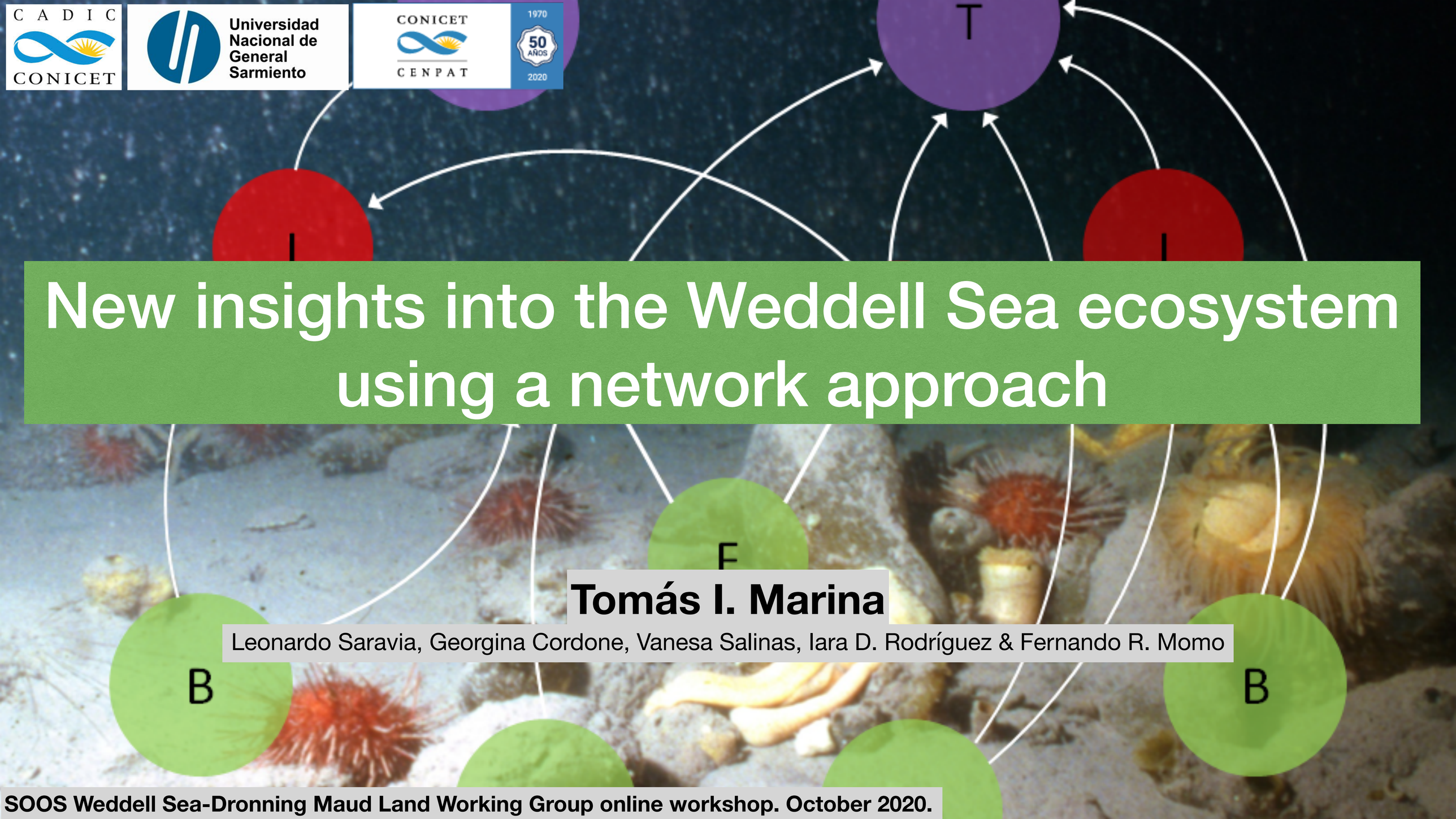


New insights into the Weddell Sea ecosystem using a network approach

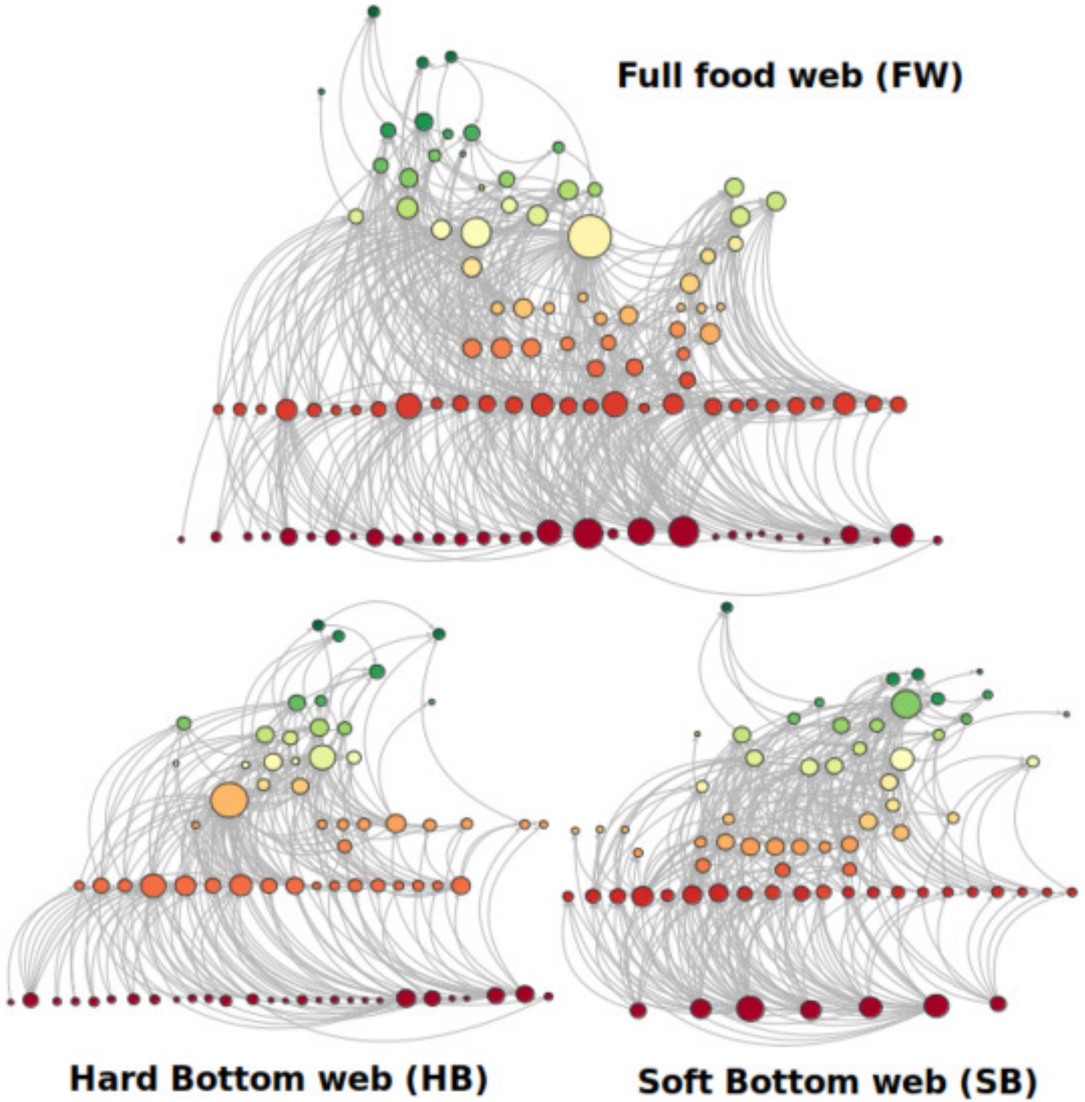
Tomás I. Marina

Leonardo Saravia, Georgina Cordone, Vanesa Salinas, Iara D. Rodríguez & Fernando R. Momo

SOOS Weddell Sea-Dronning Maud Land Working Group online workshop. October 2020.

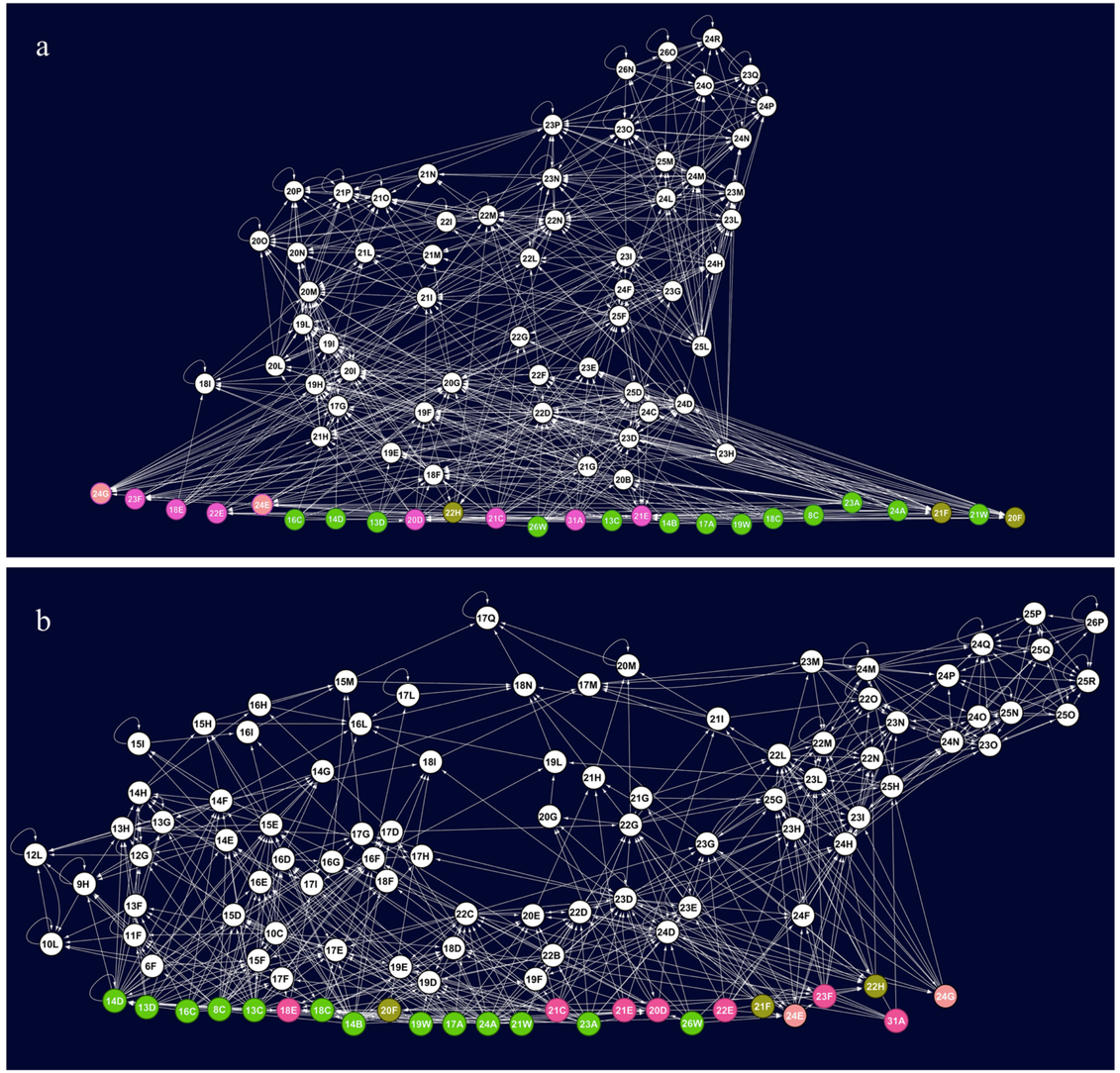
Antarctic ecosystems are too complex for a ‘few-species’ approach

