Climate forcing on *Calanus* and fish populations in the NA BASIN

Svein Sundby

BASIN workshop, Hamburg, 23 – 25 January 2007

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

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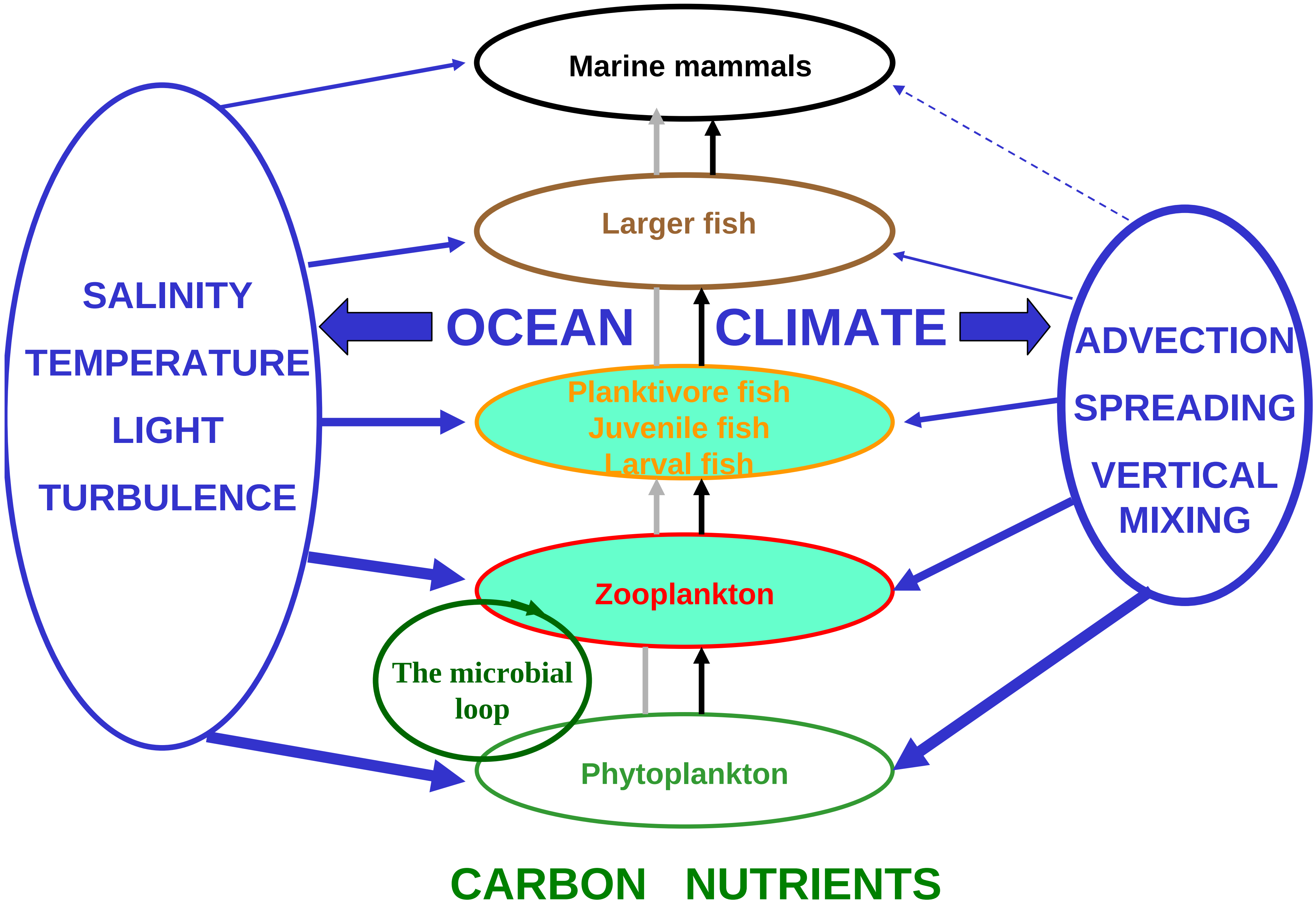
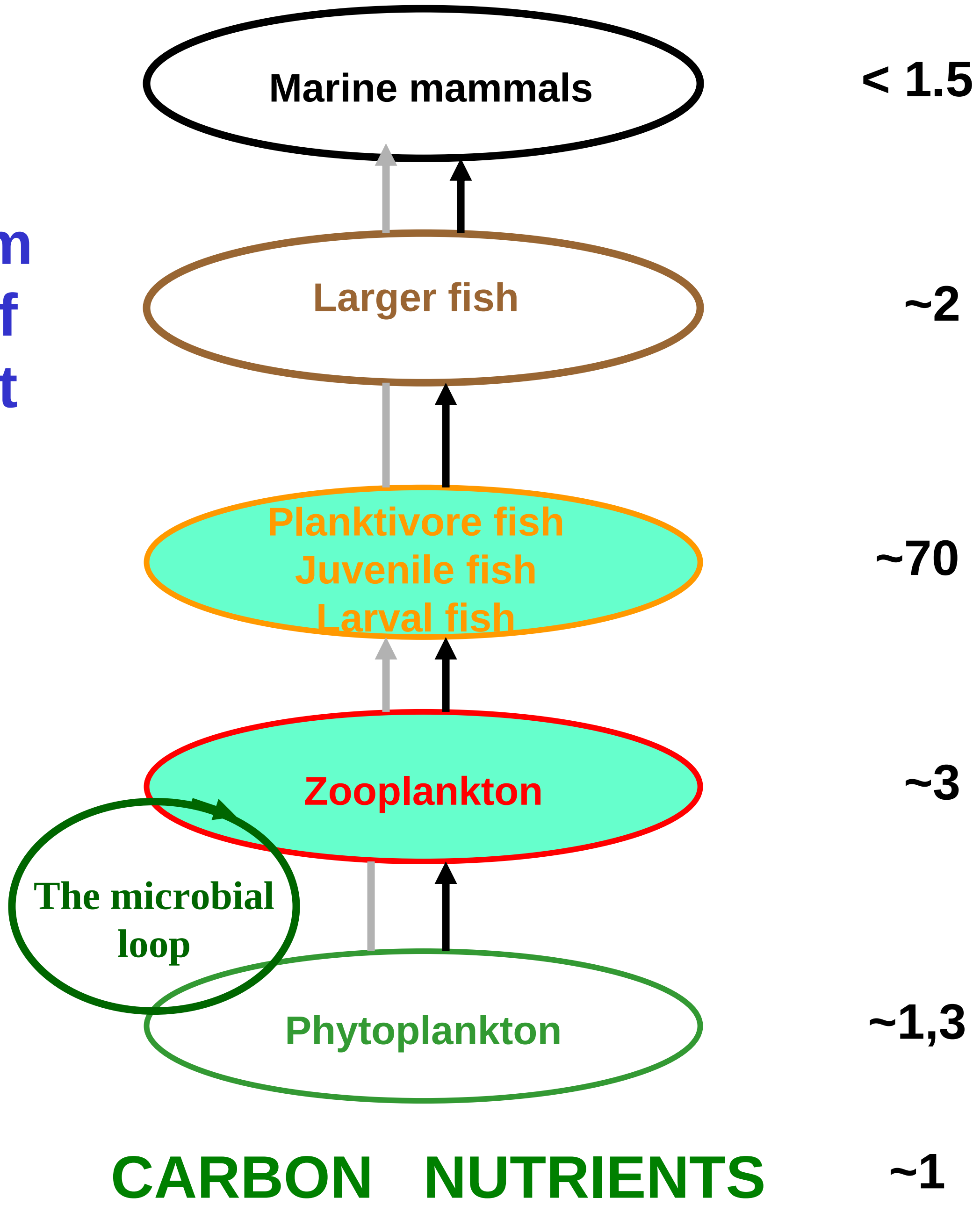
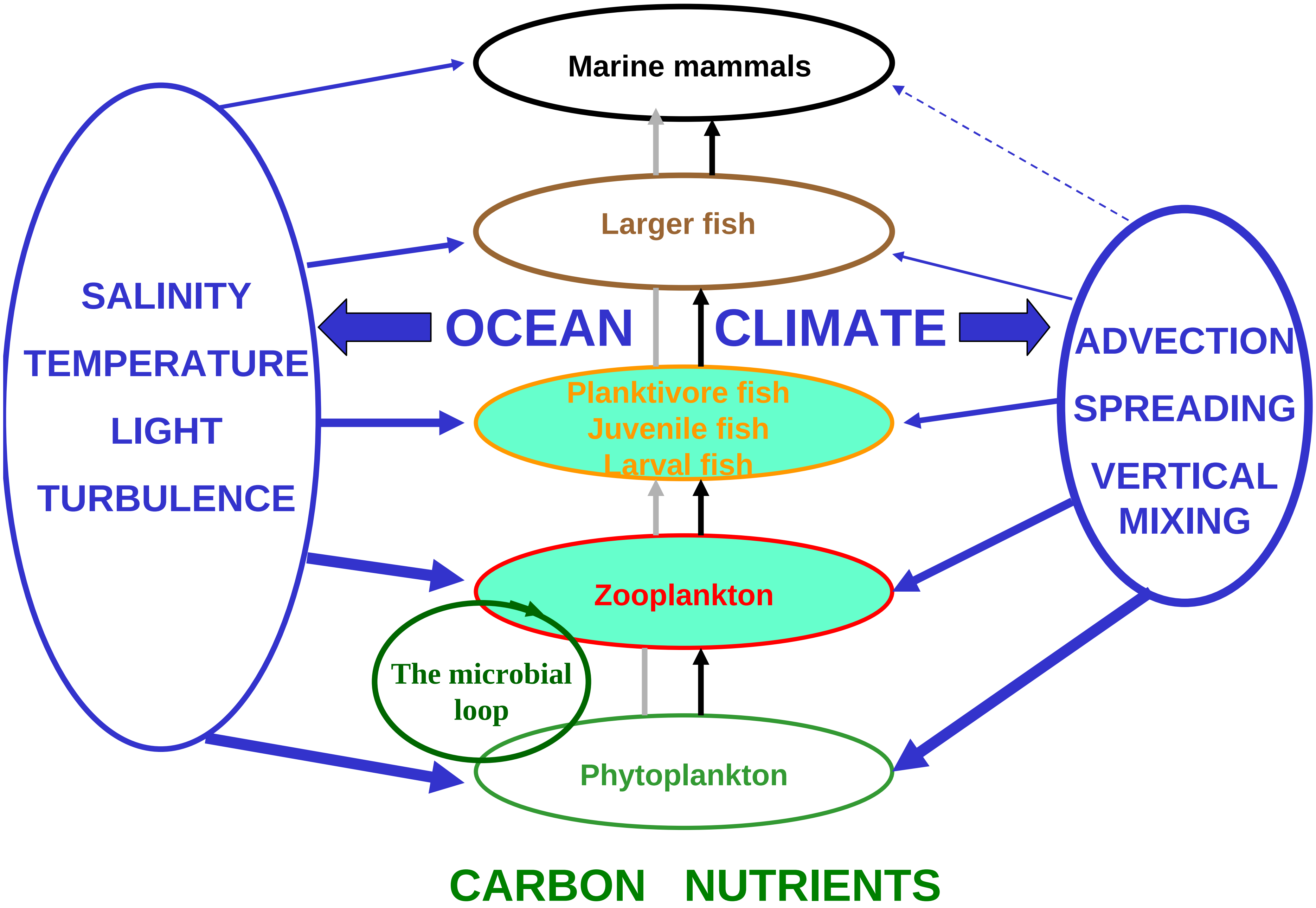

