

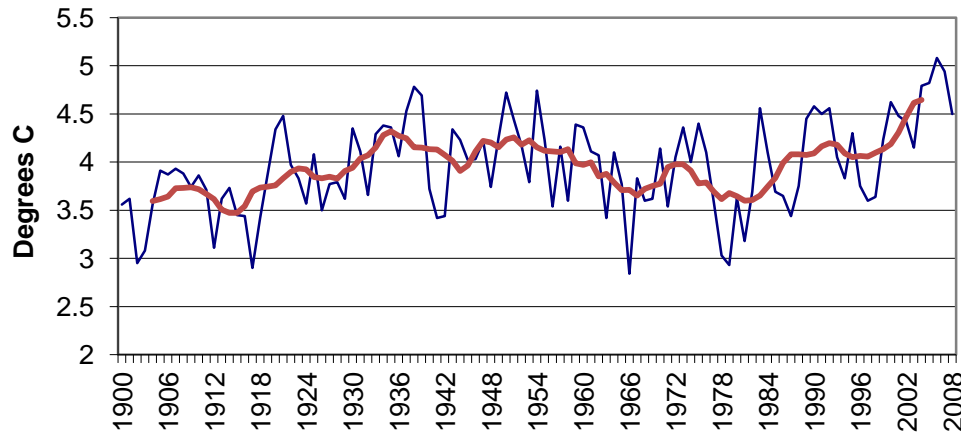
# Climate change impacts on international fisheries and adaptation strategies

Rögnvaldur Hannesson  
Norwegian School of Economics &  
Business Administration  
Bergen, Norway

# The ocean climate has always been variable

- Year to year variations
- Recurring events (El Niño)
- Regime shifts (decadal oscillations)

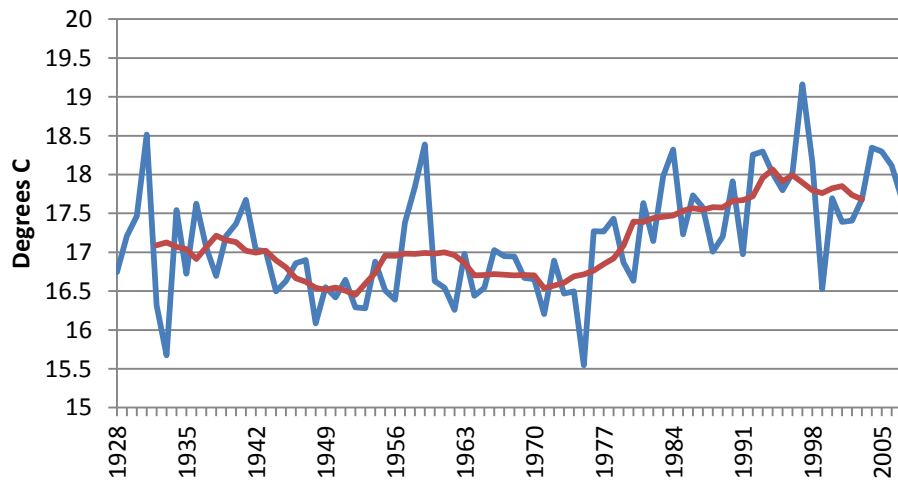
**Average annual temperature, Kola section**



Temperature Kola  
Section (Barents  
Sea)

Warming?

**Average annual temperature Scripps pier**



Scripps, La Jolla  
California

Regime shifts?

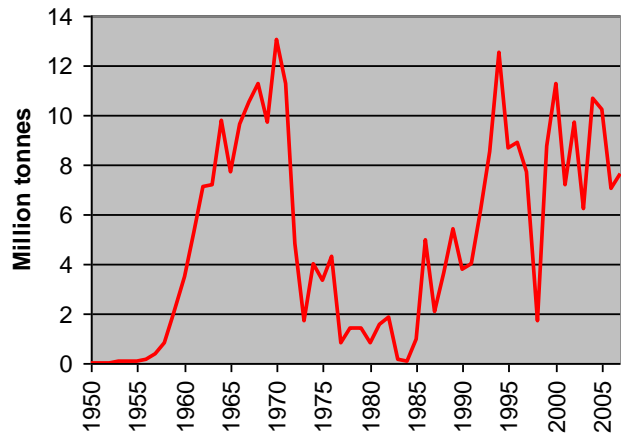
Warming?

