

Is the hyperiid amphipod *Themisto gaudichaudii* poised to displace krill in the warming region of the Southern Ocean?

ICES Zooplankton Production Symposium, Bergen, 9th May 2016



Charlotte Havermans, Christoph Held, Holger Auel, Wilhelm Hagen

Pelagic amphipods: the hyperiids

Themisto



Lanceola



Primno



Vibilia



Adaptations



Paraphronima

Co-evolution



Phronima

Cystisoma



Hyperia spp.



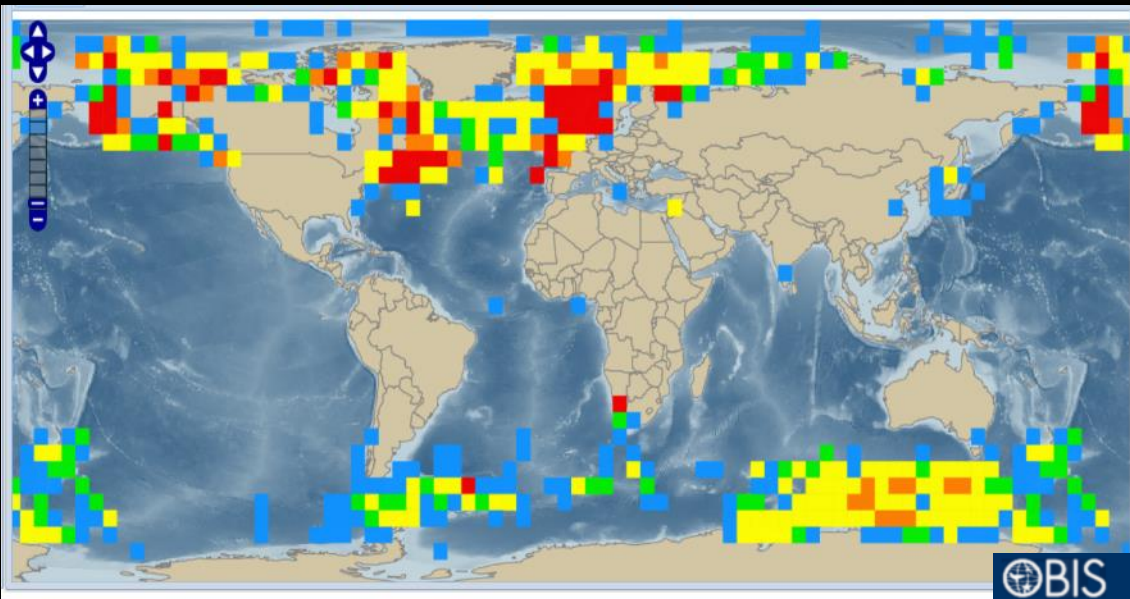
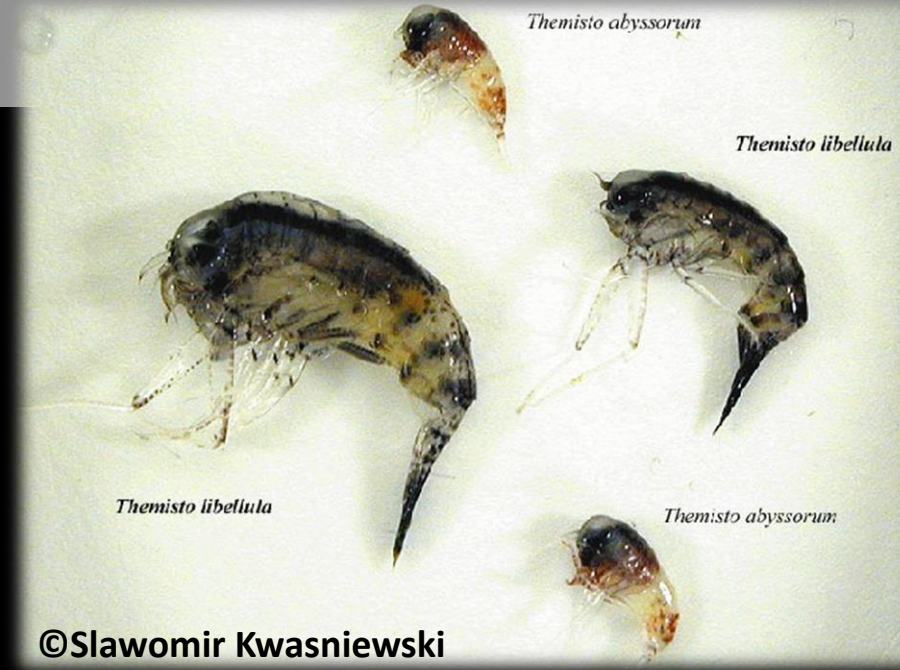
Specializations