Antarctic Peninsula



Potter Cove (South Shetland Is.) food webs by habitat type.

Ross Sea



Benthic food web structure in Terra Nova Bay, Antarctica.

Cordone et al. 2020, Rossi et al. 2019

Study area, general objective and data source

STUDY AREA

High Antarctic Weddell Sea shelf (74-78º S), length ~ 450 km.

GENERAL OBJECTIVE

Analyze the Weddell Sea ecosystem in terms of complexity, structure and function by means of network approach.

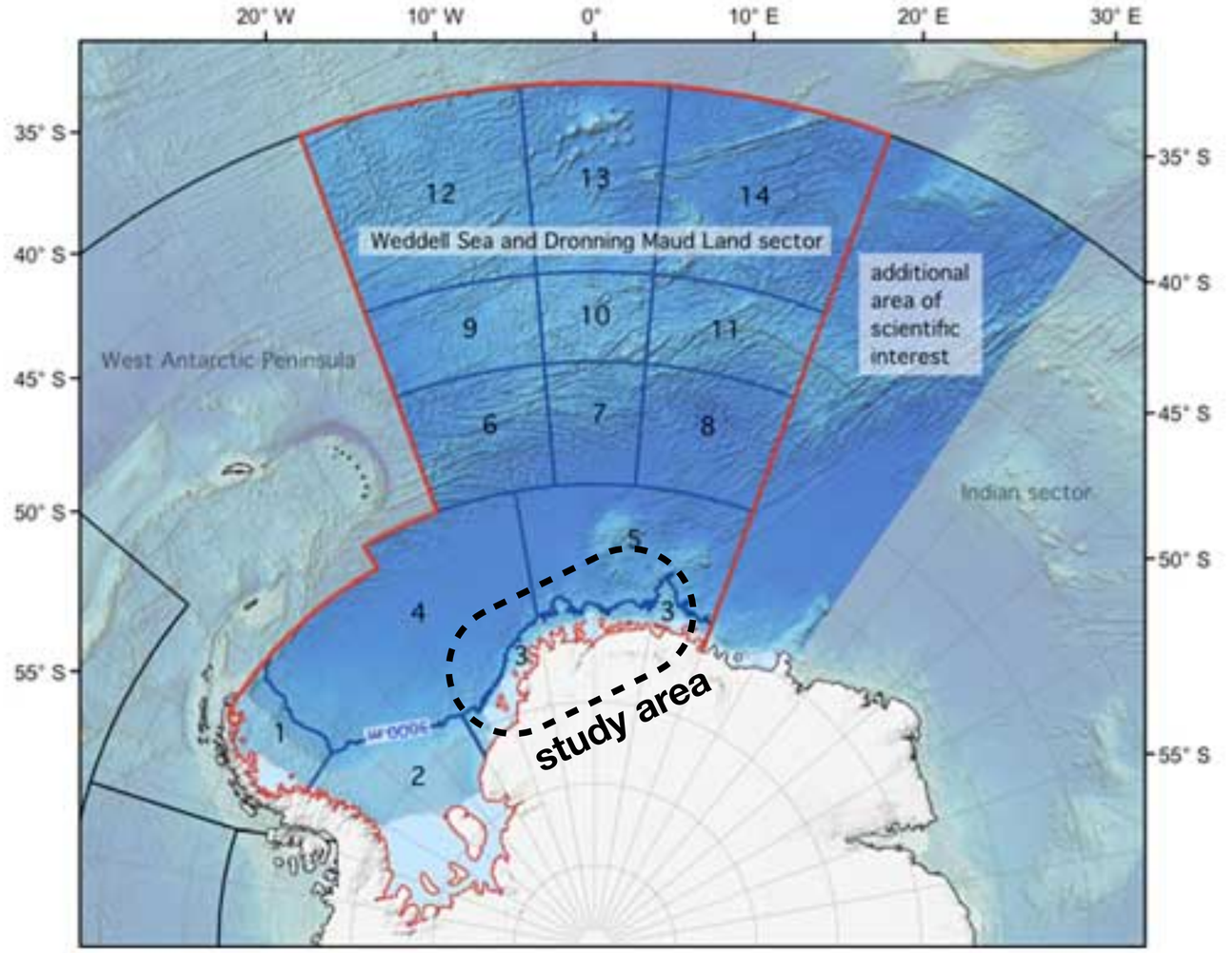
DATA SOURCE

The Role of Body Size in Complex Food Webs: A Cold Case

UTE JACOB,[1,*] AARON THIERRY,[2,3] ULRICH BROSE,[4] WOLF E. ARNTZ,[5] SOFIA BERG,[6] THOMAS BREY,[5] INGO FETZER,[7] TOMAS JONSSON,[6] KATJA MINTENBECK,[5] CHRISTIAN MÖLLMANN,[1] OWEN L. PETCHEY,[8] JENS O. RIEDE[4] AND JENNIFER A. DUNNE[9,10]

[1]*Institute for Hydrobiology and Fisheries Science, University of Hamburg, Grosse Elbstrasse 133, Hamburg, Germany*

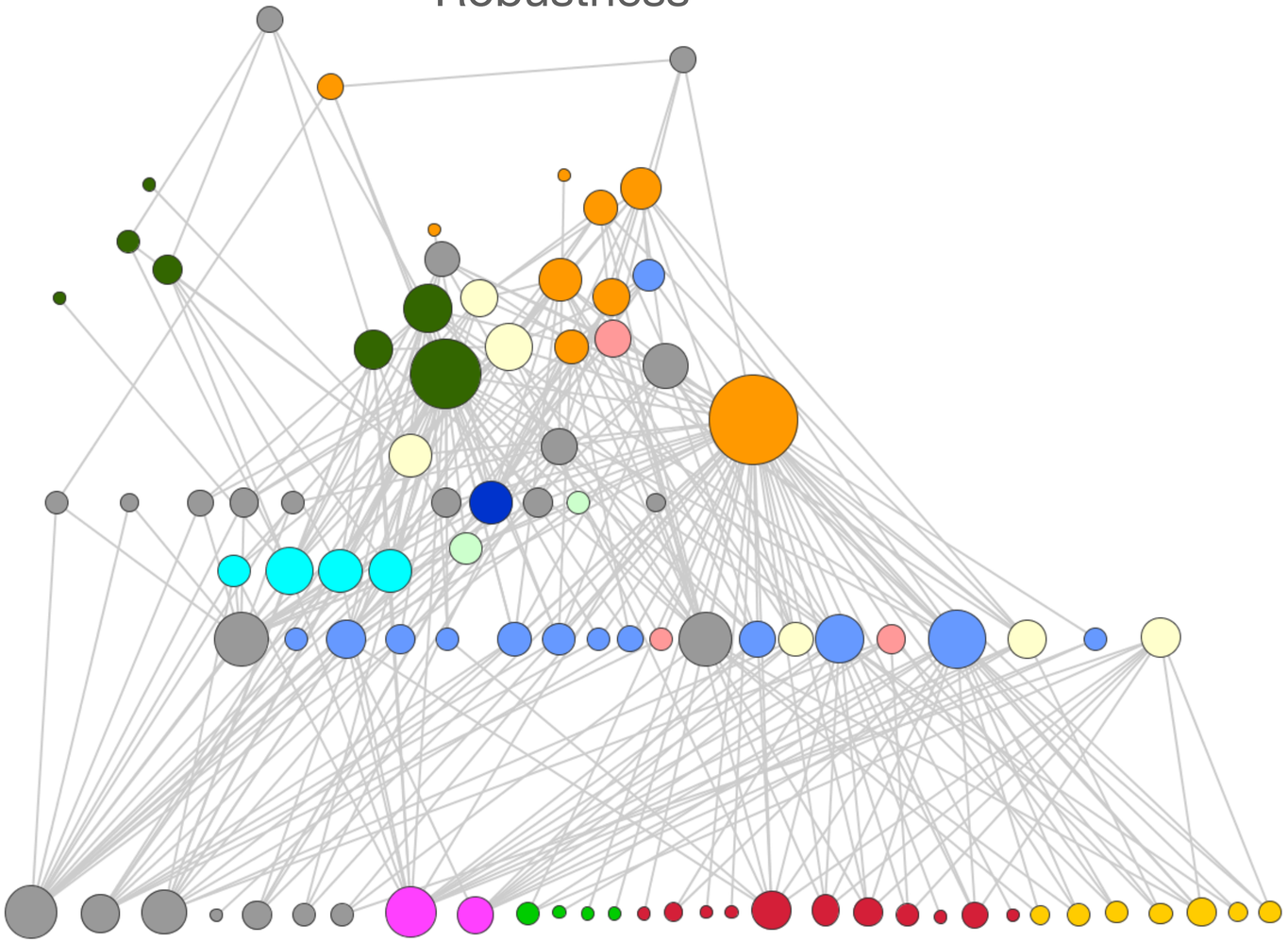
https://doi.org/10.1016/B978-0-12-386475-8.00005-8