Marine mammals
Larger fish
SALINITY
TEMPERATURE
LIGHT
TURBULENCE
OCEAN
CLIMATE
ADVECTION
SPREADING
VERTICAL
MIXING
Planktivore fish
Juvenile fish
Larval fish
Zooplankton
The microbial
loop
Phytoplankton
CARBON NUTRIENTS

Interannual variability in the ecosystem production of the Northeast Atlantic




Marine mammals
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SALINITY
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CLIMATE
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Larval fish
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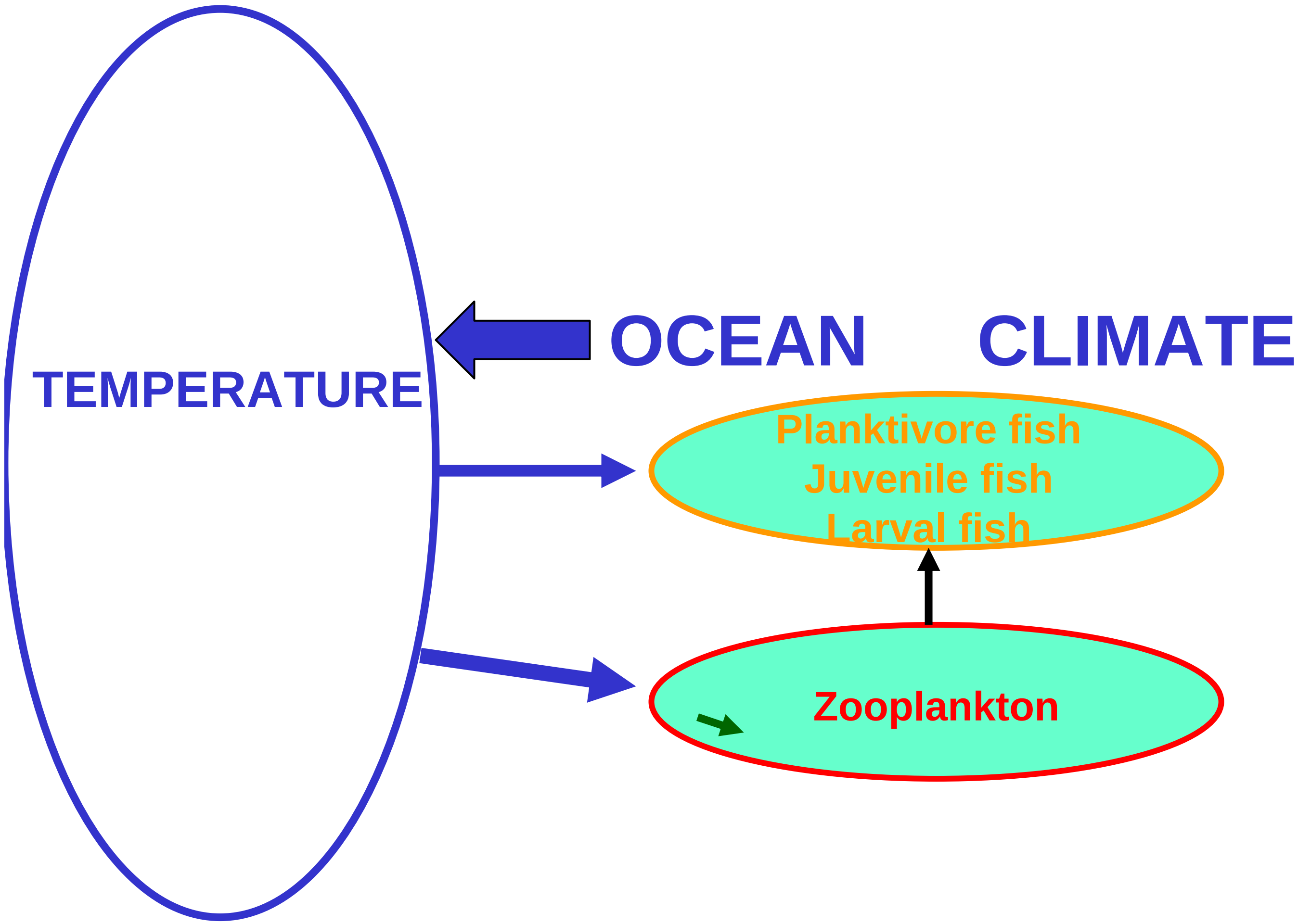
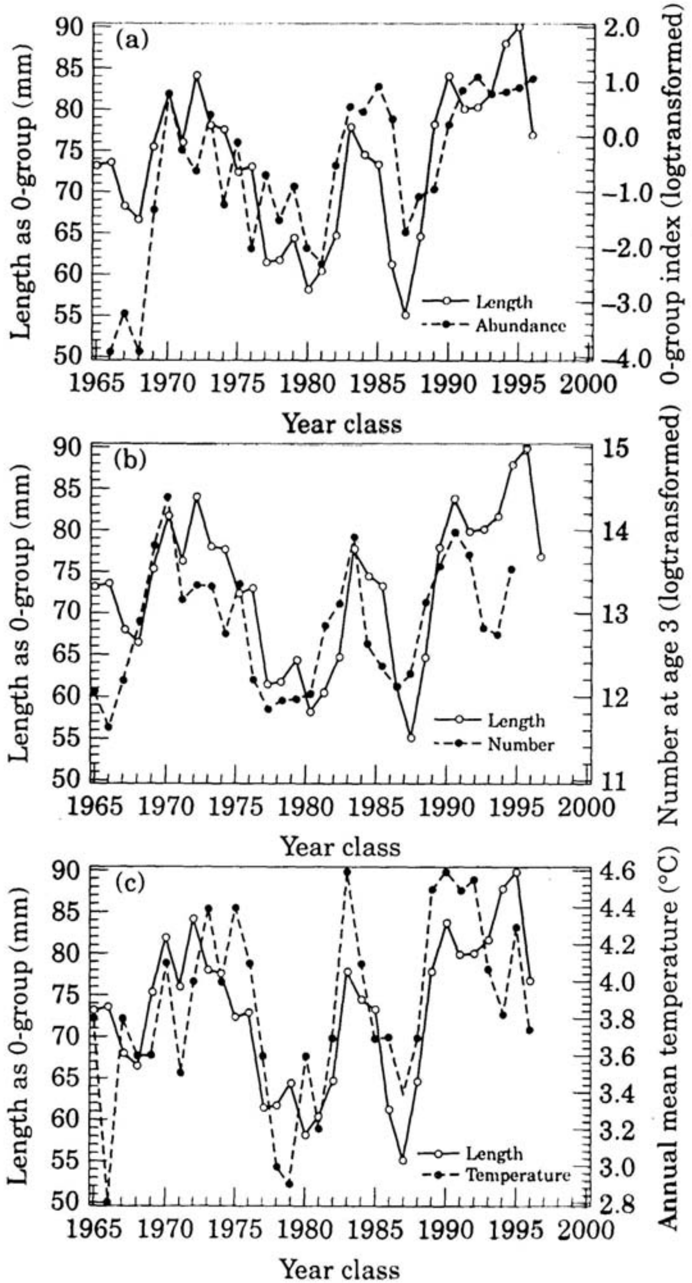
Phytoplankton
CARBON
NUTRIENTS



