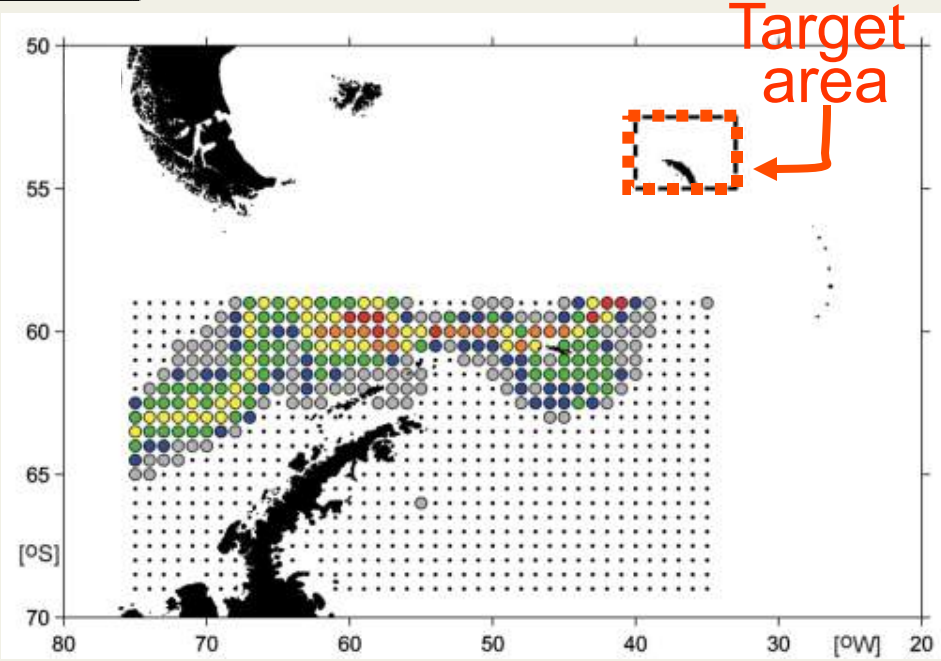


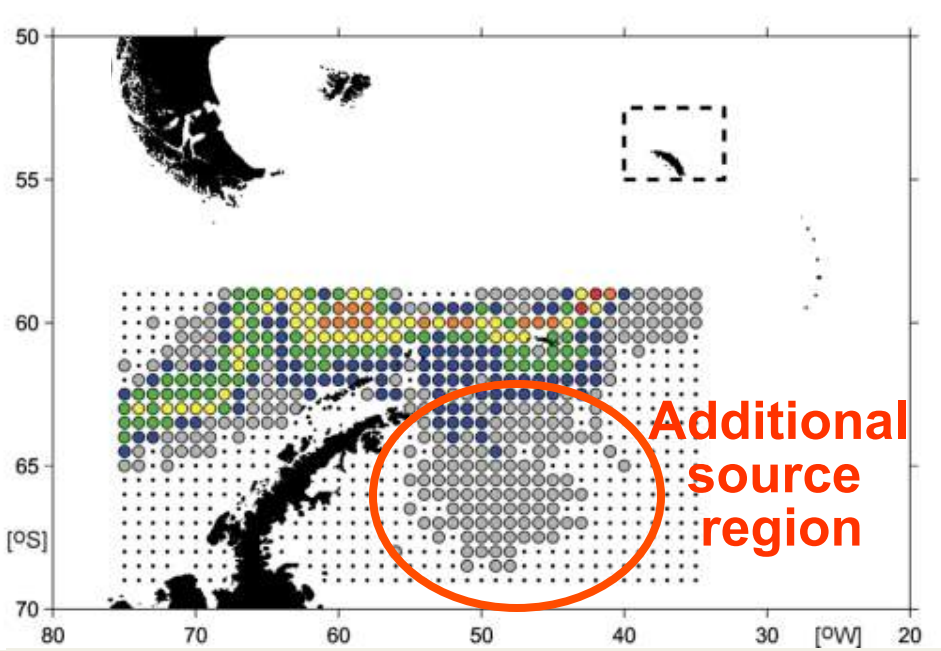
South Georgia - Connectivity

Variability in Source Regions

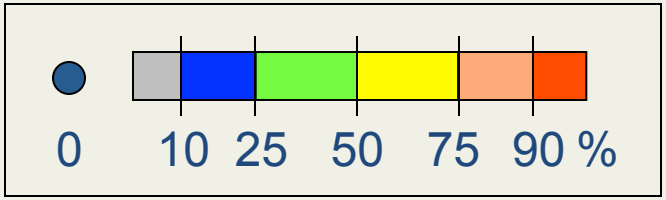
Lagrangian Simulations

Murphy et al. 2004





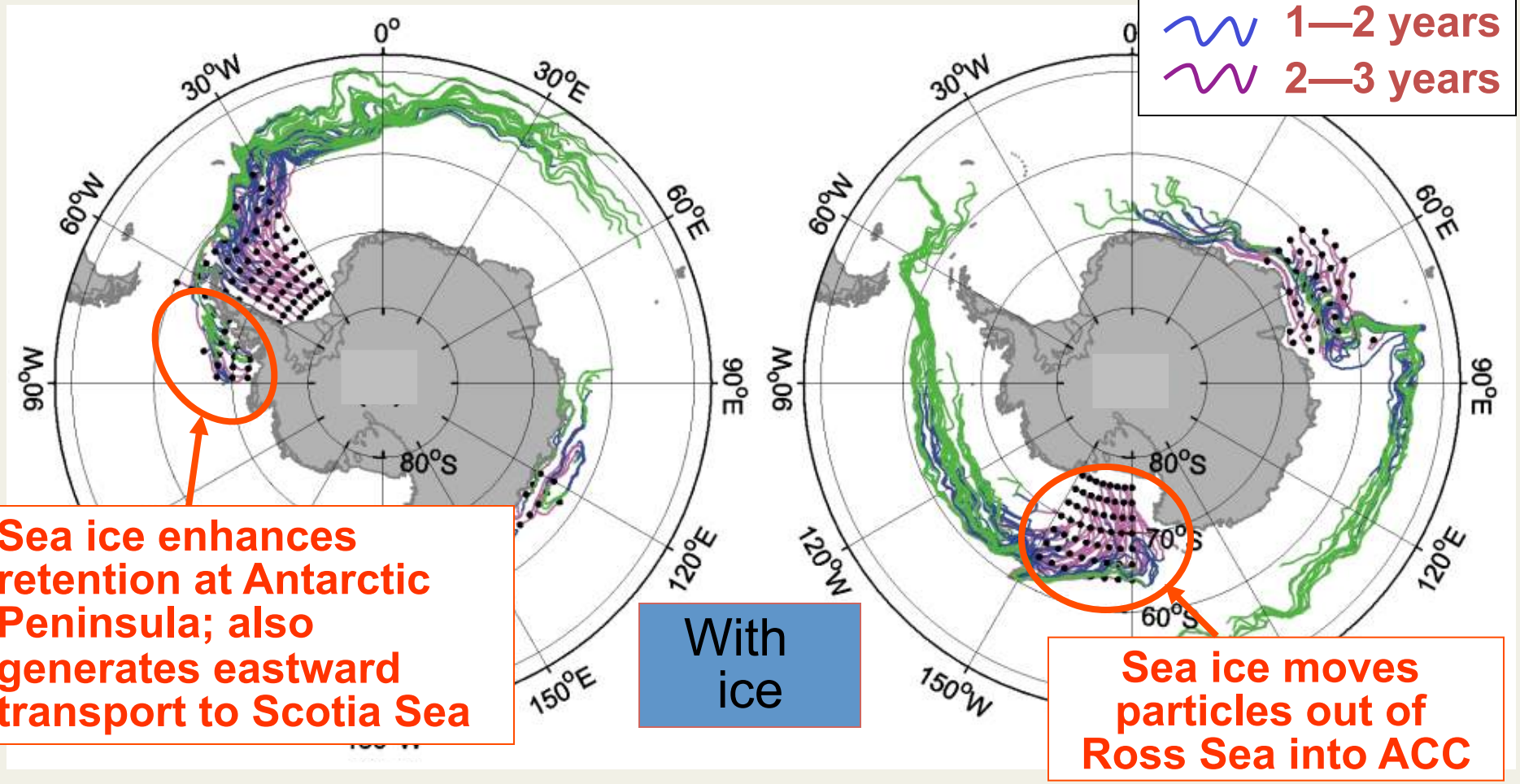
Ocean only advection



Ocean + sea ice advection

