Evidence of bifurcations (regime shifts) in marine plankton communities in relation to increasing temperature, resulting in recruitment failure in fish

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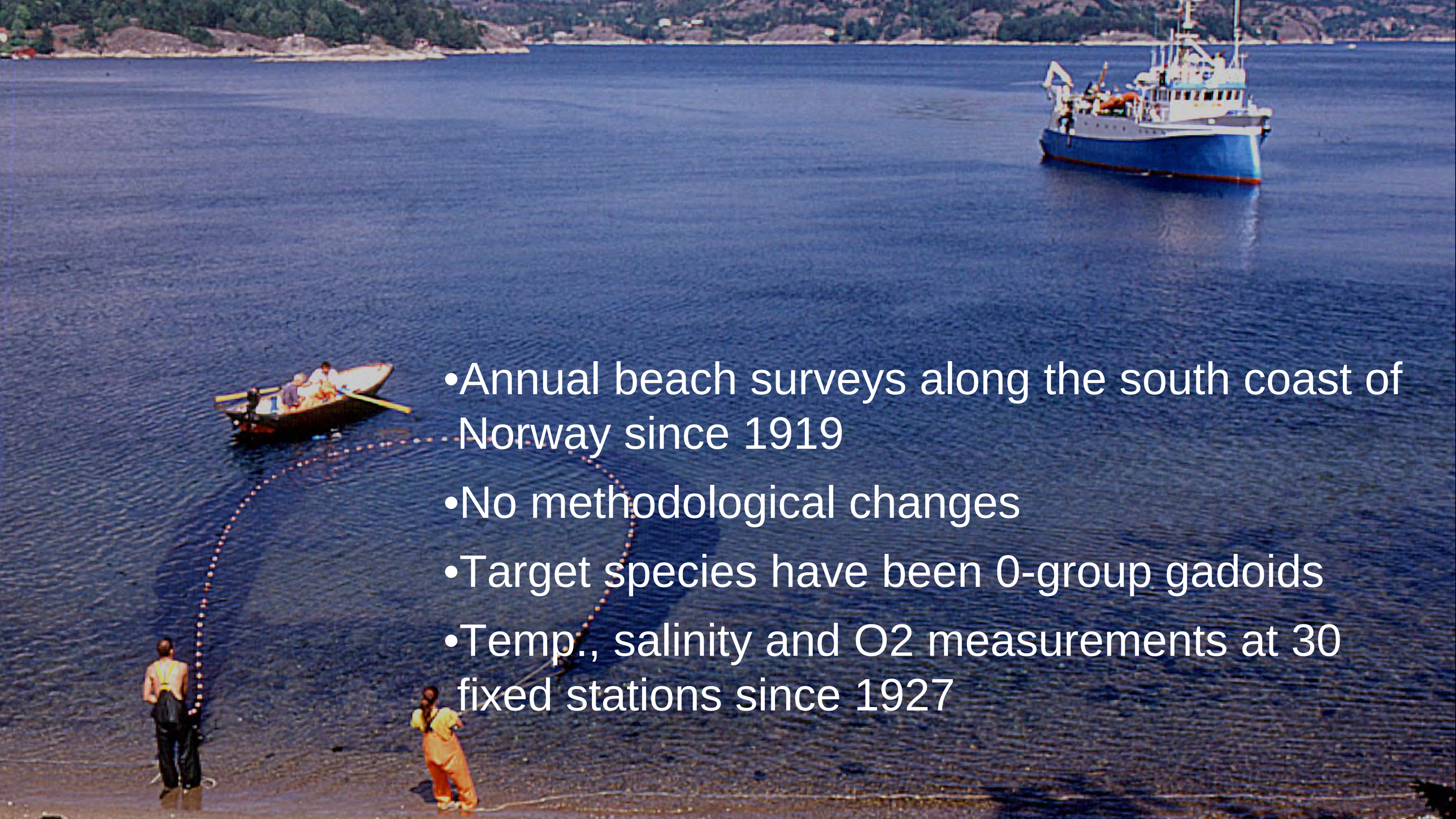
Outline

1. Evidence of abrupt and persistent recruitment collapses in gadoid fishes

2. Concurrent shifts in the plankton community with that of the recruitment collapses

3. New evidence of collapse in forage fishes, which has exacerbated the dismal situation for the gadoids

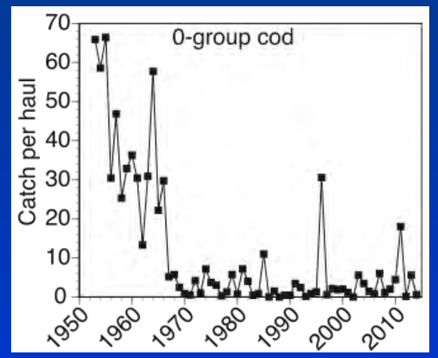
4. Summary and conclusion

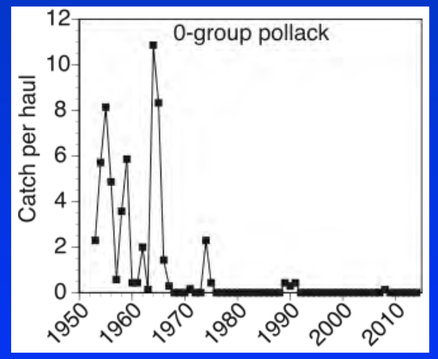


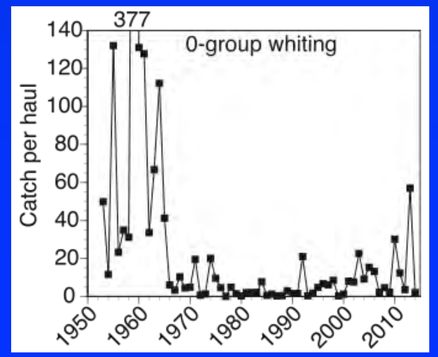
- Annual beach surveys along the south coast of Norway since 1919
- No methodological changes
- Target species have been 0-group gadoids
- Temp., salinity and O2 measurements at 30 fixed stations since 1927