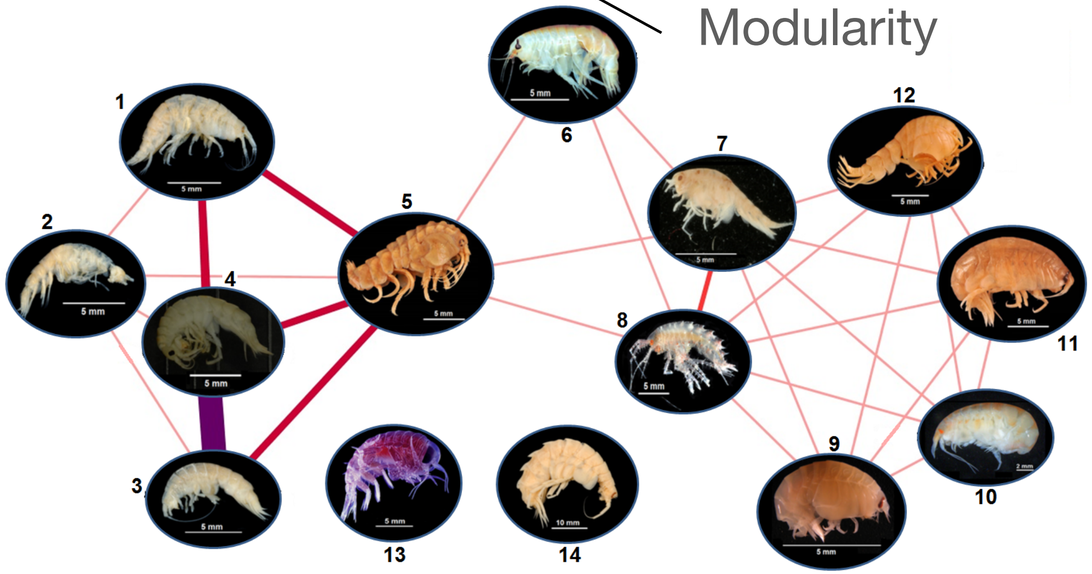
Taken from www.soos.aq

Network analysis at 3 levels: global, sub-network and species

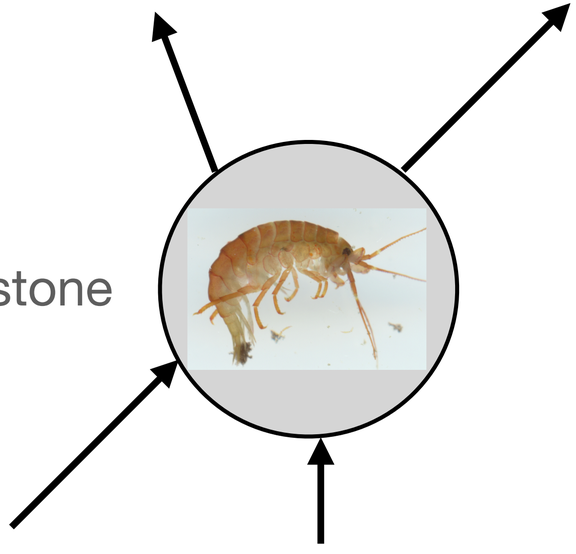
GLOBAL
- Complexity
- Topology
- Robustness



SUB-NETWORK
- Prey network
- Predator network
- Modularity



SPECIES
- Topological role
- Keystone



The Weddell Sea food web is a highly-resolved network

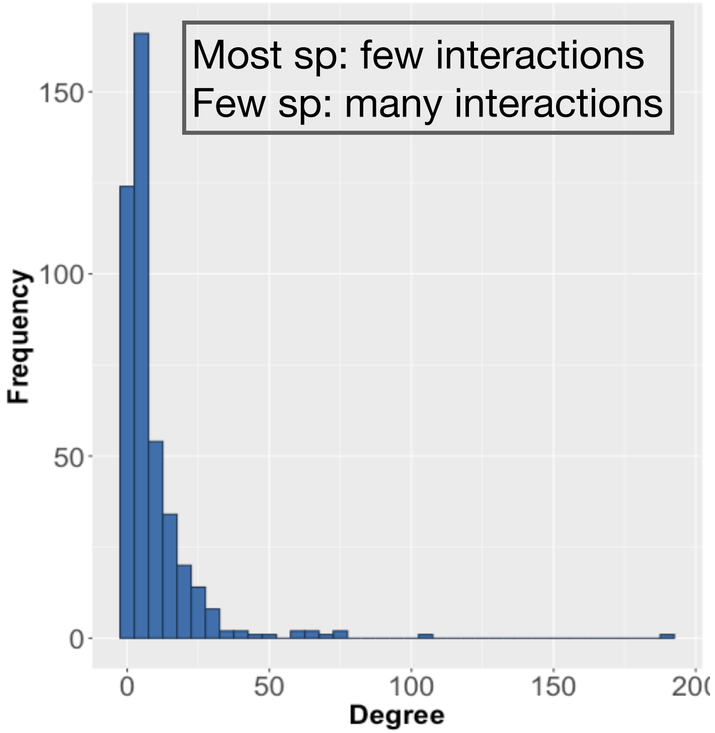
GLOBAL level

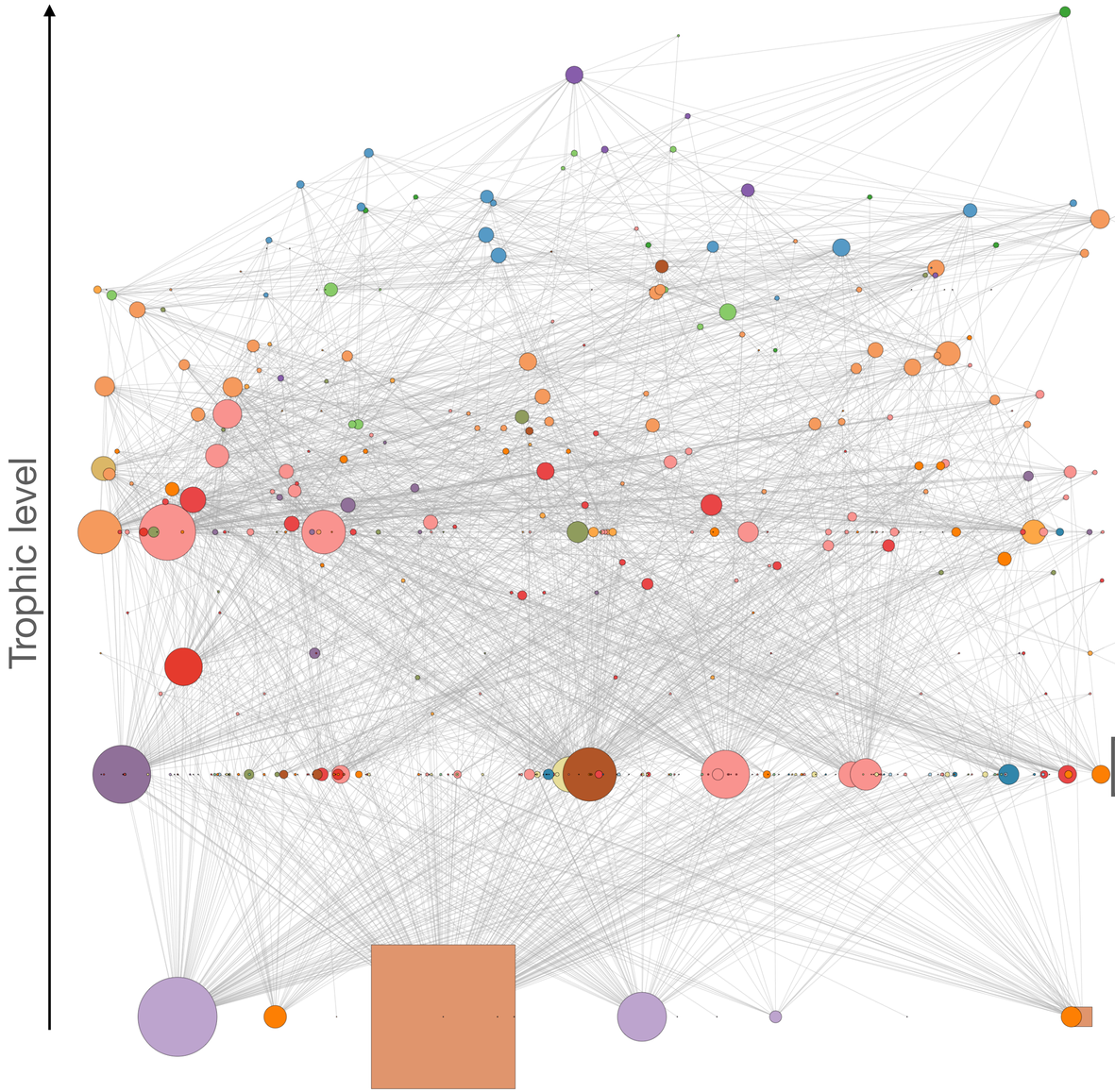
COMPLEXITY

Trophic species
435

Trophic interactions
1978

Interactions per species
4.55





TOPOLOGY

✓Short path btw species
✓High clustering coefficient

Small-world structure

Effects on dynamics

Rapid perturbation spread (& response)