Scypholanceola

Pictures:
©Karen Osborn,
Smithsonian

The hyperiid genus *Themisto*

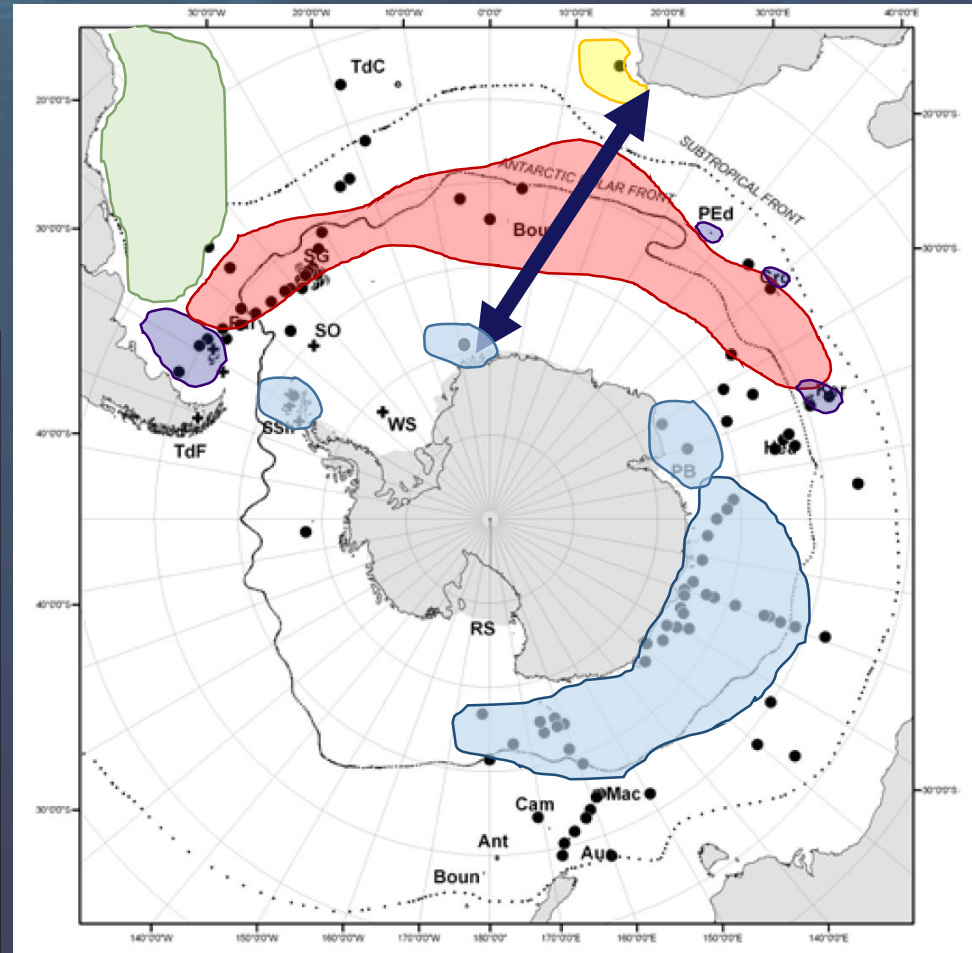


- Cold-water genus
- 7 species



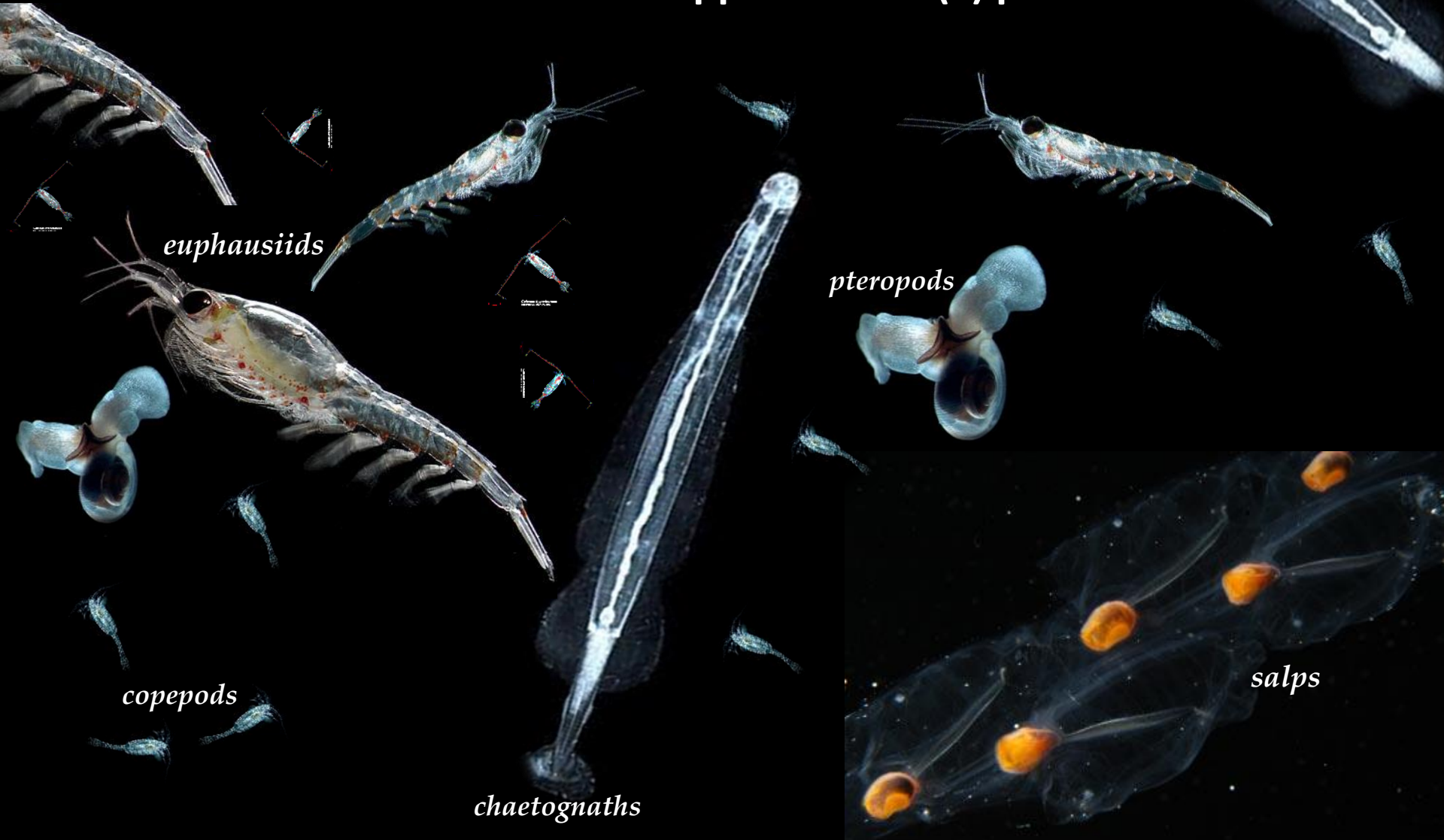
Distribution of *Themisto gaudichaudii*

- circumpolar but patchy
- latitudinal gradient
- high densities (swarms)



Themisto gaudichaudii: key component of the SO pelagic food web

✓ Voracious non-selective & opportunistic (?) predator



On the menu: *Themisto*



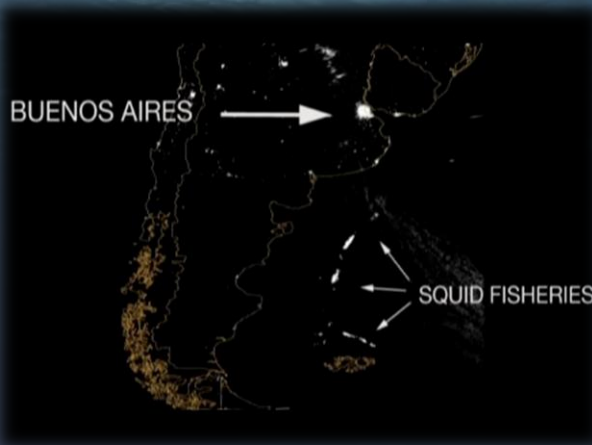
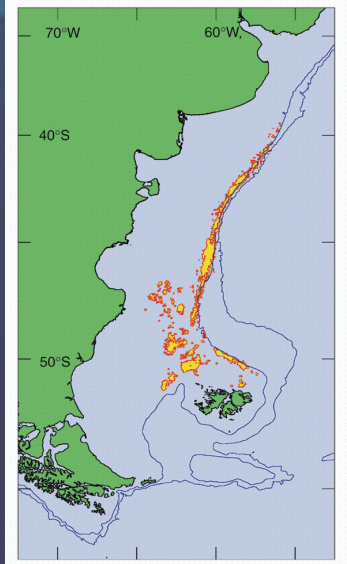
Themisto: krill of the North



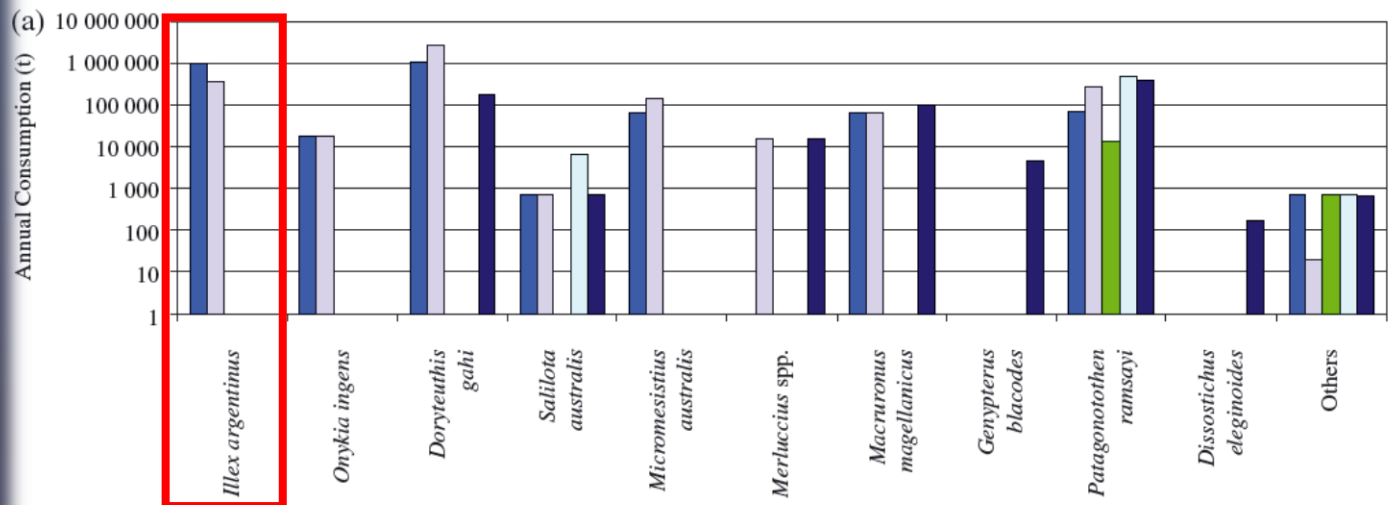
Illex argentinus or Argentine shortfin squid
510 000 t annually (FAO 2003)