The south coast of Norway

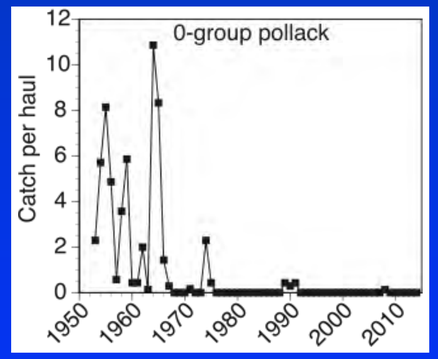
The Grenland fjords

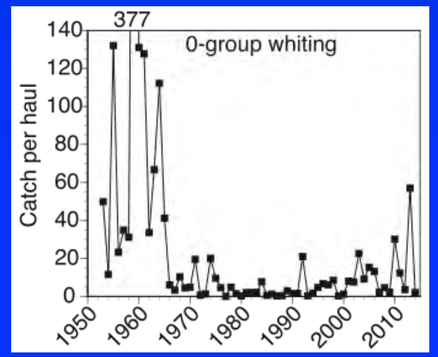


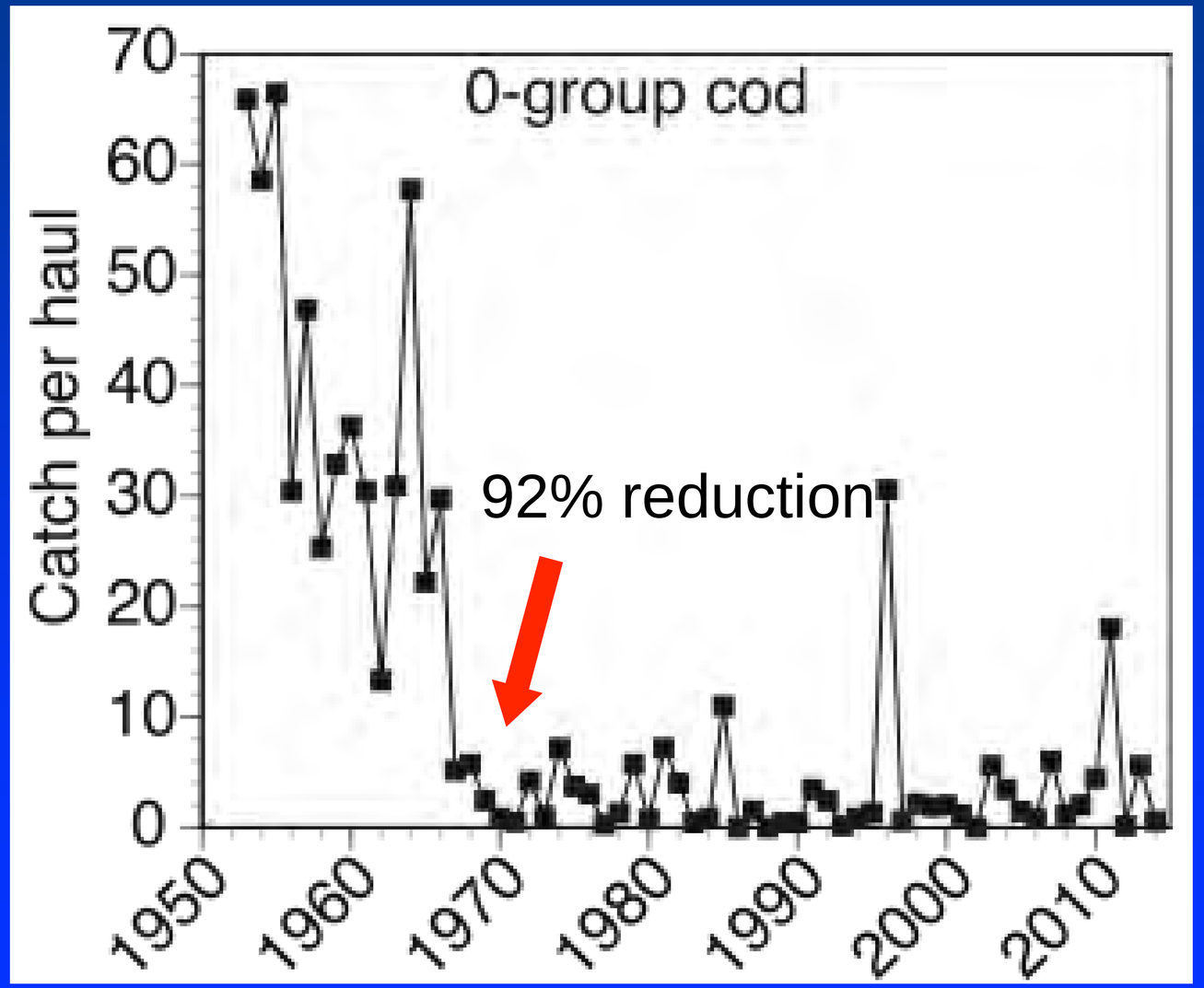




The Grenlandfjords







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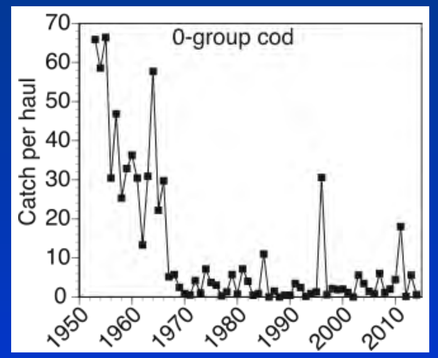

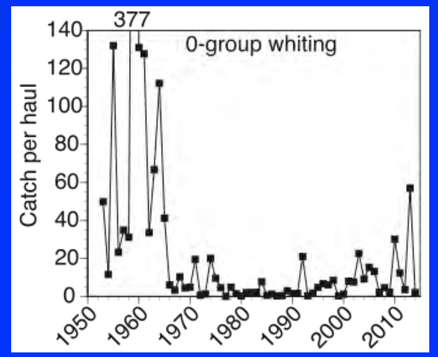

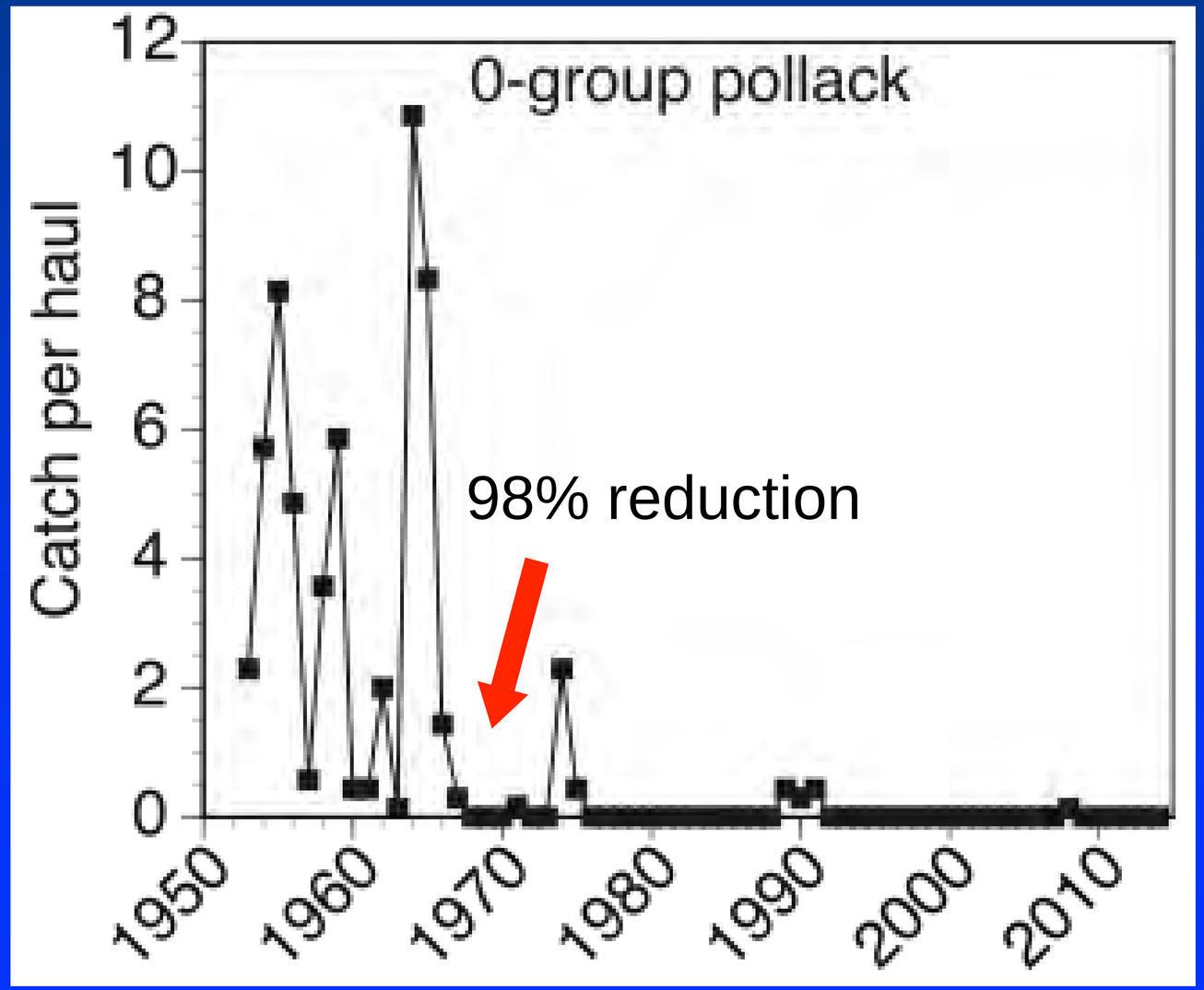

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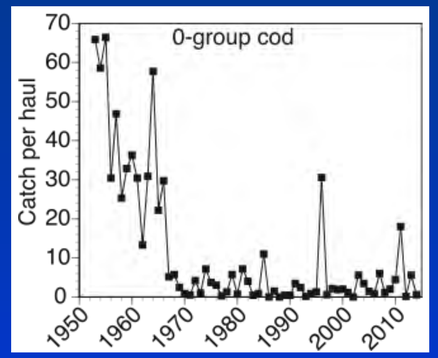