Circumpolar-scale Connectivity

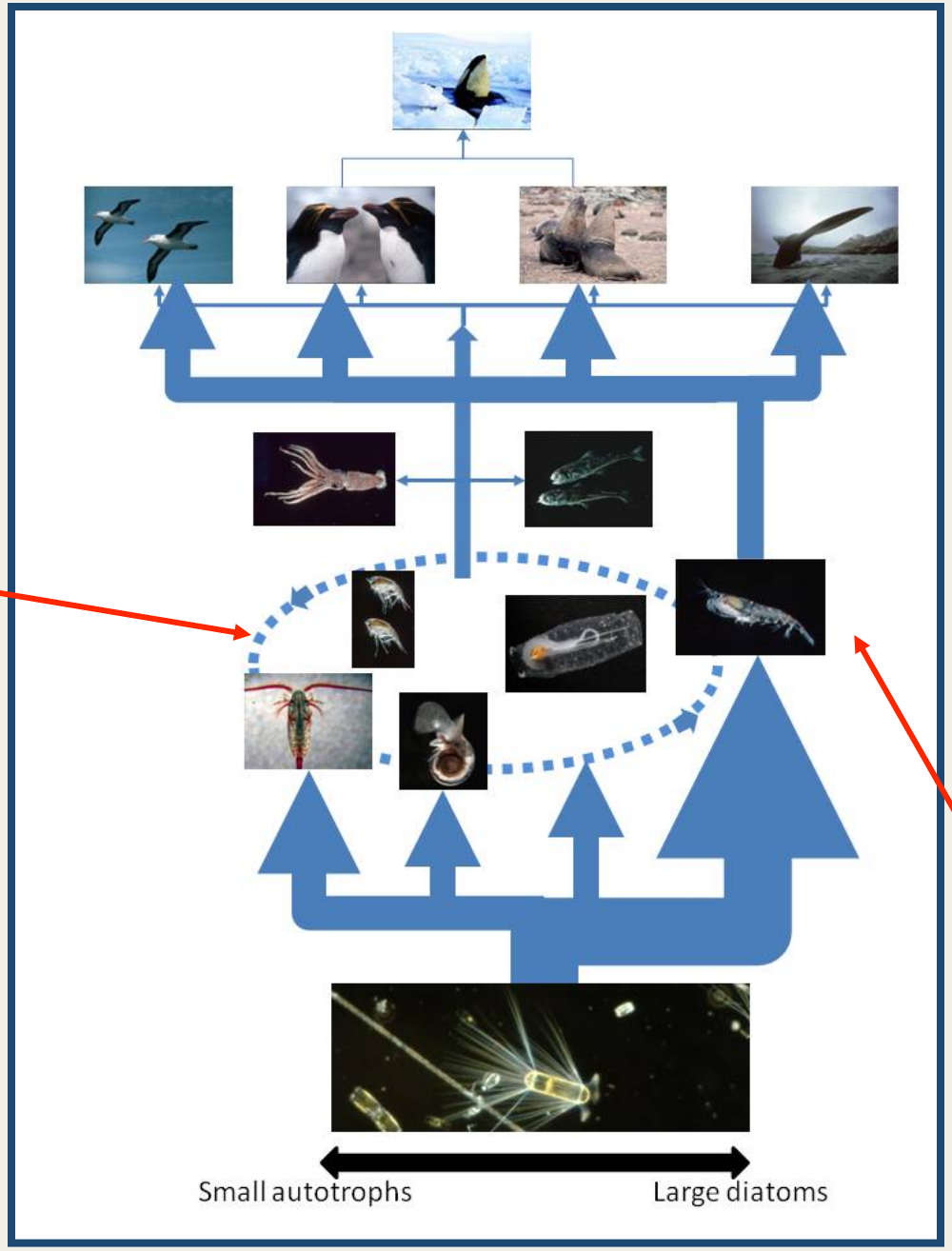
Thorpe et al. (2007)



Sea ice enhances retention at Antarctic Peninsula; also generates eastward transport to Scotia Sea

Sea ice moves particles out of Ross Sea into ACC

Alternative pathways of energy flow through the zooplankton and nekton communities