The robustness of the food web is higher than expected

GLOBAL level

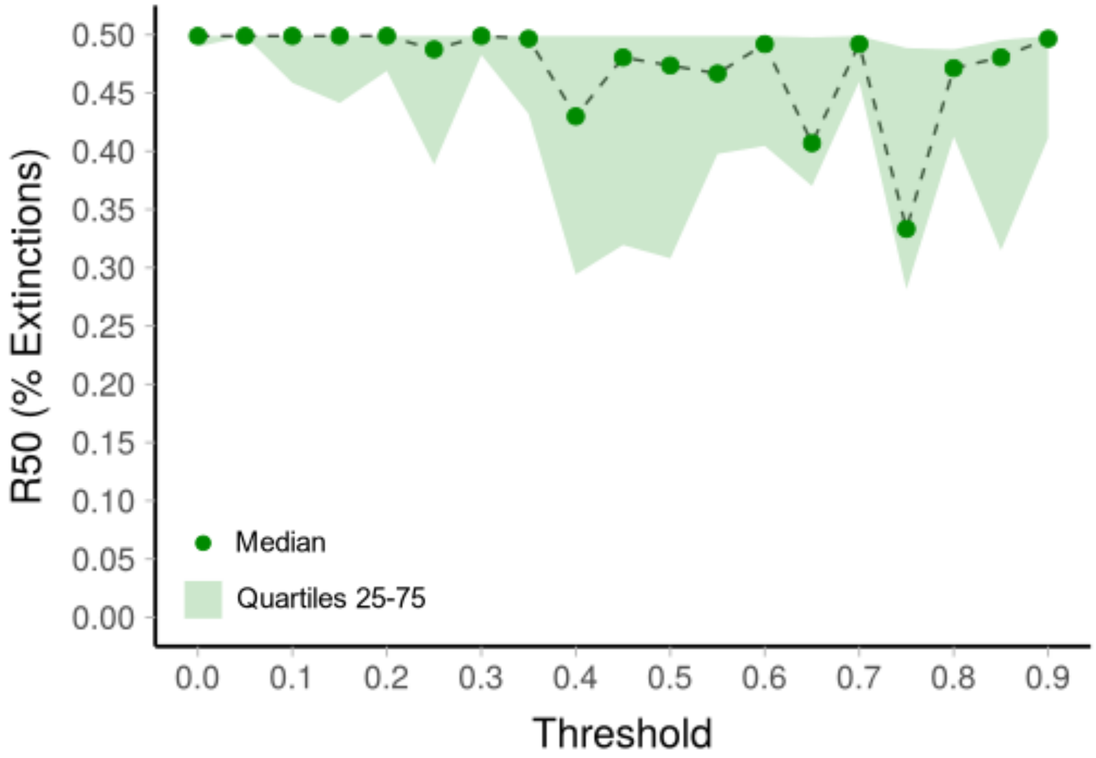
ROBUSTNESS

We performed **extinction *in silico* experiments** by randomly deleting species from the network, and calculated **robustness 50 (R50)**, that indicates the number of extinctions needed to reduce the network by 50%. We tested different **thresholds for secondary extinctions**: a higher value implies that a predator needs most of its prey to survive.

According to similar experiments in other Antarctic food webs, we expected a decrease of R50 with increasing thresholds.

This apparent robustness might be a consequence of the complexity of Weddell Sea food web.

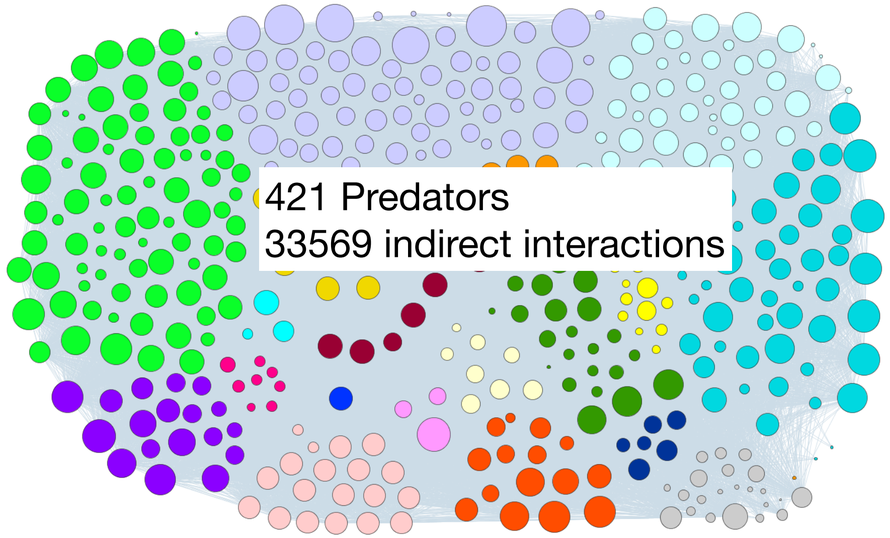
We need to perform more simulations with different criteria (connectance, functional group) to further assess network robustness.



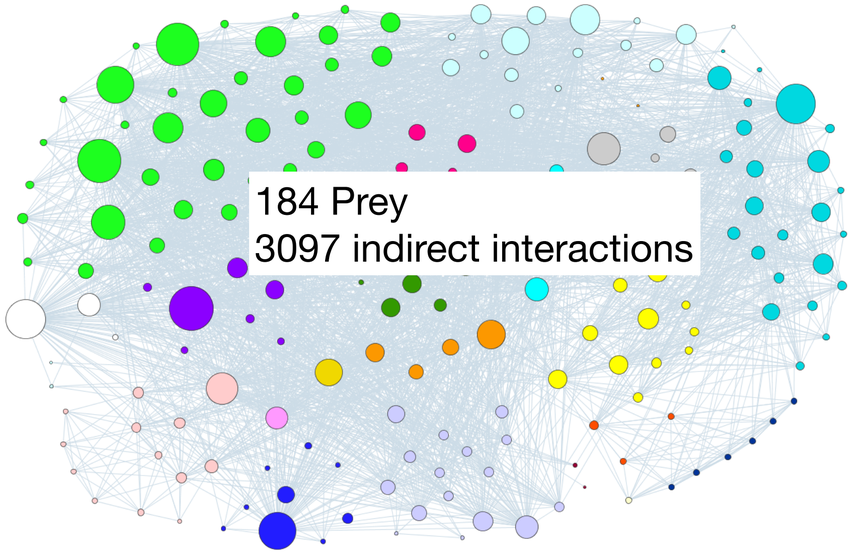
Most species interact in an exploitative competition way