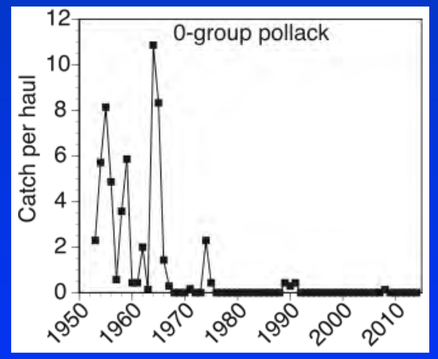

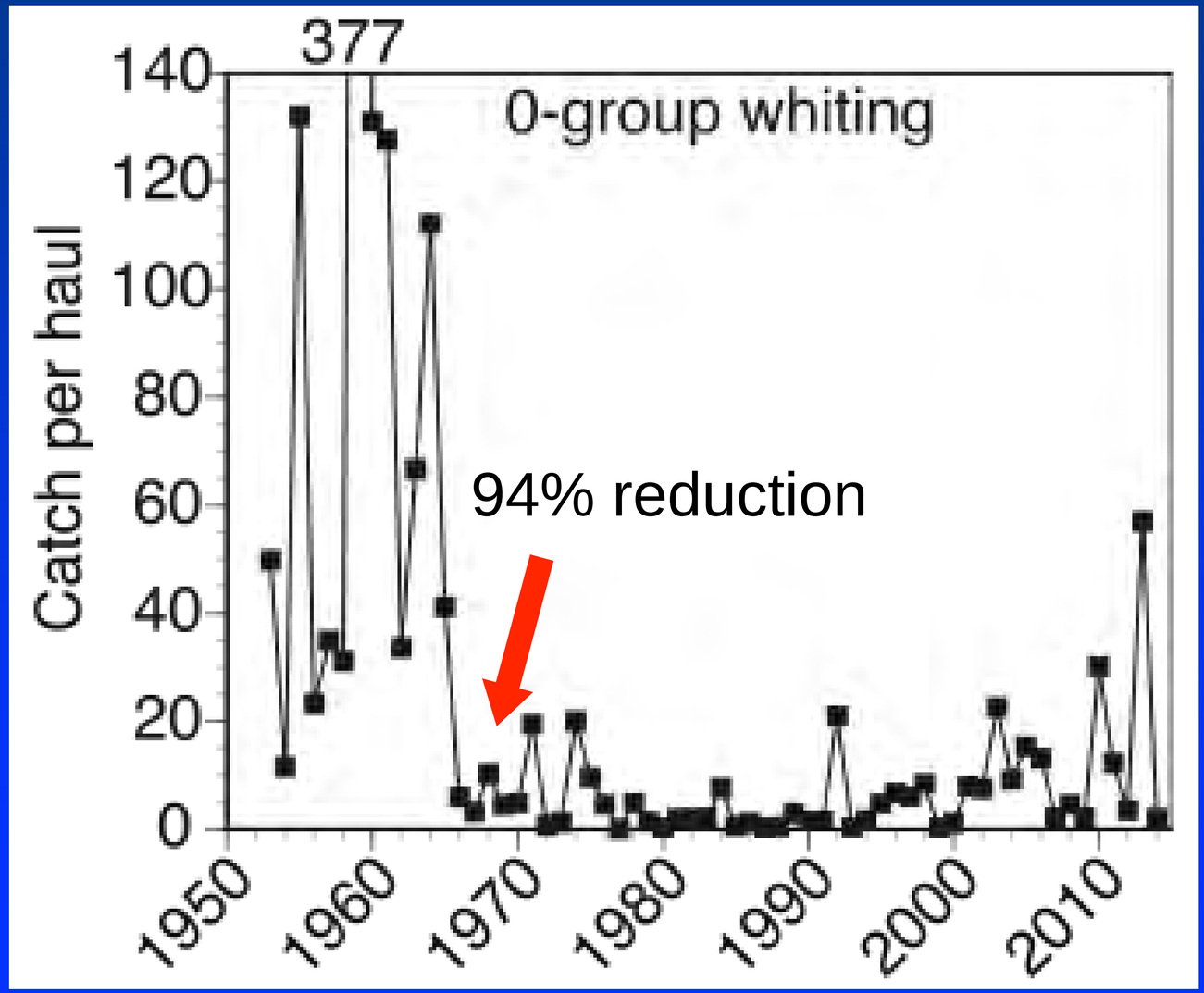

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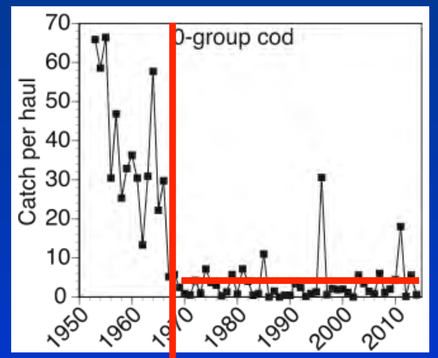
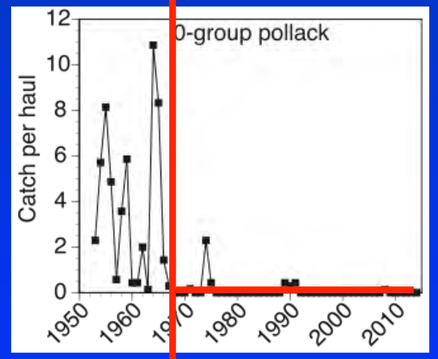
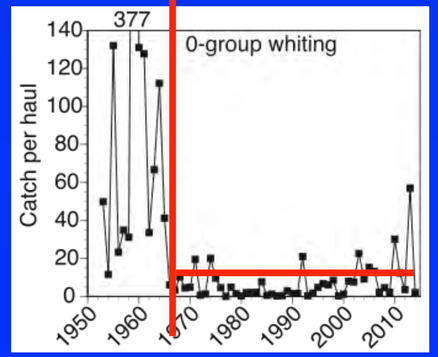