# Changes in ocean climate drive fluctuations in fish stocks

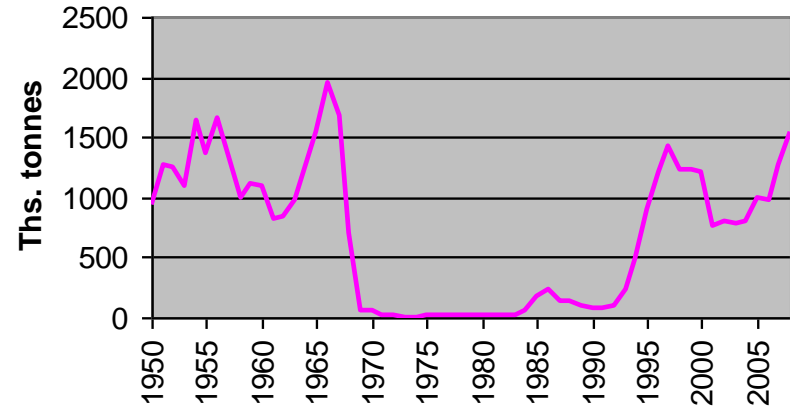
## Stock collapses

- Probably a conjunction of environmental effects & overexploitation

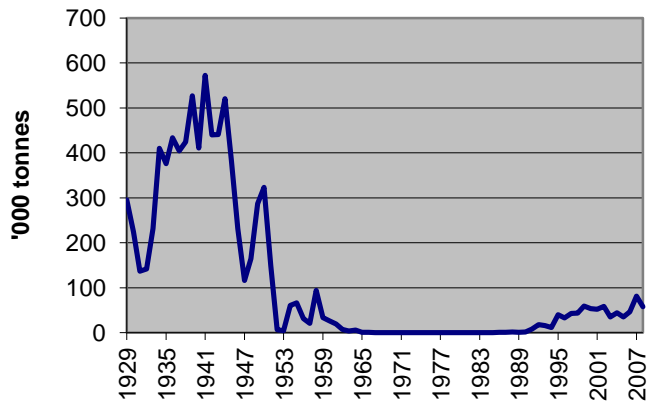
### Catches of Peruvian Anchovy



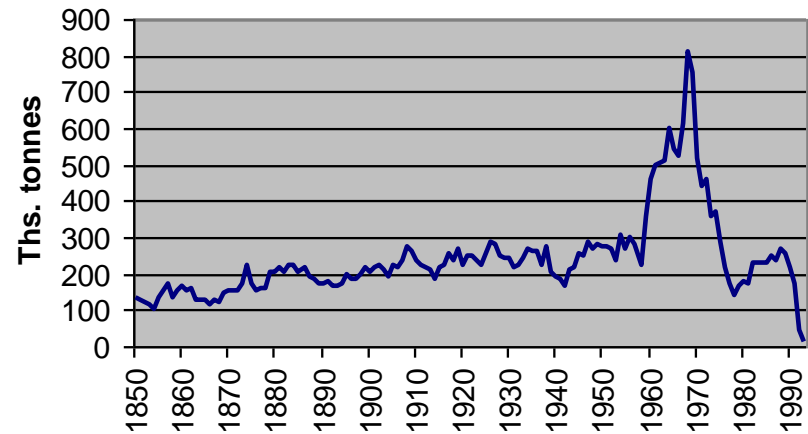
