Productivity and Linkages in Southern Ocean Food Webs: Comparisons and Implications

Eileen Hofmann

John Klinck, Mike Dinniman, Andrea Piñones, Tosca Ballerini

SO GLOBEC and ICED Science Investigators

Eugene Murphy (BAS)











Presentation Outline

- Comparative analysis of west Antarctic Peninsula and South Georgia structure, variability, connectivity
- Consider possible effects of climate change on habitat and consequences for food webs
- Challenges for modeling food webs
- Implications of understanding food webs

What is a Southern Ocean Food Web?



Range of Food Webs





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

West Antarctic Peninsula Closed system - export

- ~400 m deep
- Influenced by ACC
- Deep trenches provide connection between shelf and oceanic environments
- Both influenced by Circumpolar Deep Water
- Direct connection to mesopelagic
- Biological hot spots

South Georgia Open system

Murphy et al. (2012)



High-resolution circulation models exist for both systems

Used with Lagrangian particle tracking studies

Transport pathways and connectivity



Connectivity - WAP

Lagrangian Simulations

Upstream Remote Inputs

Local Inputs and Retention



82

78

62

70

66

62

74

⁸² 78 74 70 66 Pinones et al. (2013) 82

78

74

Longitude (^oW)

62

70

66

50 days

64

Latitude (^oS) 89 99

70







Circumpolar-scale dispersal



A range of alternative pathways of energy flow through the zooplankton and nekton communities are crucial in maintaining food web structure



Antarctic krill provide efficient energy transfer to highest trophic levels

Present southern WAP and South Georgia food webs: Relative efficiency of alternative trophic pathways

Two principal trophic pathways from primary producers to top predators for WAP and South Georgia

The efficiency of each trophic pathway varies

Non-krill pathway buffers change but may not be sustainable in long term



WAP Food Web

South Georgia Food Web



Potential Consequences

- Reduction in winter sea ice along WAP current food web components disappear transition to South Georgia system
- Reduction in export to South Georgia current food web cease to exist
- Timing of productivity changed same annual production but different time distribution

ligh		low
ce		ice
cold	warm	
high macro- and micronutrients (incl. iro	low macro- and/or n) micronutrients (incl. iron)	Loss of ice habitat – restricted to areas further south
strong influence of pola waters on lower latitude	ar weak influence of polar es waters on lower latitudes ?	
	reduced stabilisation associated with reduced freshwater and increased winds?	Disruption of ice dependent life cycles
		Impacts on
large diatoms	small autrotophs	seasonality. Disruption of
high seasonal production	low production	phenology and generation mis-
krill	copepods small zooplankton	matches in interaction timings
	salps	Enhanced
high energy flow through krill	complex interactions and energy flows	poleward distribution of warmer water
large predators	small predators	species
high abundance of largest predators	low abundance of largest predators	
potentially high fishing intensity and yield	potentially low fishing intensity and yield	

ecosystem transitions

Change in habitat structure and food web linkages from reduced sea ice and increased CDW

Close/open areas of habitat Krill, Adelie penguins

Modify timing and generate mis-matches in life history

More emphasis on benthic system

Poleward movement of warm water species

Western Antarctic Peninsula Food Web





Analyses of Southern Ocean Food Webs

How to deal with:

- Complexity ?
- Variability ?
- Uncertainty ?

Generalized Models?







Couple Food Webs and Biogeochemcial Cycling



Southern Ocean Food Webs

Model development - 3 main foci

1. Food webs

- Focus on food web quantification
- Network-budget analyses

2. Mechanistic models

- Biogeochemical zooplankton links
- Regional high resolution models
- 3. Scenario testing
 - Theoretical analyses of food webs
 - End-to-end models, alternative models, generalised models
 - Uncertainty





Southern Ocean Food Webs - Concluding Comments

- 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 are being developed
 - Need to develop large-scale views
 - Requires systematic quantification major gaps in knowledge
 - Focused process studies for key regions
- Analyses of variability & change
 - Analyse responses => mechanisms





Relevance?



Biomass (g C m ⁻²)	Predator group with doubled biomass	Surplus/deficit production
1.6	Initial values in Table 1	-9
3.2	Initial values in Table 1	+46
3.2	Cephalopods	+14
3.2	Off-shelf pelagic fish	+33
3.2	On-shelf pelagic fish	+19
3.2	Benthic fish	+8
3.2	All fish and cephalopods	-1
3.2	All seabirds and marine mammals	+33
3.2	All fish, cephalopods, seabirds and marine mammals	-5

BBC NEWS SCIENCE & ENVIRONMENT

16 July 2013 Last updated at 08:44 ET

No deal on huge Antarctic marine reserves

COMMENTS (76)

International talks on establishing huge marine reserves in Antarctica have failed to reach a consensus.

Russia blocked attempts by western countries to set up the protected areas in the Ross Sea and Eastern Antarctica.

The Russian representative challenged the legal basis that would allow for the creation of such reserves, according to organisations at the talks in Germany.

Lack of scientific knowledge and understanding to design and implement Marine Protected Areas in the Southern Ocean



IMBER Regional Program

- Circumpolar, interdisciplinary program focused on climate interactions and feedbacks to ecosystem function and biogeochemical cycles
- Extend and further develop circulation, ecosystem, and biogeochemical models
- Planning field program 2015 onwards
- Combine food web and biogeochemical communities