Arkhipkin et al. 2012 *Journal of Fish Biology*

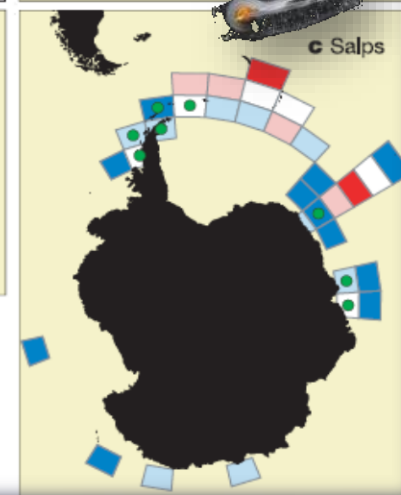
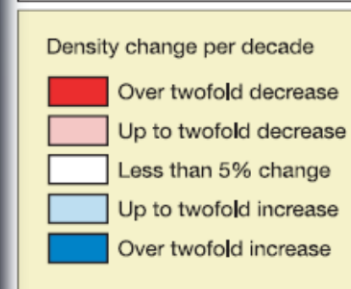
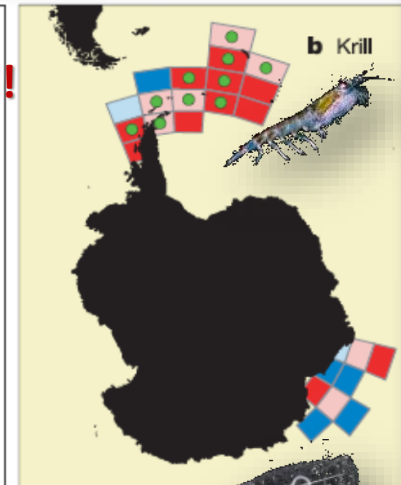
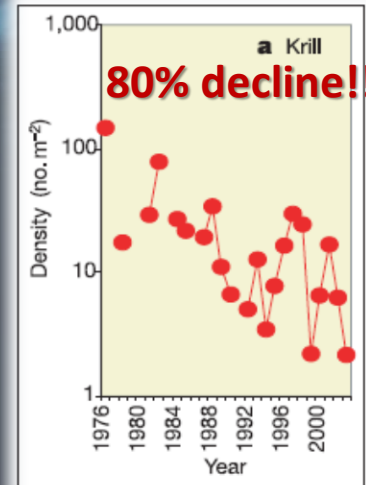
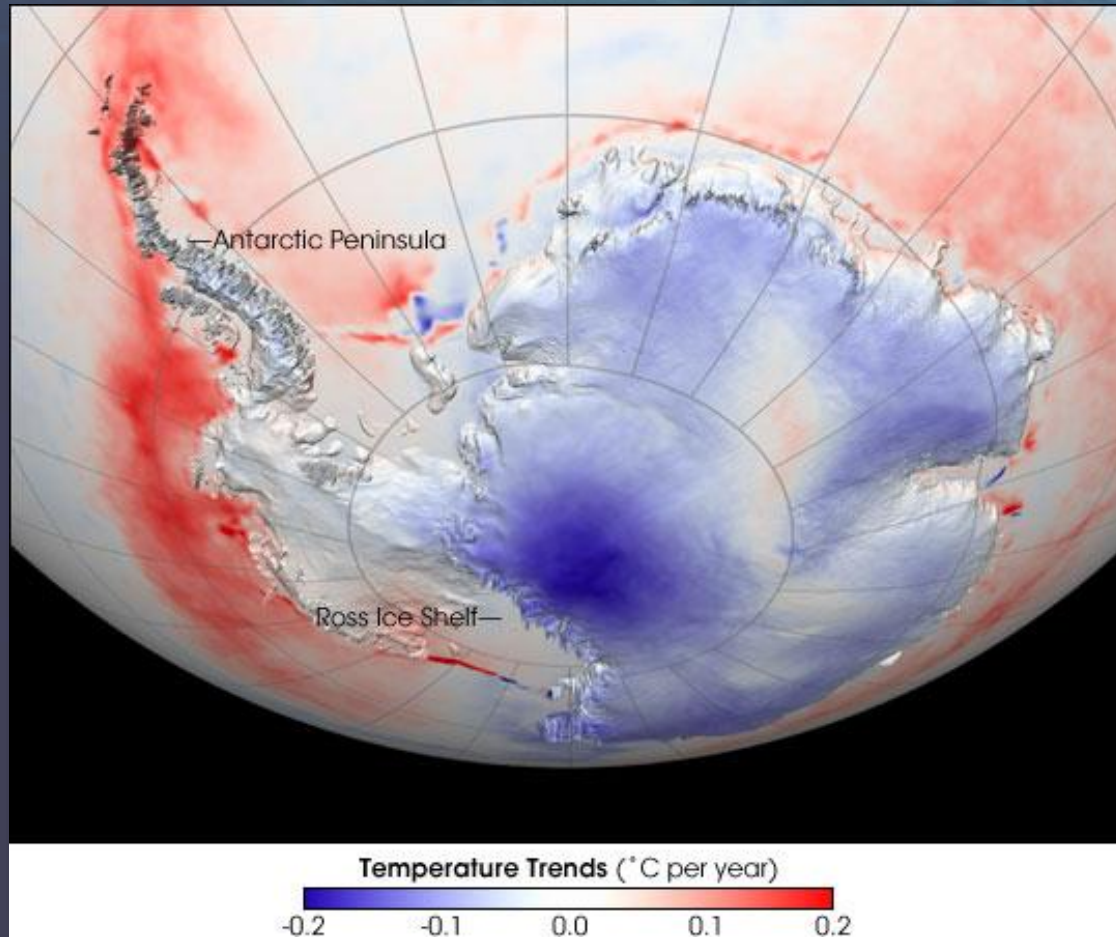


©Karen Osborn



Illex argentinus consumes 1 million t of *Themisto* per year

The Southwest Atlantic sector is changing...