Antarctic krill provide efficient energy transfer to highest trophic levels

Murphy et al., 2013

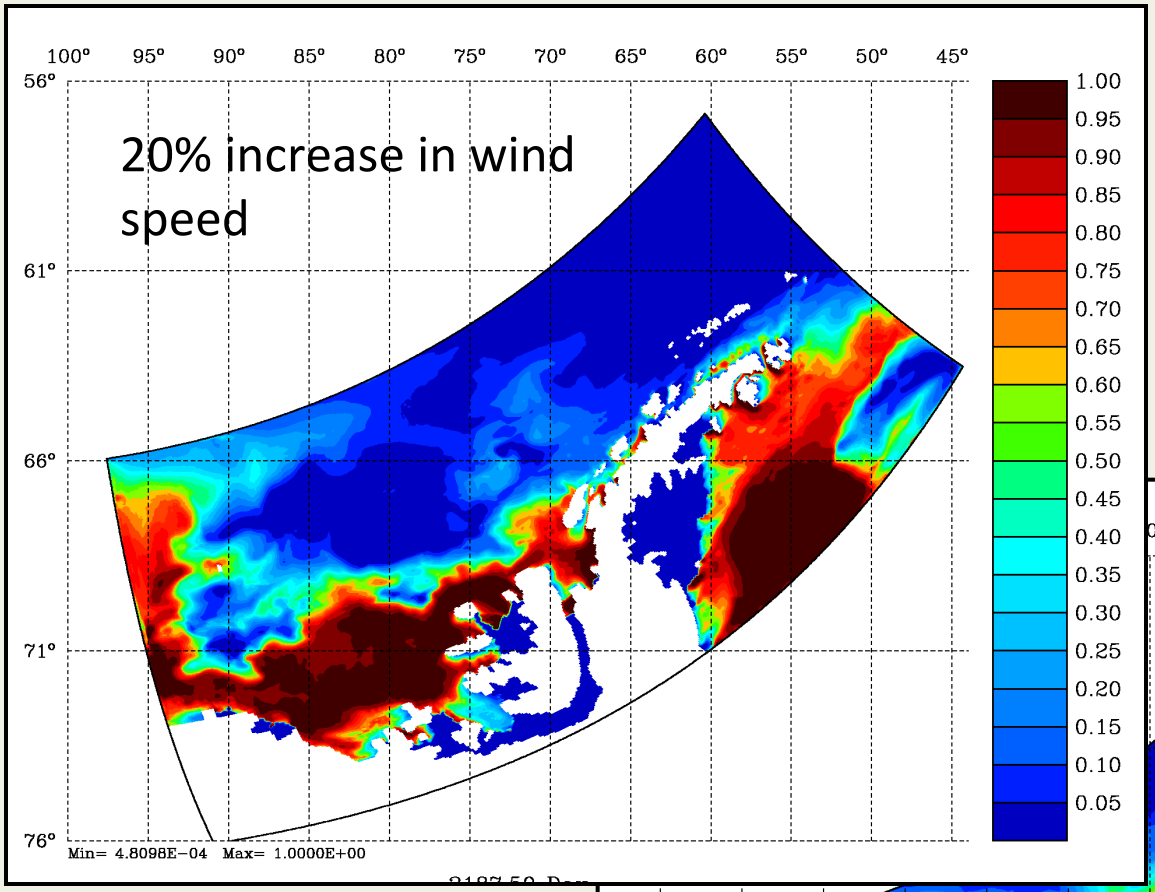
What next?

