Empirical evidence suggests that global warming may induce abrupt shifts in plankton communities and subsequent recruitment failure in fishes

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Outline

1. Historical evidence of abrupt recruitment collapses in gadoids
2. Recent recruitment patterns
3. Trends in oxygen
4. Trends in phytoplankton
5. Trends in copepods
6. Summary and conclusion

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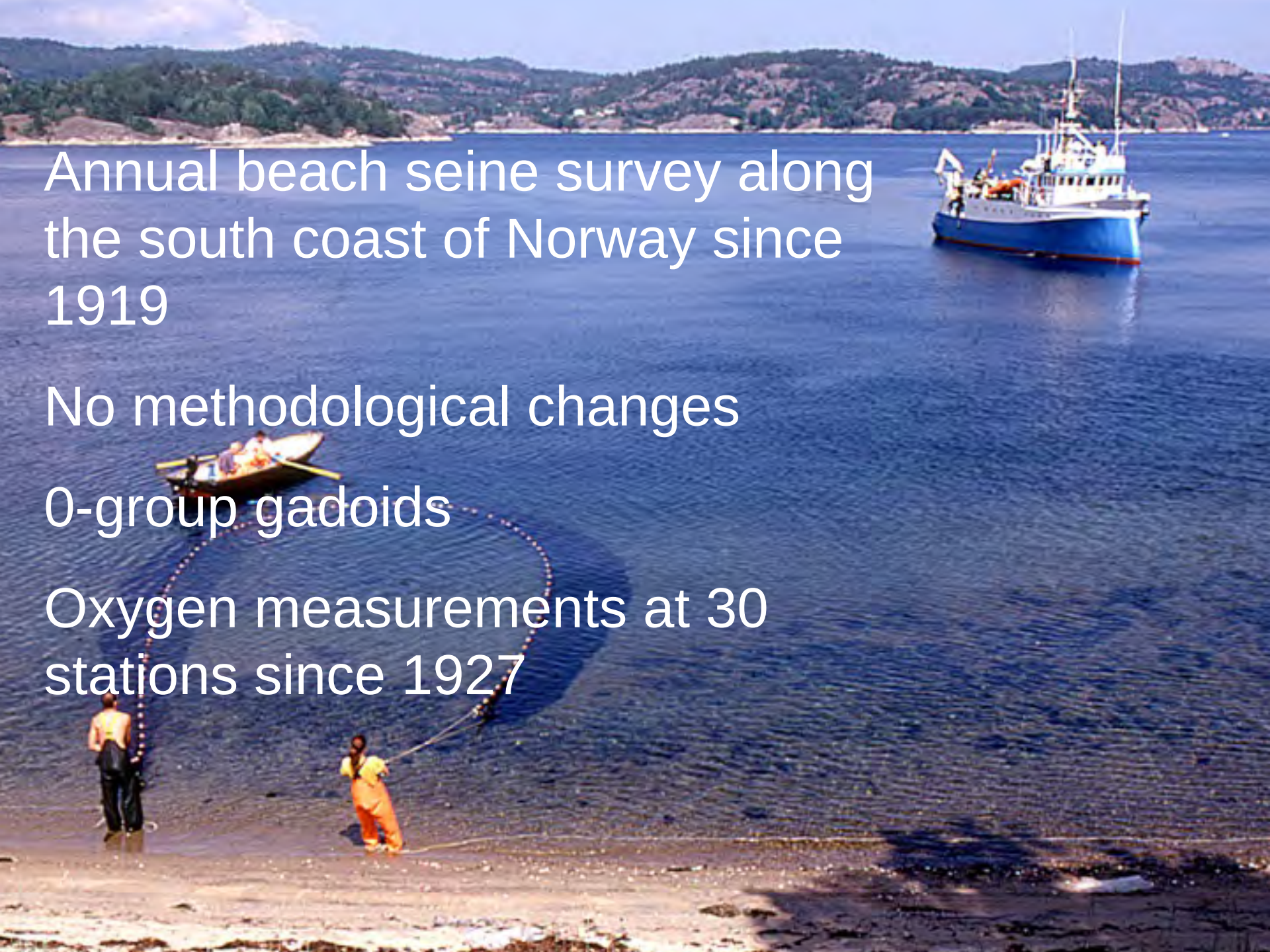


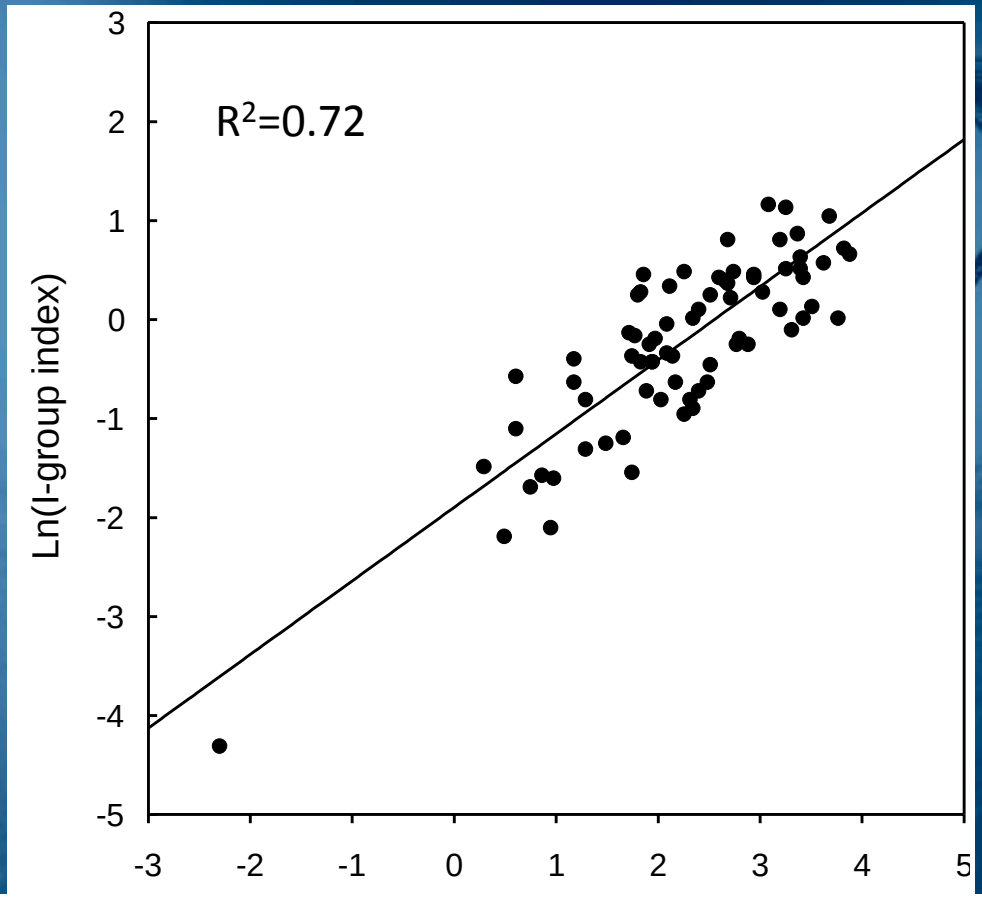
Annual beach seine survey along the south coast of Norway since 1919

No methodological changes

0-group gadoids

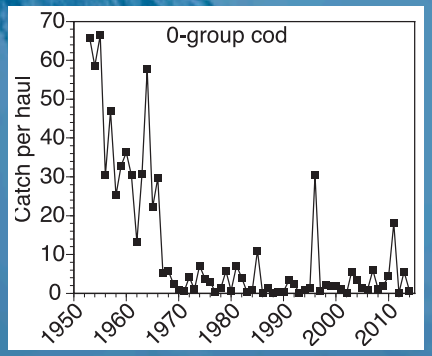
Oxygen measurements at 30 stations since 1927

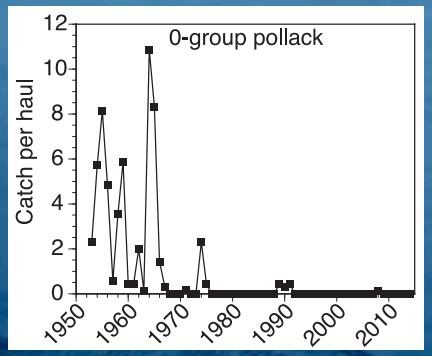
Relationship between 0- and I-group cod (same year-class)

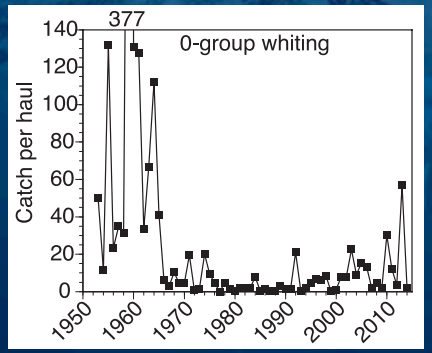


1. The year-class strength in cod seems mainly determined at the 0-group stage (September).
2. The beach seine sample 0-group cod in relatively precise numbers.