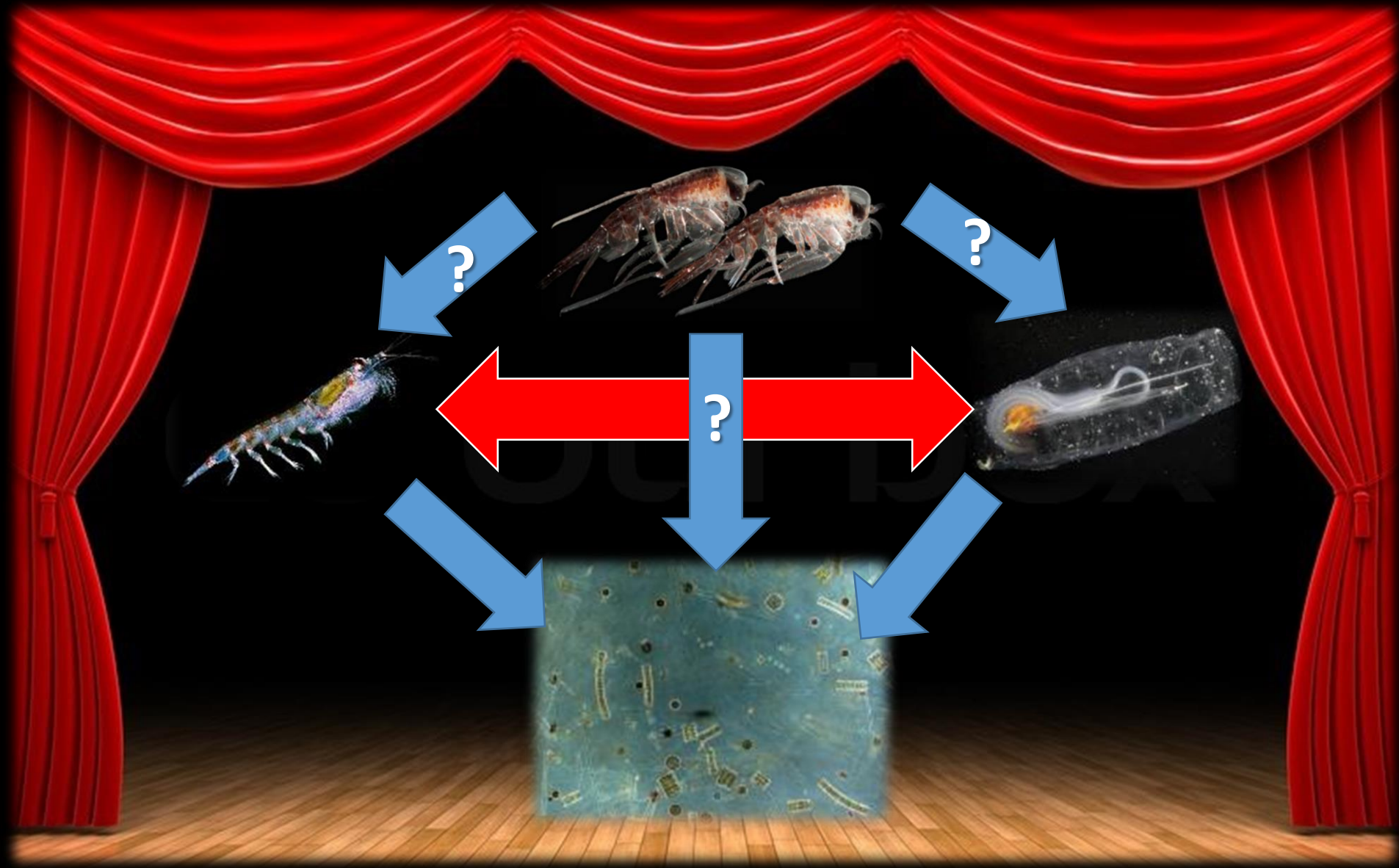
Atkinson et al. 2007

→ Alterations phytoplankton blooms and winter sea-ice extent
(Loeb et al. 1997, Atkinson et al. 2004)

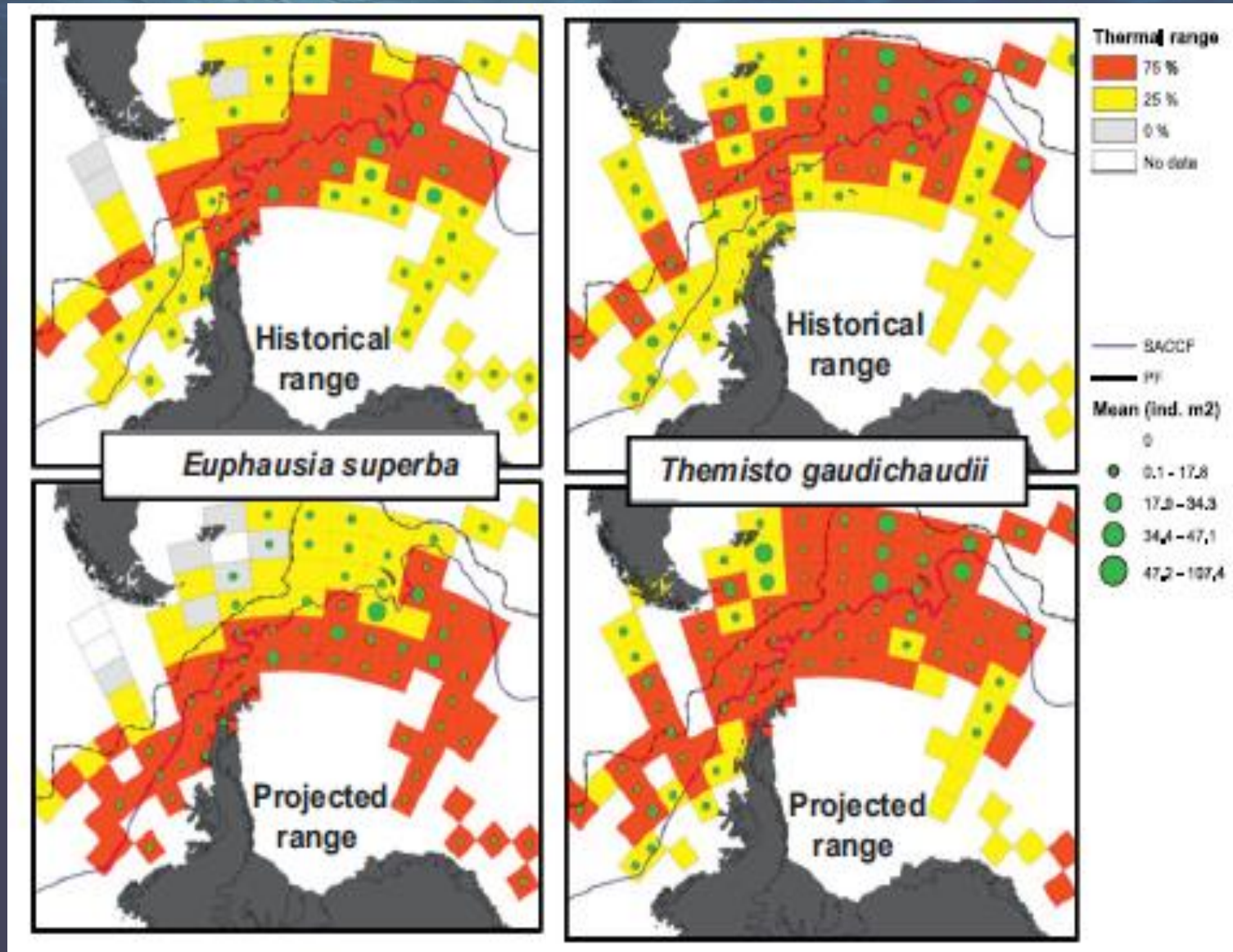
What will happen on the planktonic stage?