Synthesize, Evaluate, and Revise

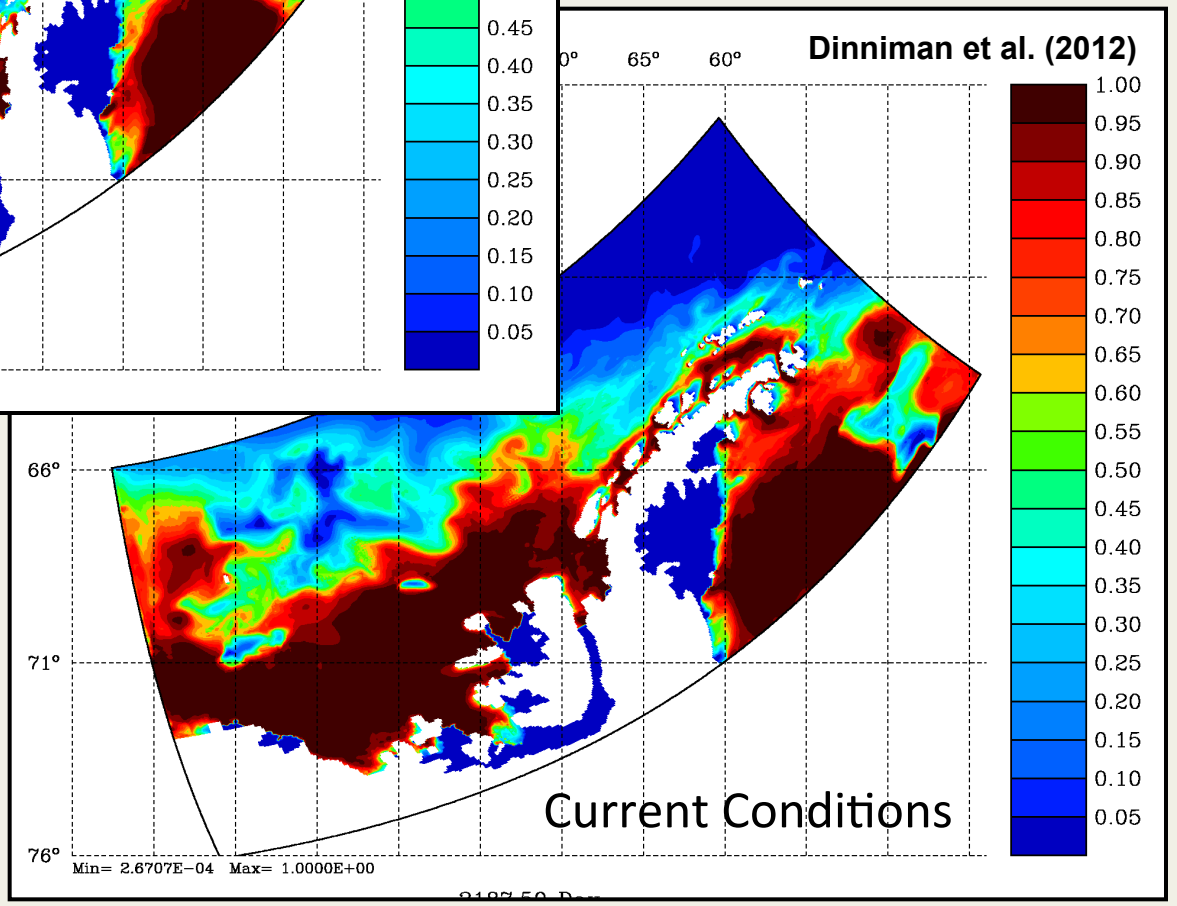
Reflect on Food Web Understanding

Comfort Zone

Leave our Comfort Zone

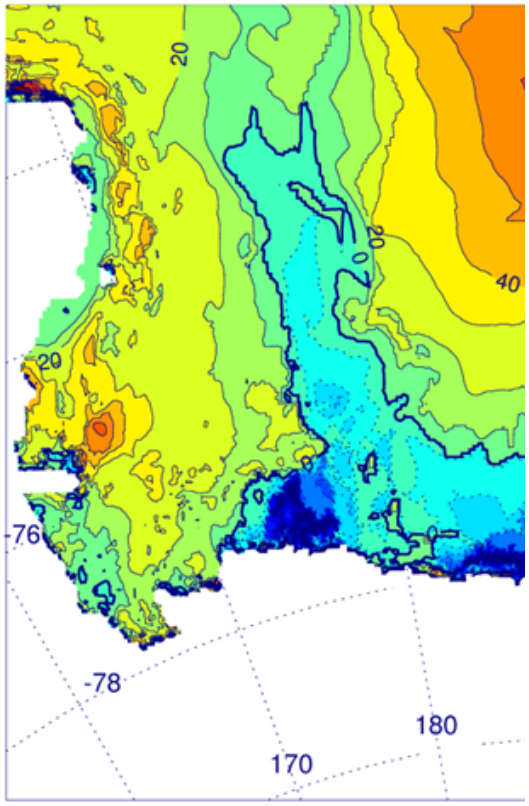


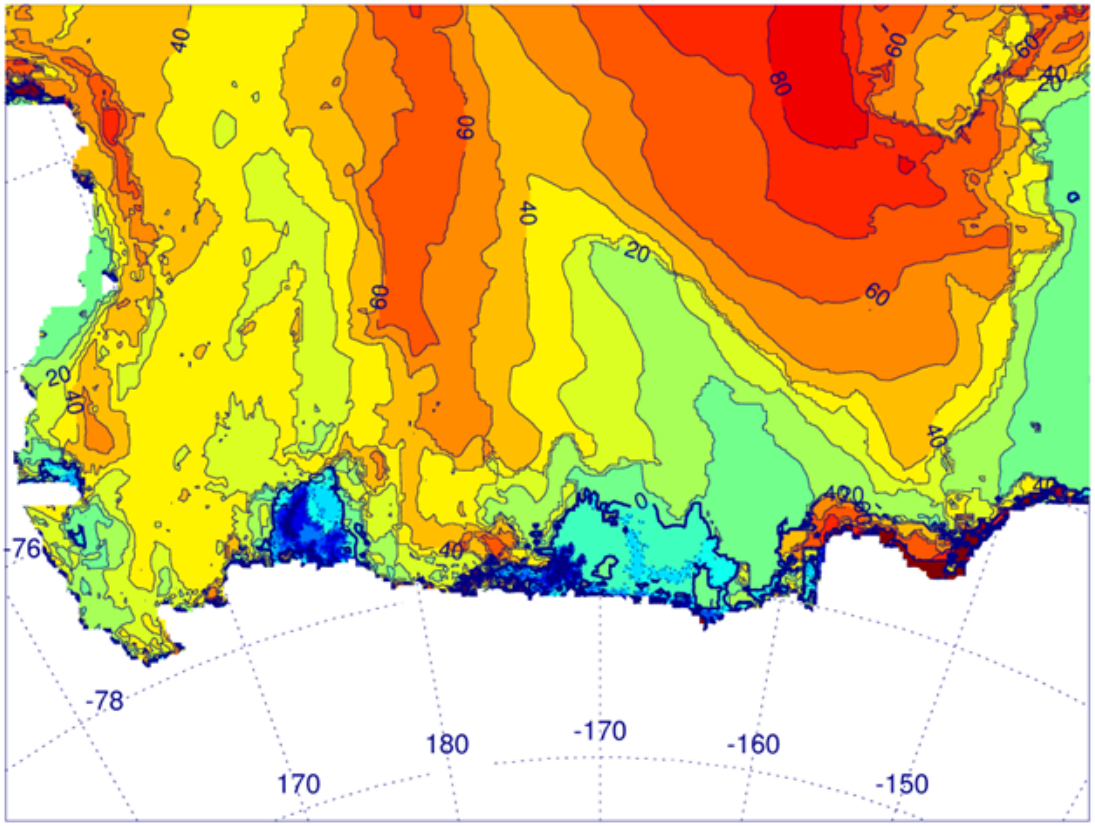
Winter sea ice distribution



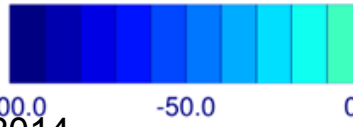