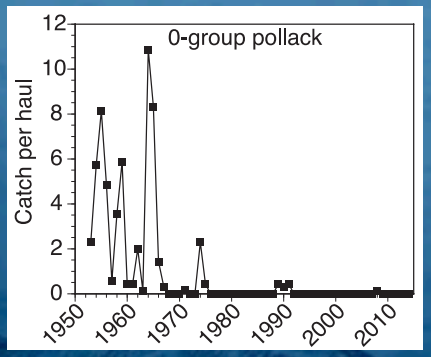
The Grenlandfjords

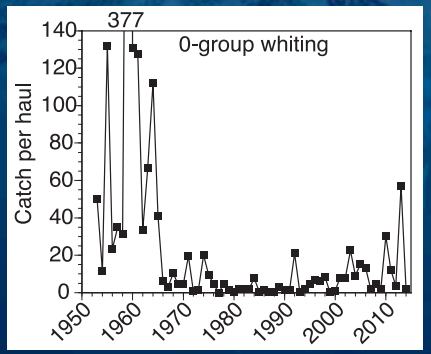


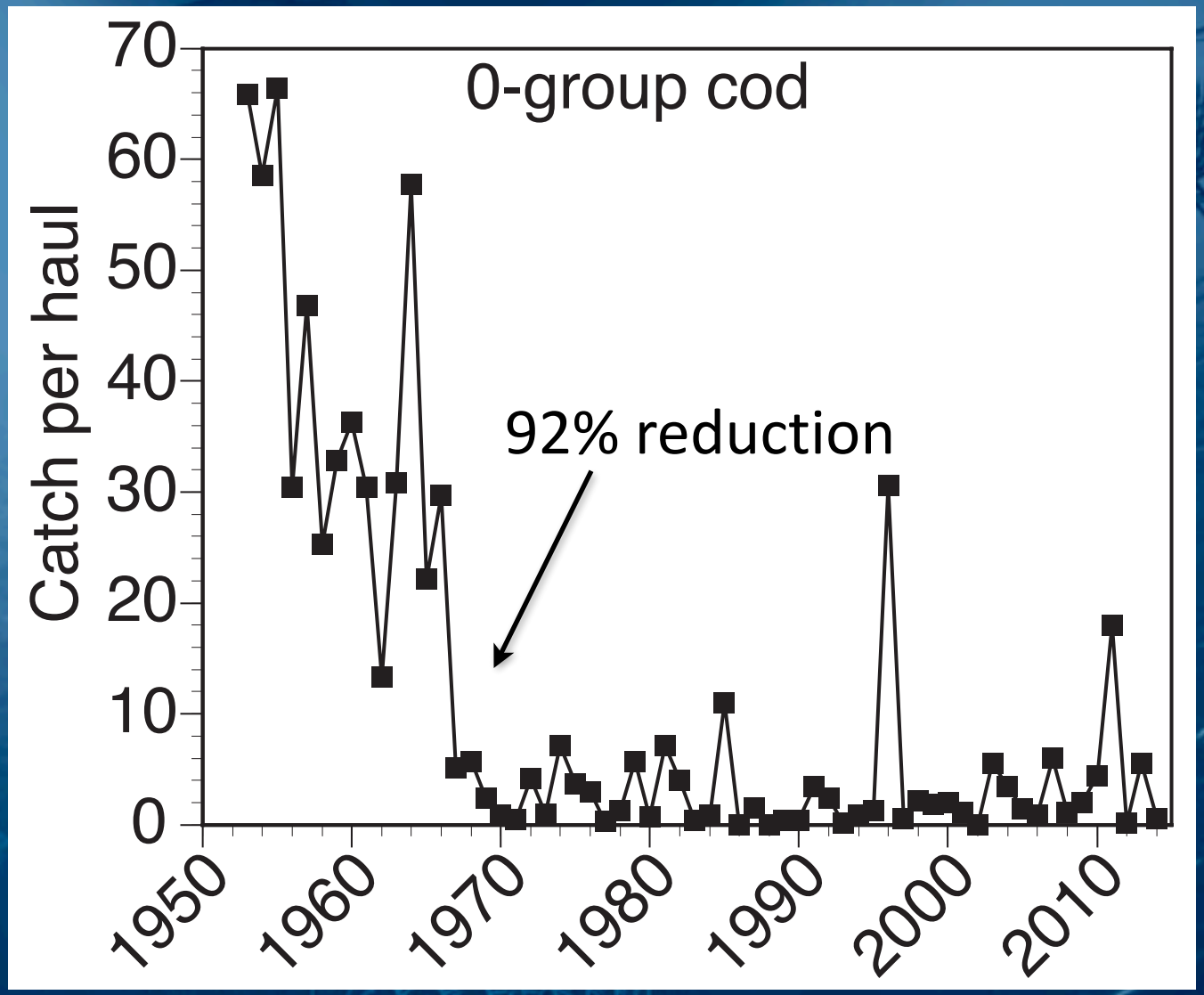




The Grenlandfjords







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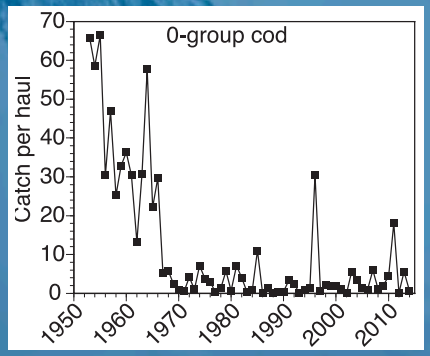
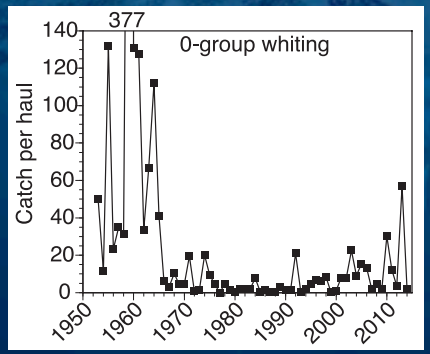
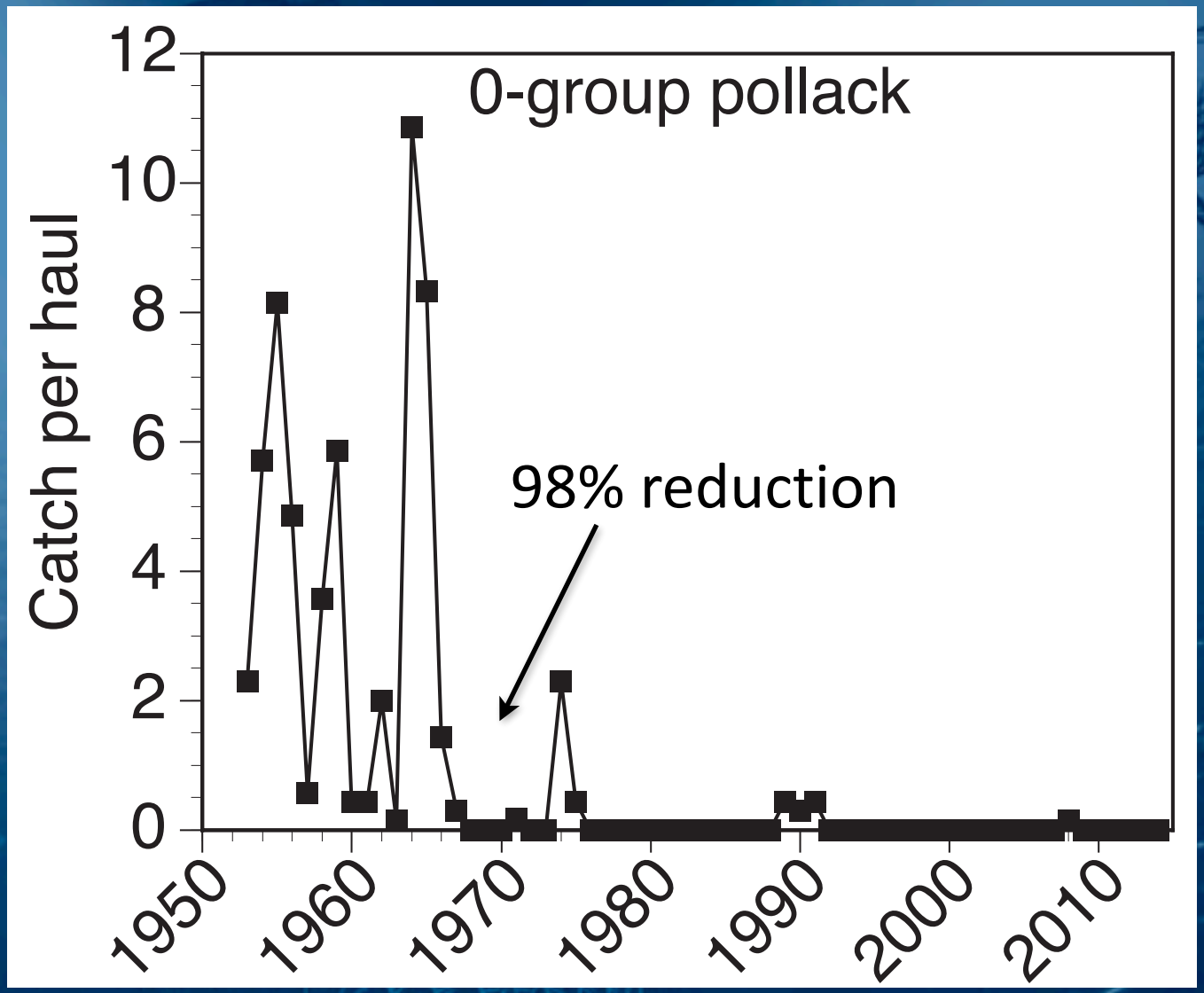
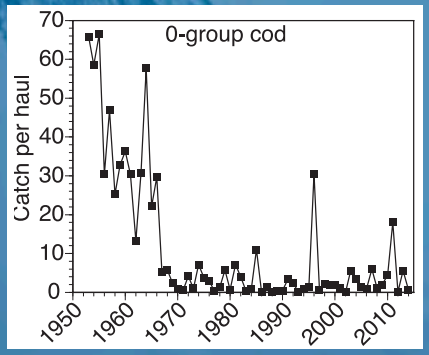
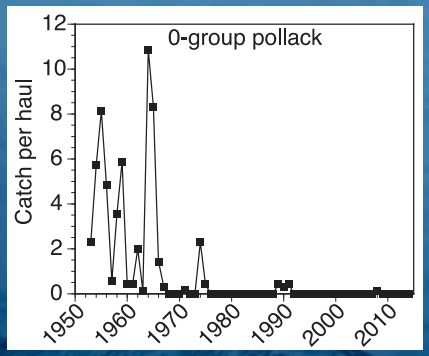