OCEAN CLIMATE
TEMPERATURE
Planktivore fish
Juvenile fish
Larval fish
Zooplankton

Length of 0-group (5months old) cod



Abundance of 0-group cod

Abundance of 3-group cod

Annual mean temperature

Ottersen and Loeng (2000)

Continuity equation for plankton:

$$\partial P/\partial t = \text{Diffusion} - \text{Advection} + \text{Plankton motion} + \text{Production} - \text{Mortality}$$

$$\mathbf{V} \cdot \nabla P$$

The advection term of the equation becomes important compared to the other terms when:

1. **The organism, P, has a long life time compared to the time scale of advection pattern.**
2. **The horisontal gradient, ∇P is large.**

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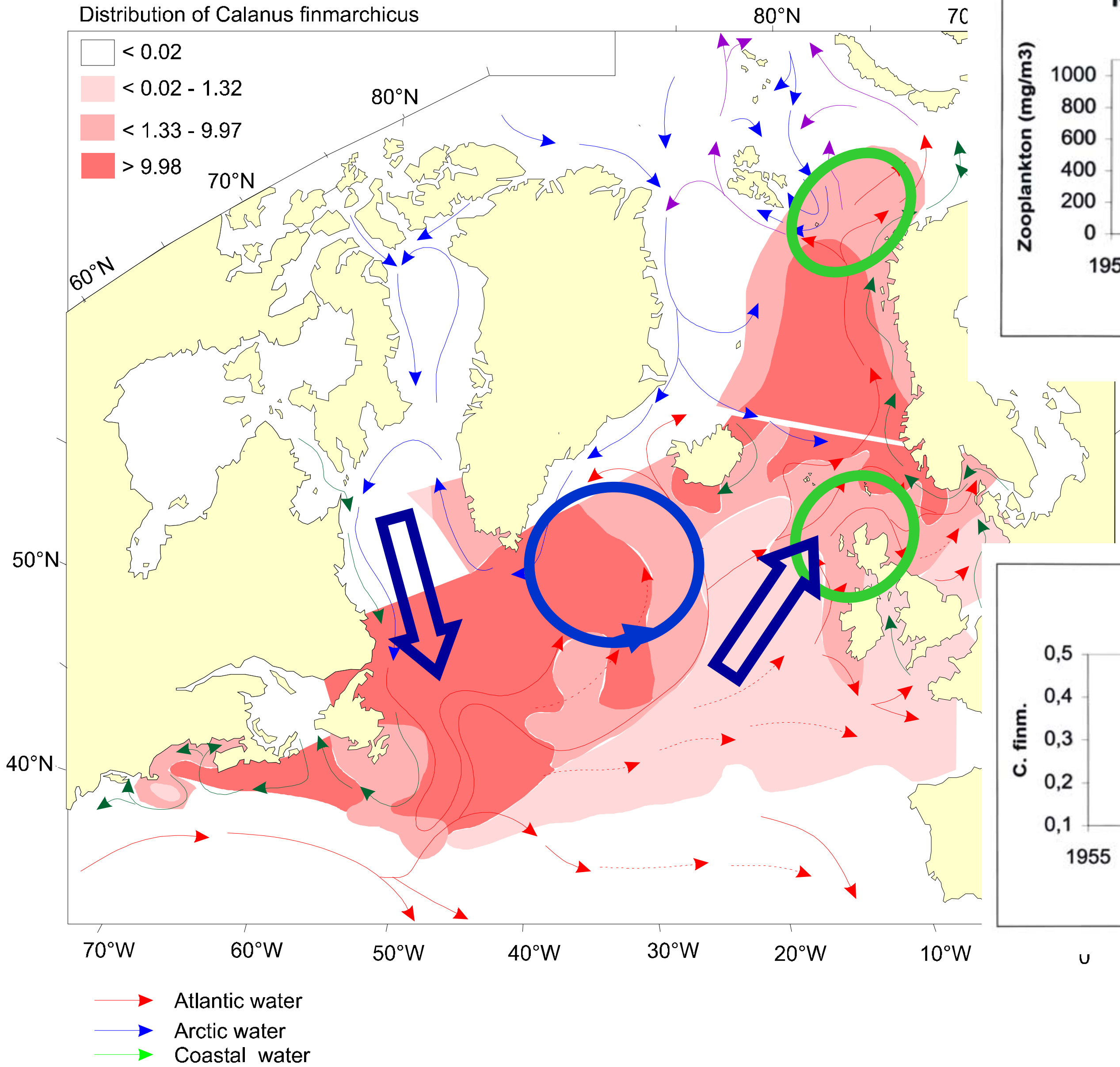
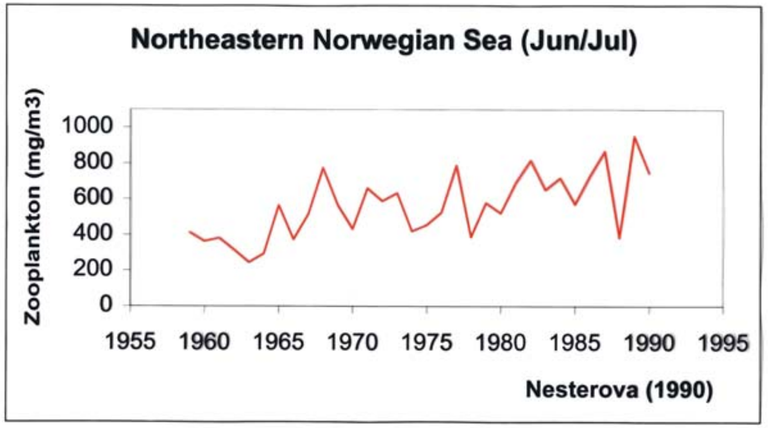
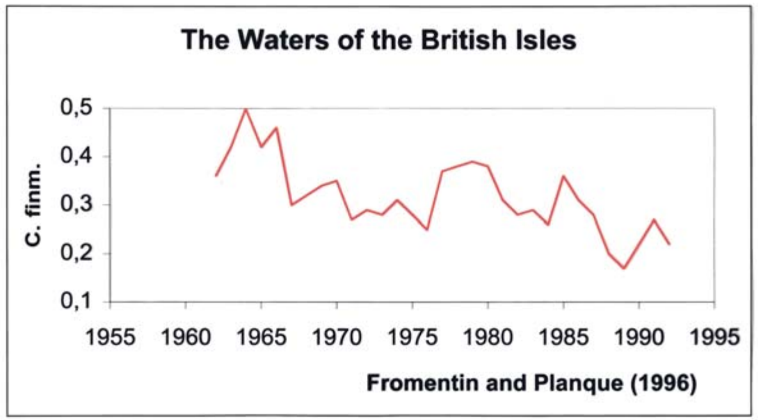
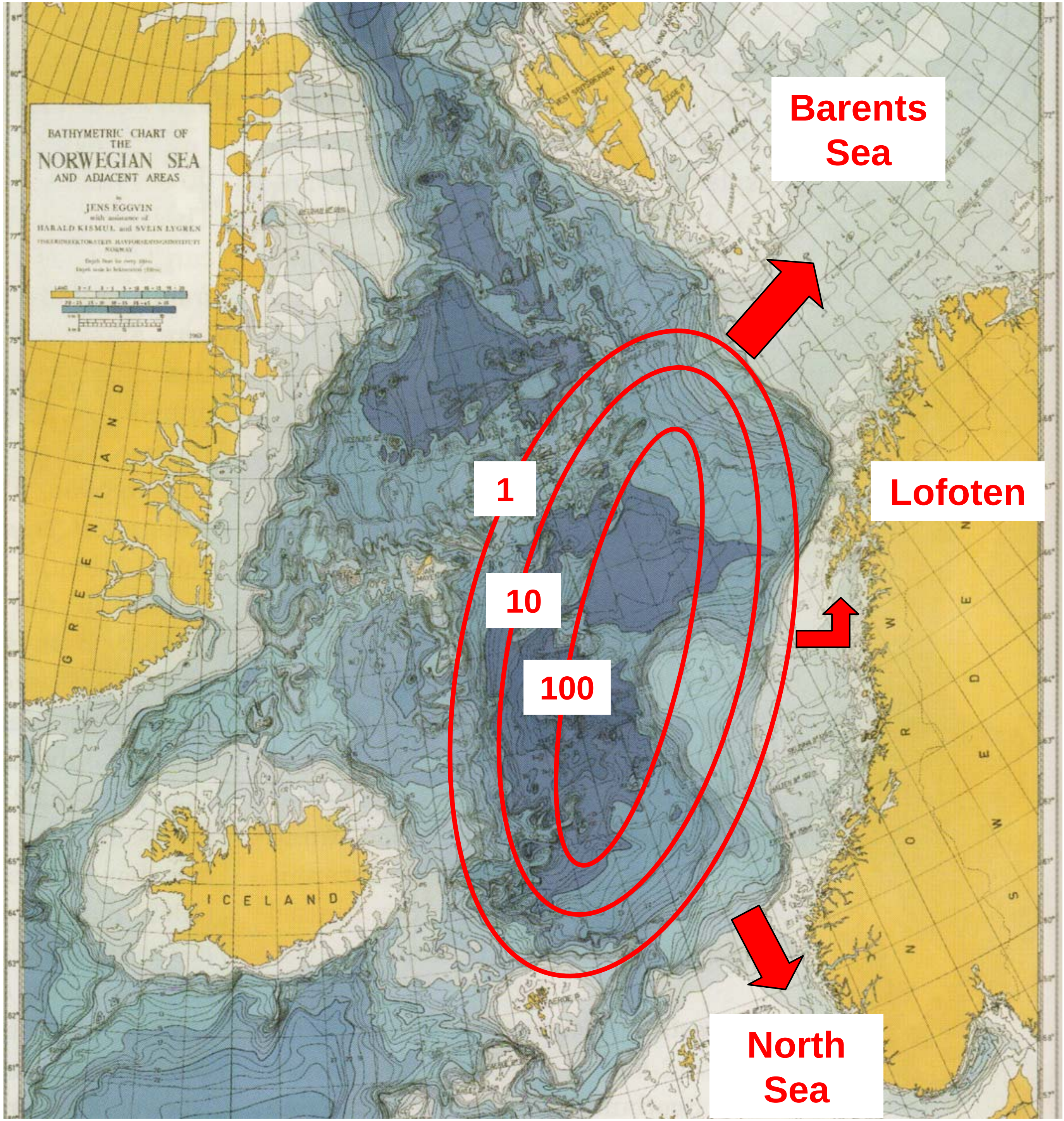
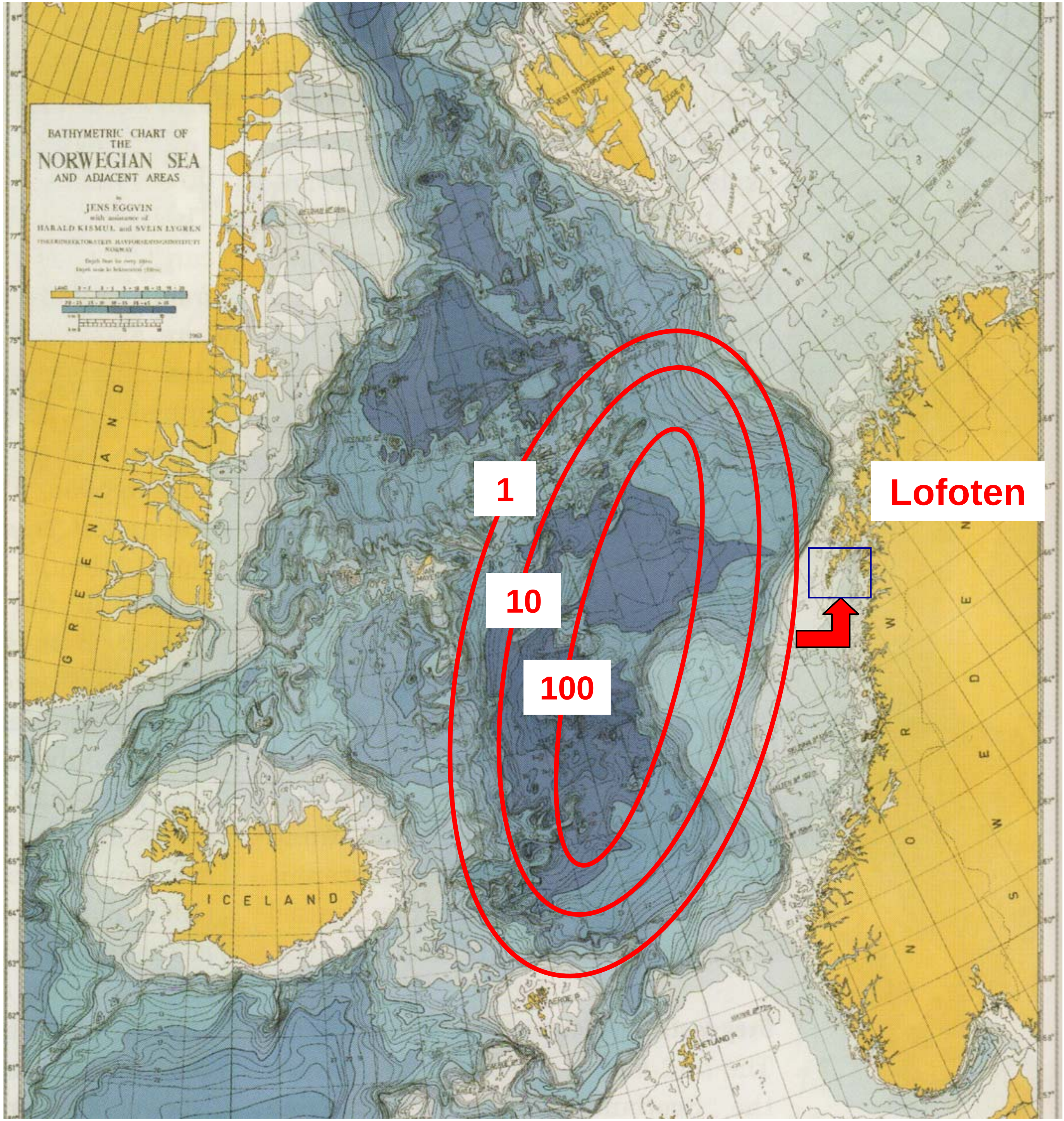