West Antarctic Peninsula

Ross Sea



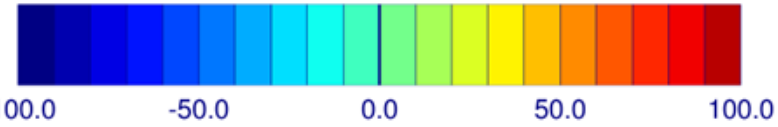


Ice free durati
2050



Smith et al., 2014

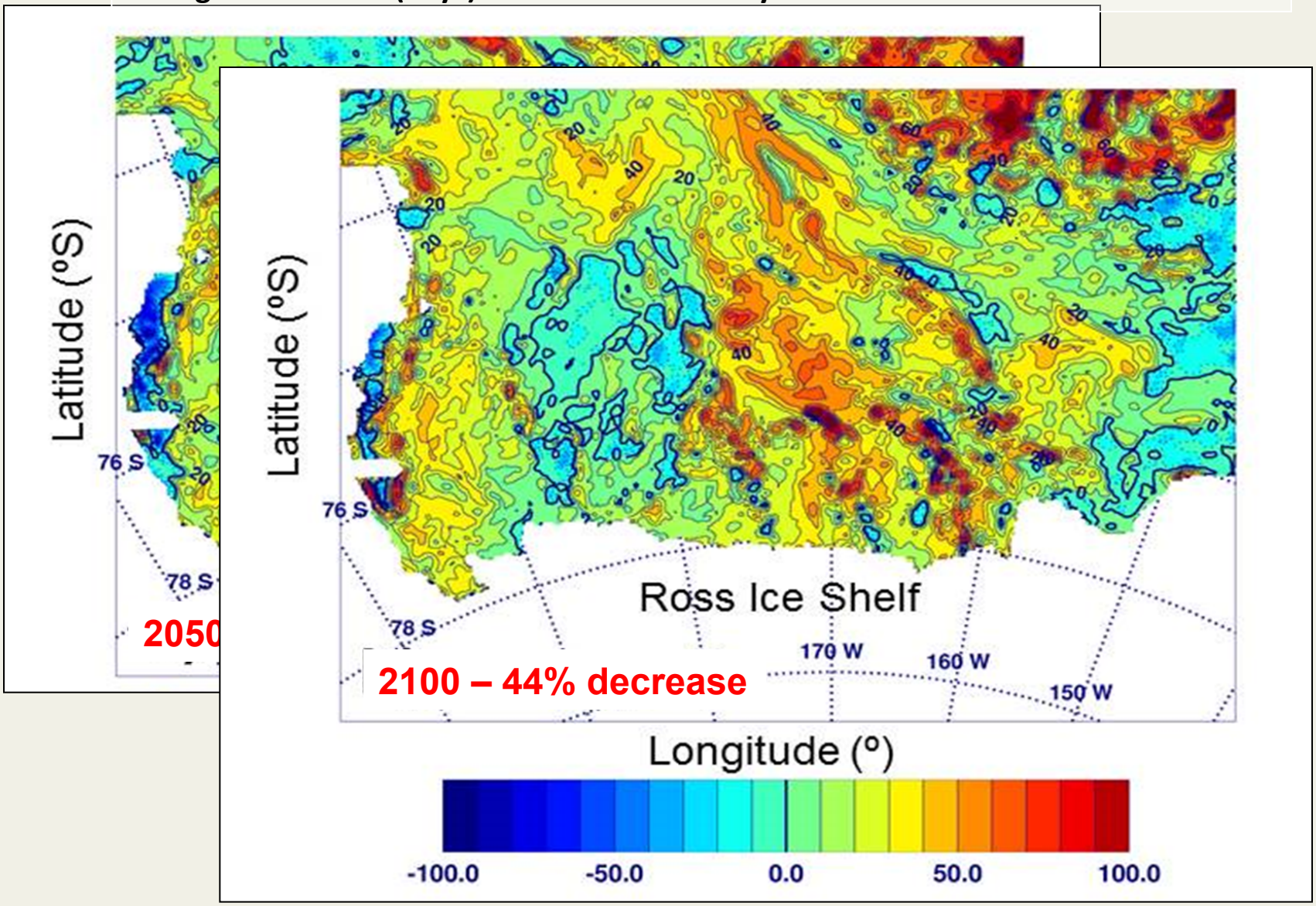
Ice free duration (days)
2100



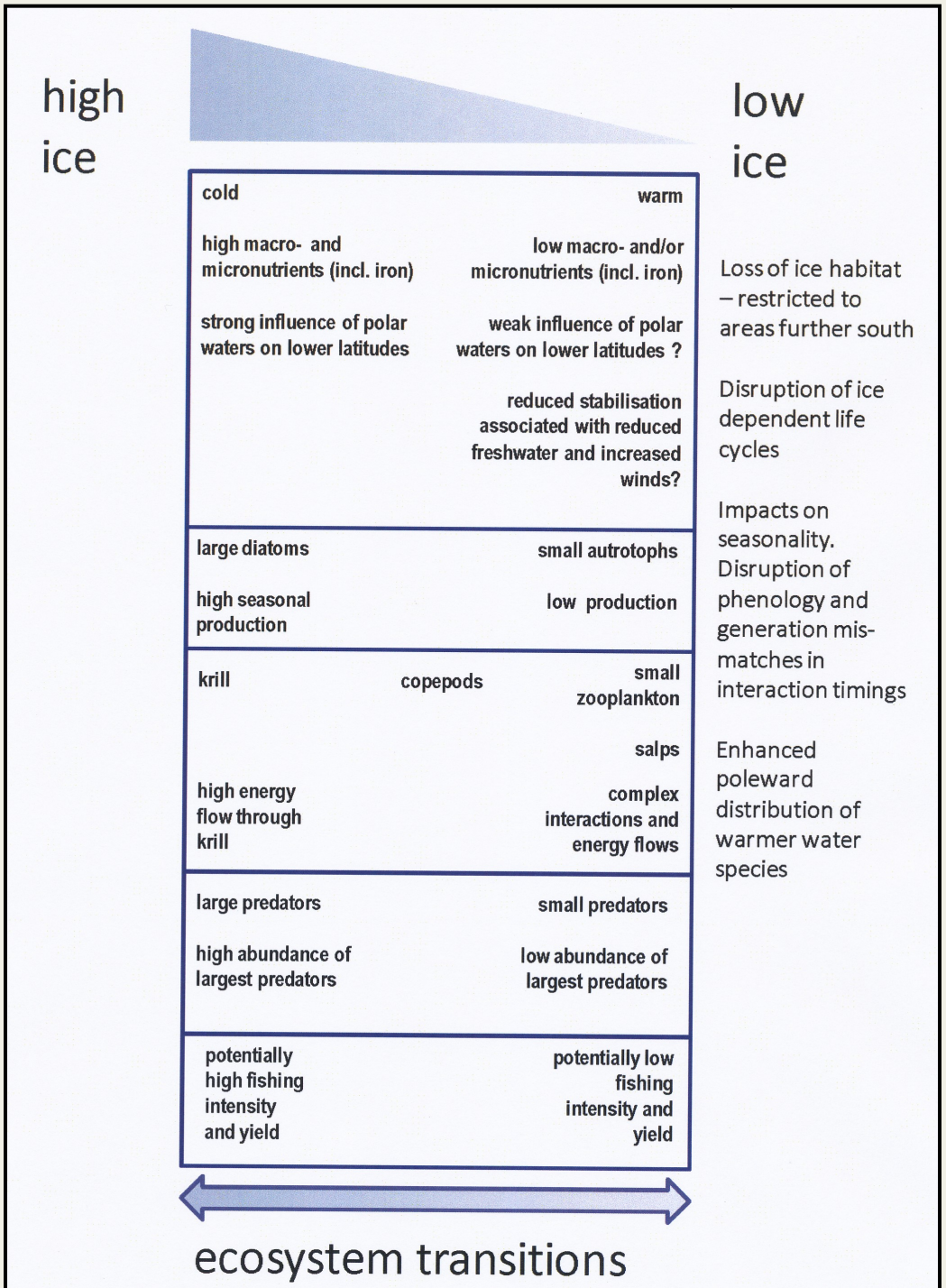
mean increase of 5 days