### Catches of Atlanto-Scandian Herring



### Sardine catches, California



### Catches of Northern Cod



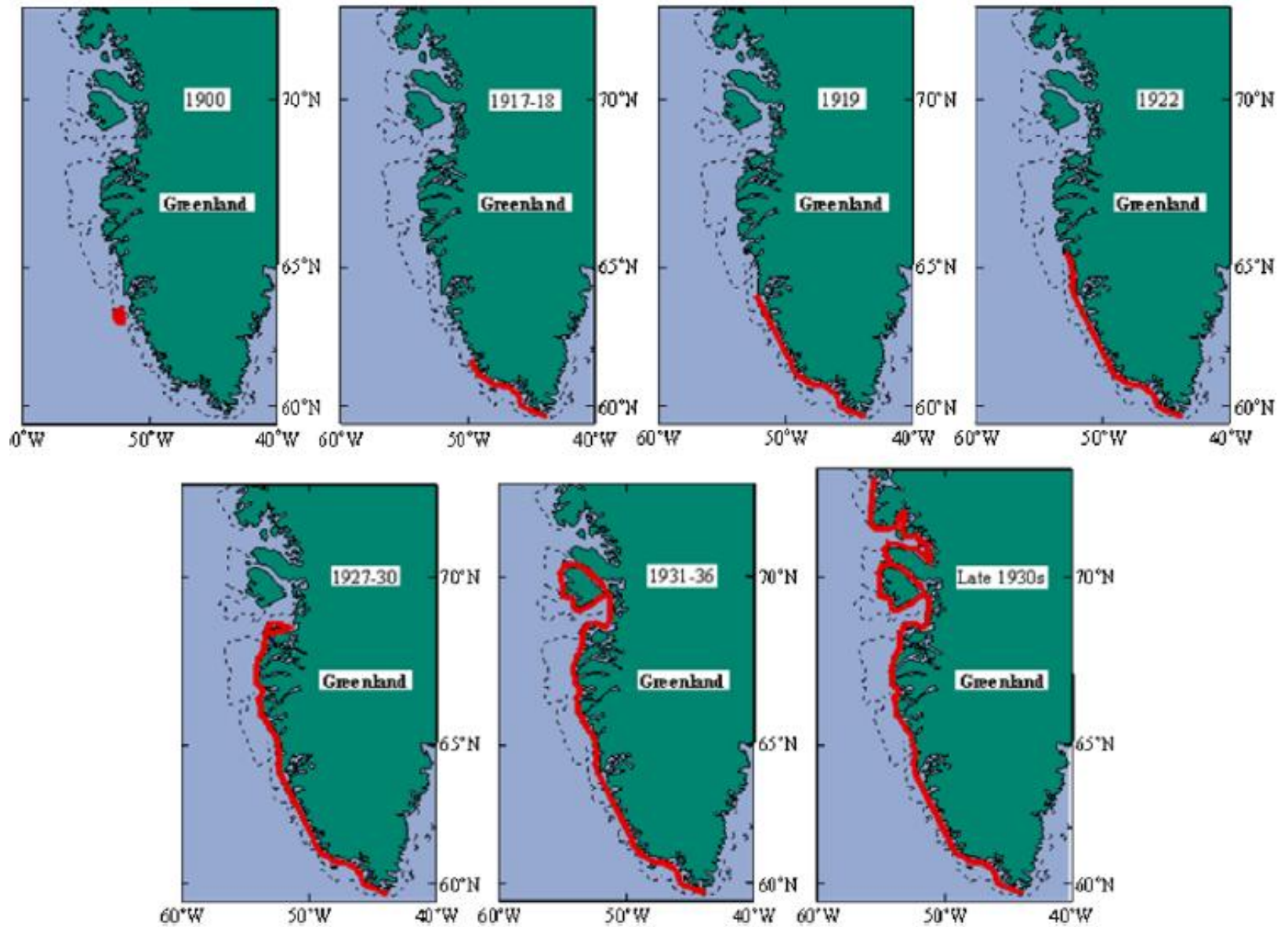
# So what is new?

Global warming will be an underlying trend

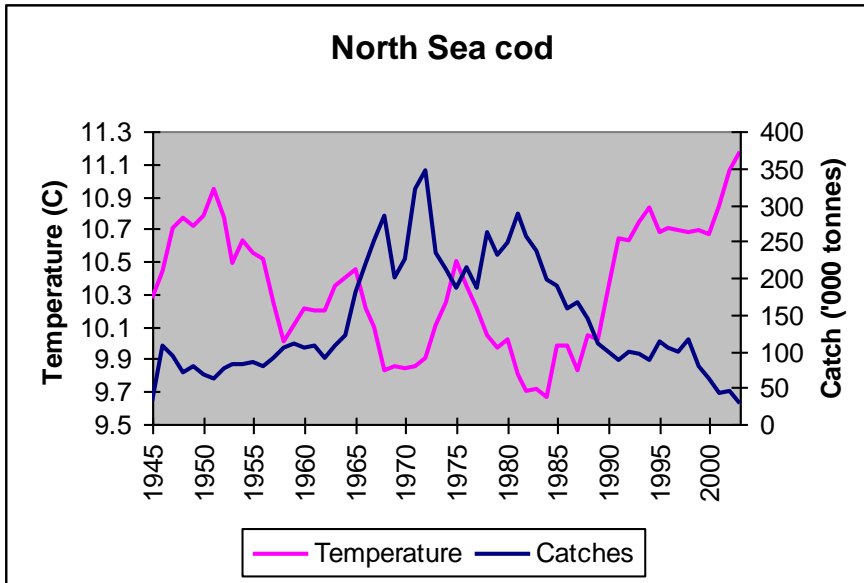
- But there will be major fluctuations around it
- Changes may also be irreversible