BATHYMETRIC CHART OF THE
NORWEGIAN SEA
AND ADJACENT AREAS
JENS EGGVIN
HARALD KISMUL and SVEIN LYGREN
GREENLAND
ICELAND
Barents Sea
Lofoten
North Sea
1
10
100


BATHYMETRIC CHART OF THE
NORWEGIAN SEA
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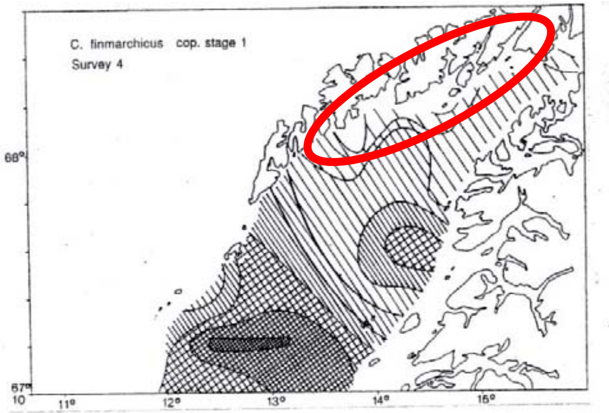
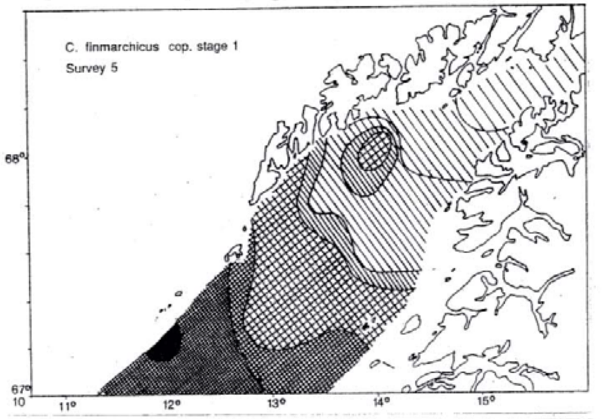
JENS EGGVIN
HARALD KISMUL and SVEIN LYGREN
1
10
100
Lofoten
ICELAND

Calanus finmarchicus
Cop. Stage 1

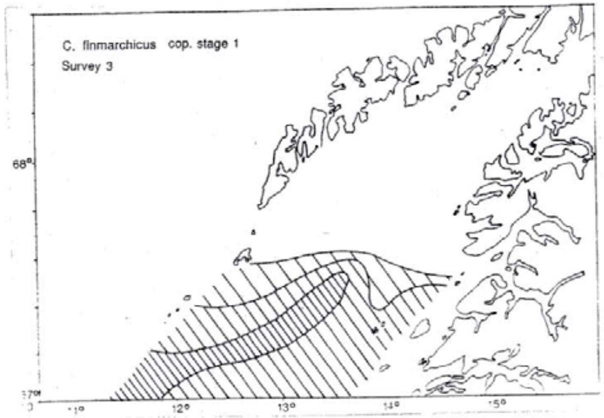


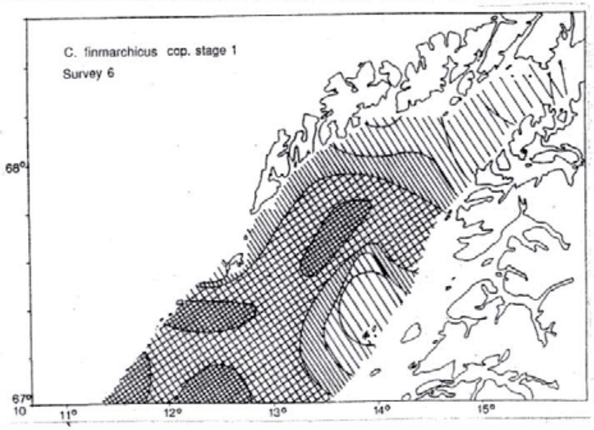
9 –13 April



14-20 April

25-28 March

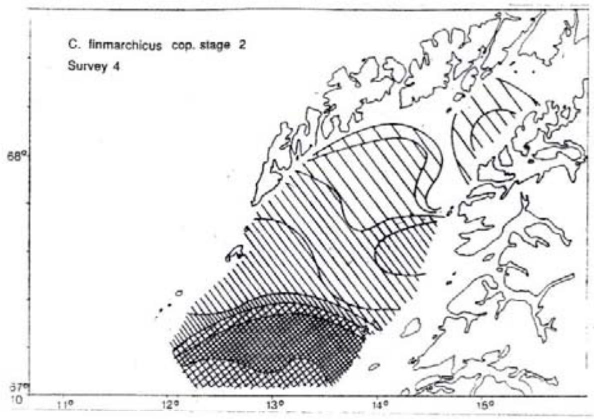




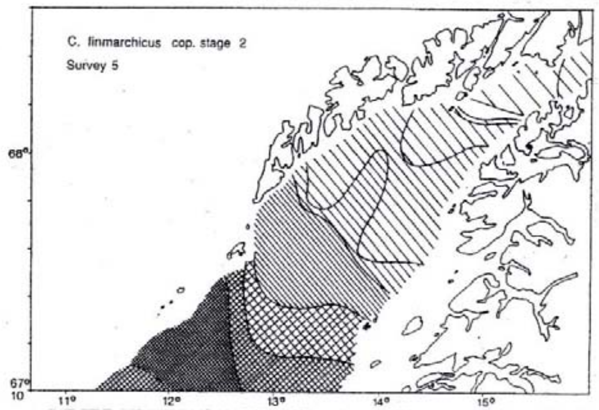
20-26 April

Ellertsen and Sundby (ECONORTH symp March 2007)