mean increase of 28 days

Change in duration (days) of summer mixed layers shallower than 25 m



Surface mixed layer depths will decrease relative to current conditions



Modify food web linkages

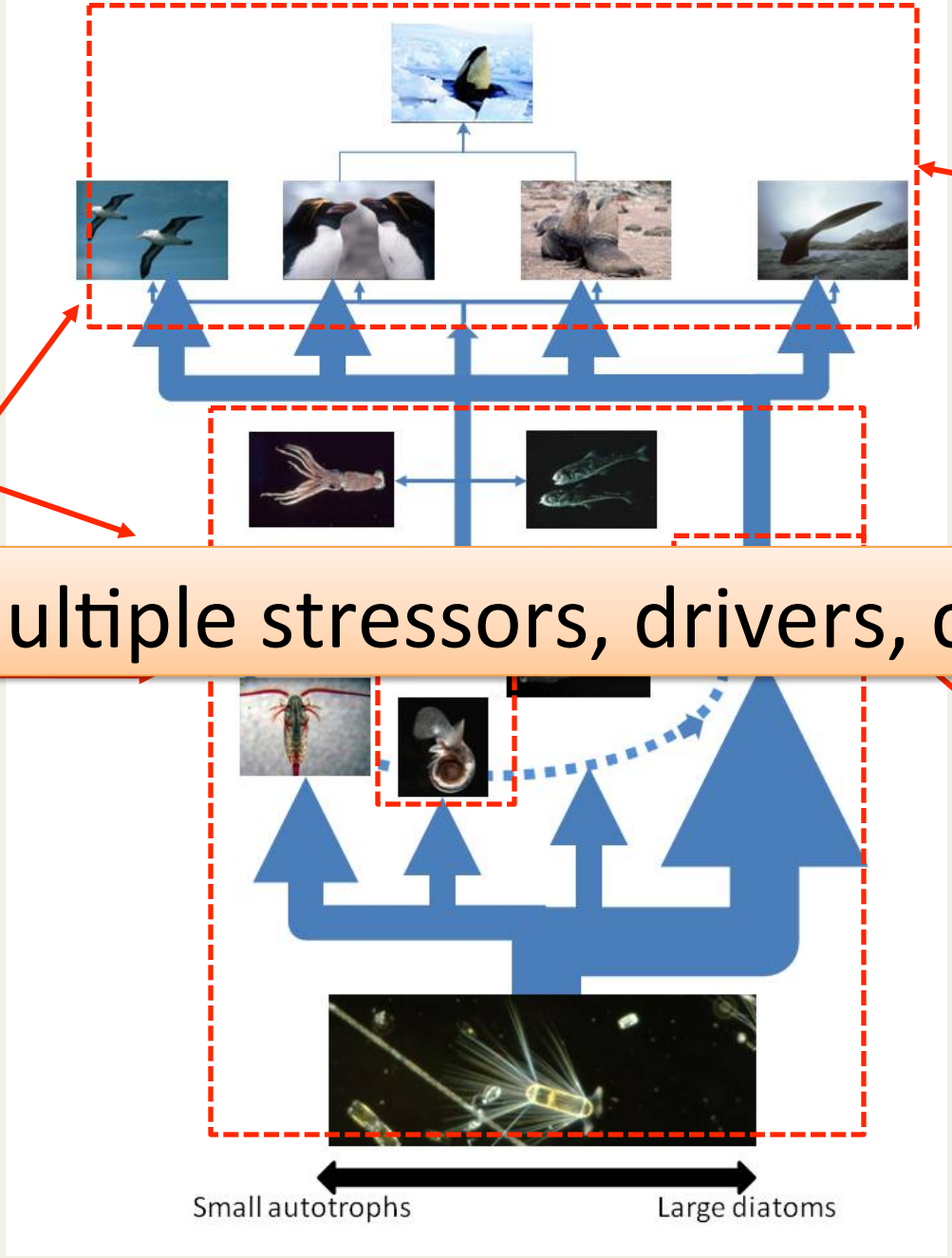
Close/open areas of habitat (Krill, penguins)