The principal actors and their interactions



Predicted distributional shifts (Mackey et al. 2012)



Consequences of changing mesozooplankton?

- Fluctuations in abundance of Antarctic krill around South Georgia:
→ Consequences for breeding success, adult survival (Croxall et al. 1999)

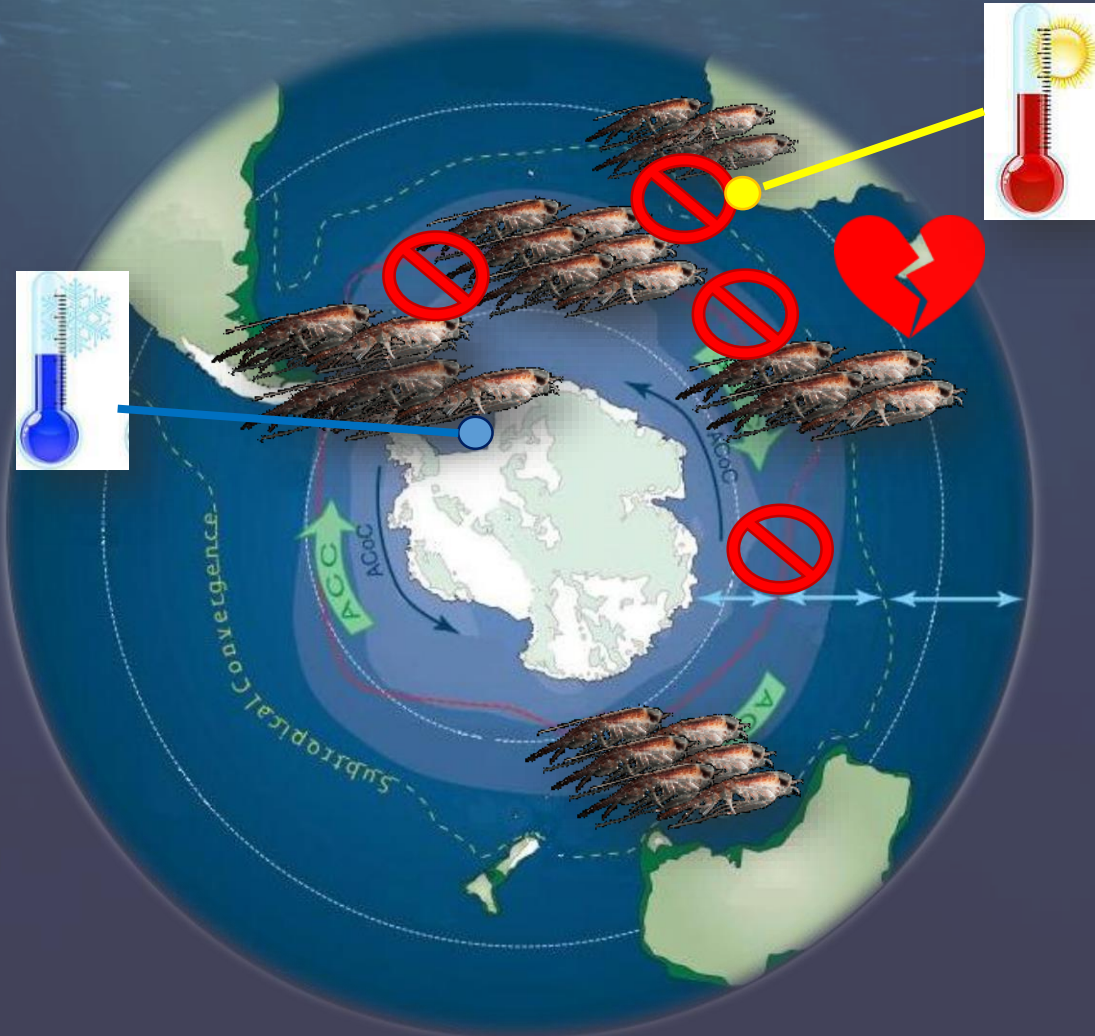


- Blue whales avoid *Themisto* despite abundance and mixed swarms (Mackintosh & Wheeler 1929, Hardy 1967)

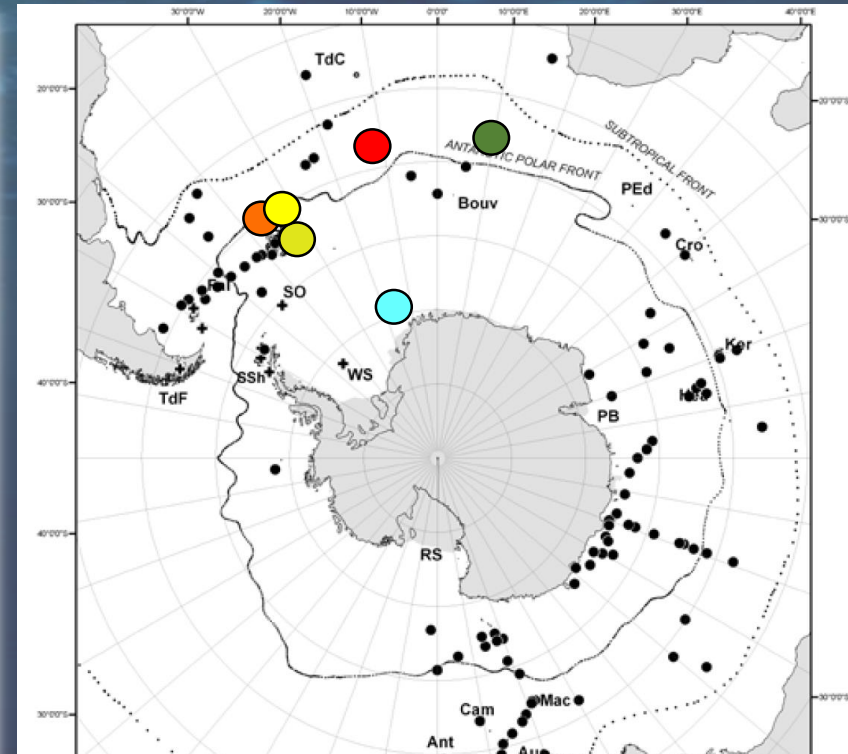
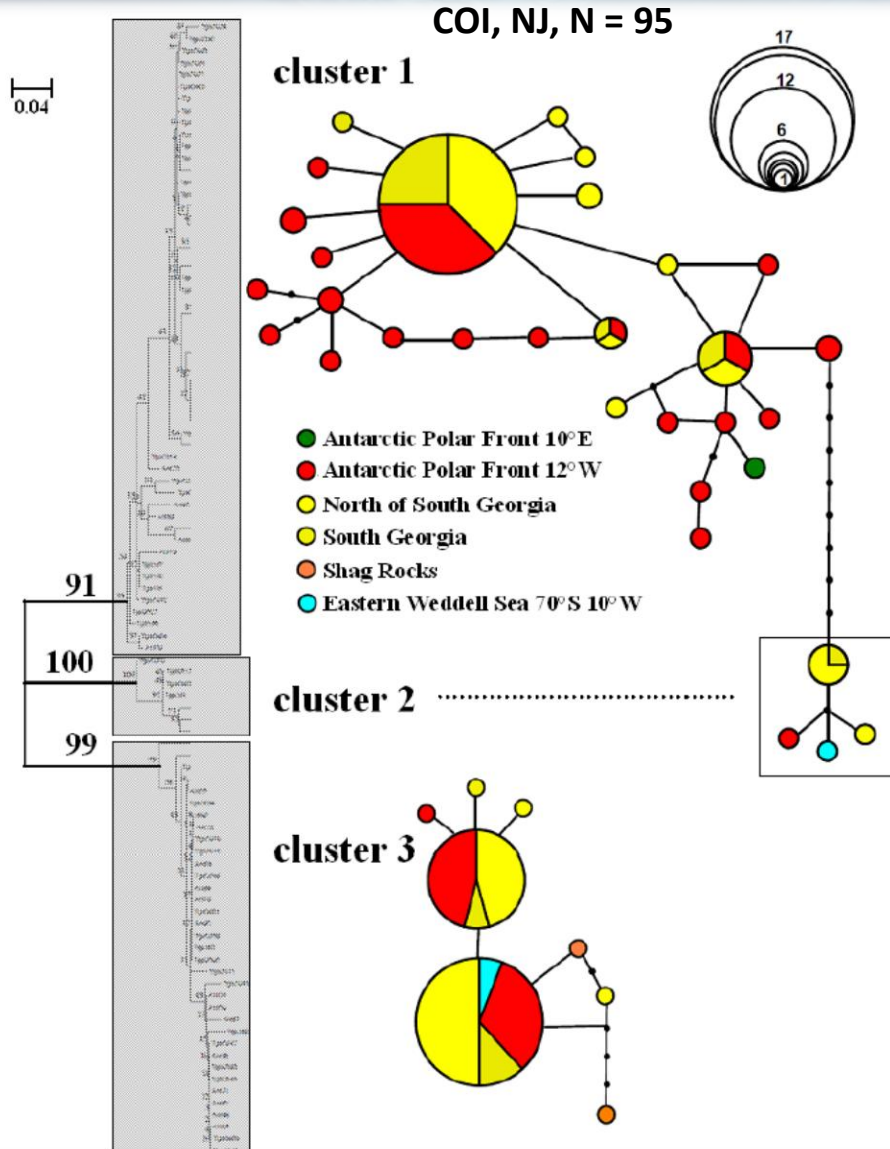