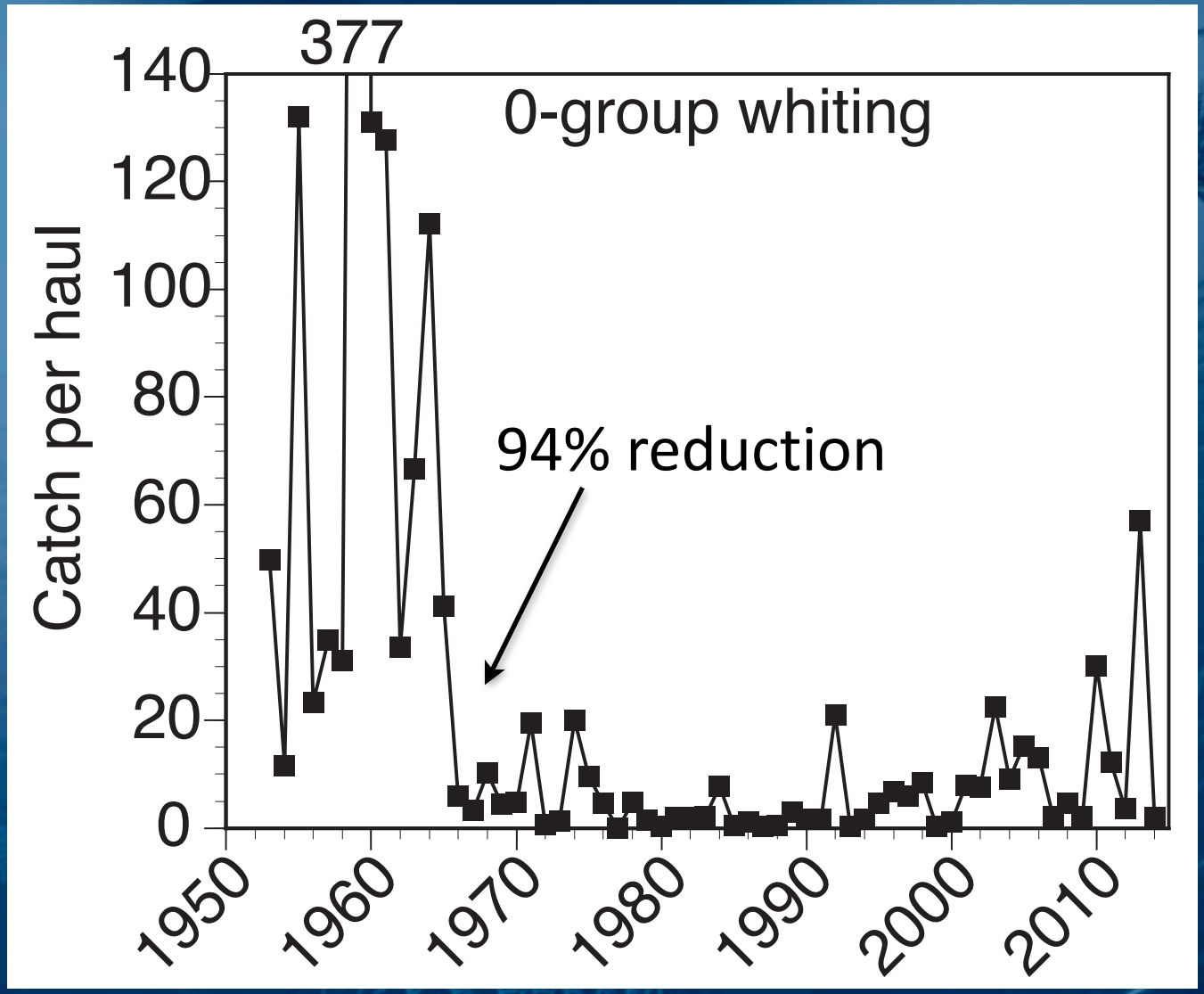




The Grenlandfjords







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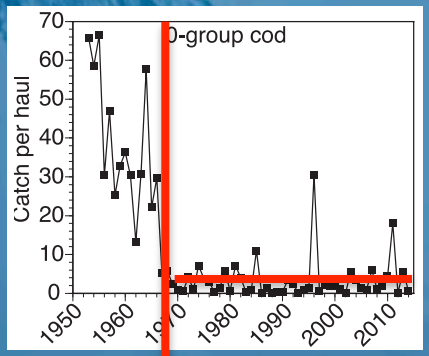

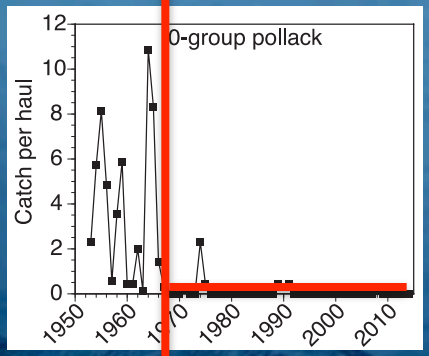

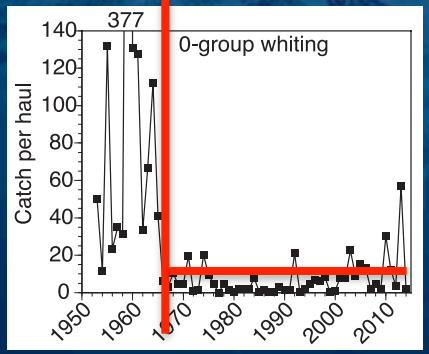

Simultaneous collapses

No sign of recovery

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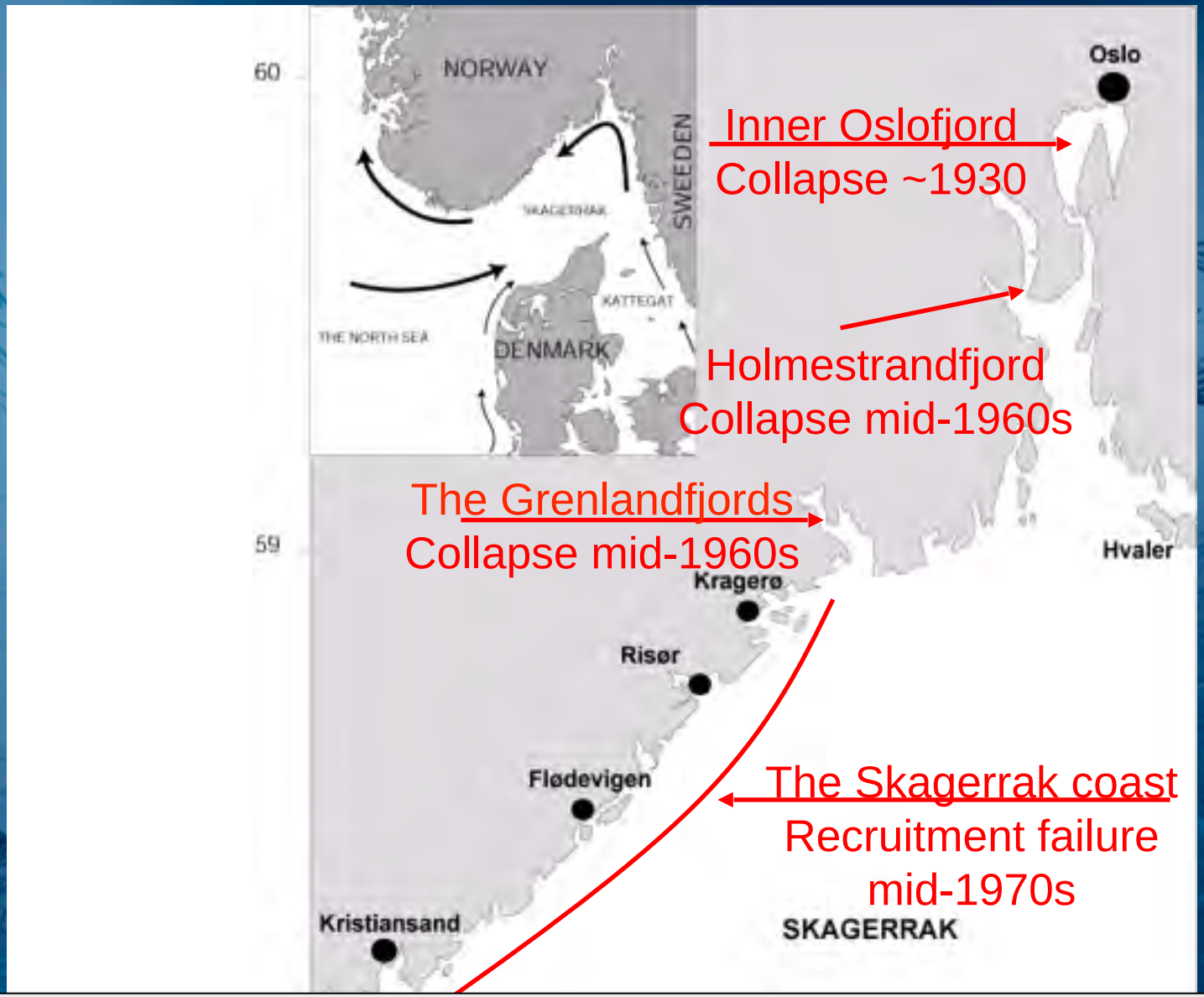
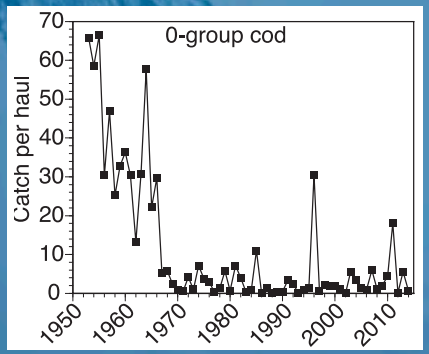
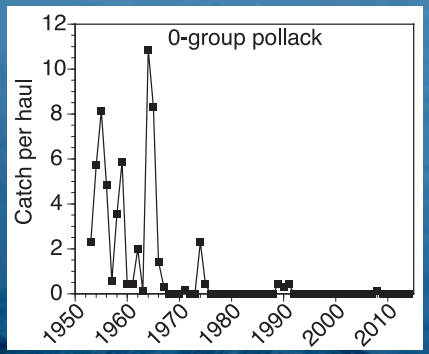
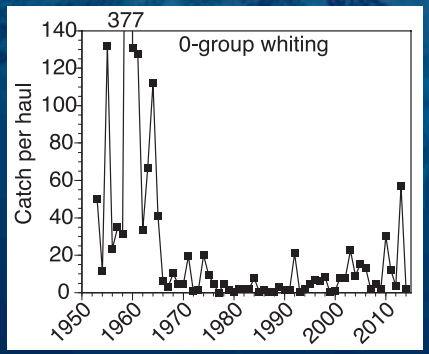


One thing in common:
gradually increasing nutrient loads







Potental causes

Low oxygen: No

Overfishing: No

Contaminants: No

Habitat changes: No

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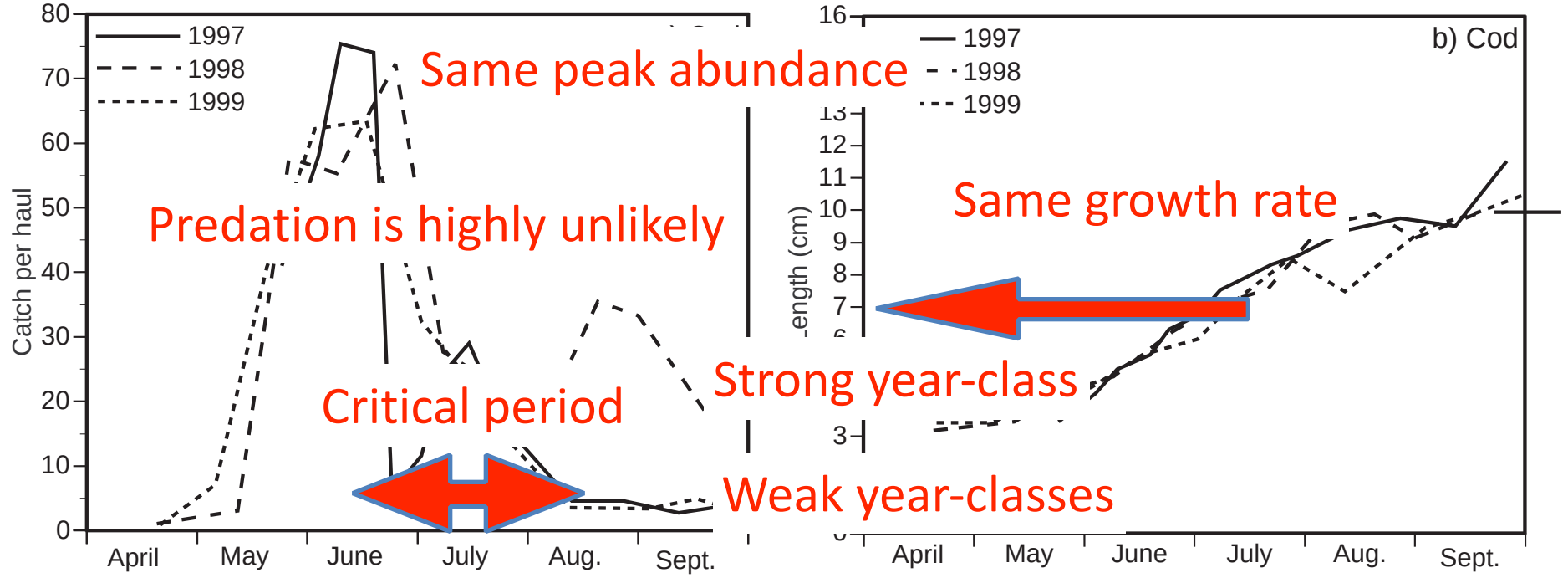
Cod was used as a model species to test the underlying mechanism