Effects of global warming on fish stocks

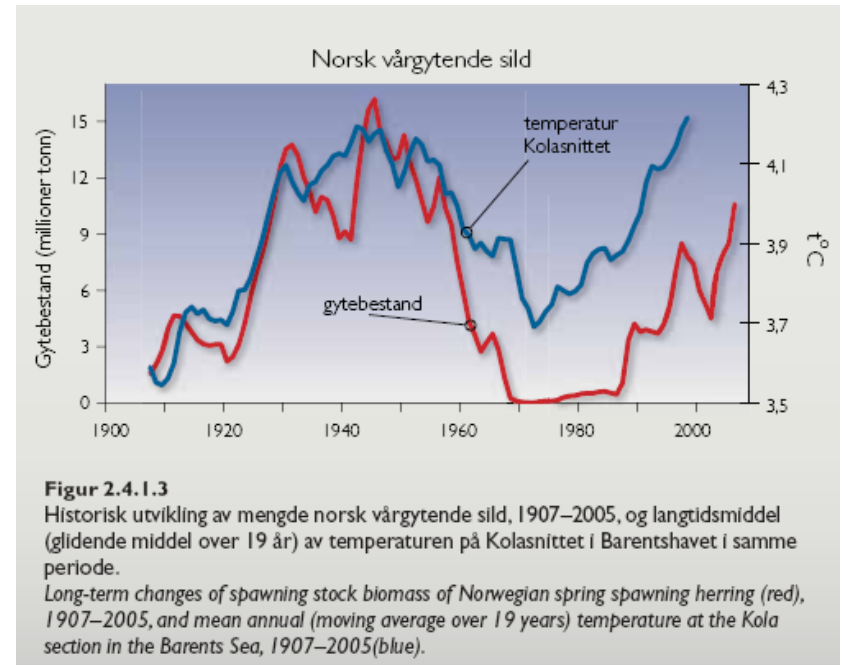
- Changes in productivity
  - Negative in some places, positive in others
- Changes in migration or location



Cod at Greenland. From Drinkwater (2006)



Maybe it's not just overfishing....