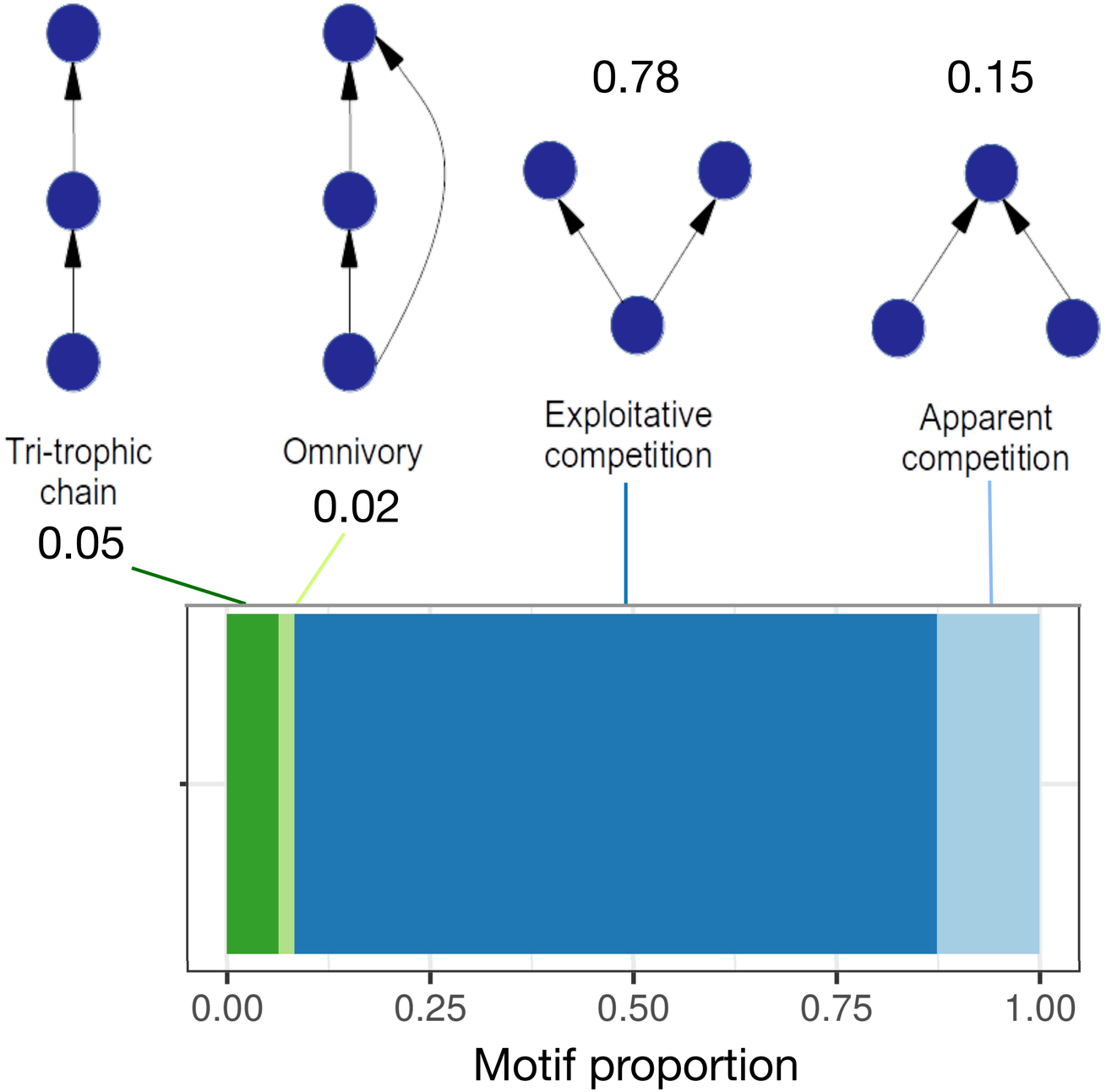
SUB-NETWORK level

Predators sharing prey



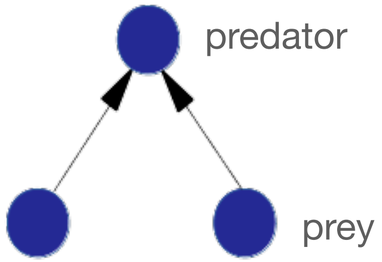
Prey sharing predators





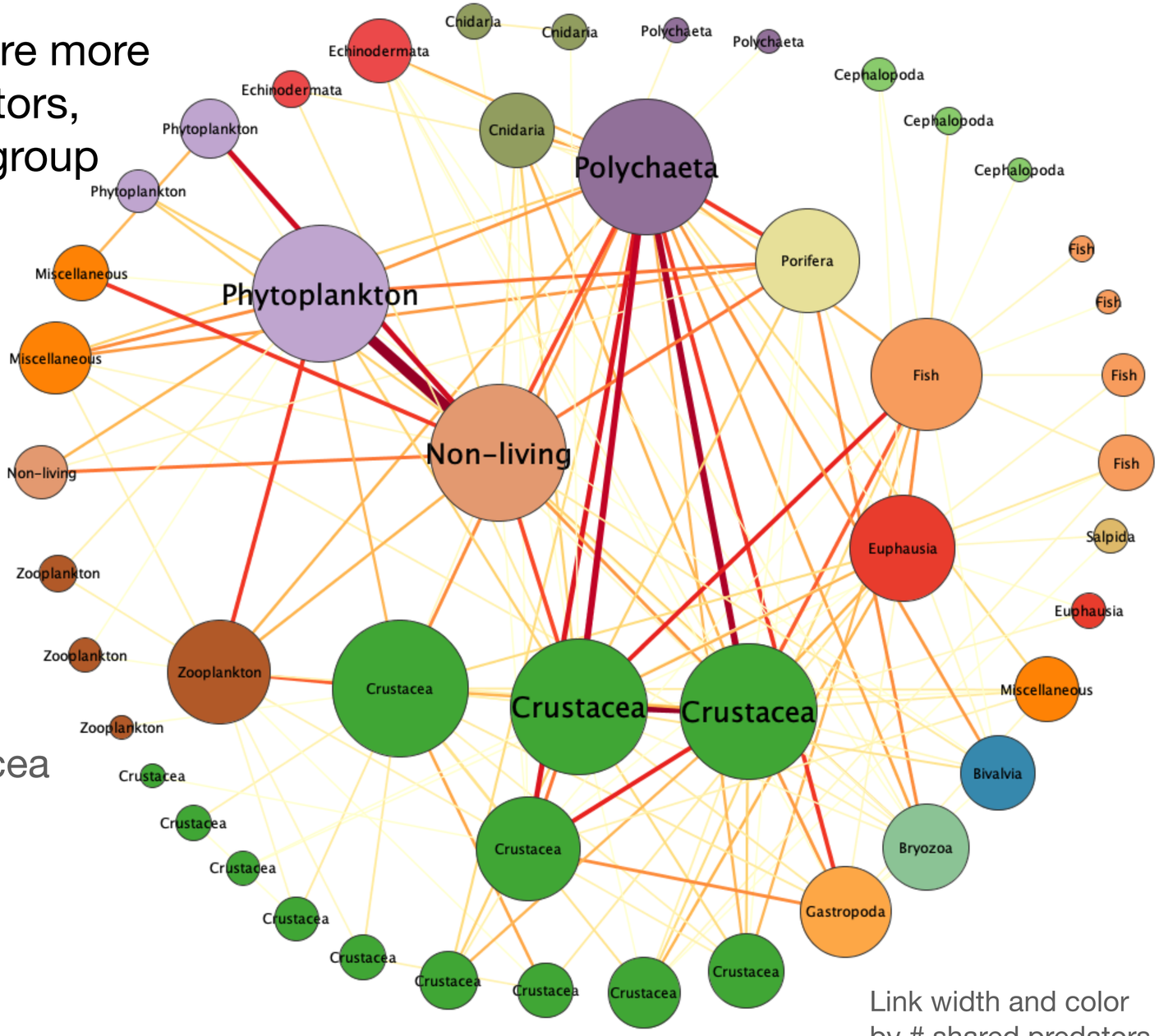
Diffusive control of energy flow

SUB-NETWORK level



Apparent competition

Preys that share more than 10 predators, by functional group



Link width and color by # shared predators.

Most of the “prey” groups are represented

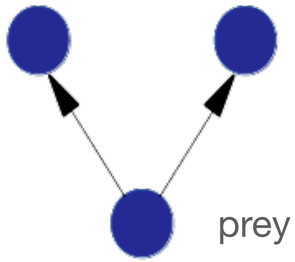
Diffusive control of energy flow

Non-living — Phytoplankton, Polychaeta — Crustacea indirect interactions are strong

Great inter-dependance

Different trophic guilds: fish, birds and echinoderms

SUB-NETWORK level



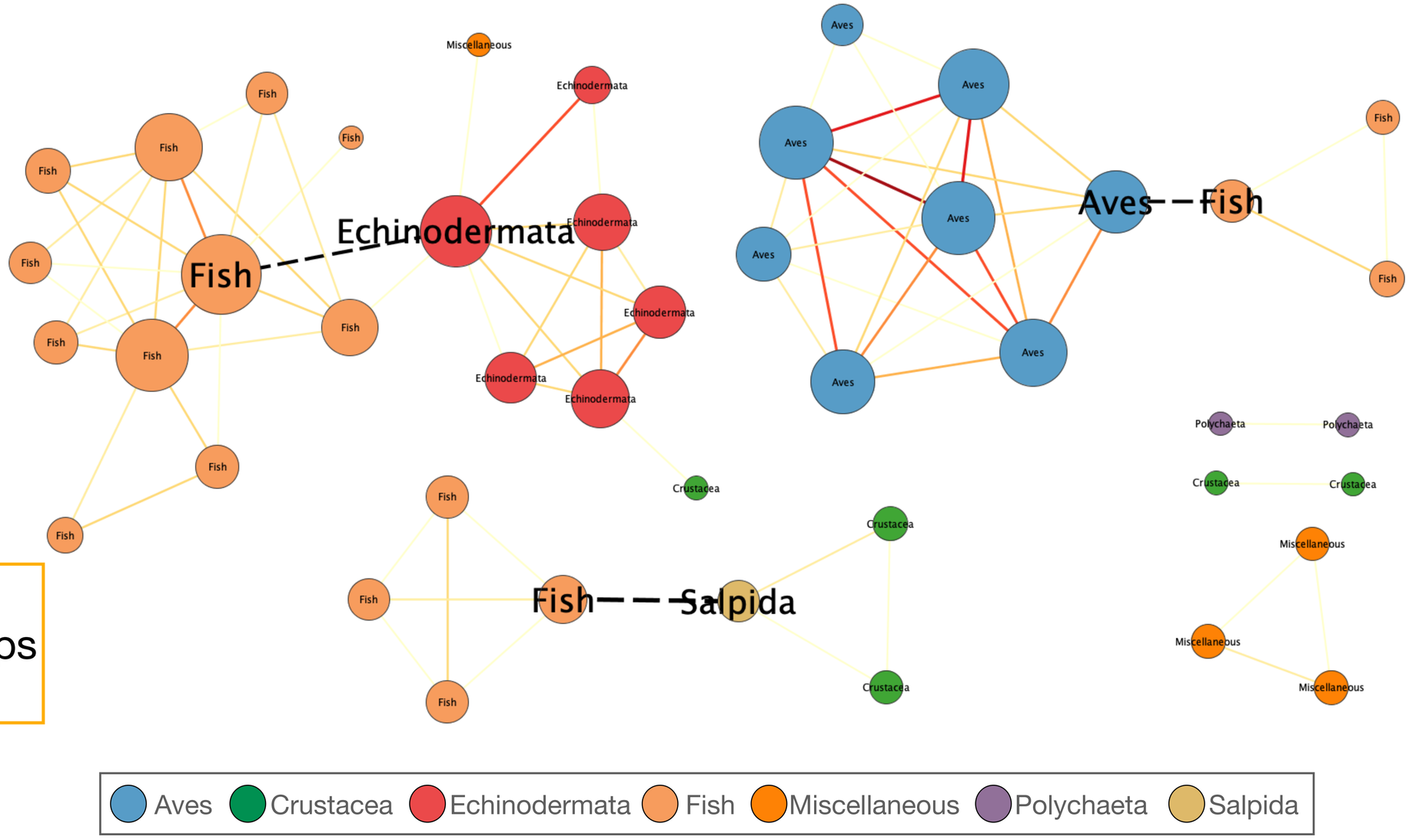
Exploitative competition

Distinct trophic guilds: fish, birds, echinoderms.

Fish are versatile predators, competing with different groups and at different habitats.

Predators that share more than 10 prey, by functional group

Link width and color by # shared prey



Combining modularity and species topological roles

SUB-NETWORK & SPECIES levels

MODULARITY

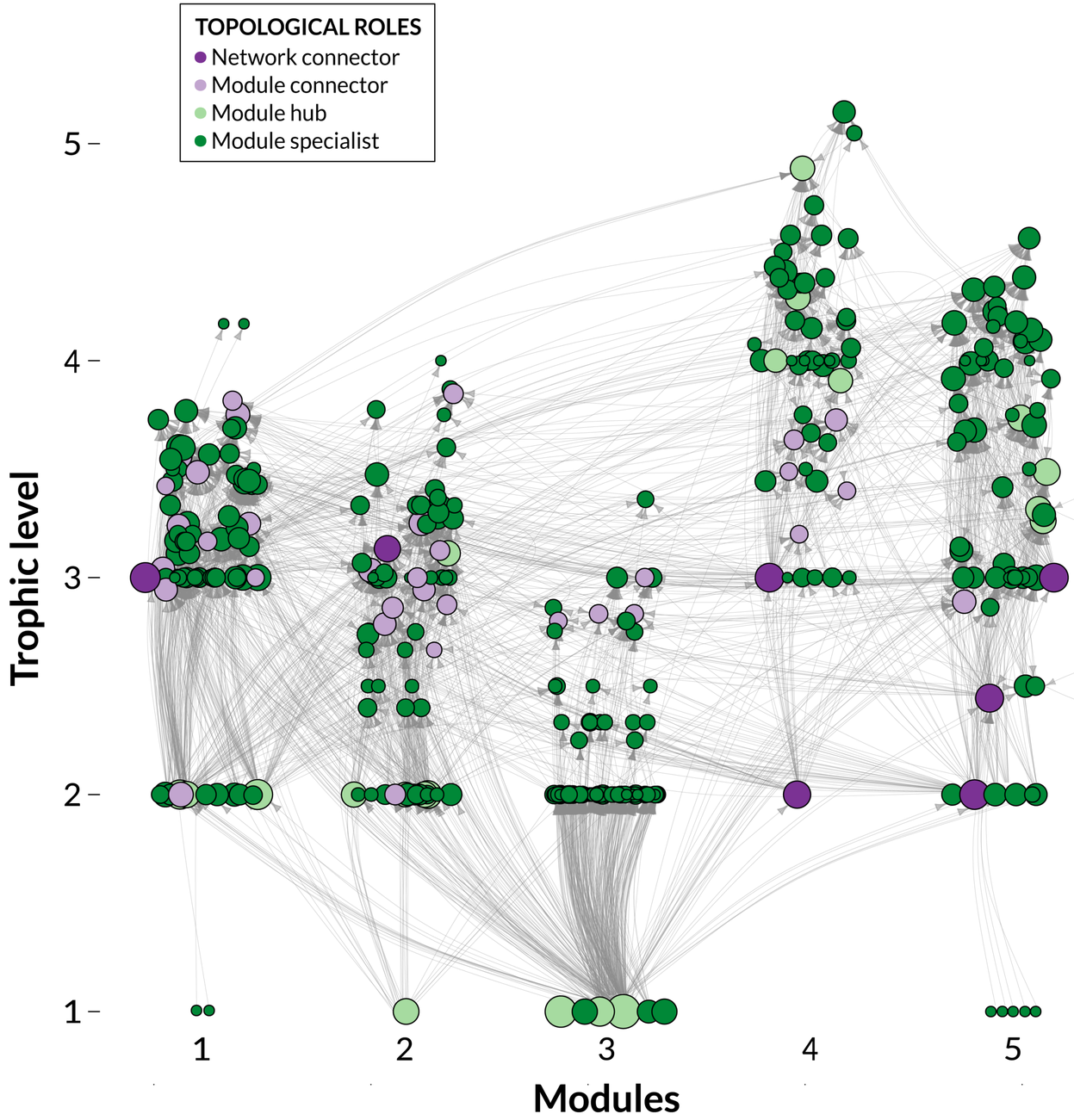
Measures how strongly sub-groups of species interact between them compared with the strength of interaction with other sub-groups.