The known unknowns (1): *Themisto*'s genetic structure?

✓ Several morphospecies or species-level lineages? Their distributions ?



Several lineages within *T. gaudichaudii* across the SO

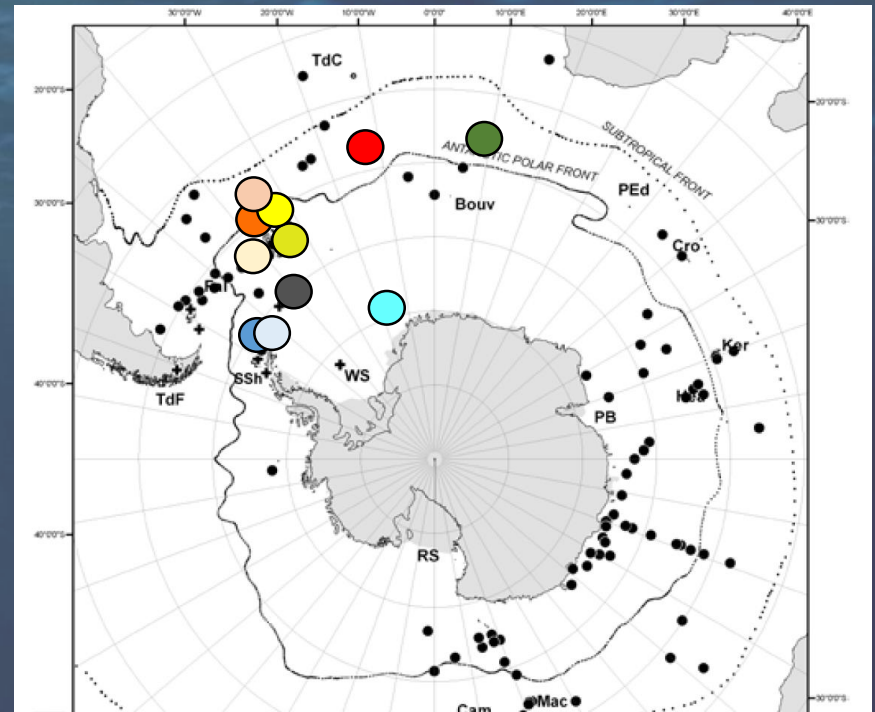
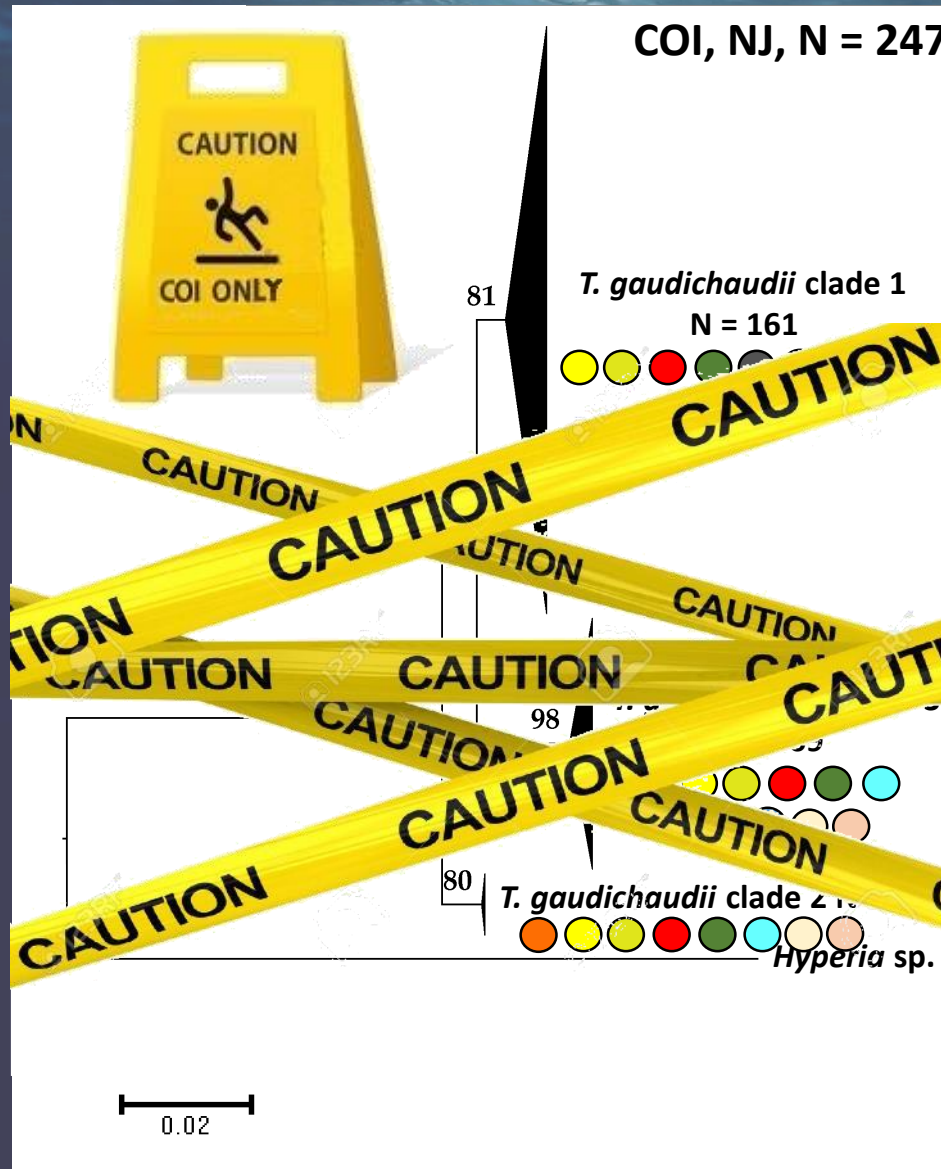


COI gene fragment:

3 sympatric lineages composed of mix of different forms (*bispinosa* & *compressa*)

→ distinct feeding modes/ecology?