Calanus finmarchicus
Cop. Stage 2

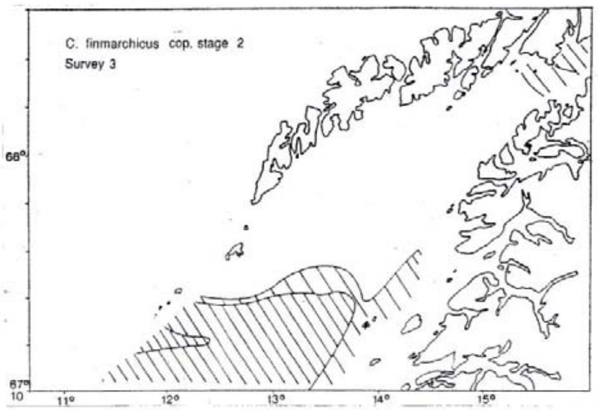


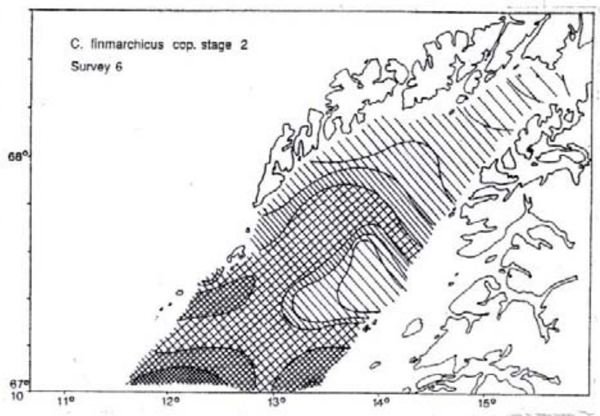
9 –13 April



14-20 April

25-28 March

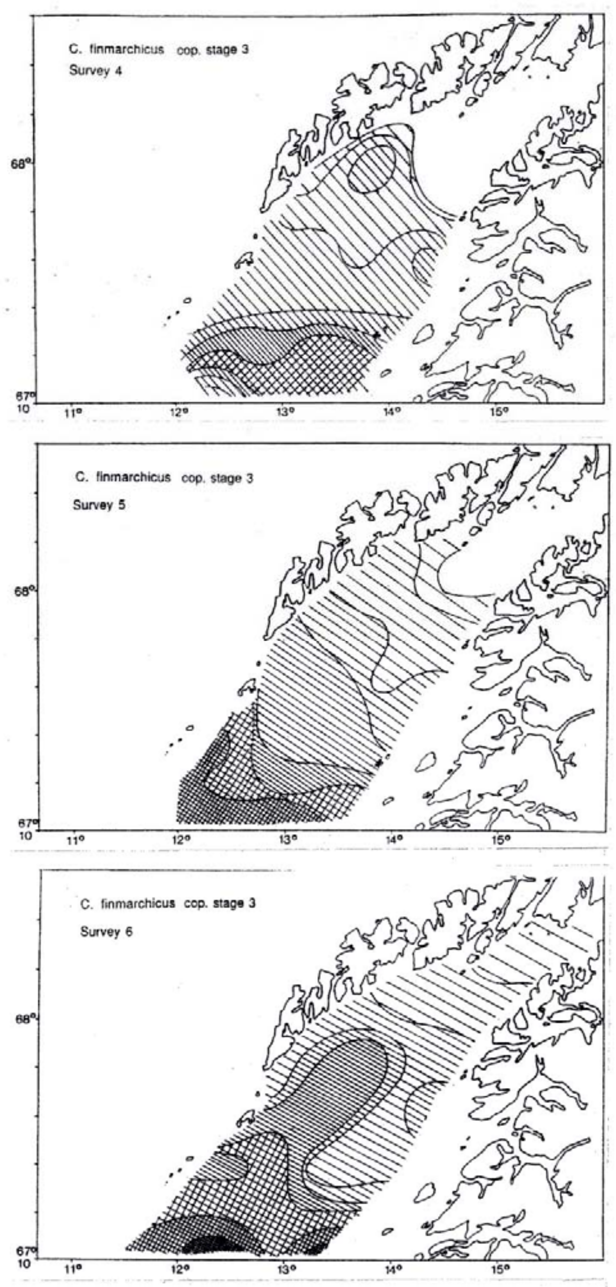




20-26 April

Ellertsen and Sundby (ECONORTH symp March 2007)