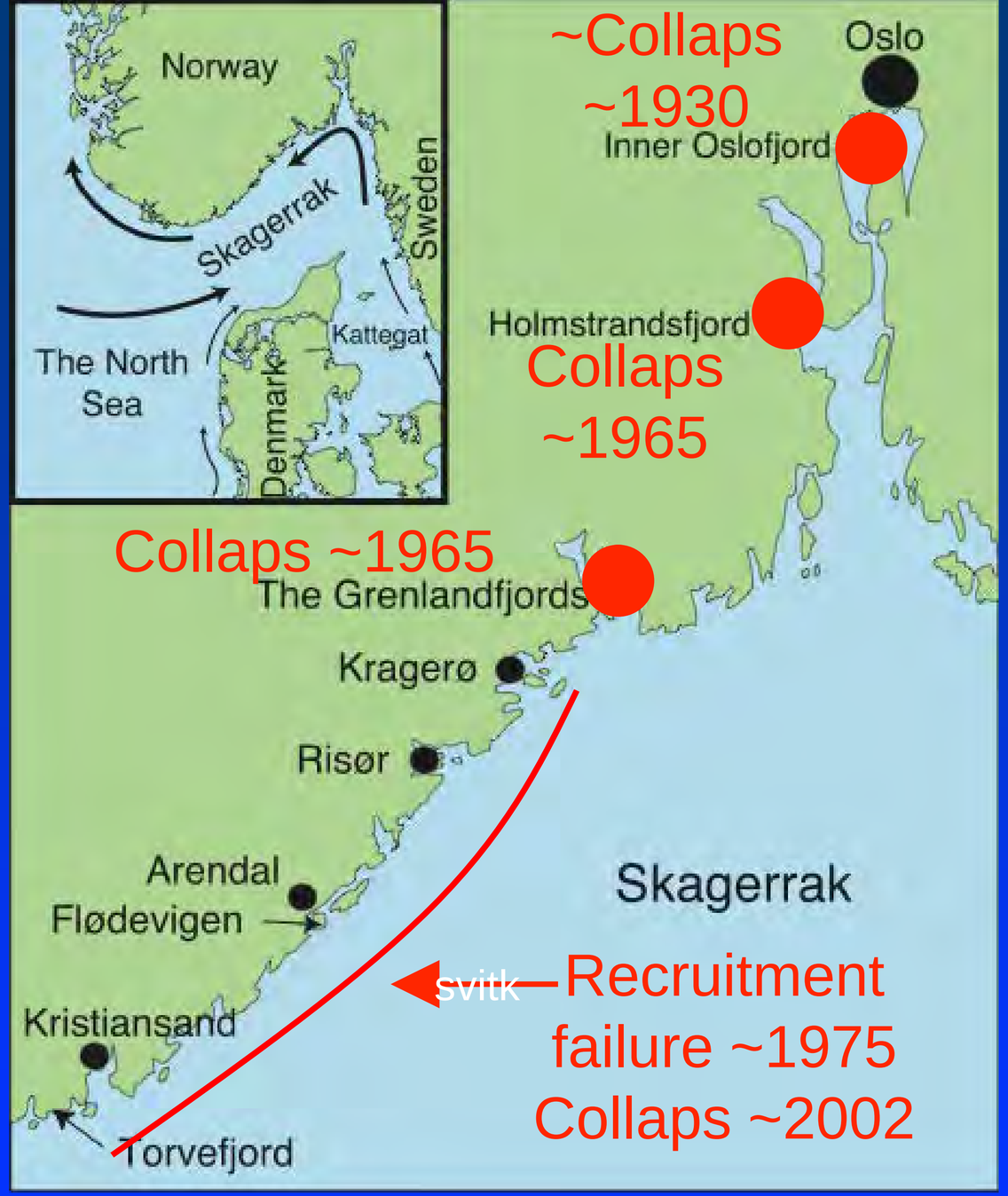
Concurrent collapses

No sign of recovery

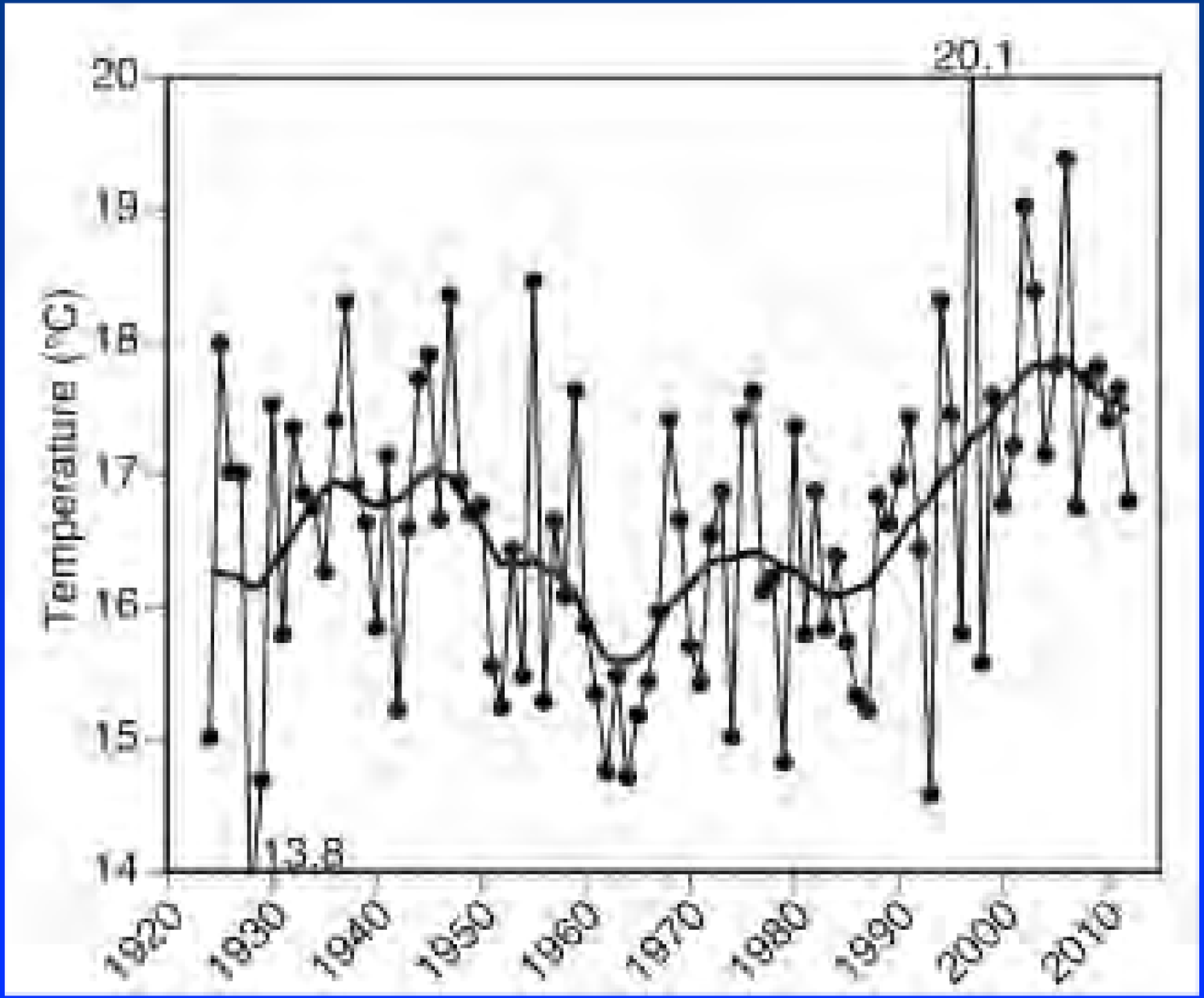
Recurring event

Before 2000:
Gradually increasing nutrient loads

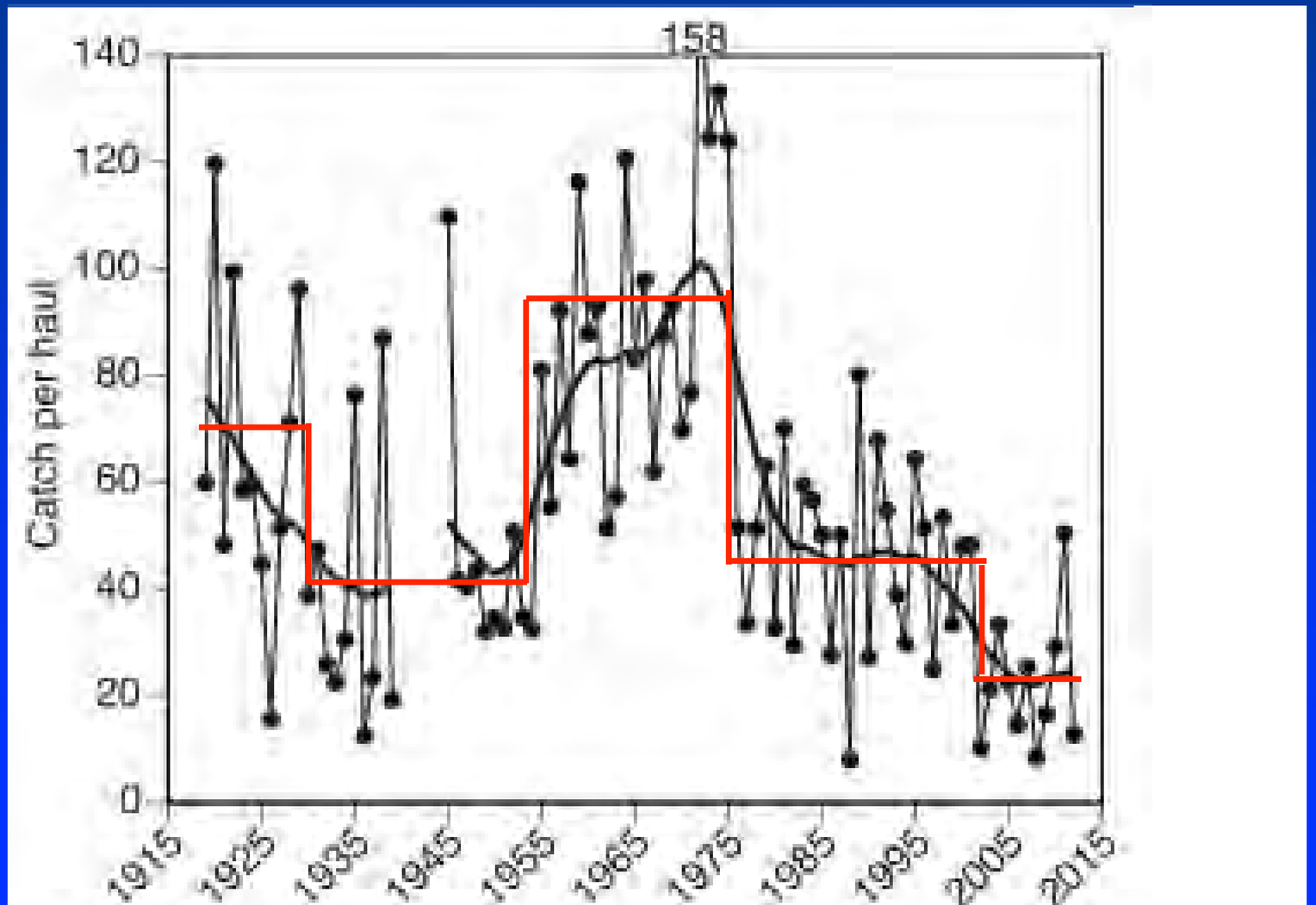
~2002:
Gradually increasing temperatures - reduced nutrient loads



Summer Sea Surface Temperature (SST
SST has increased by ~1.5°C



0-group cod, pollack and whiting (STARS - regime shift detection)



Eelgrass

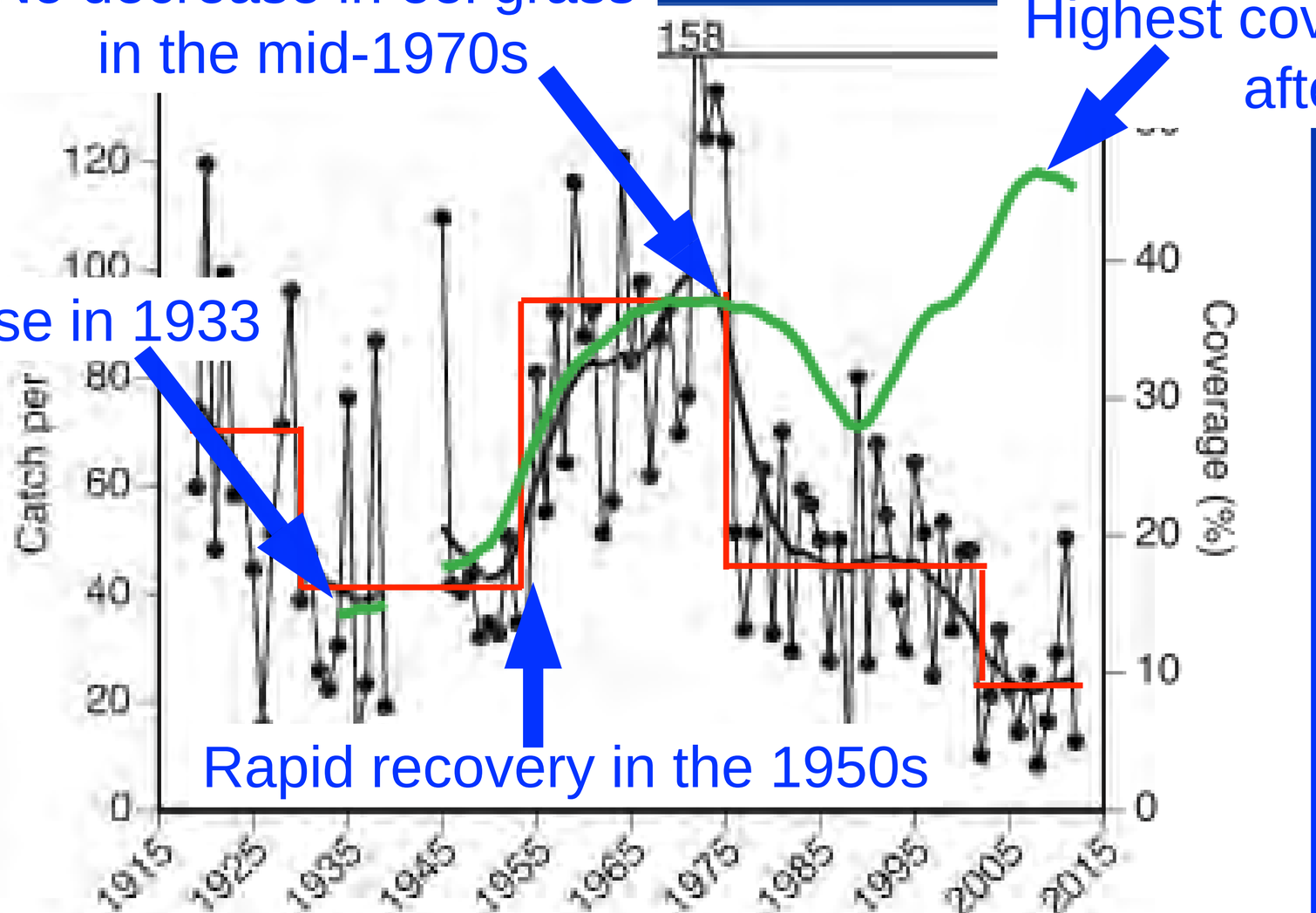
0-group cod, pollack and whiting

Bottom vegetation (eelgrass)