Strength = number of connections.

Algorithm maximizes modularity by simulated annealing.

TOPOLOGICAL ROLES

- ✓ **Network connector** = high number of interactions within and between modules.
- ✓ **Module connector** = relatively few interactions, mostly between modules.
- ✓ **Module hub** = relatively high number of interactions, mostly within its module.
- ✓ **Module specialist** = relatively few interactions, mostly within its module.



Combining modularity and species topological roles

SUB-NETWORK & SPECIES levels

- ➡ 5 modules were identified.
- ➡ Most of the species are module specialists.
- ➡ *Euphausia superba* (krill) is a network connector.
- ➡ Module #2 energy source is Foraminifera.
- ➡ Module #4 energy source is Euphausiacea (krill).

TOPOLOGICAL ROLES

- ✓ **Network connector** = high number of interactions within and between modules.
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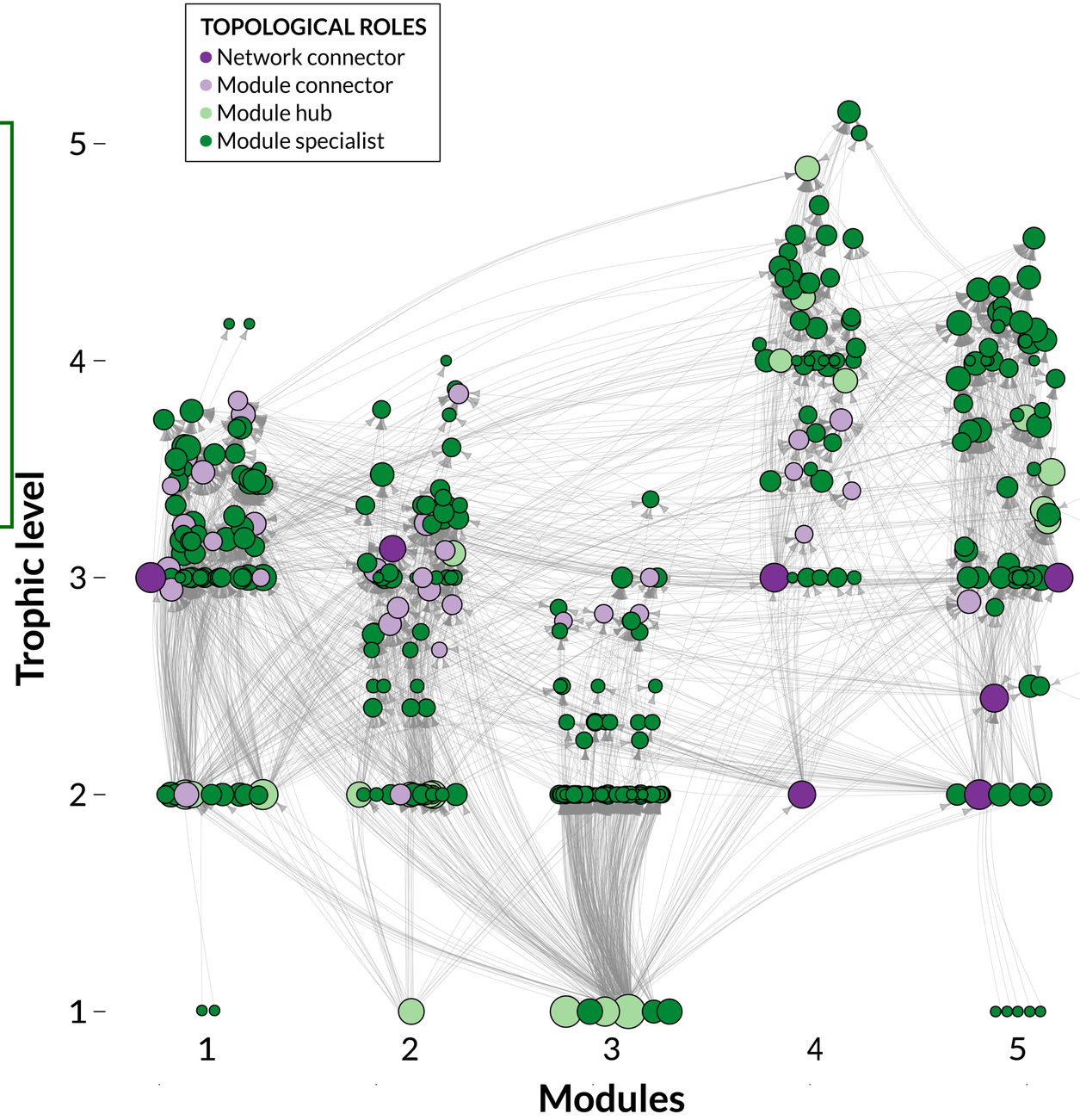
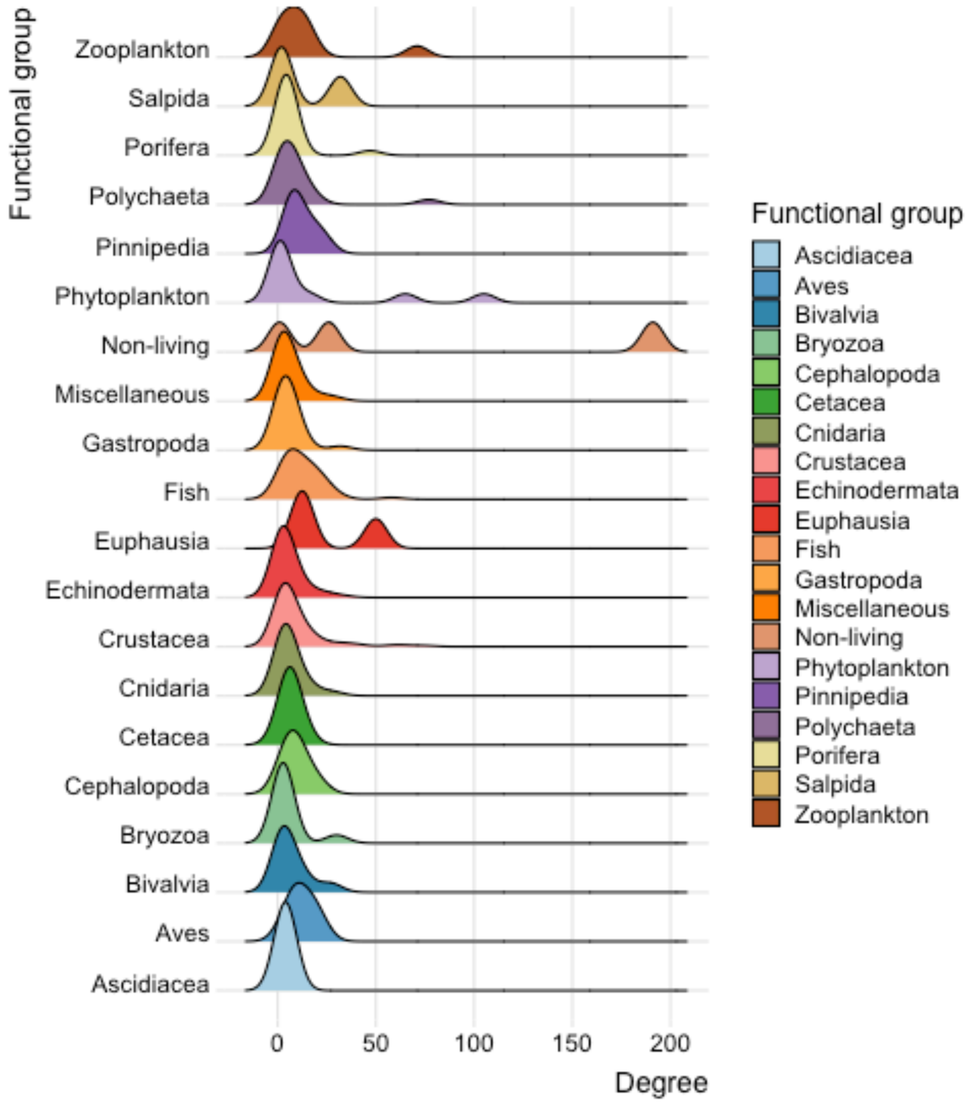