Calanus finmarchicus
Cop Stage 3

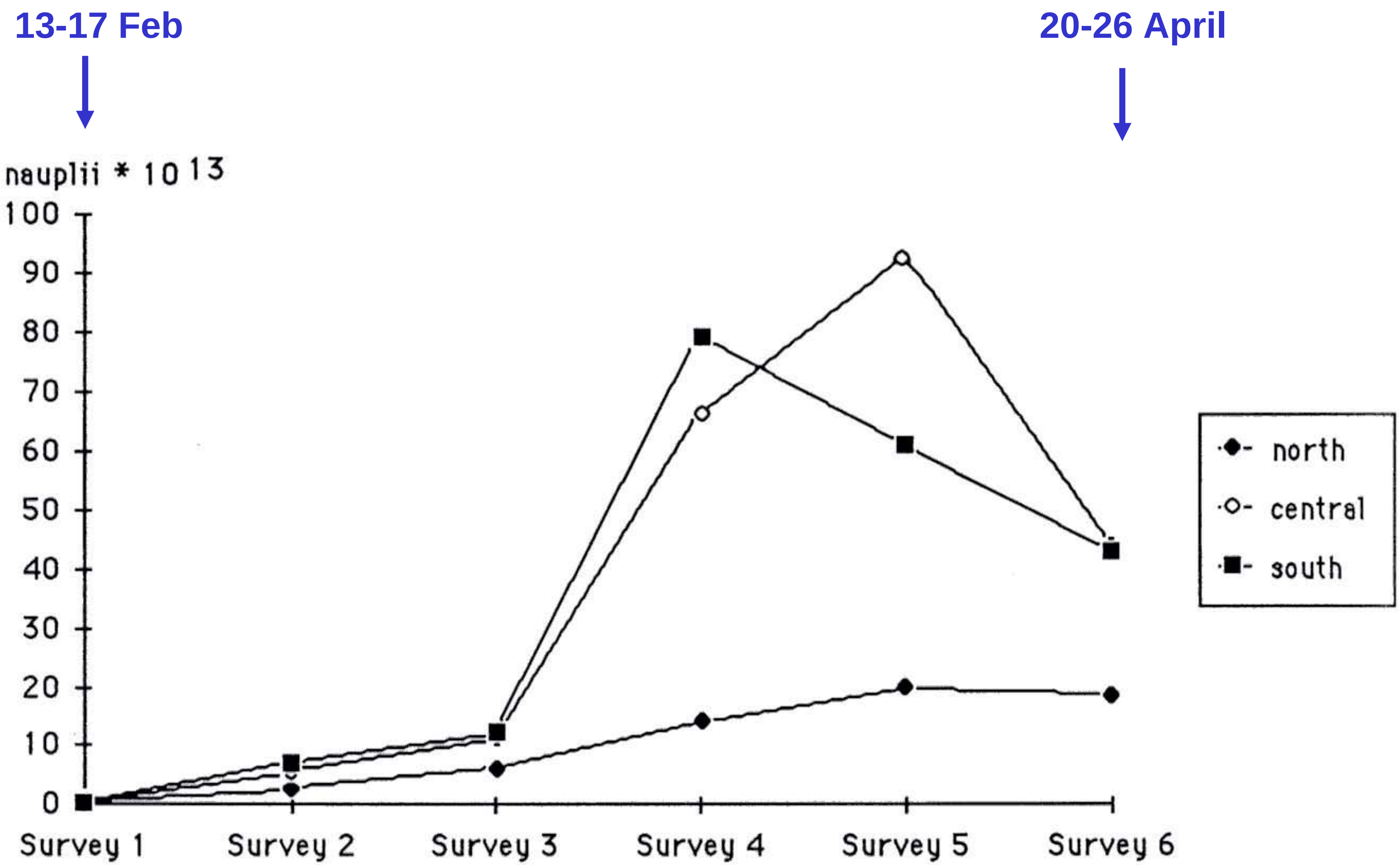


9 –13 April

14-20 April

20-26 April

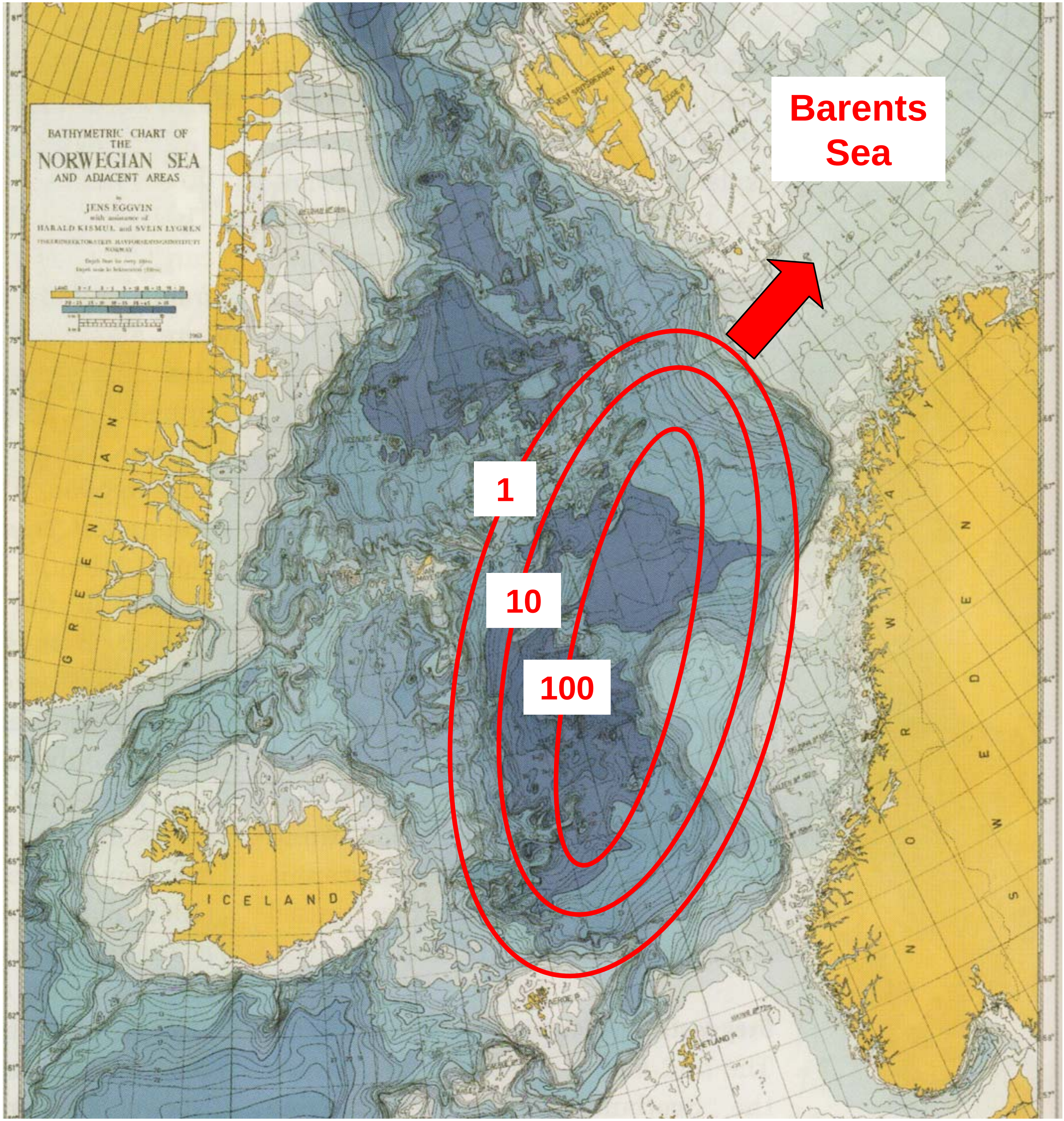
Ellertsen and Sundby (ECONORTH symp March 2007)



Abundance of nauplii in Vestfjorden during the period 12 Feb-28 April 1987. Vestfjorden south = 67°10′- 67°30′, central = 67°30′ - 68°00′, and north = north of 68°00′N

Ellertsen and Sundby (ECONORTH symp March 2007)

ECOBE


BATHYMETRIC CHART OF THE NORWEGIAN SEA AND ADJACENT AREAS
JENS EGGVIN
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GREENLAND
ICELAND
Barents Sea
1
10
100

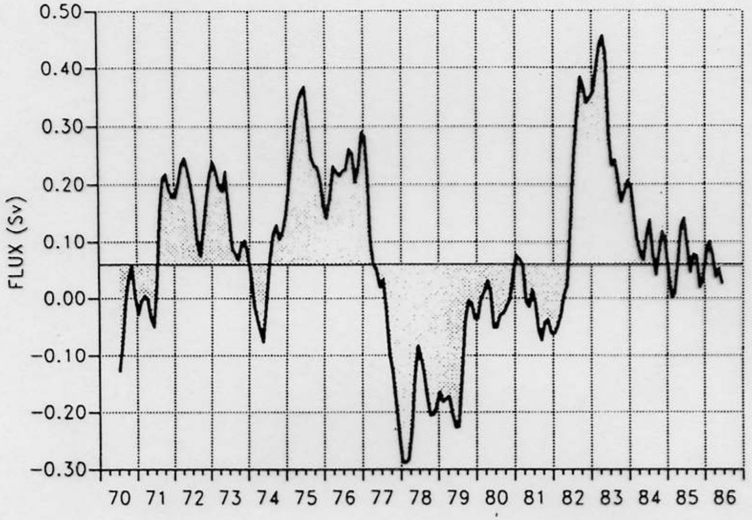


Fig. 3. The moving one-year average of monthly values of computed atmospherically driven volume flux through the Fugløya-Bjørnøya, section, 1970–1986.

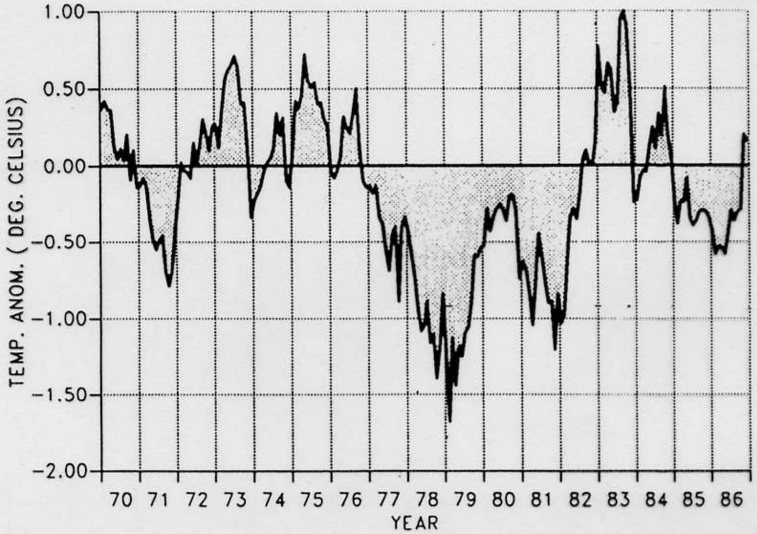


Fig. 5. Monthly temperature anomalies from the Kola section, 1970–1986.

Volume flux variation in/out of the Barents Sea

Temperature variations in the Barents Sea

Ådlandsvik and Loeng (1991)

Zooplankton abundance and the abundance pelagic juvenile cod in the western Barents Sea