No decrease in eel grass in the mid-1970s

Highest coverage recorded after 2000

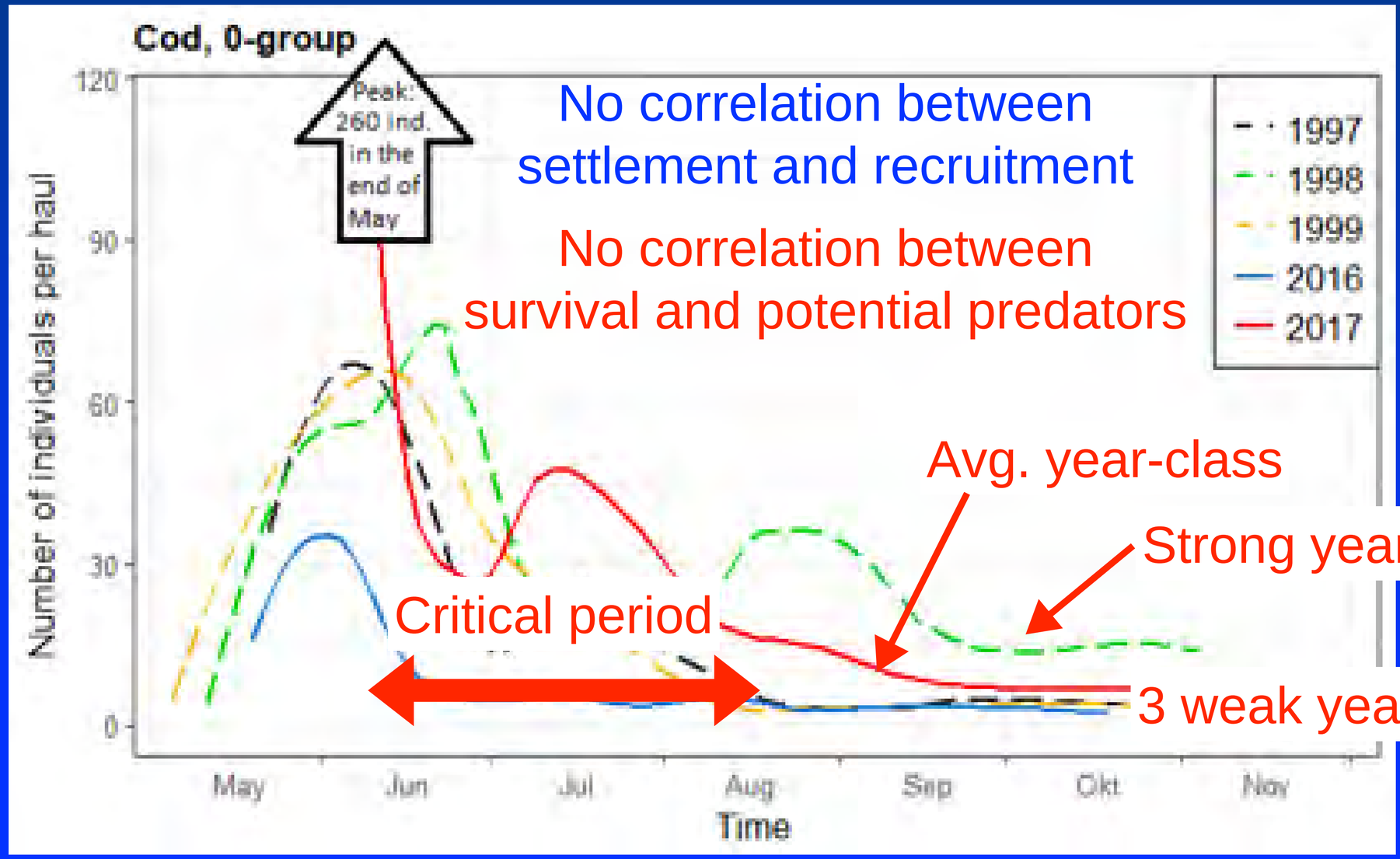
Eel grass disease in 1933



Rapid recovery in the 1950s

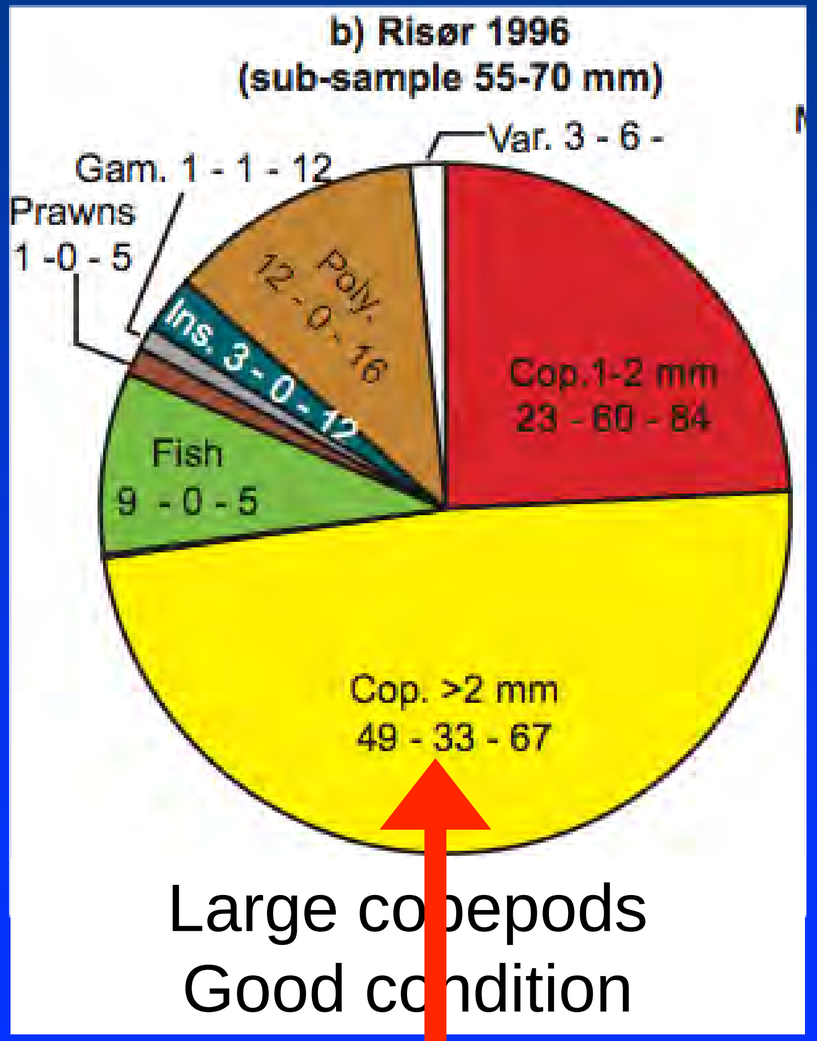
Biweekly sampling of 0-group cod after settlement at 6 stations
The year-class strength of cod is mainly determined by September
(6-8 months old)