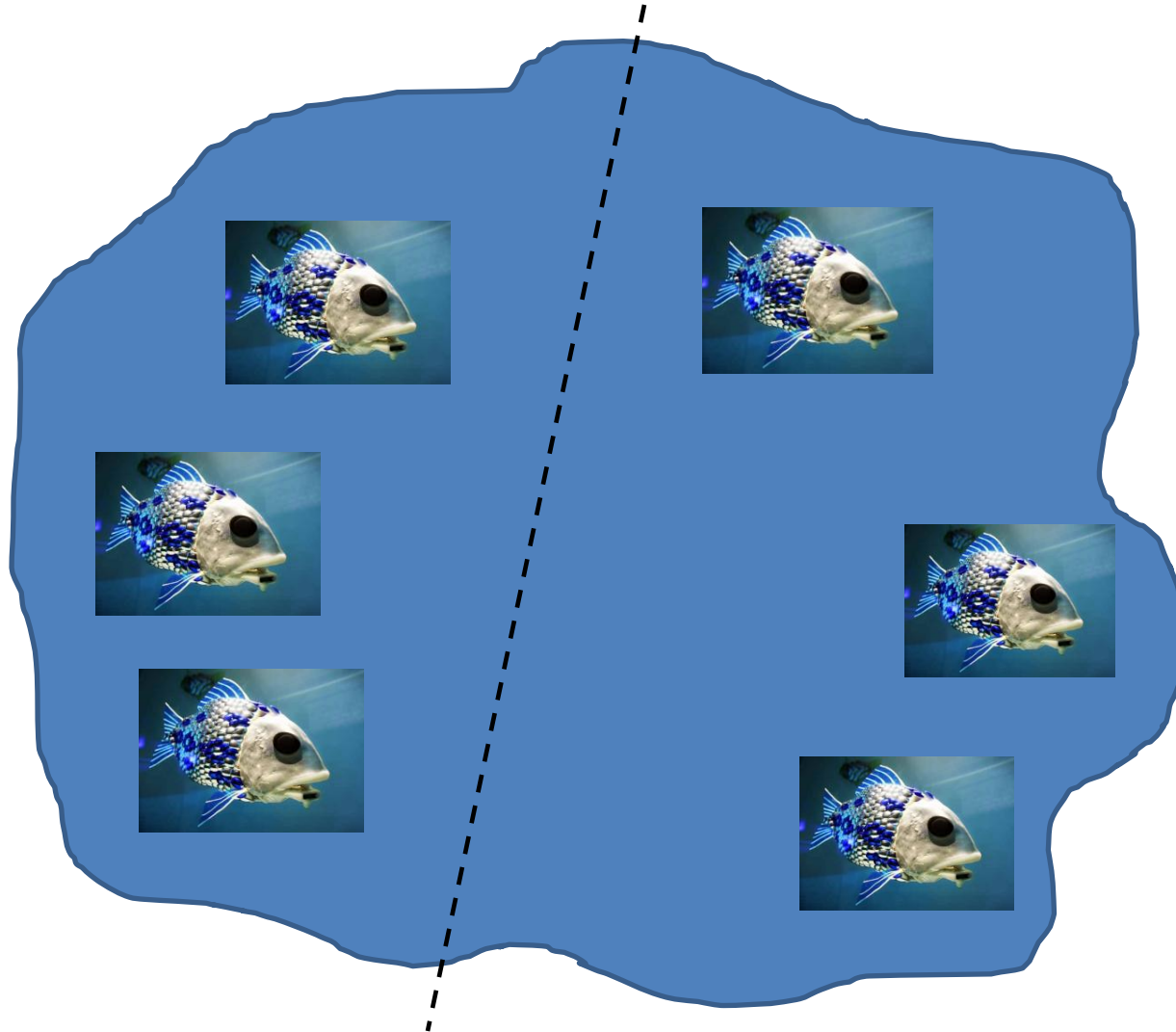


**Figur 2.4.1.3**  
 Historisk utvikling av mengde norsk vårgytende sild, 1907–2005, og langtidsmiddel (glidende middel over 19 år) av temperaturen på Kolasnittet i Barentshavet i samme periode.  
 Long-term changes of spawning stock biomass of Norwegian spring spawning herring (red), 1907–2005, and mean annual (moving average over 19 years) temperature at the Kola section in the Barents Sea, 1907–2005 (blue).

The collapse of the NSS herring coincided with a cooling of the ocean (Toresen & Østvedt)



Changed location (or migrations) of a stock will affect the share of a stock in each country's zone



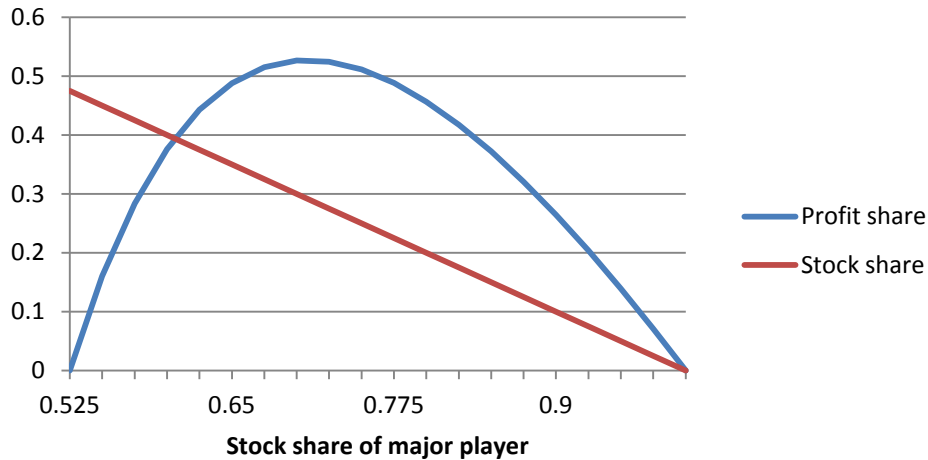
# How will changes in location affect sharing of fish stocks?

1. Sharing and zonal attachment, a simple model
2. Zonal attachment and sharing of North Sea stocks
3. North Sea herring
4. The Atlanto-Scandian herring
5. Northeast-Arctic cod; hypothetical example
6. A model of dramatic change, with a stock moving from Country A to Country B, possibly disastrous consequences

# 1. Zonal attachment and sharing of stocks

- Each country must get a share making it as well off as without an agreement
- Countries with a small share of a stock in their zone must be offered a larger share
- Why?
  - They have a weaker incentive to conserve
  - Most benefits of conservation go to the country with a large share

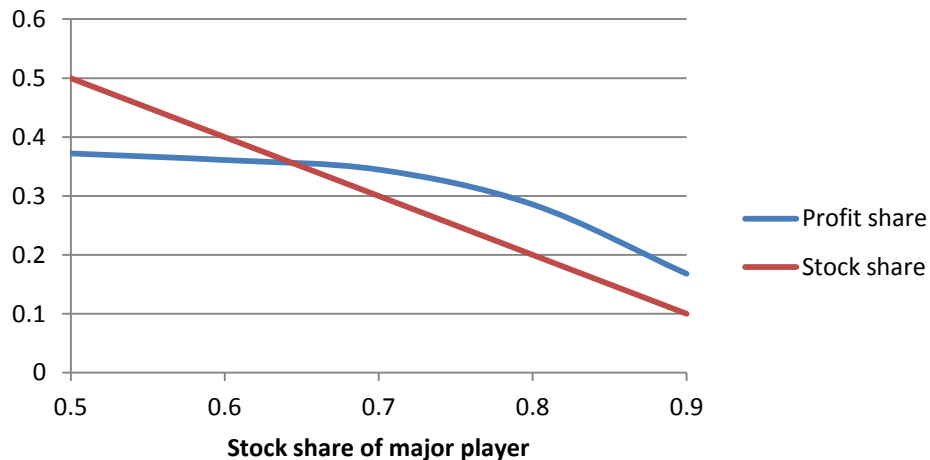
Minor player: critical profit share



Minor player must be offered a larger share of profits than his stock share if stock share small.