Settlement and growth in 0-group cod (6 beach stations)

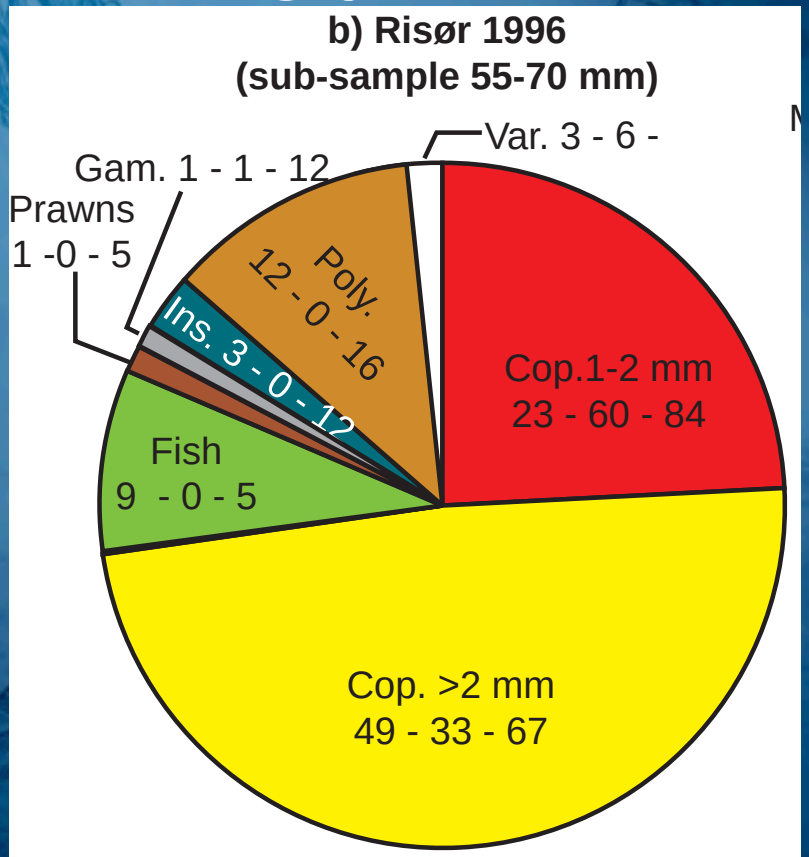
Abundance

Length



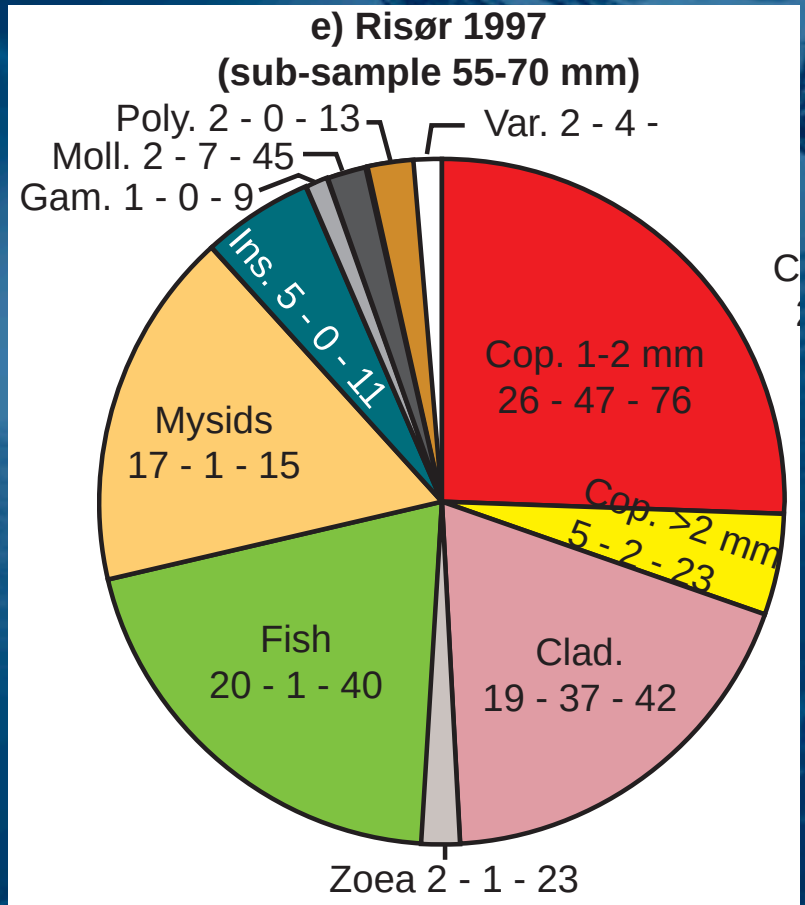
Diet of 0-group cod in July

Strong year-class



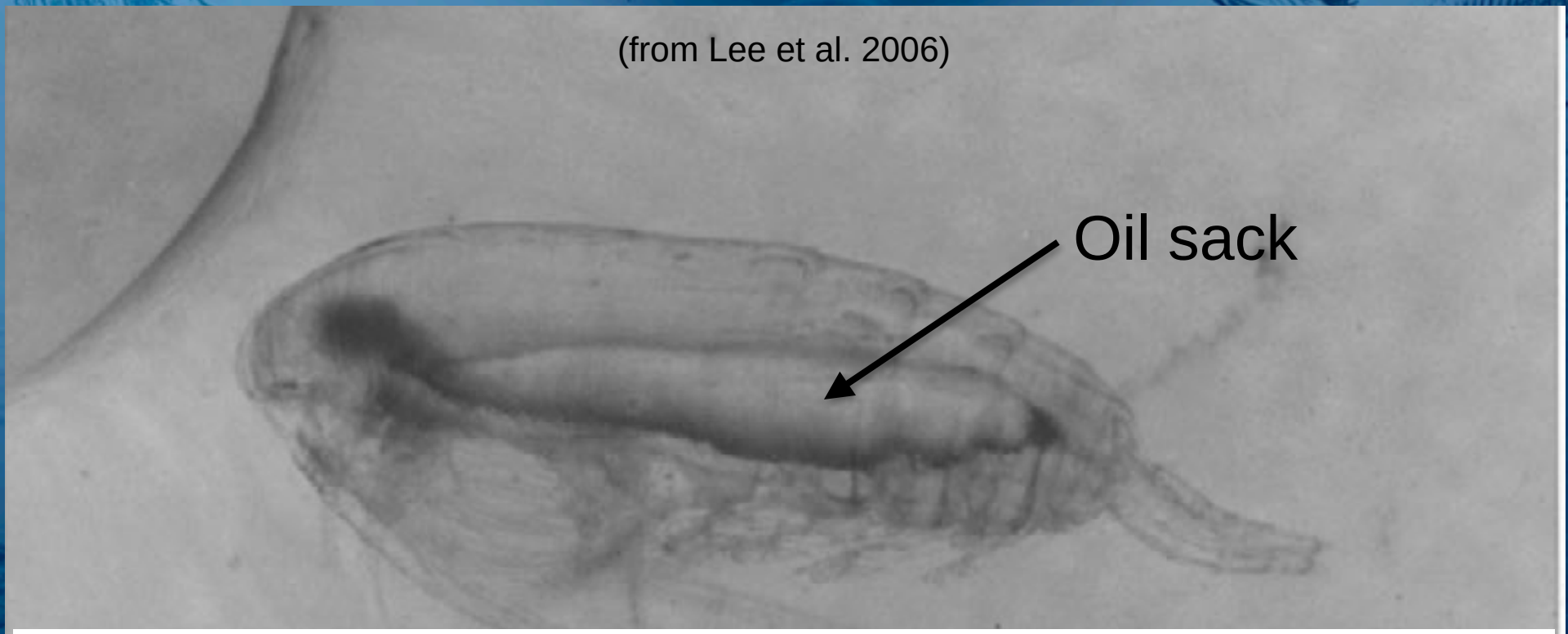
Large copepods
Good condition

Weak year-class

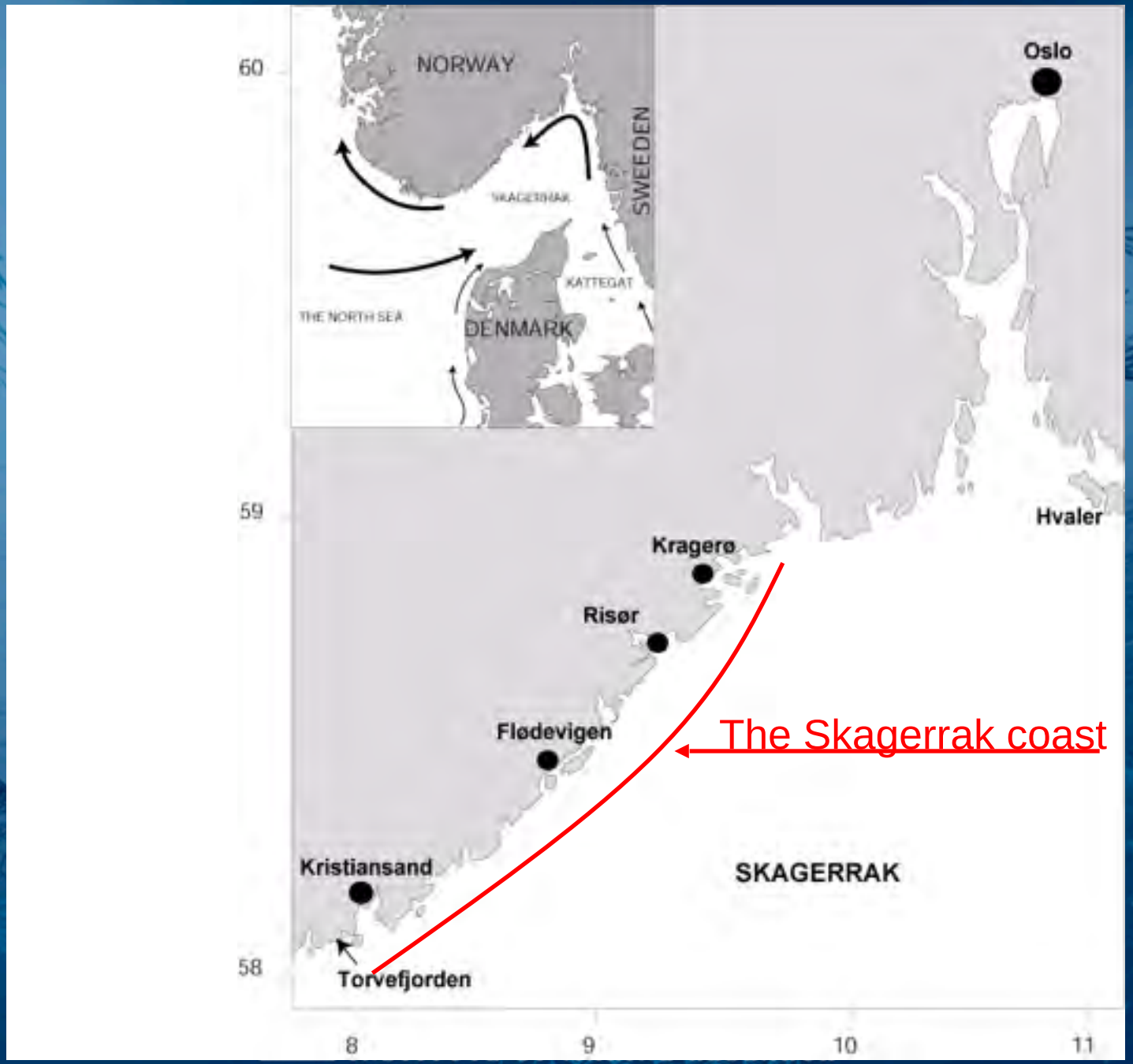


Hyperbenthic prey
Bad condition

Calanus with oil sack

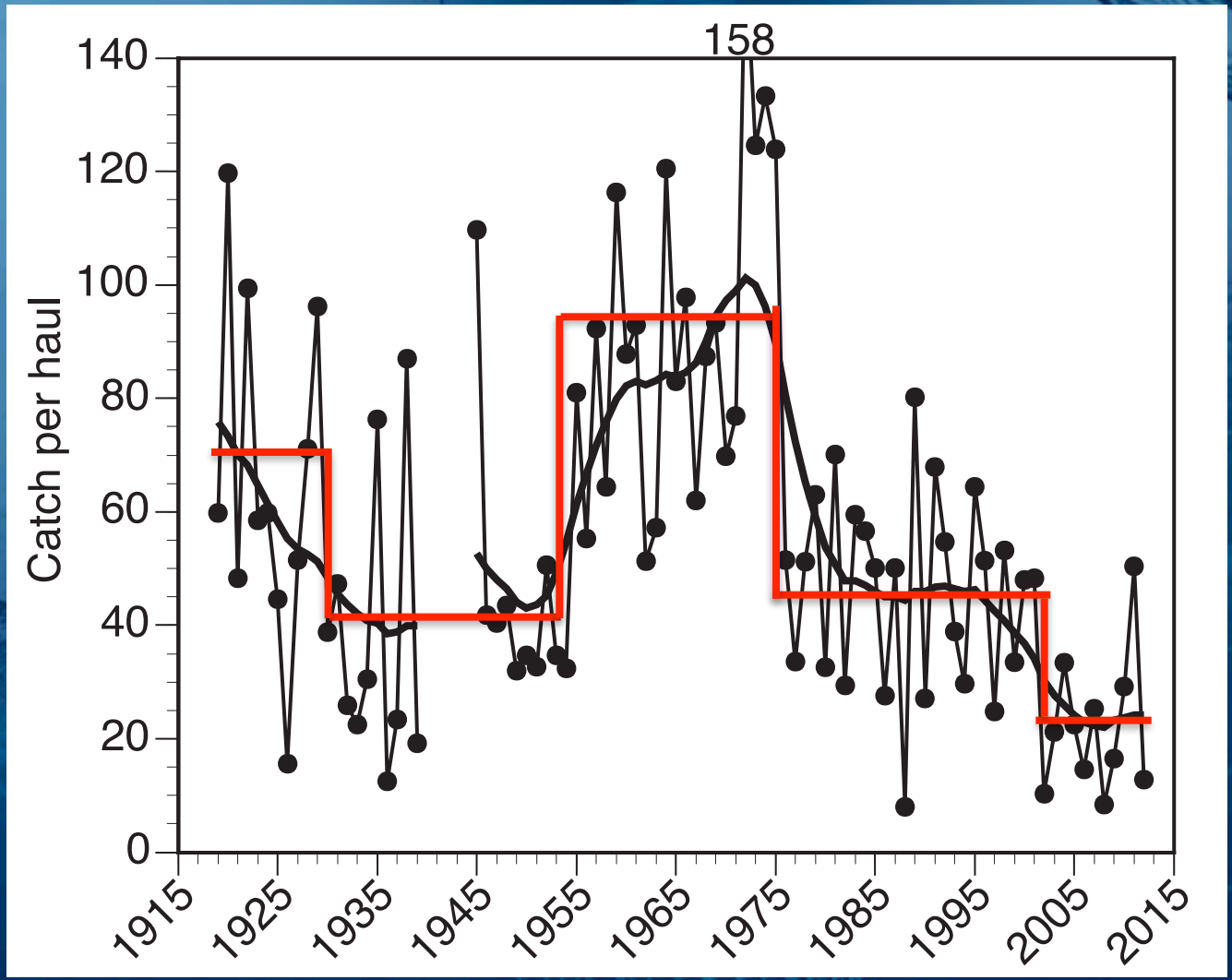


Large, herbivorous copepods have generally much higher energy content than small carnivorous copepods and hypebenthic organisms (e.g. fish and mysids)


NORWAY
SWEEDEN
SKAGERRAK
KATTEGAT
THE NORTH SEA
DENMARK
Oslo
Hvaler
Kragerø
Risør
Flødevigen
Kristiansand
Torvefjorden
SKAGERRAK
The Skagerrak coast
60
59
58
8
9
10
11