High inter-annual variability in no. of cod settling



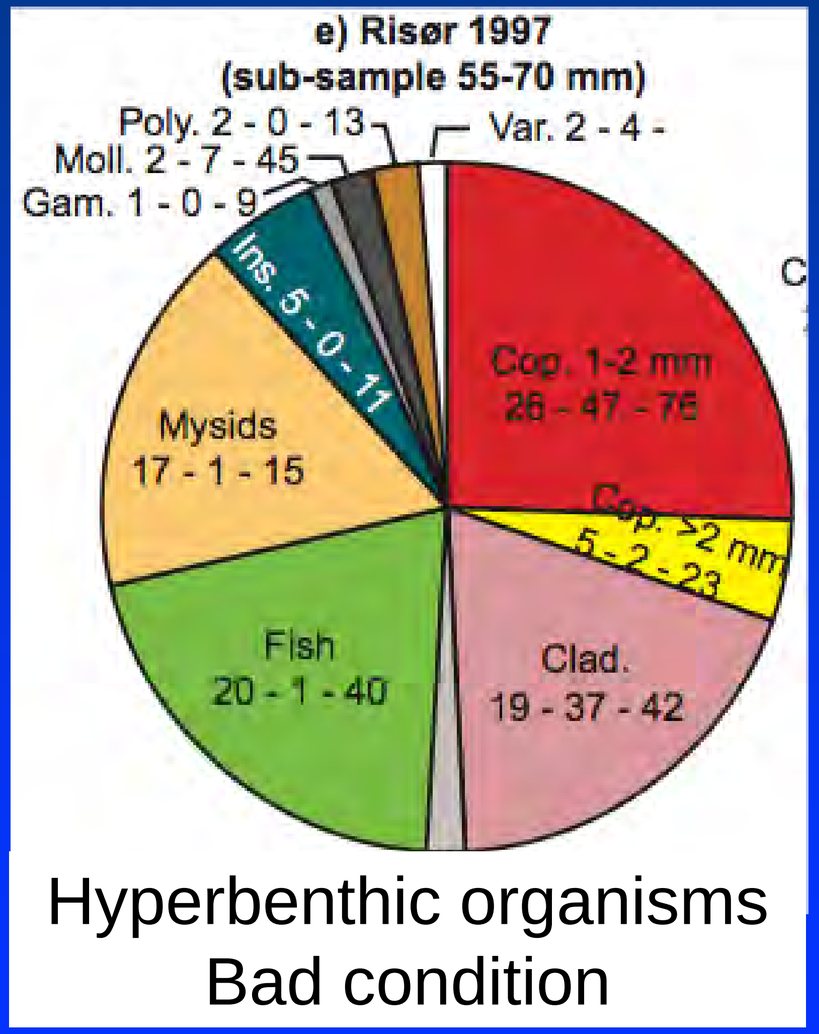
Diett of 0-group cod in July

Strong year-class



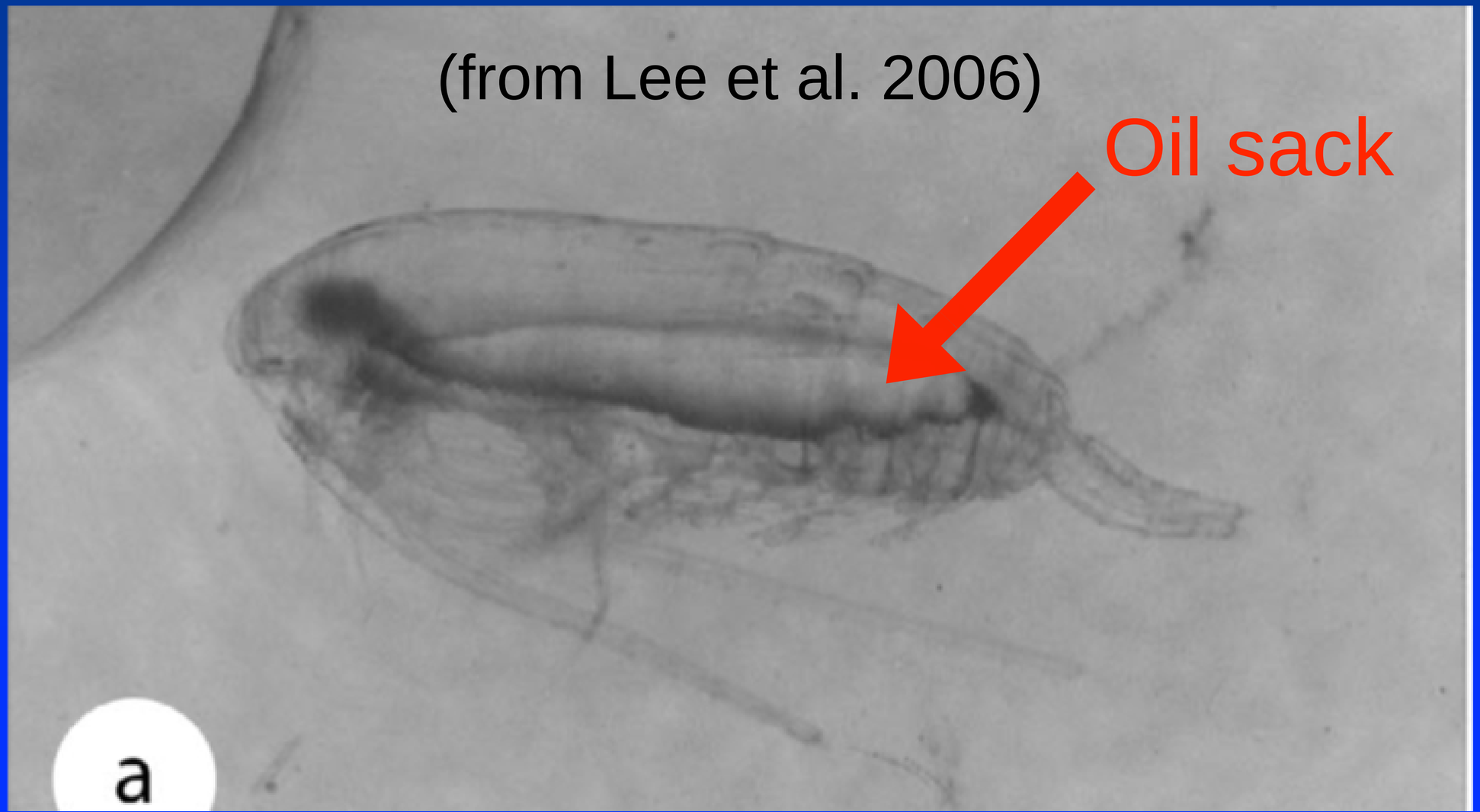
Large copepods
Good condition

Weak year-class



Hyperbenthic organisms
Bad condition

Calanus with oil sack



Calanus with oil sack

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

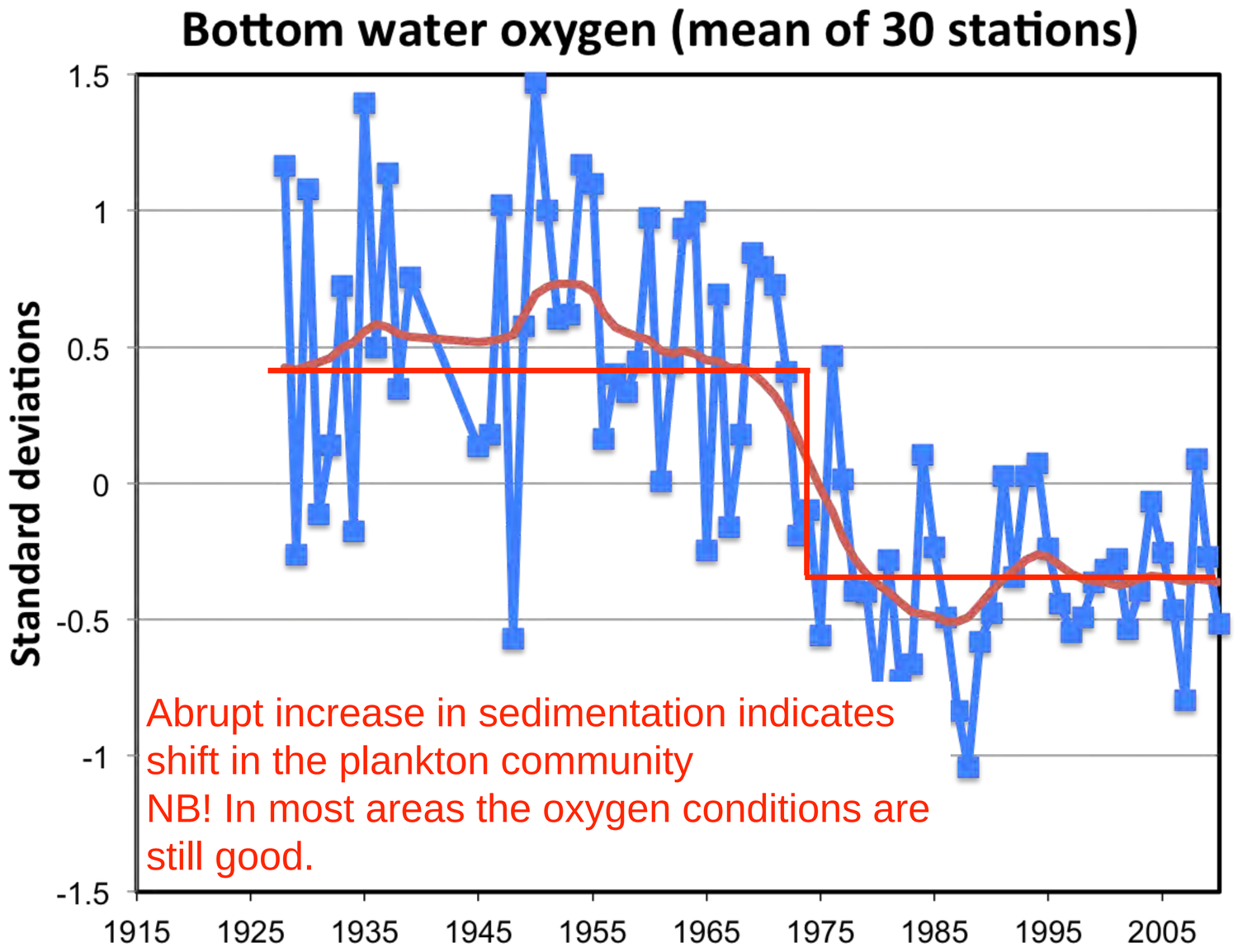
Preliminary conclusions:

1. There appears to be sufficient settlement of 0-group cod to give rise to strong year-classes.

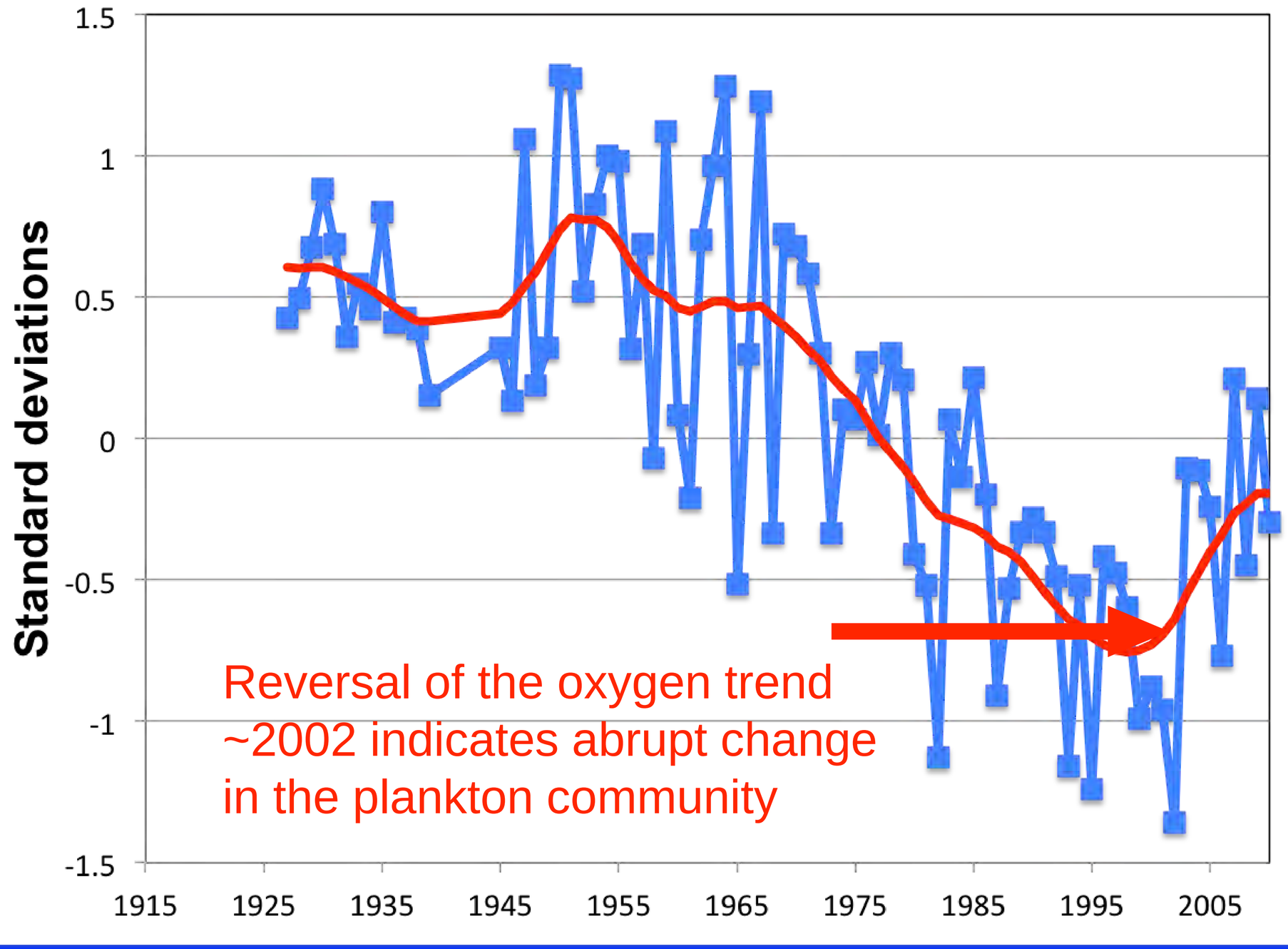
2. This is also the case in areas with recruitment collapses.