“Zonal attachment” not necessarily a rule all can agree on.

Minor player: critical profit share



Cases with stock-dependent (lower) versus constant (upper) unit cost of fish.

## 2. Zonal attachment and sharing of North Sea stocks

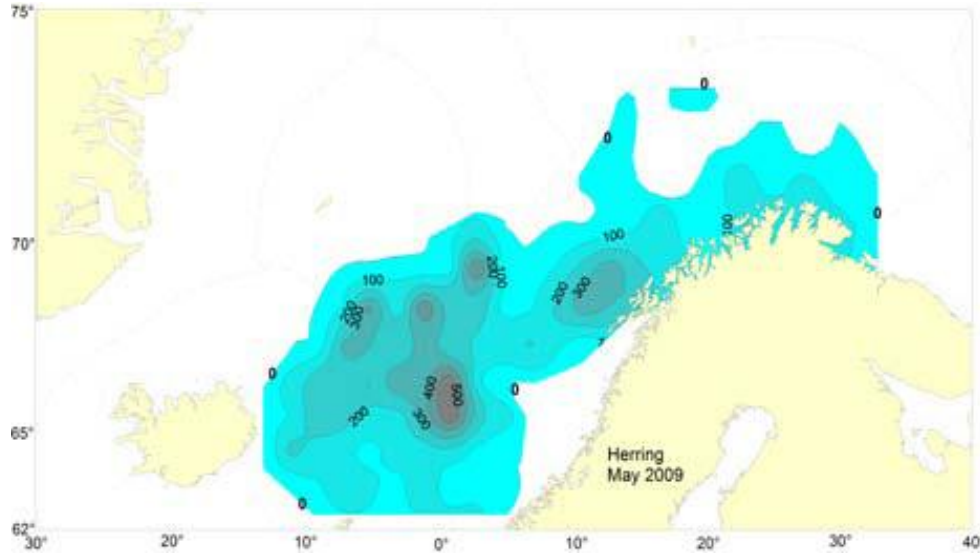
- Sharing between Norway and EU based on zonal attachment in early 1980s
- Has worked well in most cases
- Shares have remained unchanged since early 1980s
- But no dramatic changes in stock migration and distributions

# 3. The North Sea herring

- Stock depleted in the 1970s
- Stock concentrated in a small area; only 4% in Norwegian zone
- When fishery reopened in mid-1980s, Norway was offered 4%
- Norway said no thanks, fished at will, was offered 29% next time around
- A larger stock more widespread, zonal attachment depends on size and ocean climate

## 4. The Atlanto-Scandian herring (Norwegian spring spawning herring)

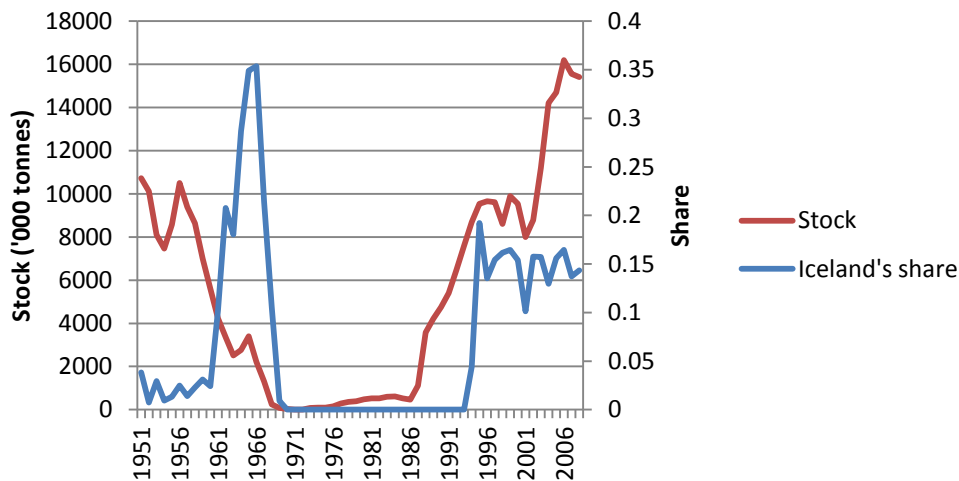
- Depleted in late 1960s
- Small stock confined to Norwegian zone
- A large stock migrates into other zones and the high seas
- Shares based on zonal attachment:
  - Obsolete
  - Must be dynamic
  - Or able to withstand changes in distribution
- Shares now agreed, but have been controversial