Modify timing and generate mis-matches in life history

Change primary production

Shift to diatoms

Poleward movement of warm water species



Historical impacts of harvesting

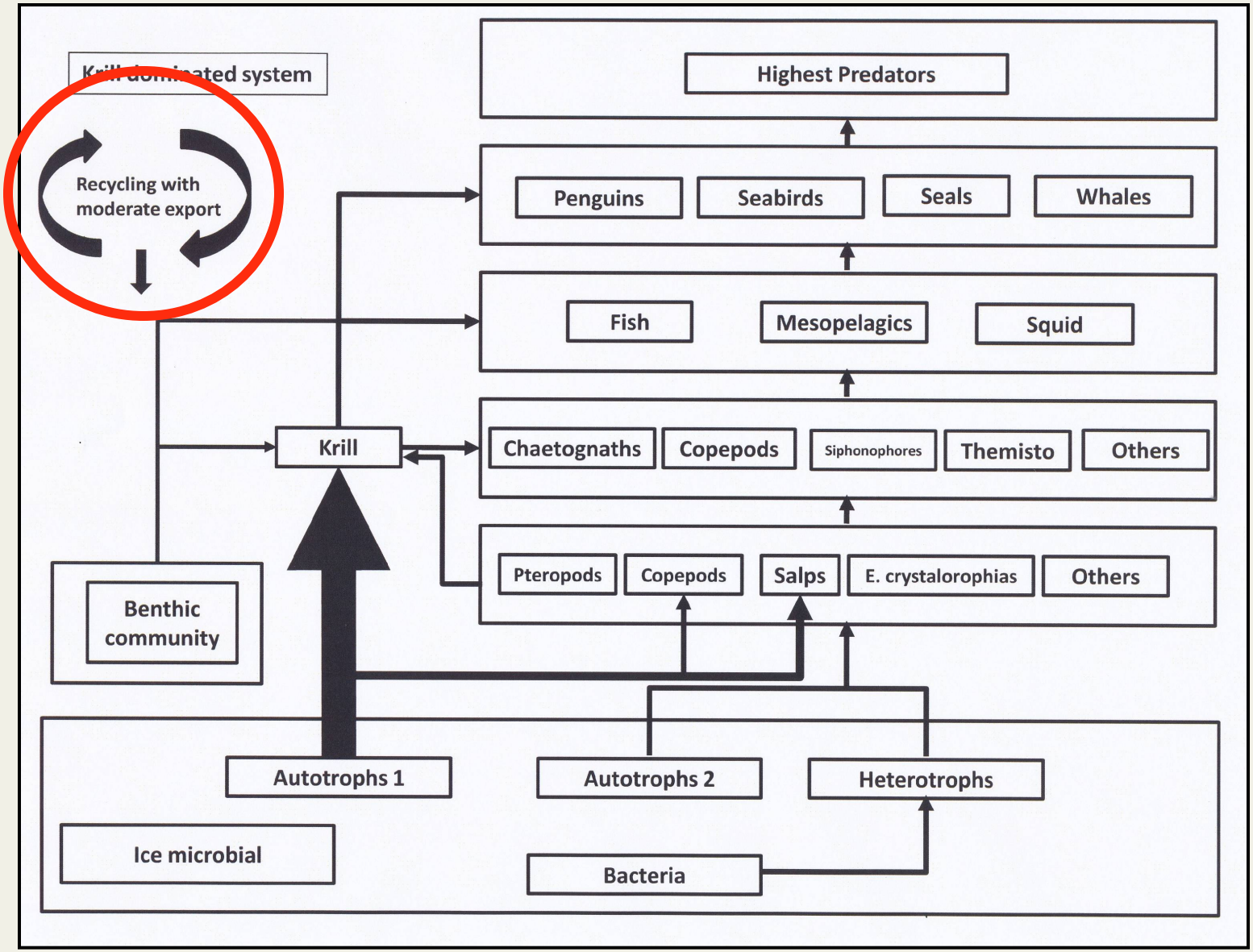
Habitats change and life cycles disrupted

Warmin and pH

Multiple stressors, drivers, challenges

Current fishing impacts food web interactions

Couple Food Webs and Biogeochemcial Cycling



End-to-End (E2E) Models

General questions asked….

What are the effects of the environment (*bottom-up forcing*) and fishing (*top-down forcing*) on marine ecosystems?

What regulates patterns of biodiversity in marine ecosystems?

Scenarios……integration

Climate – multiply forcing by 0.4x, 1x (baseline), 1.5x, 1.8x, …

Fishing – multiply fishing mortality by 0x (no fishing), 0.5x, 1x (baseline), 2x, …

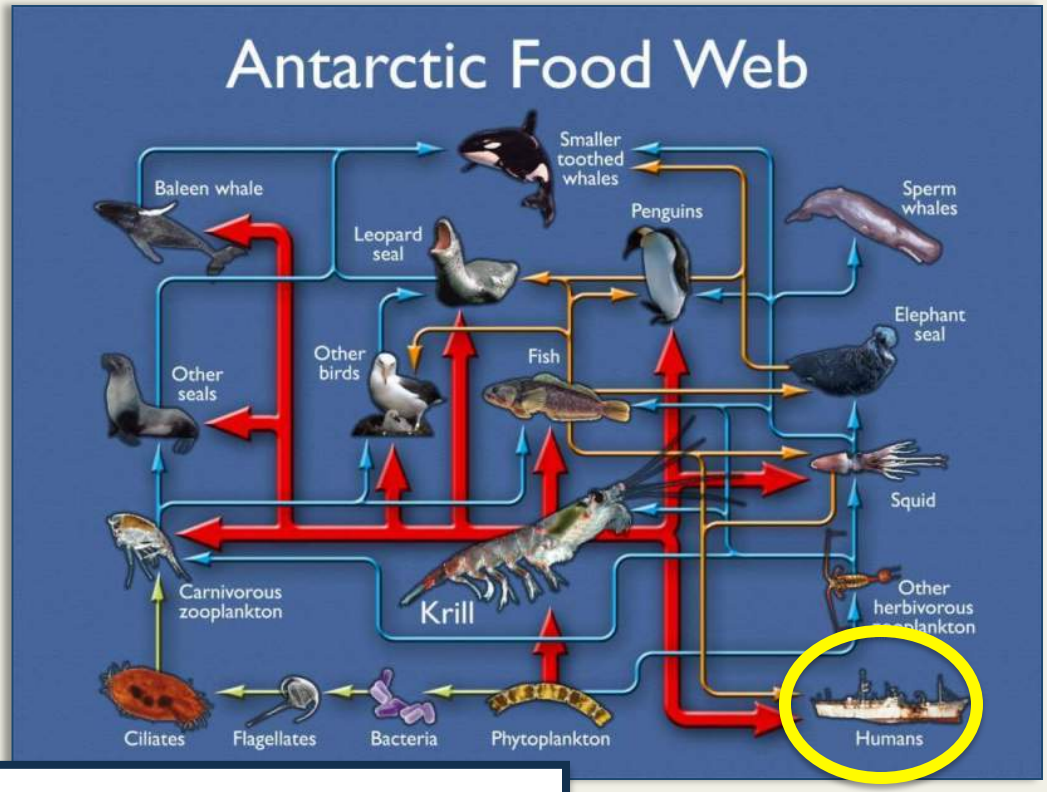
Adaptation Capacities

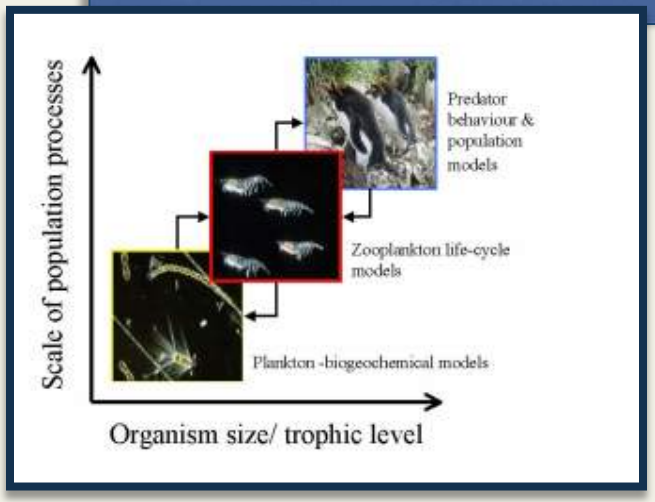
species, ecosystems (emerging), human impacts