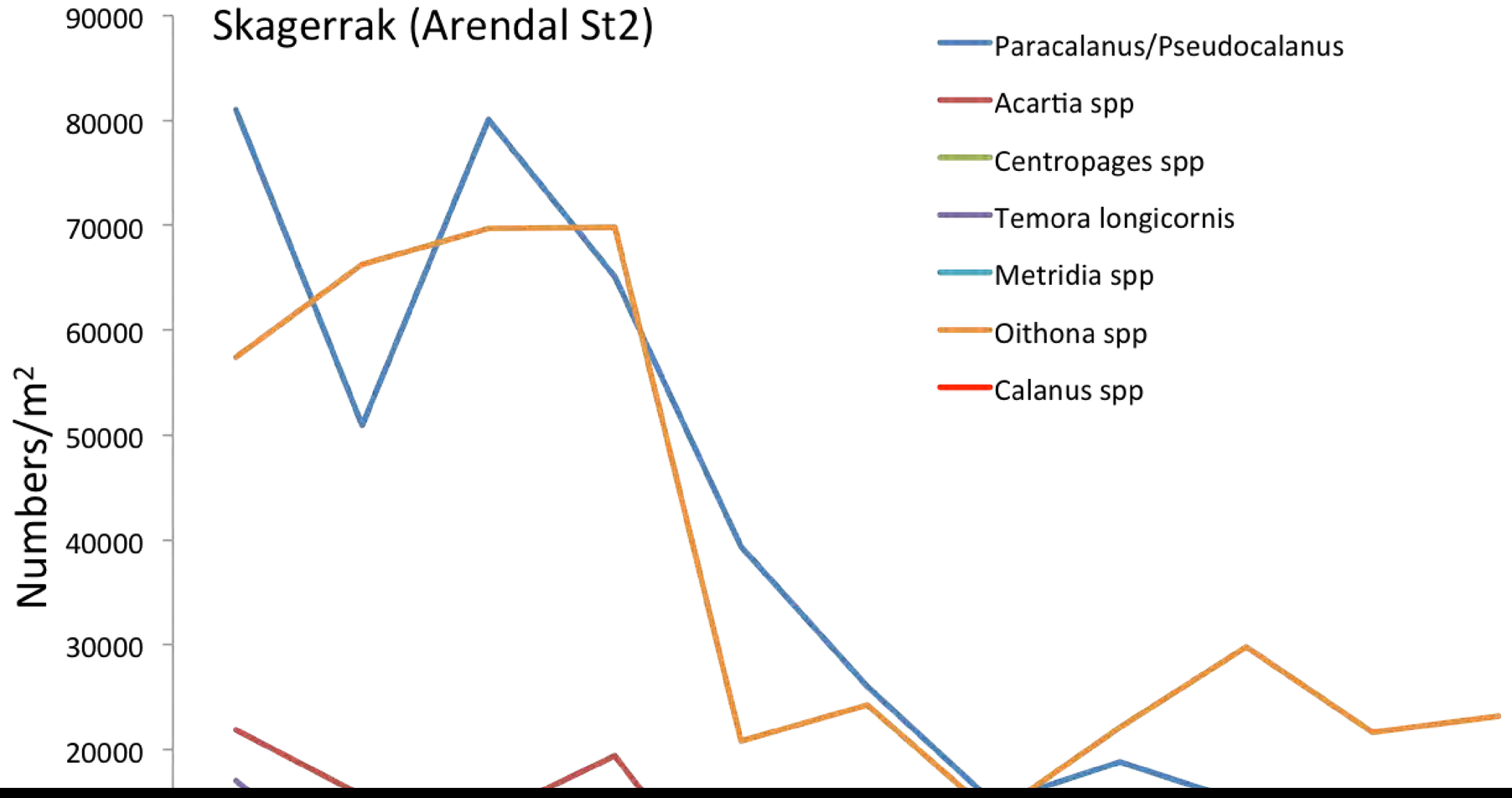
3. High inter-annual variability in recruitment suggests high variability in plankton. This will affect all organisms that depend on plankton during early life stages

4. Abrupt recruitment collapses suggest abrupt changes in plankton


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
NB! In most areas the oxygen conditions are still good.

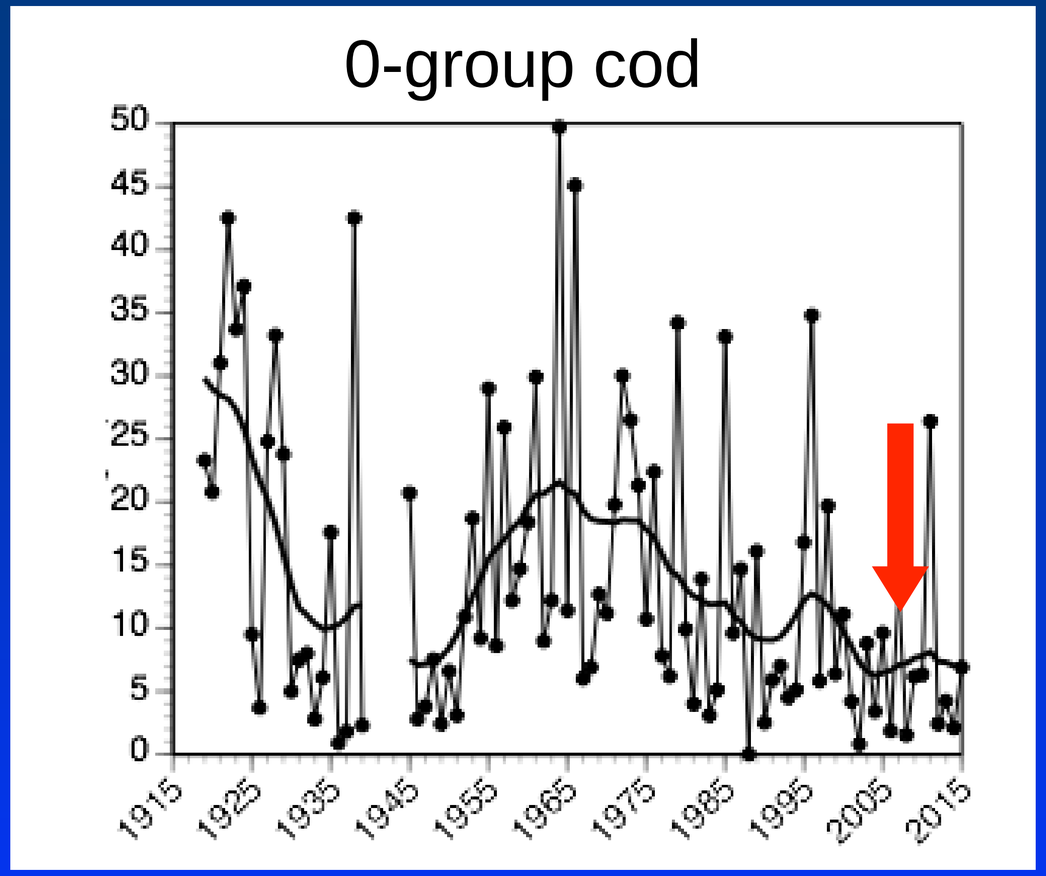
Oxygen at 30 m depth (mean of 30 stations)