Distribution of NSS herring depends on ocean climate

Icelandic share of catches high when stock is large

**Norwegian spring spawning herring**

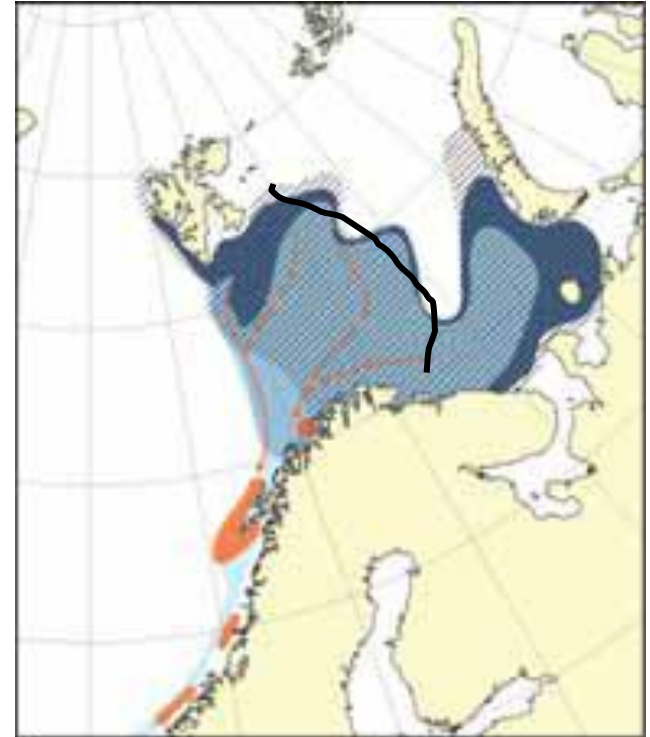




## 5. The Northeast Arctic cod

Shared 50-50 between Norway and Russia

What would happen if the stock shifts into the Russian zone?



Red: Spawning areas  
Blue: Feeding areas  
Black: Border (rough)  
between Norway and  
Russia

Norway's bargaining position would be strengthened as her share of the stock declines, but only up to a point

Norway's share of stock	Norway's minimum share to accept cooperation	Russia's minimum share to accept cooperation
0.5	0.47	0.47
0.4	0.48	0.45
0.3	0.52	0.42
0.2	0.53	0.38
0.1	0.34	0.64

Based on an age-structured model with spawning migrations to the coast of Norway

## 6. A dramatic case: A stock shifts from Country A to Country B

- Climate varies but with an underlying trend
- Location of stock follows climate
- Countries look backwards and predict share of stock in their zone

An intermediate period:

- Stock in zone of both countries
- Unknown distribution except in hindsight

Stock could be threatened

- If "old" country realizes it is losing it permanently
- If "new" country does not realize it is taking it over

Upper panel: Temperature follows random walk with trend  
Lower panel: Share of stock in country A's zone