Several lineages within *Themisto* across the SO

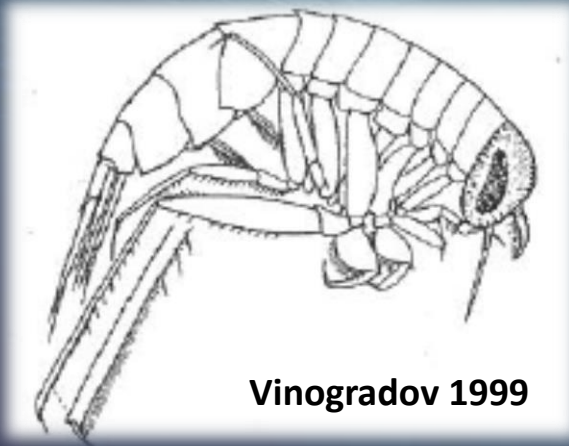


Wide environmental gradient:
From the Weddell Sea to North of the
Antarctic Polar Front

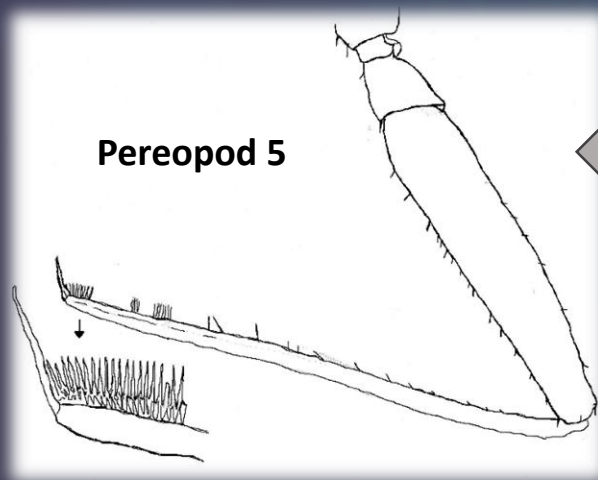
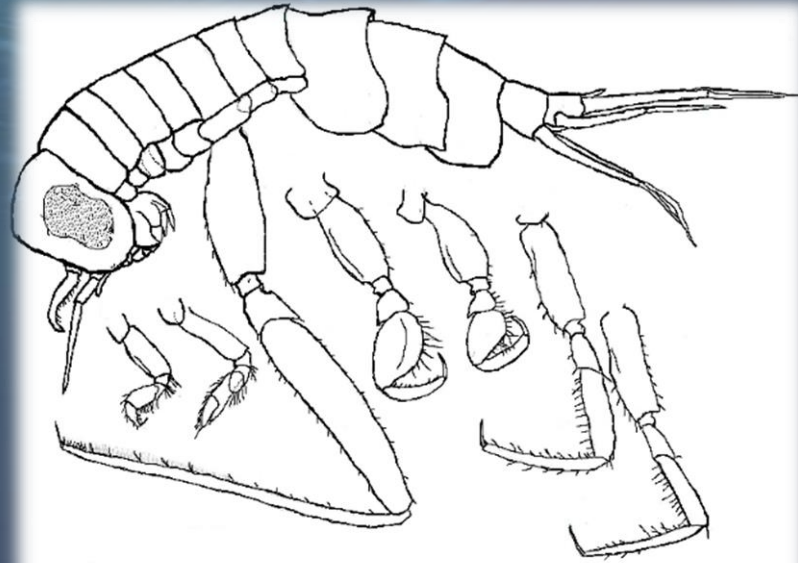


Potential for a southward expansion?!

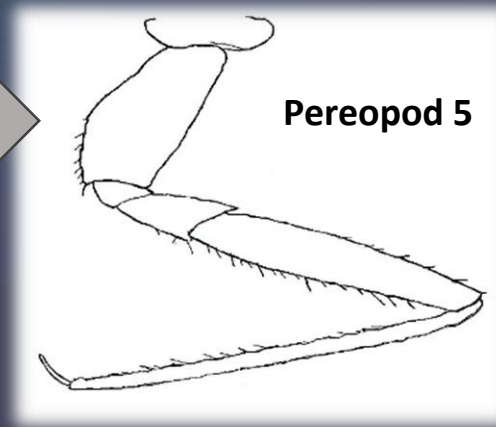
Themisto revisited with an integrative approach



Vinogradov 1999



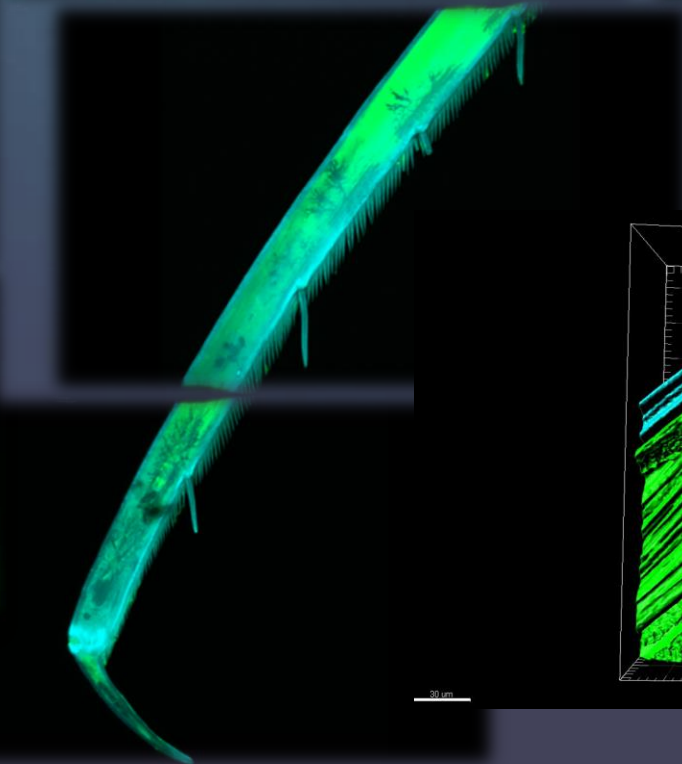
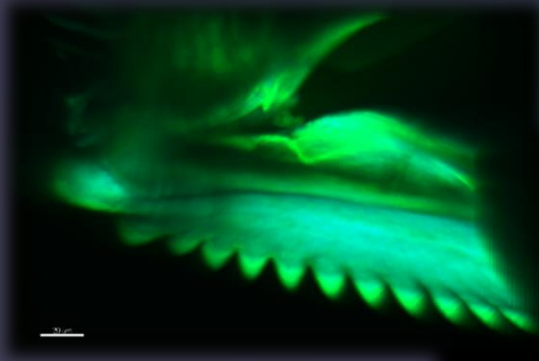
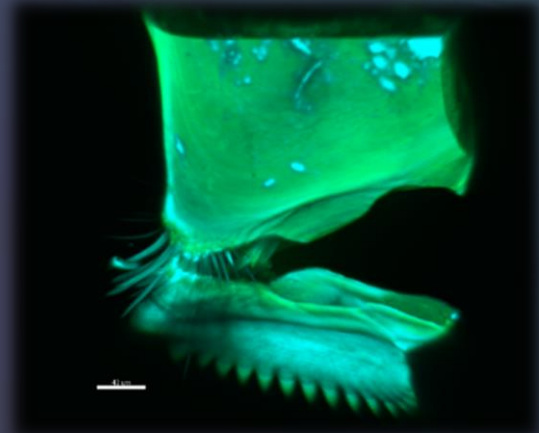
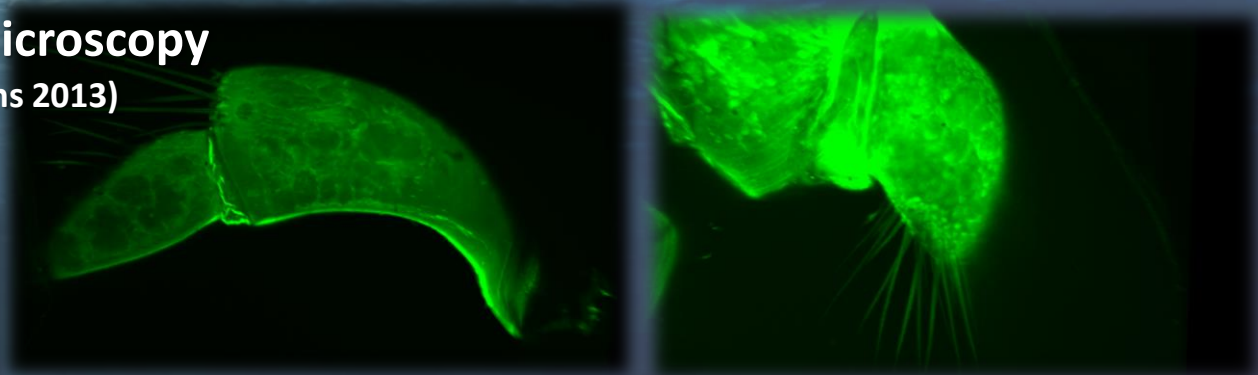
Pereopod 5