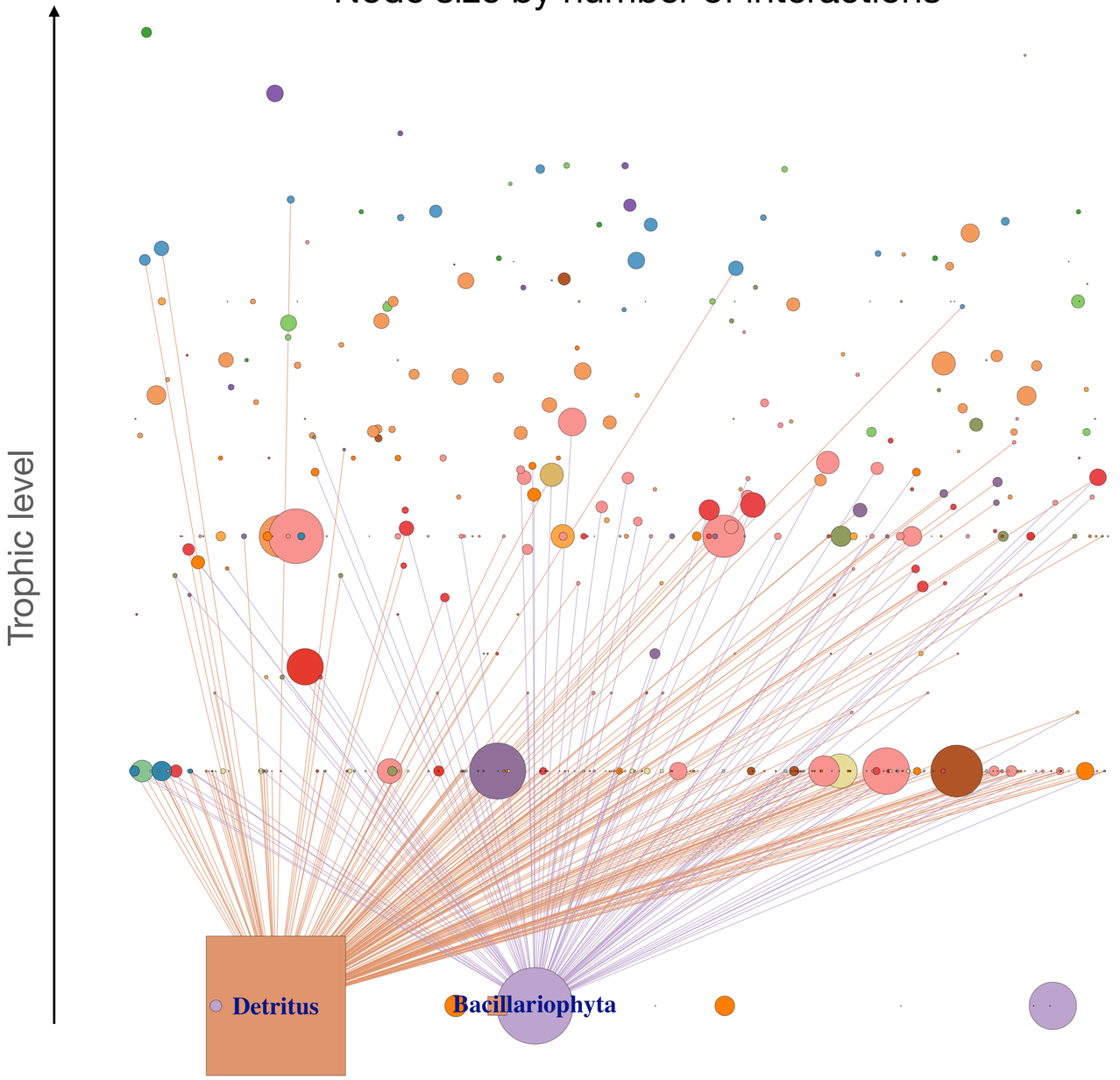
Detritus and diatoms are the principal food sources

SPECIES level

Number of interactions by functional group



Node size by number of interactions



Keystone species: a seal, a sea anemone, two squids and a bivalve

SPECIES level

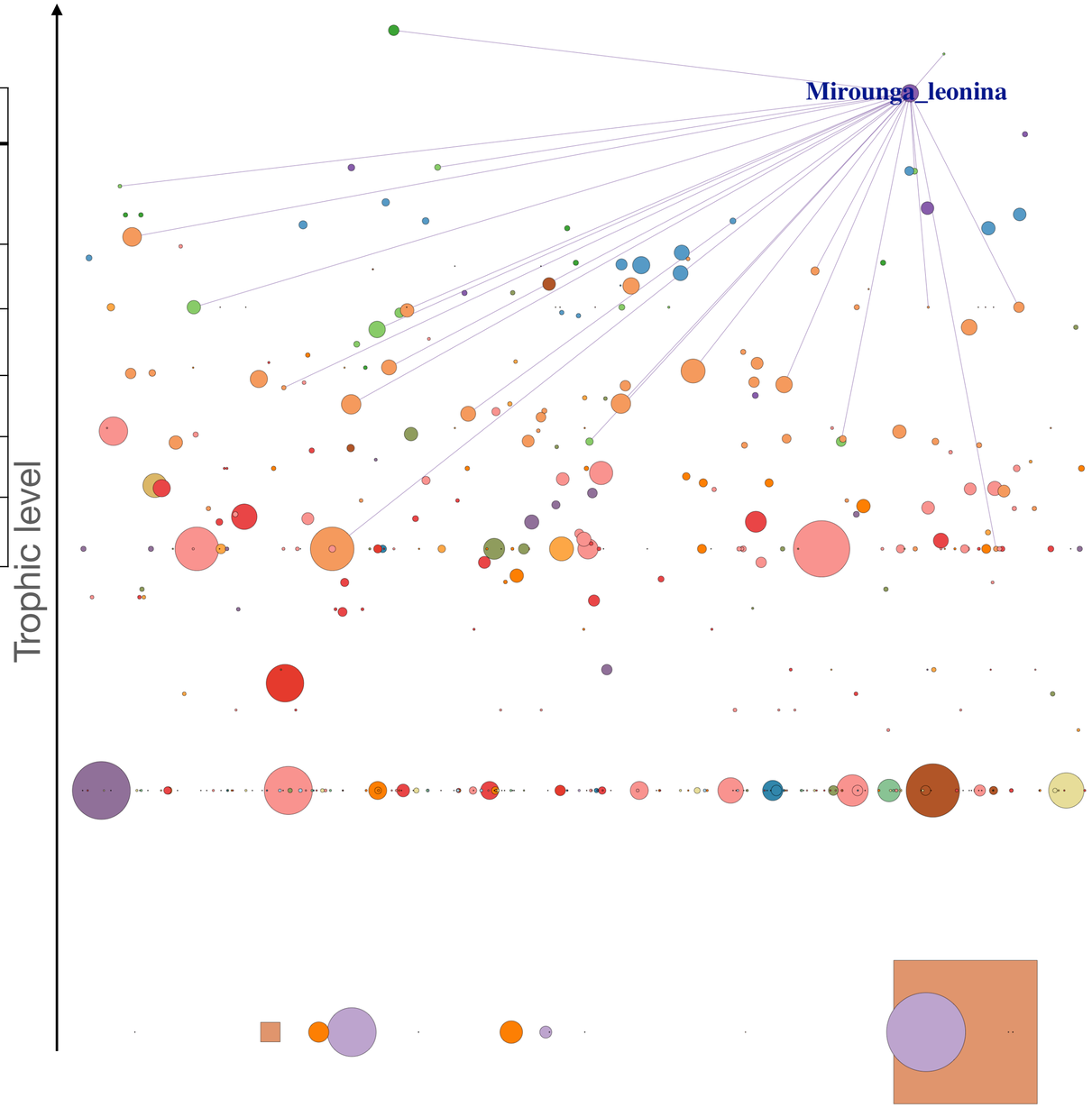
Keystone species ranking

				Species ranking	
Species	**Functional group**	**Trophic level**	**Degree**	**Closeness**	**Btwness**
Mirounga leonina	Pinnipedia	4.89	23	83	38
Urticinopsis antarctia	Cnidaria	3.47	18	135	1
Moroteuthis ingens	Cephalopoda	4.58	8	85	24
Adamussium colbecki	Bivalvia	3.00	10	97	37
Galiteuthis glacialis	Cephalopoda	3.44	13	105	58

✓Degree = total number of interactions.

✓Closeness = steps required to access every other sp from a given sp. If removed, would affect the most other sp.

✓Betweenness = number of shortest paths in which a sp participates. “Bridges”. If removed, would have rapidly spreading effects in the food web.



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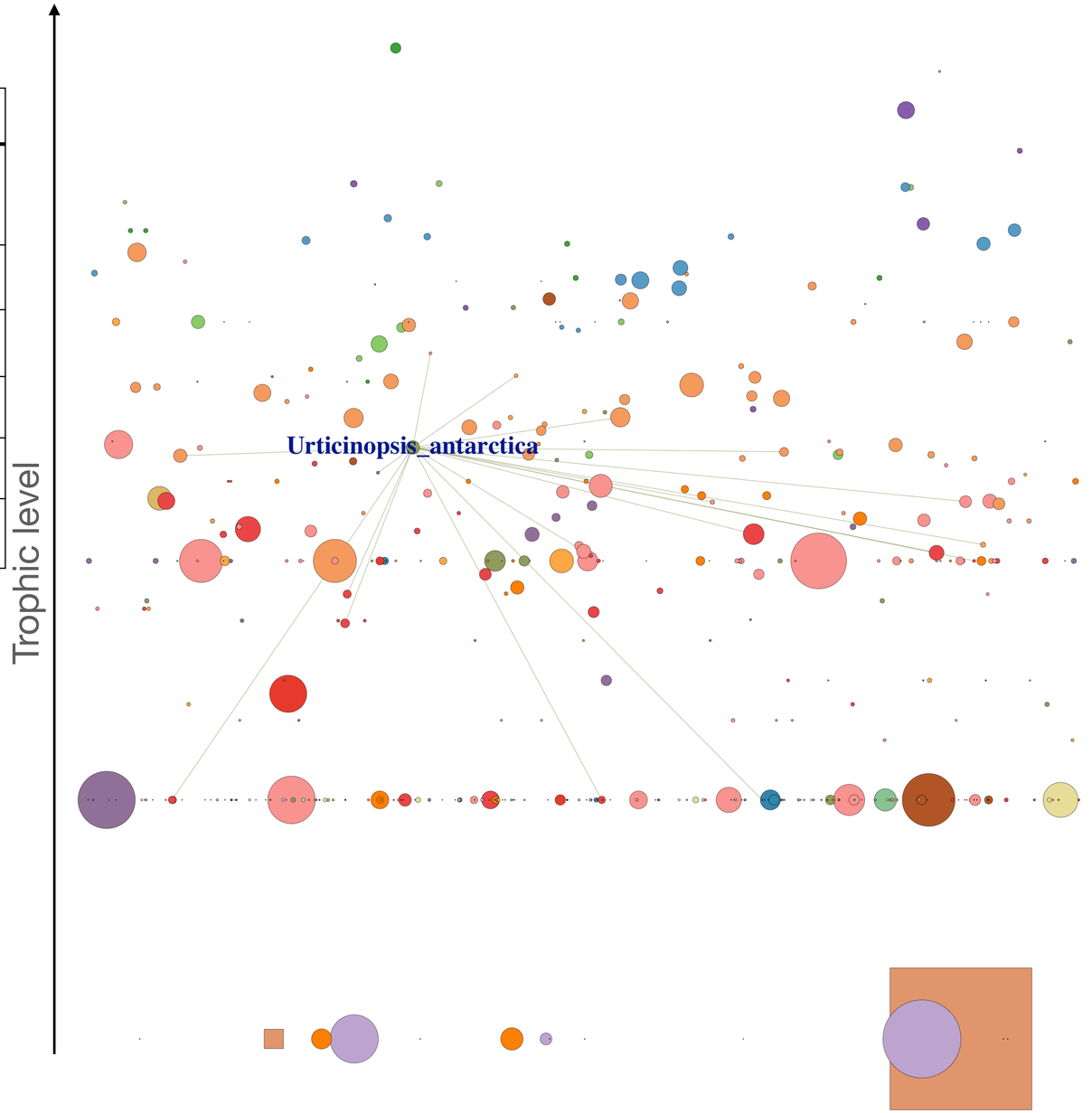