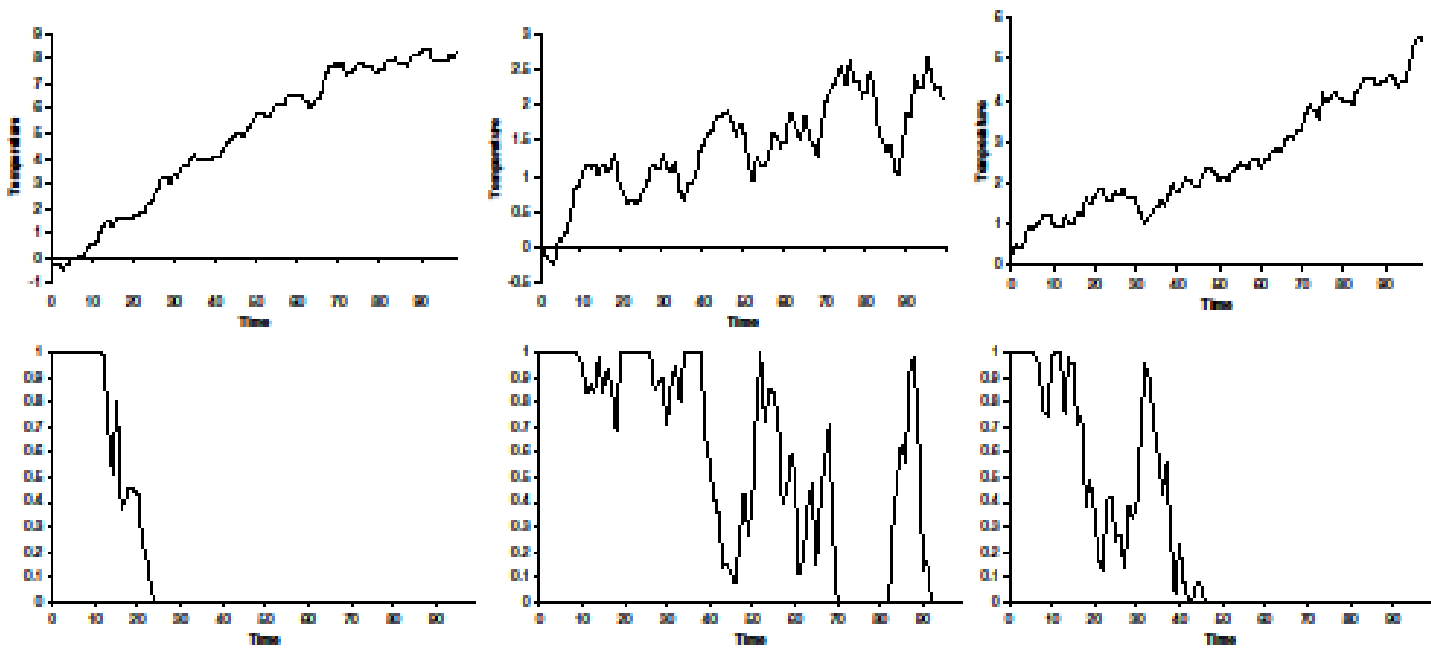


FIGURE 2. Three examples of development of temperature over 100 years (upper panel) and the implied share of the stock in the EEZ of Country One (lower panel).

A case where a stock goes extinct

Left: temperature. Middle: share of stock in Country A's zone,  
Right: stock.

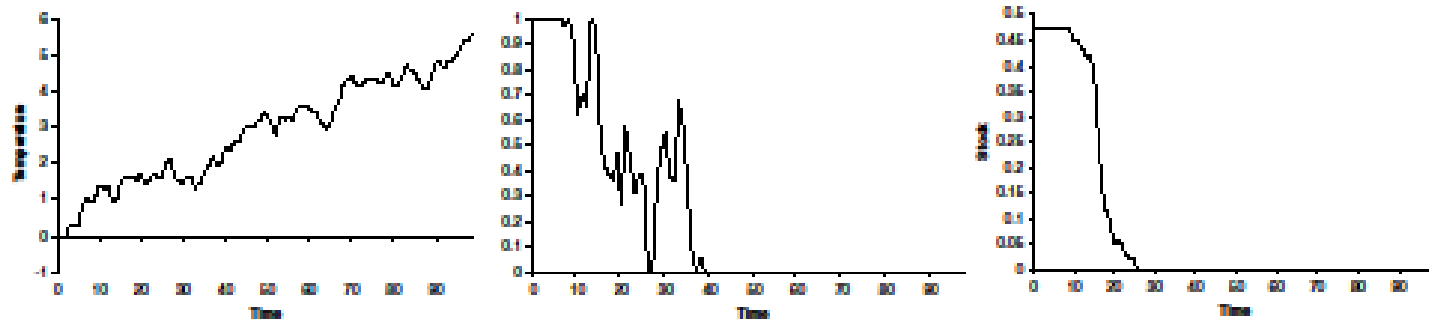


FIGURE 5. A case where the stock is fished to extinction within 100 years. From left to right: Temperature, implied share of the stock in Country One's EEZ and the stock left after fishing.

# High seas fisheries

Similar effects, probably more serious

- Reason: the open access to the high seas
  - Allocation of stocks between countries not accomplished
  - Enforcement of management decisions weak

# High seas fisheries (cont'd)

- Straddling stocks
  - Straddling into high seas weakens conservation incentives for coastal states
  - Climate change may shift stocks more into the high seas
  - Aggravates conflicts between coastal states and high seas management
- Highly migratory stocks
  - We may see more dramatic shifts in migration
  - Could be a problem where high seas interspersed with EEZs (West Central Pacific)

# Conclusions

- Climate variability may challenge sharing agreements
- Flexibility required
  - Side payments
  - Fishing in each others' zone at times
- Silver lining
  - Changes in stock distribution must be dramatic to make a difference
  - Resilience of agreements (Norway vs Russia, EU, but not US & Canada over salmon)



## Conclusion (cont'd)

- Changes in species composition likely
- Requires new technologies & markets
- Flexibility
  - Moving between fisheries
  - Access to markets
- We're unlikely to see anything more dramatic than we've seen in the past
- Our main concern and priority still:  
Better management!