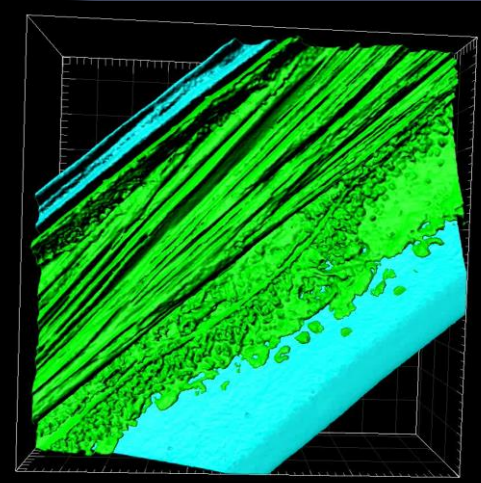
Pereopod 5

Morphological adaptations to distinct feeding ecology?

Confocal Laser Scanning Microscopy
Fluorescent Dye (protocol Friedrichs 2013)



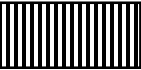
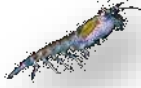


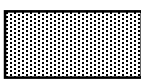






Or predation pressure?
Chitin of exoskeleton:




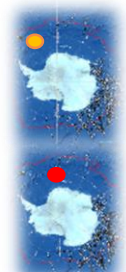
The known unknowns (2): feeding ecology of *Themisto*?

High-throughput sequencing using the Illumina MiSeq platform

-  **Chaetognath sp.** 
-  ***Euphausia superba*** 
-  ***Salpa thompsoni*** 
-  **Pteropod sp.** 
-  ***Metridia sp.*** 

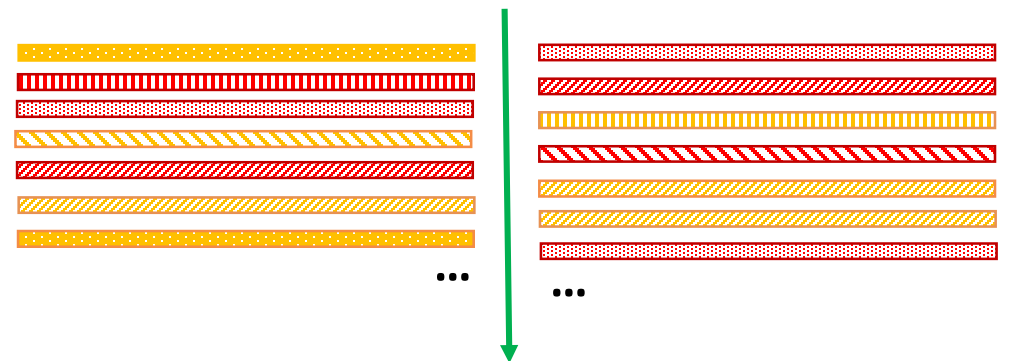
 Station/locality 1

 Station/locality 2



```

Contig Editor: +611979 B66P8:2113:1545
-----
191720 191730 191740 191750 191760 191770 191780 191790 191800 191810 191820 191830 191840
+674614 B66P8:1027:158 CTTATTCGCCCGGAGCTACCGGTACGGCTCGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATG
-674615 B66P8:1520:205 CTTATTCGCCCGGAGCTACCGGTACGGCTCGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATG
+674616 B66P8:570:256 CTTATTCGCCCGGAGCTACCGGTACGG
+674617 B66P8:1752:221 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGA
-674618 B66P8:1578:124 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTT
-674619 B66P8:2173:208 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGA
+674620 B66P8:1479:134 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTT
+674621 B66P8:2351:892 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTTC
+674622 B66P8:633:1399 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCG
+674623 B66P8:1394:643 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGG
-674624 B66P8:117:1772 CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTTCT
-674625 B66P8:1952:239 TATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCT
+674626 B66P8:2002:207 TATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACAC
+674627 B66P8:2022:972 GAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674628 B66P8:1095:435 ANGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674629 B66P8:178:1206 GCTACGGTTGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674630 B66P8:1583:149 GCTACGGTTGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
+674631 B66P8:1307:176 TACGGTTGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
+674632 B66P8:2487:969 TACGGTTGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674633 B66P8:1177:133 CTGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674634 B66P8:1181:215 TTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674635 B66P8:552:1819 TTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674636 B66P8:387:997 CAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
+674637 B66P8:1759:198 AGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674638 B66P8:964:217 AATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
+674639 B66P8:2001:167 AATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
+674640 B66P8:1220:254 GCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
-674641 B66P8:2061:117 CTAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
<> CONSENSUS -ZX-CTTATTCGCCCGGAGCTACCGGTACGGTTTATTTTCACAGAAGCAATGCTAAACGCCACGGTATGGGTTTGAAGGGATGCGCGTTCCGTTCTGGCTCCGGACACGCTC
Tag type:SVLC Direction: Comment:
    
```



Semi-quantitative prey-species identification

Conclusions

- ✓ *Themisto gaudichaudii*: several widespread genetic lineages!
- ✓ Distinct morphospecies? Feeding ecology?
- ✓ Urgent: species interactions & cascading top-down effects!
 - Conservation measures (e.g. fishery quota)
 - Ecosystem management



Travel support



Thank you!

Tusen takk!

2015-2018: HA-7627/1-1



2015



2013



2012