Sum of 0-group cod, pollack and whiting

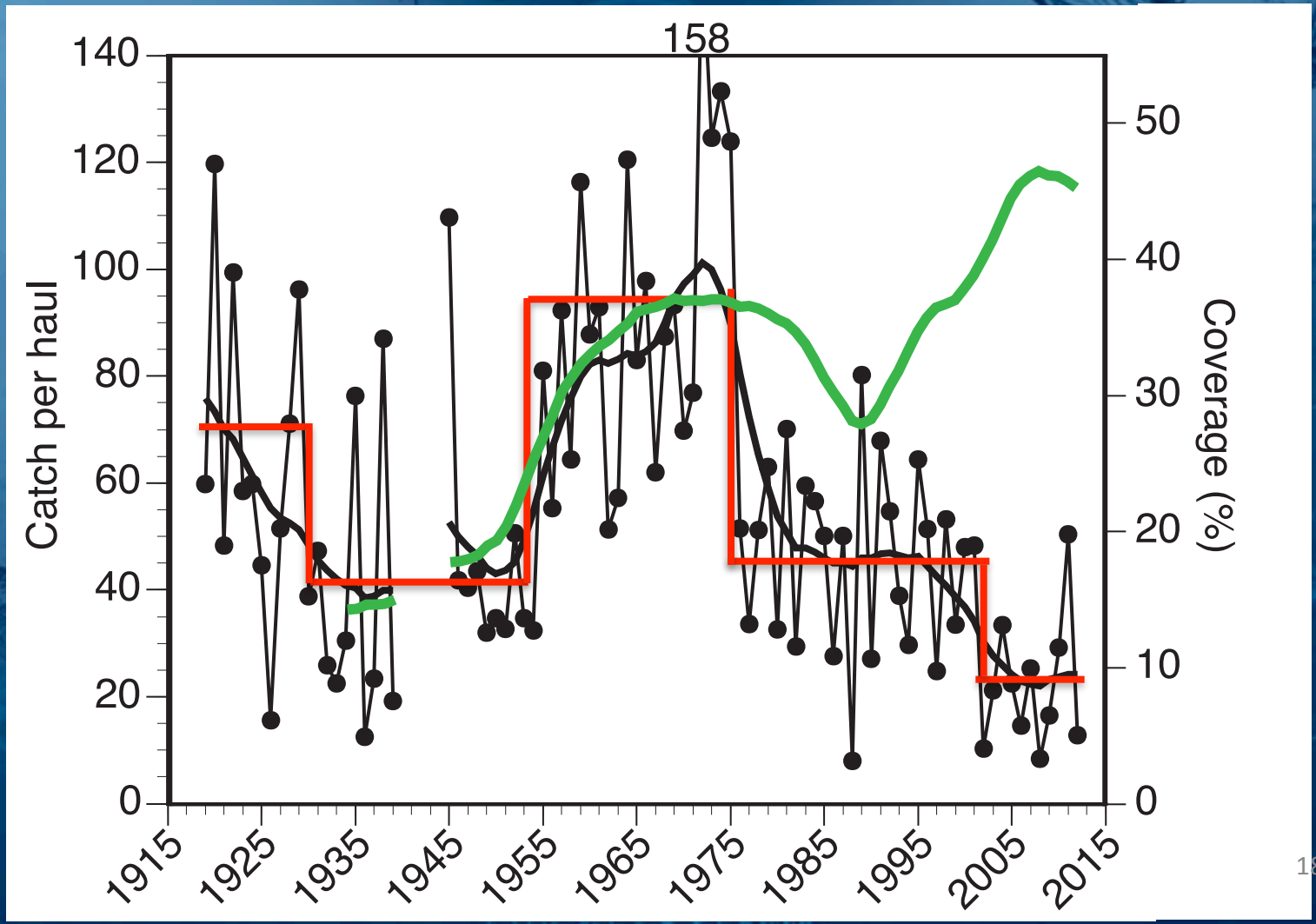
STARS regime shift detection method

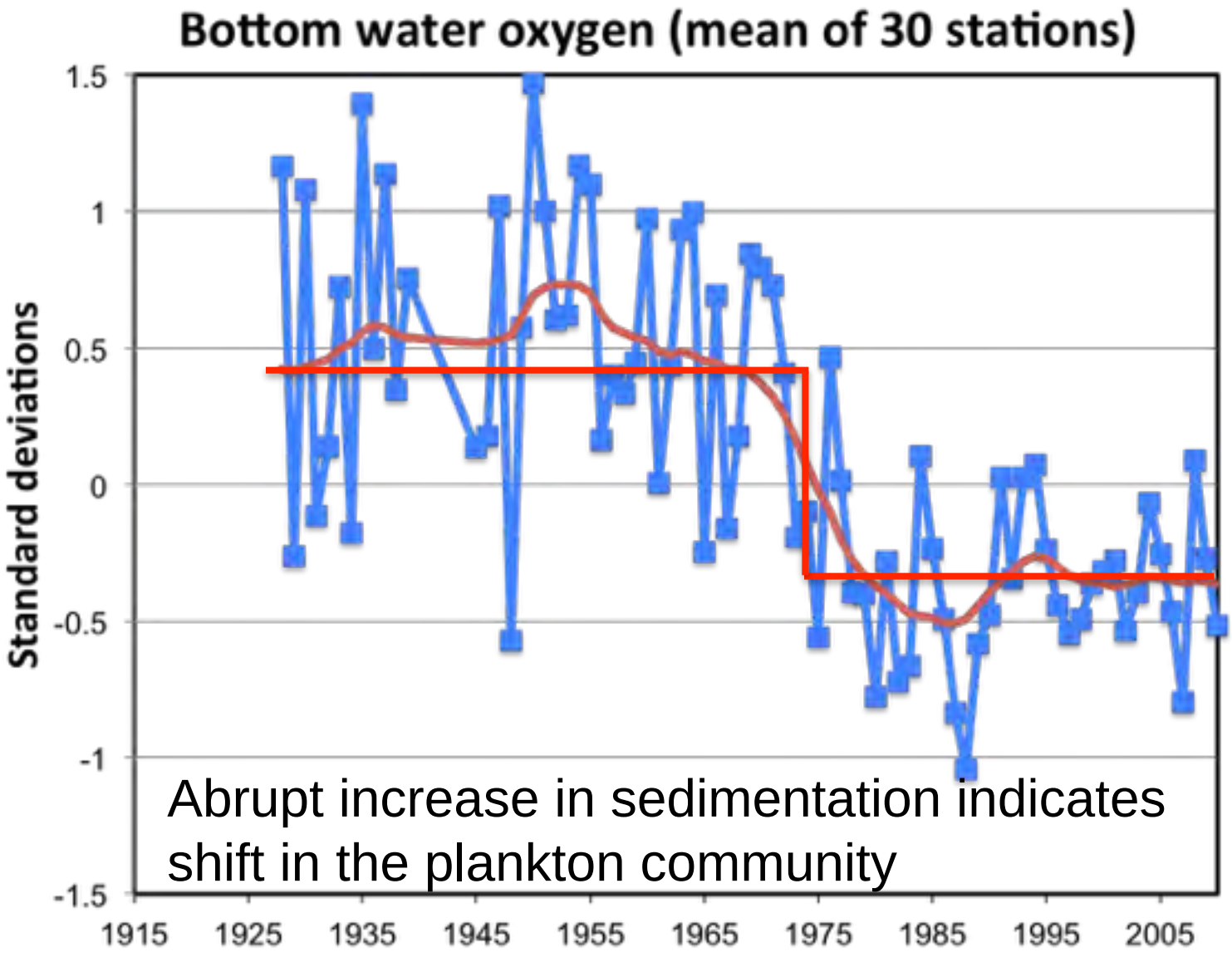


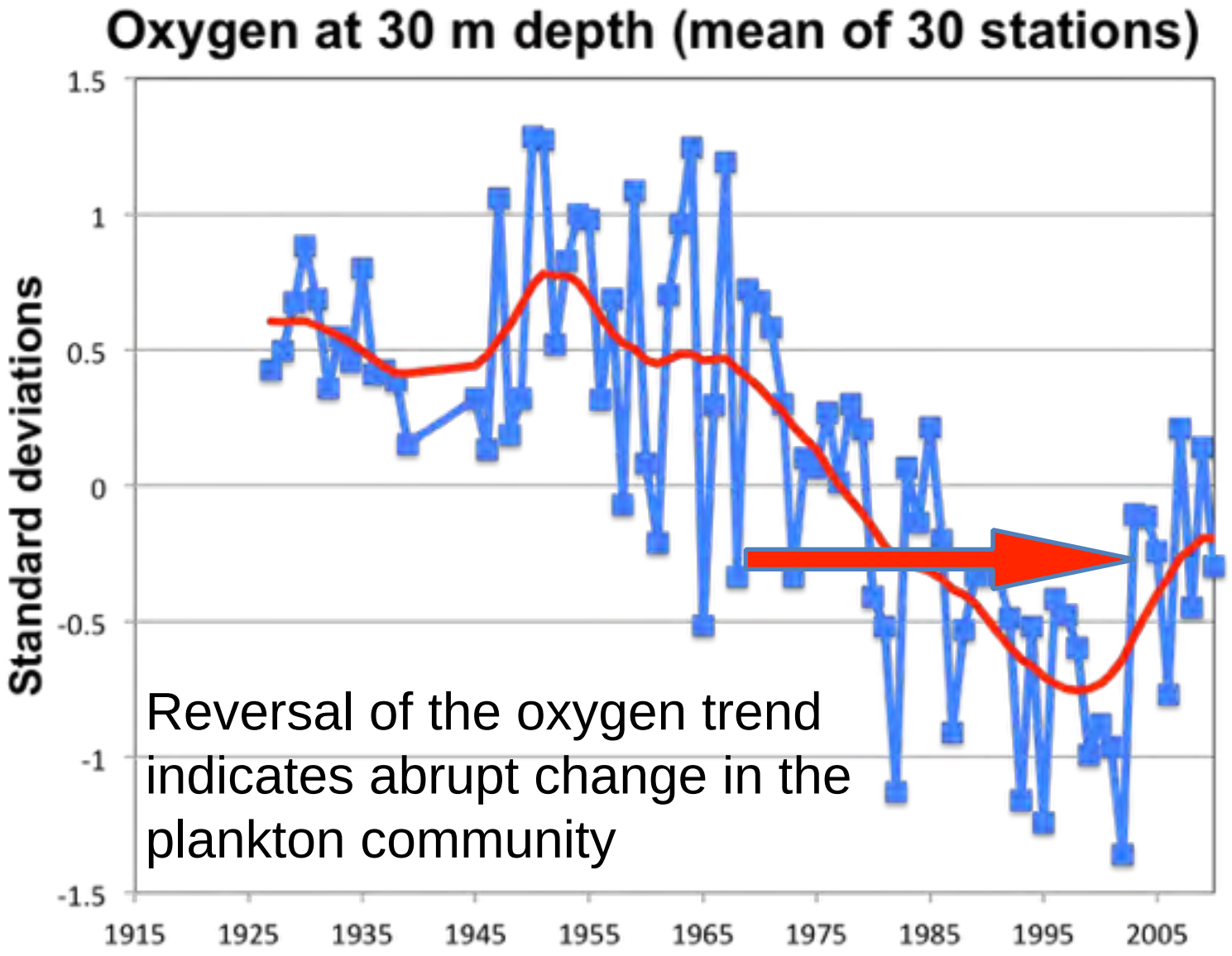
Eelgras

Sum of 0-group cod, pollack and whiting

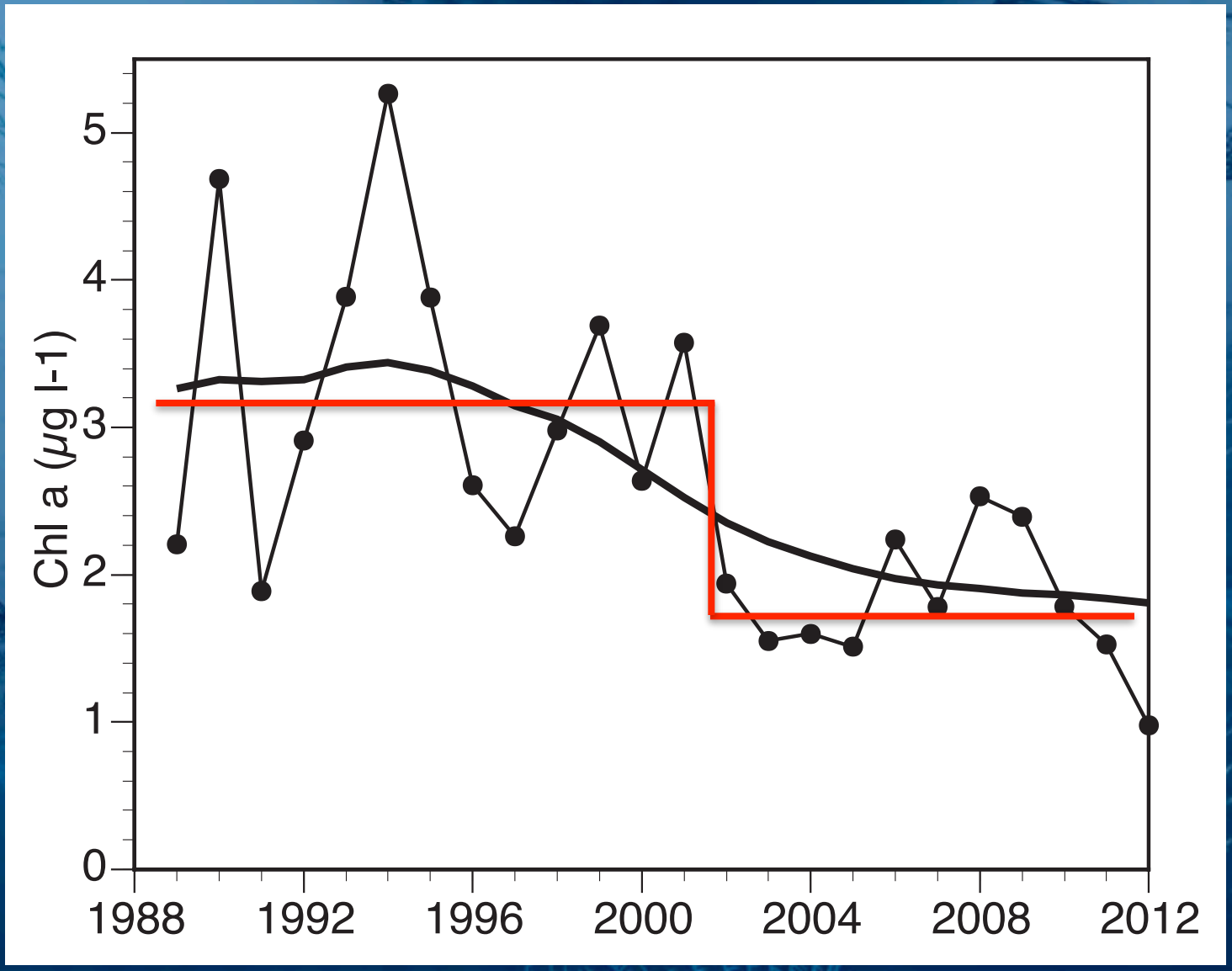
bottom vegetation



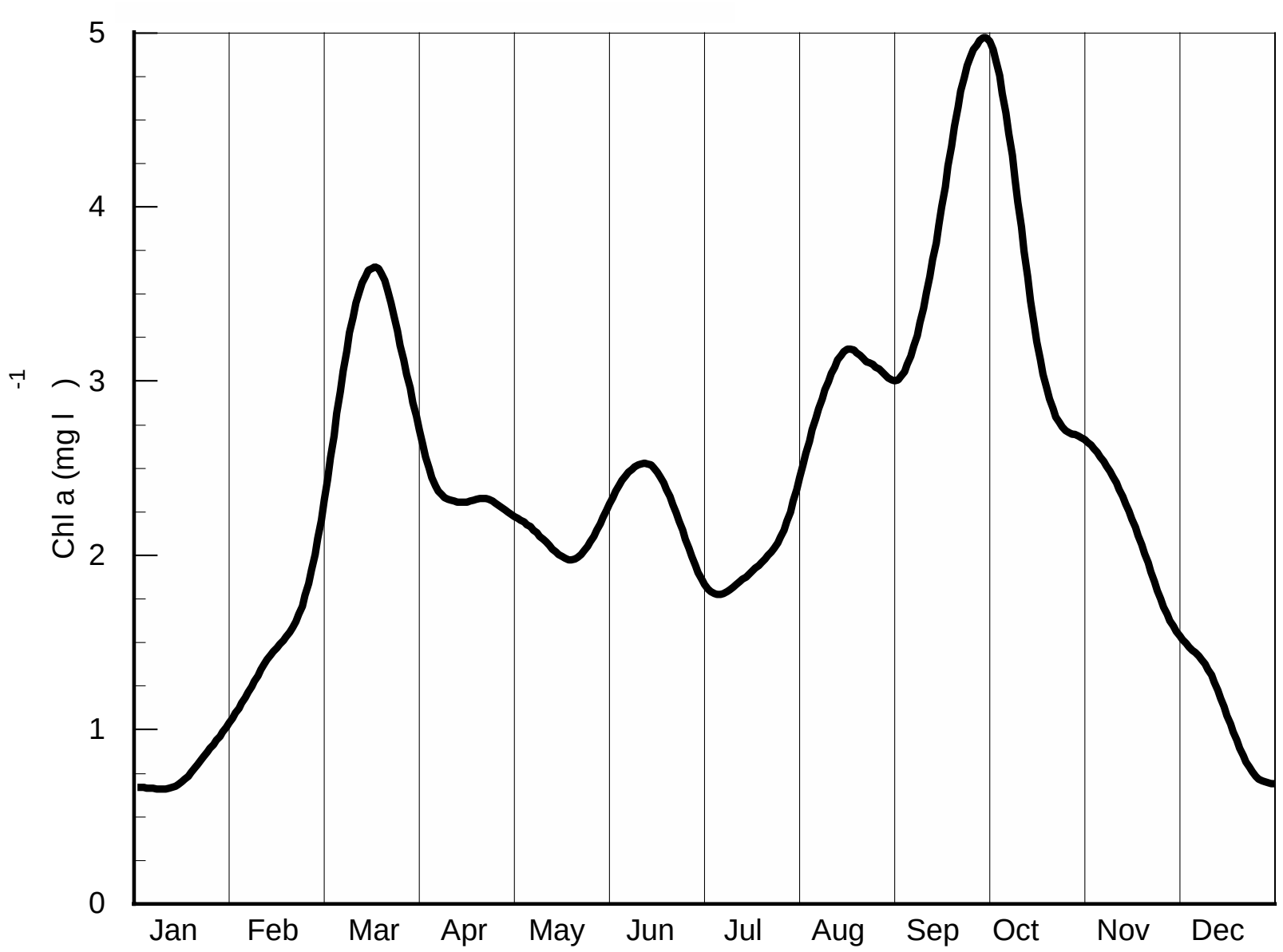

Bottom water oxygen (mean of 30 stations)
Standard deviations
1.5
1
0.5
0
-0.5
-1
-1.5
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
Abrupt increase in sedimentation indicates shift in the plankton community


Oxygen at 30 m depth (mean of 30 stations)
Standard deviations
1.5
1
0.5
0
-0.5
-1
-1.5
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
Reversal of the oxygen trend indicates abrupt change in the plankton community