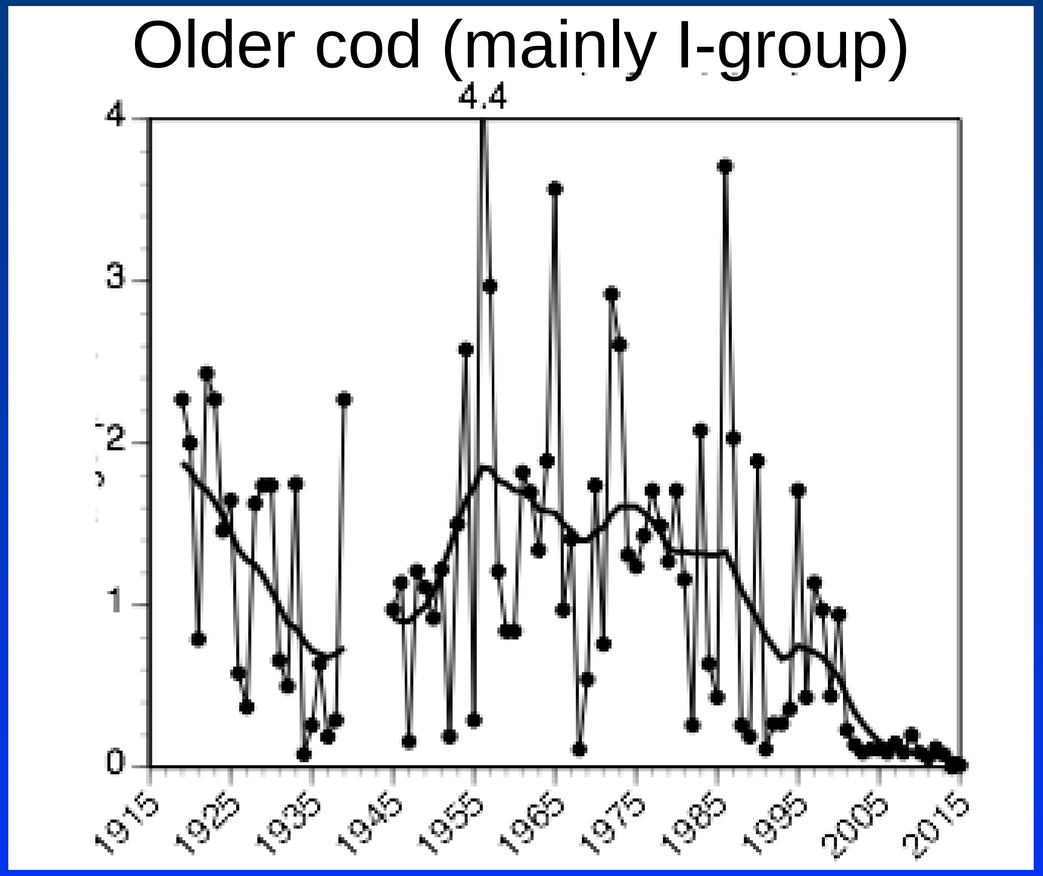




In summary, there is both direct (e.g. copepods) and indirect evidence (oxygen) of abrupt changes in the plankton community with that of the recruitment collapse in the gadoids. Abrupt changes in phytoplankton also support this conclusion.

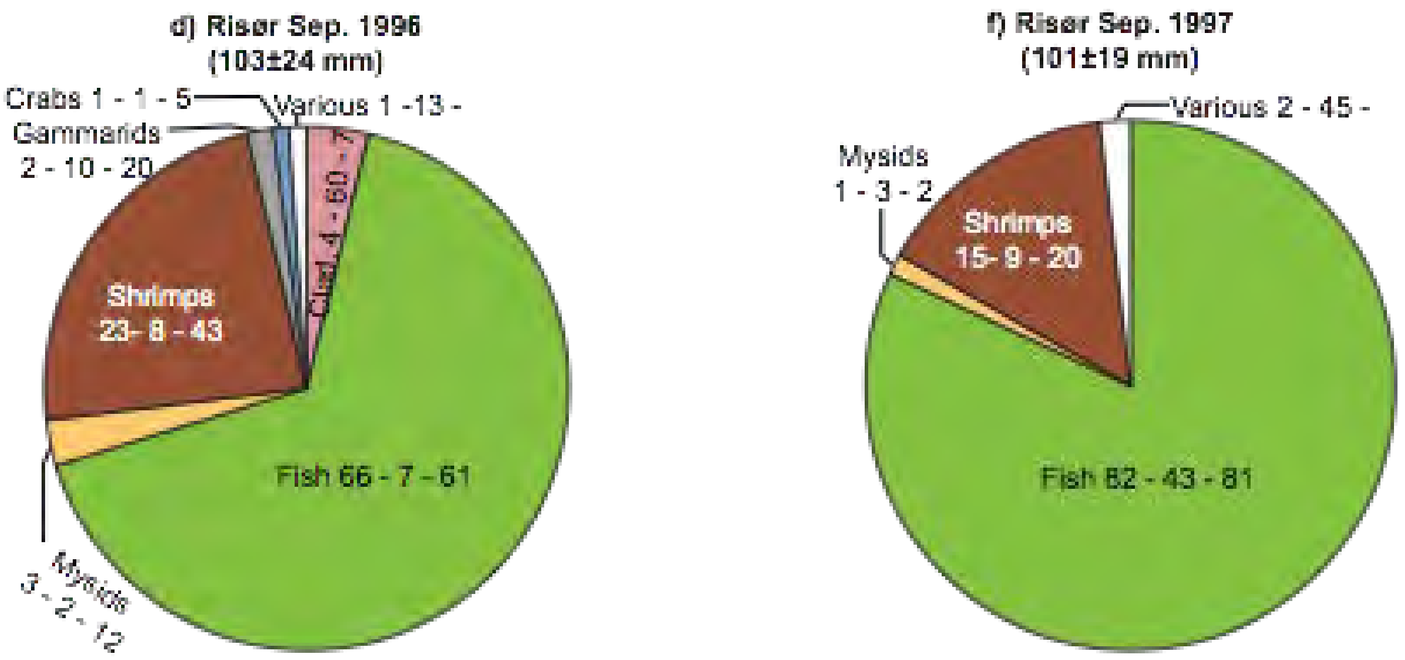
Abundance of cod along the Skagerrak coast





Before 2002, a strong year-class of 0-group would result in high abundance of I-group the
After the regime shift in ~2002, we hardly catch older any more, even after strong year-clas

Diet of 0-group cod in September



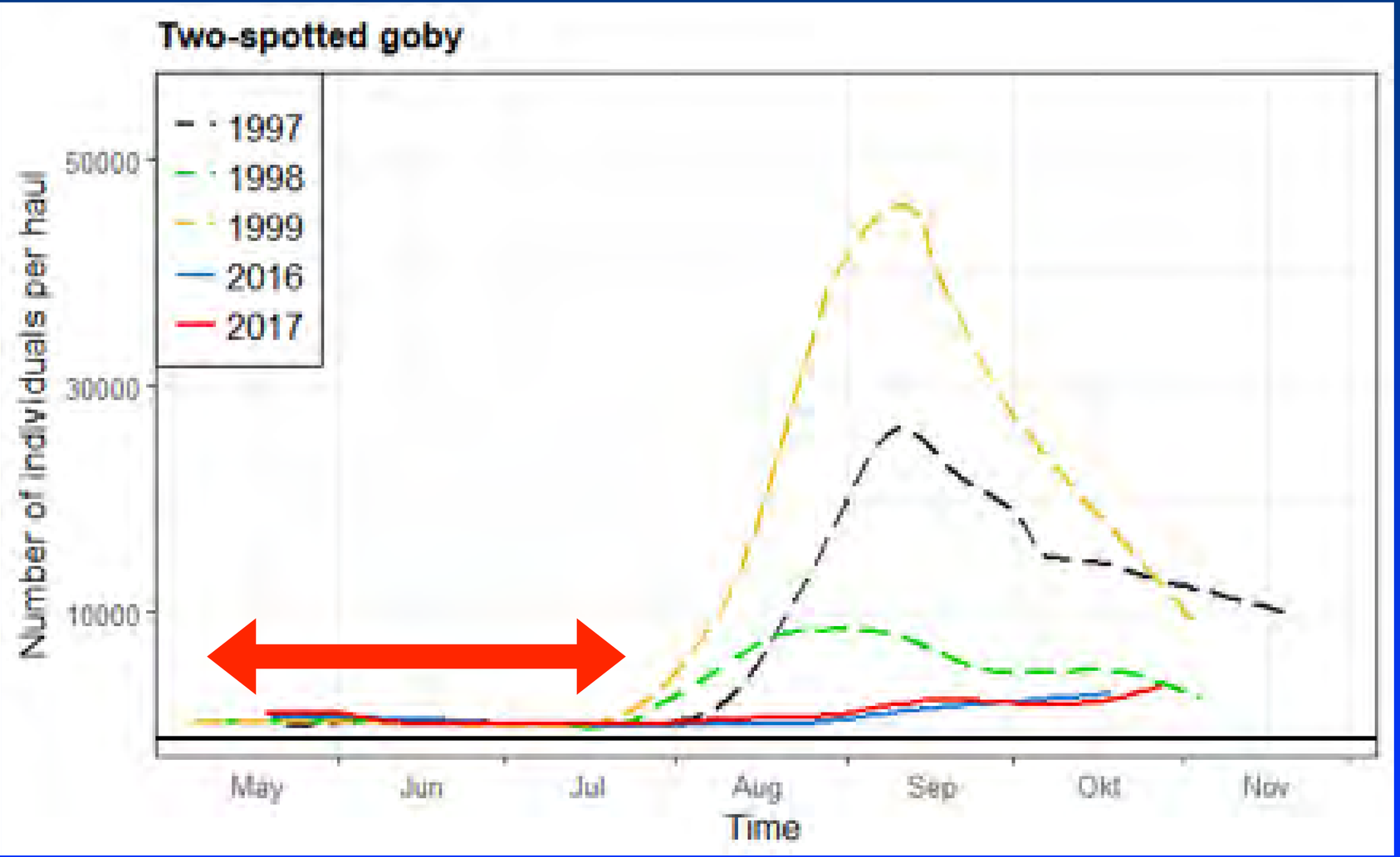
What has happened to the main prey of 0-group cod?

The main prey of 0-group cod during the first winter are small fish and shrimps that live for only one year

Two-spotted goby (*Gobiusculus flavescens*)
Length of adults ~4 cm

We don’t no much about them because they escape through the meshes of the traditional beach seine

Catch of two-spotted goby



Prey for 0-group cod during the first winter has practically vanished

Summary:

1. There have been repeated incidents of abrupt and persistent recruitment collapses in gadoids

2. There are direct and indirect observations of abrupt changes in plankton concurrent with the recruitment collapses

3. The critical period for recruitment of cod in these waters is after settlement, and good survival is positively related to high proportions of larger, energy-rich copepods in the diet

4. The shifts in plankton and subsequent recruitment collapses have been observed in relation to gradually increasing nutrient loads and increasing temperatures, i.e. bifurcations

Conclusion

Gradually increasing temperatures may result in substantially reduced abundance of fish due to abrupt shifts in plankton

Thank you for your attention!