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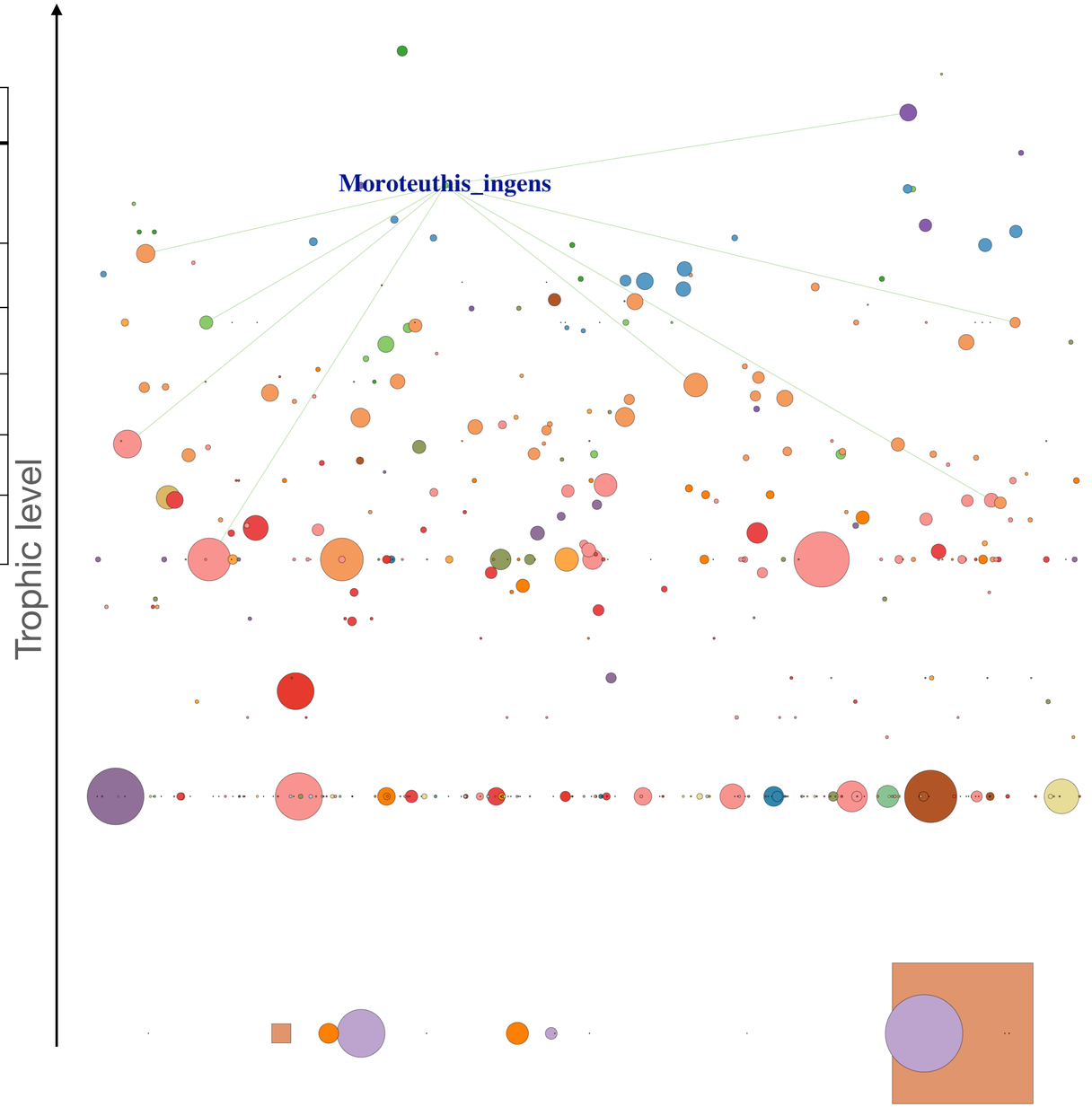

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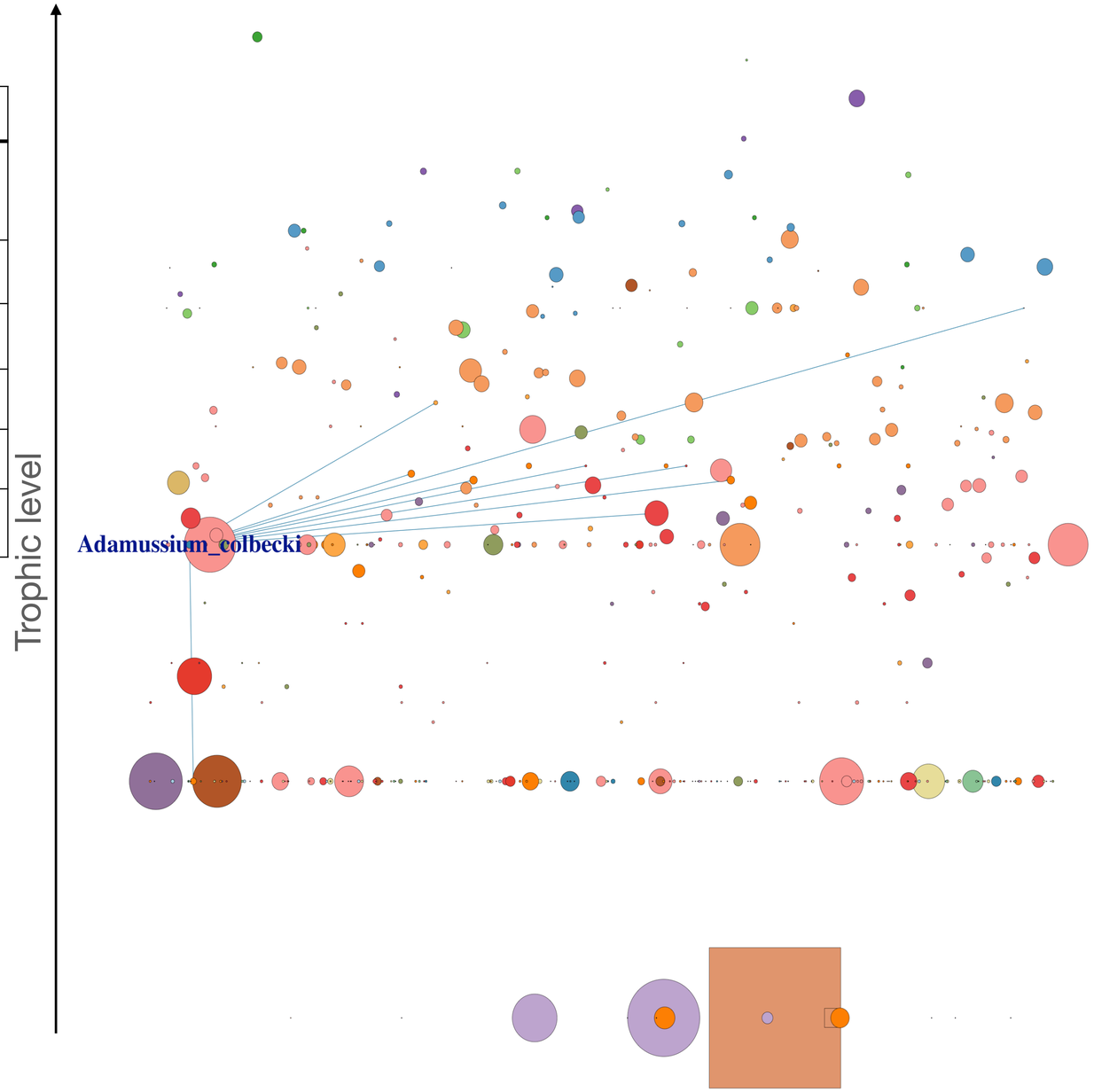

Summary

- The **Weddell Sea ecosystem** needs a **network approach** able to capture its complexity and structure.
- The Weddell Sea food web presents a **small-world topology**, implying a rapid **spread** of **perturbations** among the network.
- The main **food sources** in the Weddell Sea ecosystem are: **detritus** and **diatoms**. **Euphausiacea** species (krill) **support** the **pelagic** habitat.
- Most of the **species interact** by means of **apparent competition** and **exploitative competition**. From this we suggest a **diffusive control of energy flow** and highlight the presence of clear trophic guilds.
- The following species arise as relatively more important "**keystone**" in terms of ecosystem structure:

  the Southern elephant **seal** (*Mirounga leonina*), a **sea anemone** (*Urticinopsis antarctica*), two species of **cephalopods** (*Moroteuthis ingens* and *Galiteuthis glacialis*) and a **bivalve** (*Adamussium colbecki*). All these species present a **high trophic level** (TL > 3) = top predators.


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Thank you for your attention!

Tomás I. Marina*, Leonardo Saravia, Georgina Cordone, Vanesa Salinas, Iara D. Rodríguez & Fernando R. Momo

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