Challenges

How to deal with:

- Complexity ?
- Variability ?
- Uncertainty ?
- Human Effects ?





Southern Ocean Food Webs

Food webs

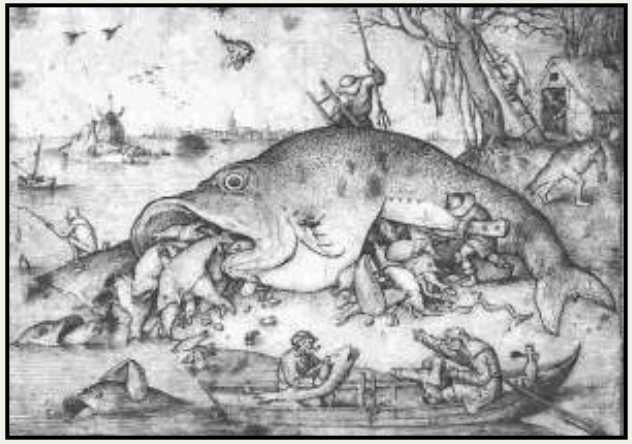
- Focus on food web quantification
- Network-budget analyses

Mechanistic models

- Biogeochemical – zooplankton links
- Genetics, trait-based (new approaches)
- Regional high resolution models

Scenario testing

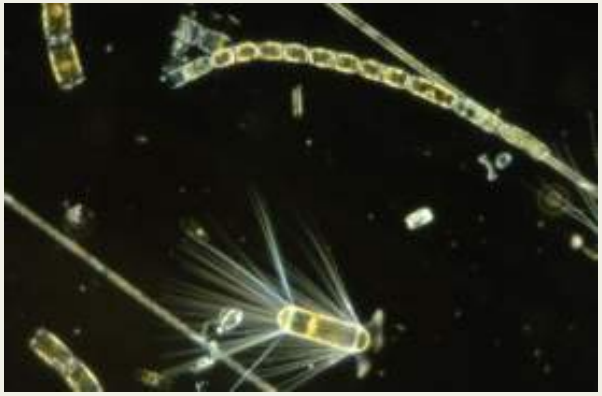
- Theoretical analyses of food webs
- End-to-end models, alternative models, generalized models
- Uncertainty



Southern Ocean Food Webs

- **Southern Ocean ecosystems changing**
  - Climate, fisheries & biogeochemistry
  - Food webs crucial in determining responses
  - Requires end-to-end understanding

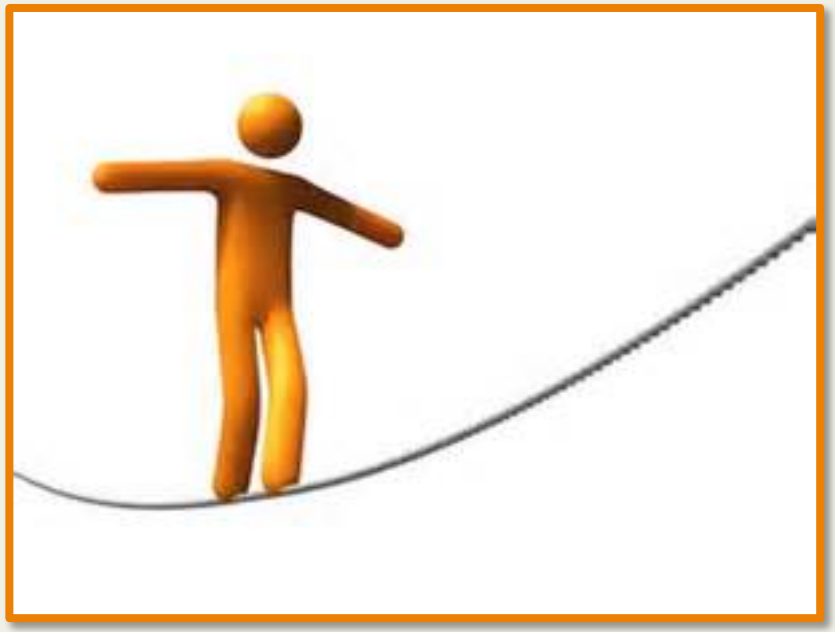
    => projection & understand feedbacks
- **Analyses of structure & function**
  - Develop large-scale views
  - Requires systematic quantification – major gaps in knowledge
  - Focused process studies for key regions
- **Analyses of variability & change**
  - Analyse responses => mechanisms



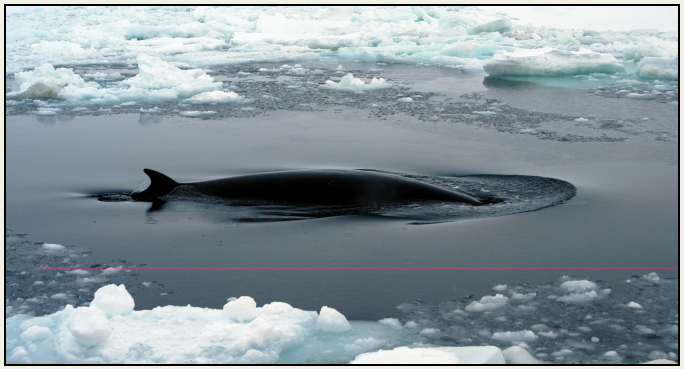
Focused Questions

Neglected trophic links

Comparative Approach



New data technologies
Links to new science sectors
Human impacts & needs
Impact & attribution
Adaptation pathways



Thanks

Photos by D. Costa