Autumn Chl *a*

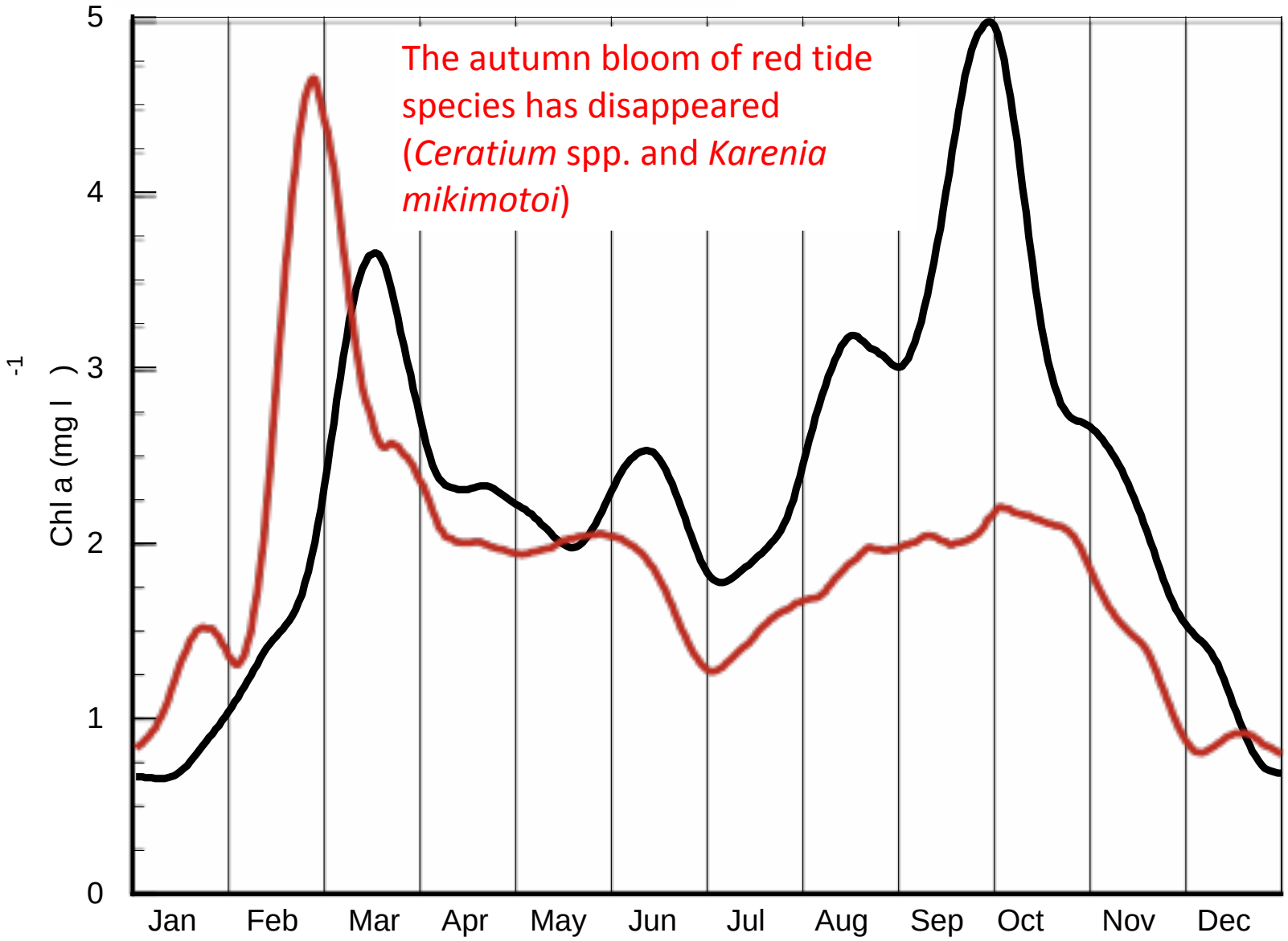


Chlorophyll *a* measured three times a week 1990-1999

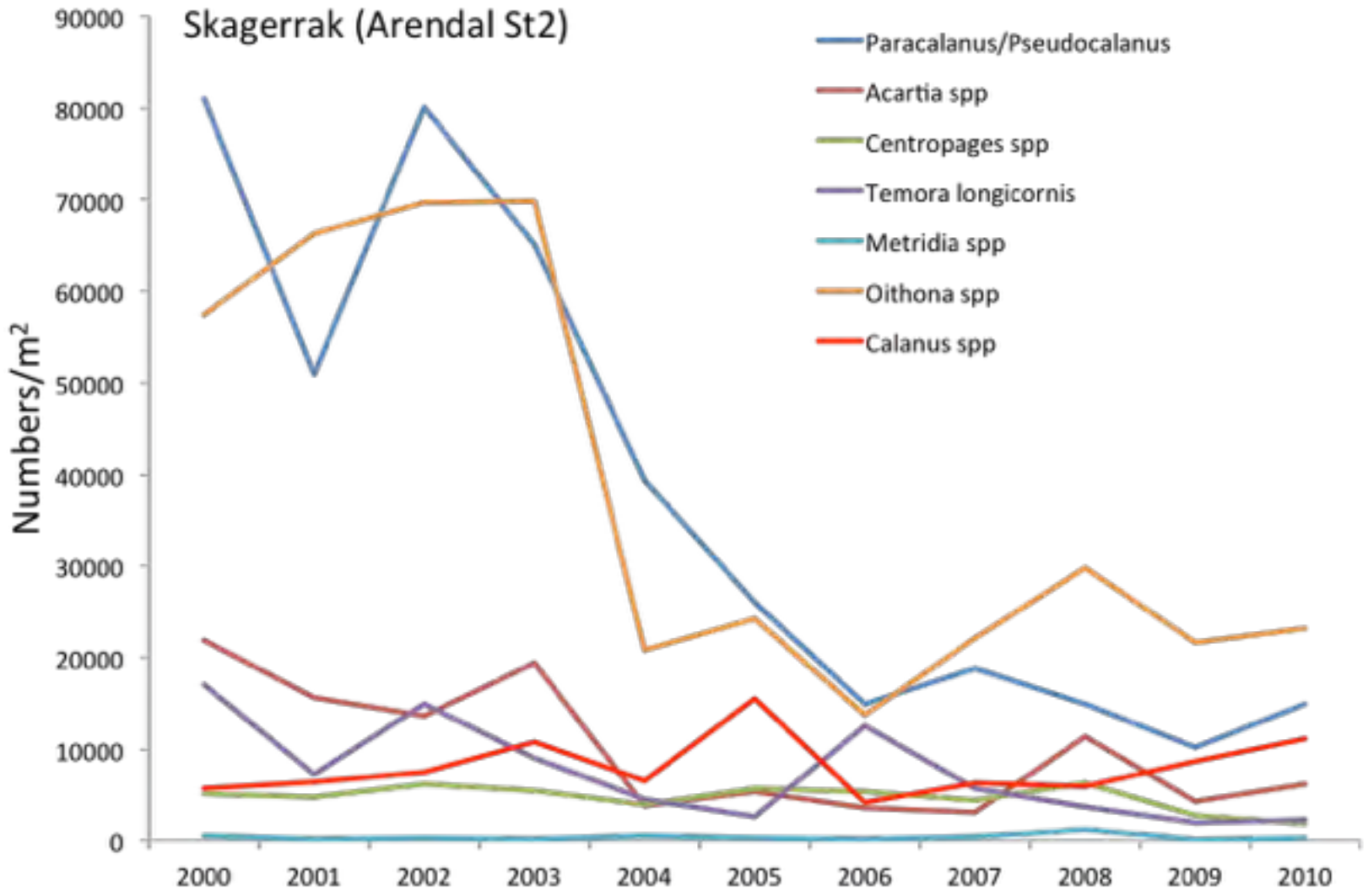


Chlorophyll *a* measured three times a week 1990-1999

Chlorophyll *a* measured three times a week 2002-2010

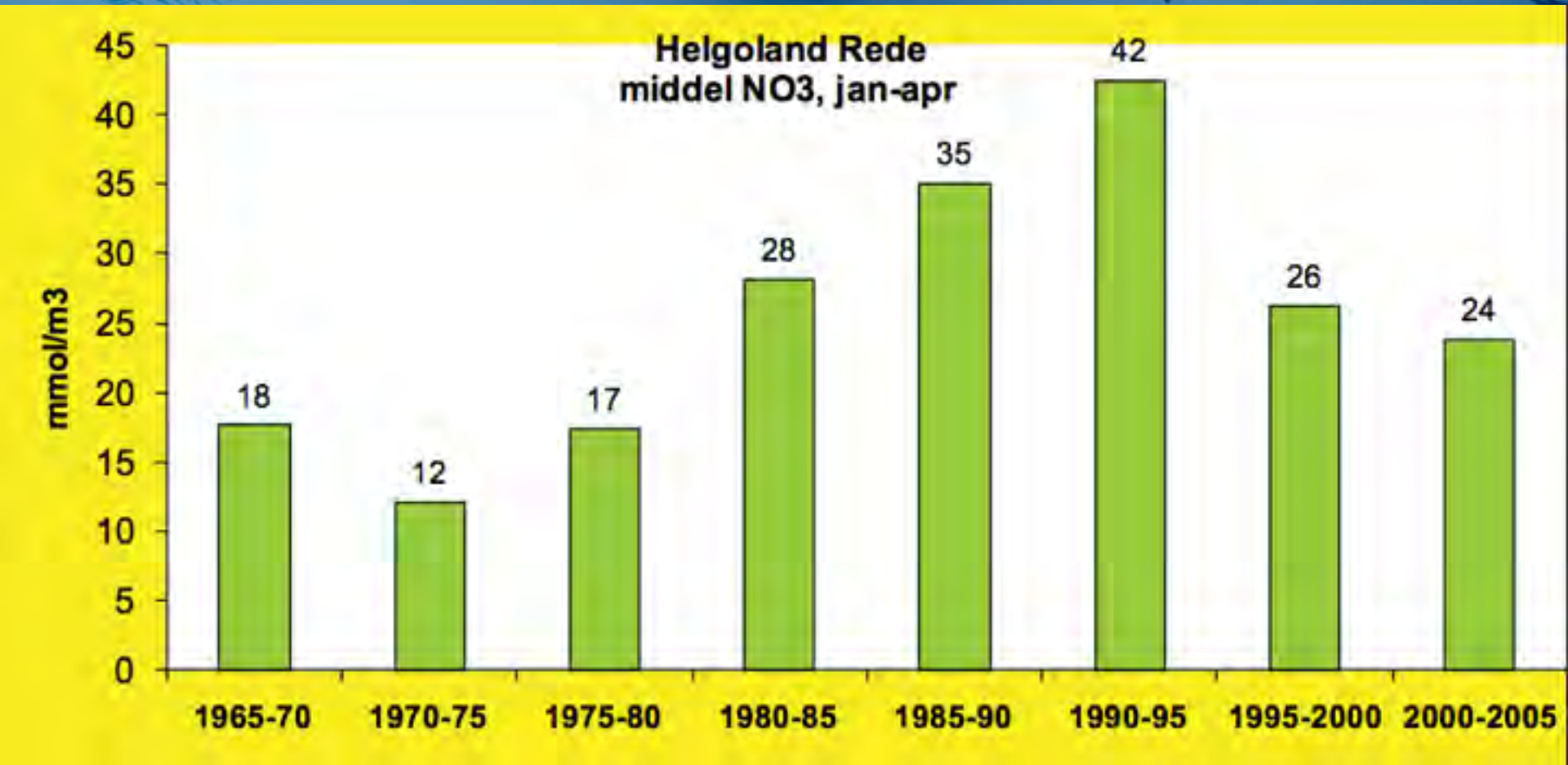


Copepods

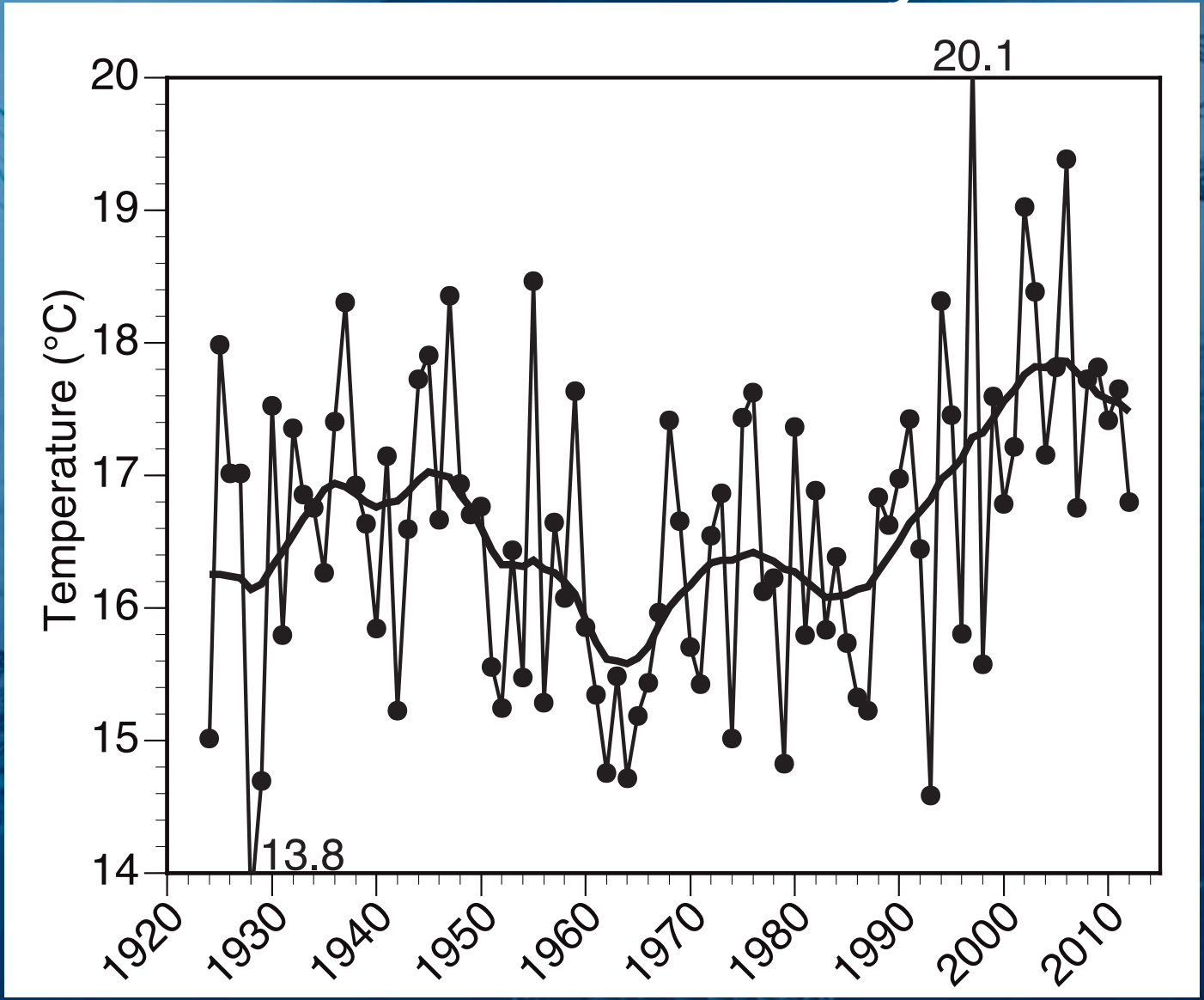

Skagerrak (Arendal St2)
Numbers/m²
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Paracalanus/Pseudocalanus
Acartia spp
Centropages spp
Temora longicornis
Metridia spp
Oithona spp
Calanus spp

Winter nitrate

(Aure and Magnusson 2010)



Summer SST
SST has increased by ~1.5°C



Summary

1. Repeated incidents of abrupt and persistent recruitment collapses in gadoids (historically)
2. Very poor recruitment in gadoids after 2002
3. Reversed trend in oxygen at intermediate depths >2002
4. Reduced phytoplankton biomass in summer ≥2002
5. Disappearance of the autumn bloom of red tide species ≥2002
6. Reduced abundance of *Oithona* spp. and Pseudocalanus/ *Paracalanus* >2003

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Conclusion

Marine plankton communities may shift abruptly from one stable state to another as a result of gradual environmental changes, i.e. bifurcations

Shifts in the plankton community are propagated to higher trophic levels by causing recruitment failure in predator fishes

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New book 2014 Elsevier

TORE JOHANNESSEN

From an Antagonistic to a Synergistic Predator Prey Perspective

Bifurcations in Marine Ecosystems

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