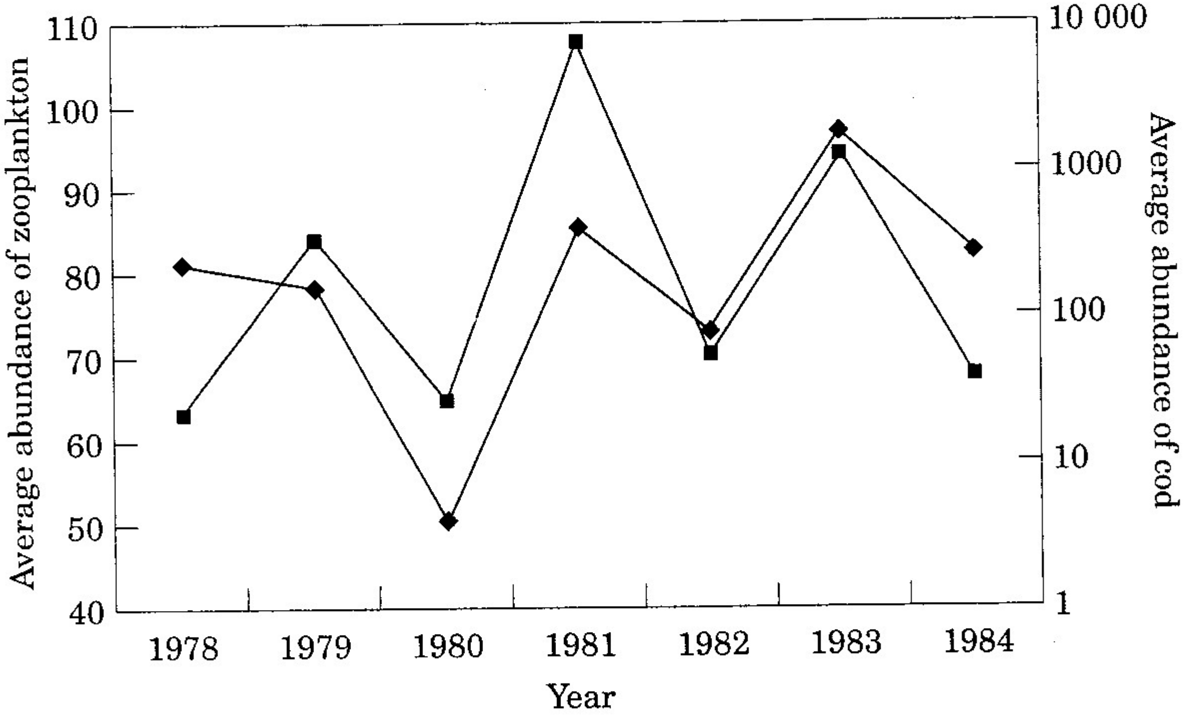
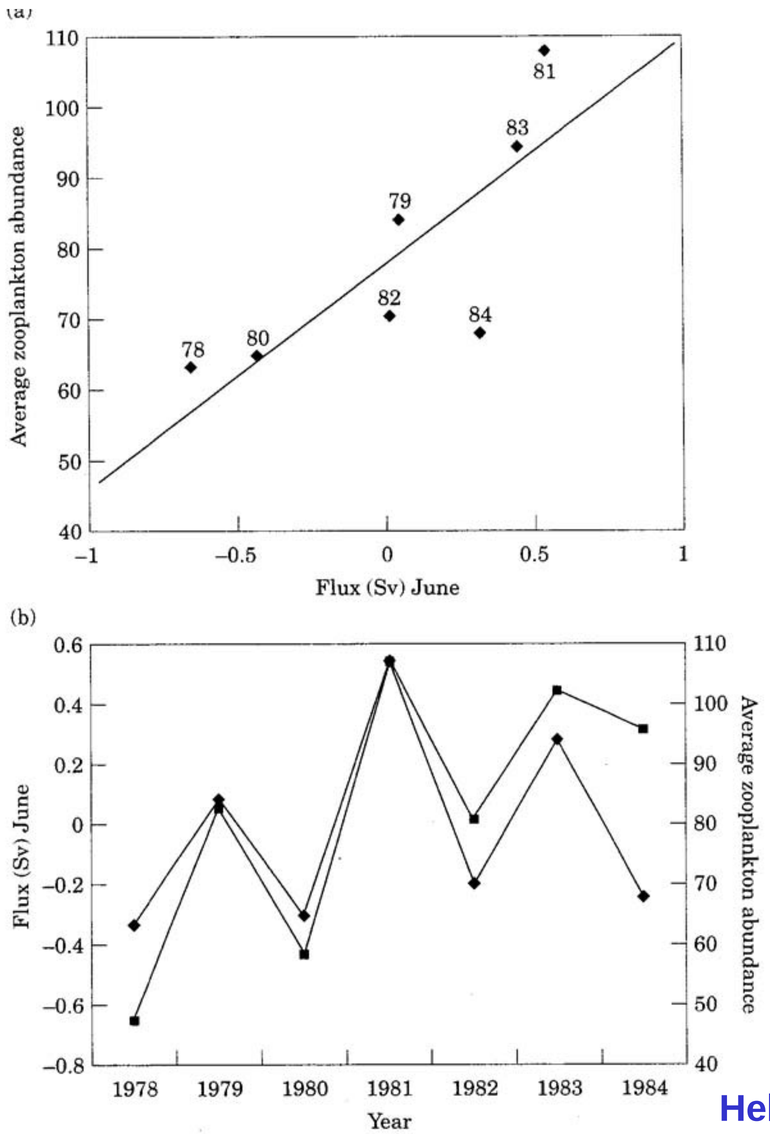


Figure 4. Average abundance of zooplankton (ml m^{-2}, squares) and the log of the average abundance of early juvenile cod (number per trawl hour, diamonds) during the period 1978–1984 in the entire survey area.

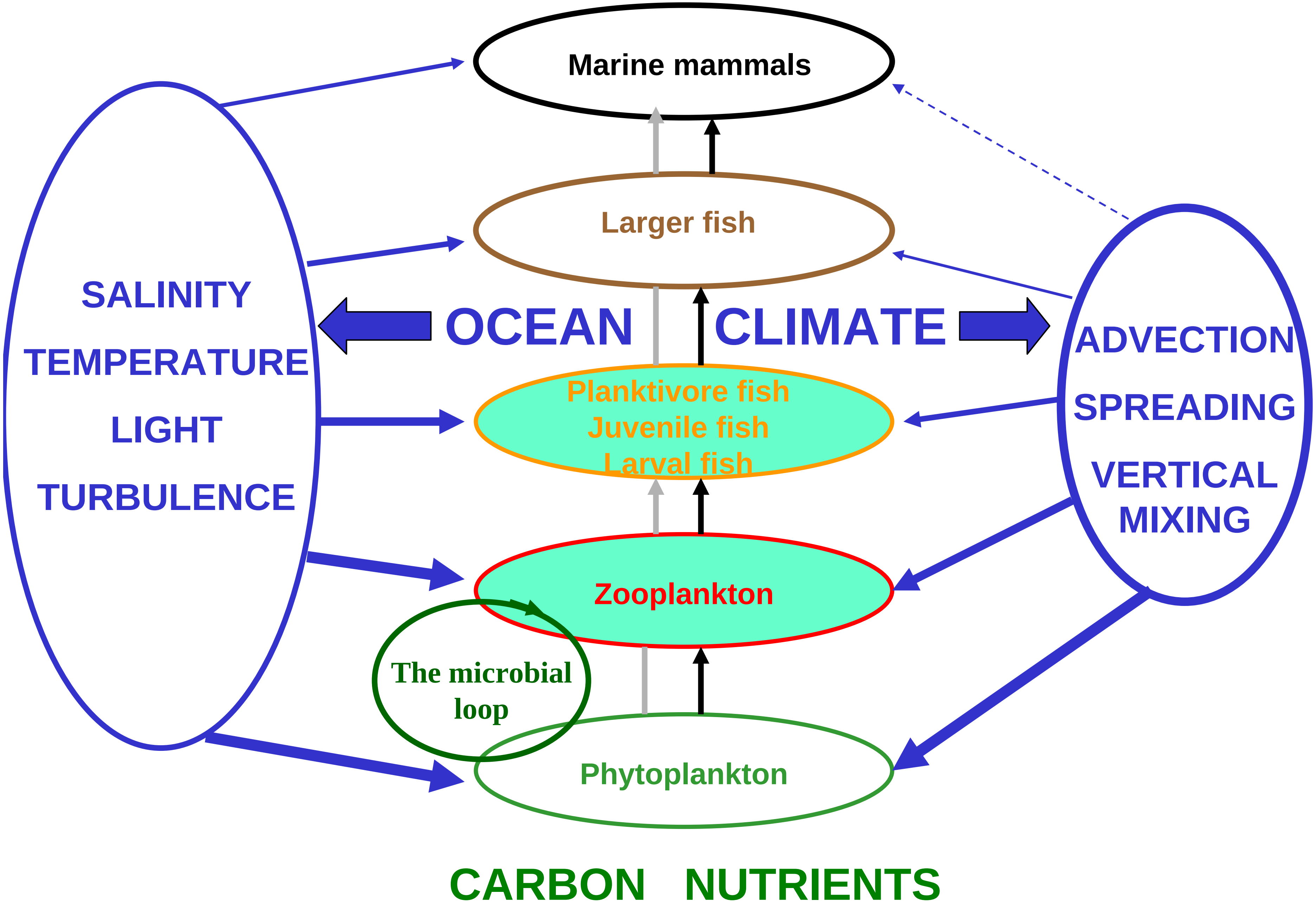
Helle and Pennington (1999)

Correlation between flux variations and zooplankton abundance at the fringe the core production area of *C.finmarchicus*



Helle and Pennington (1999)

Figure 5. (a) Average abundance of zooplankton (ml m^{-2}) vs. flux (Sv) in June through the section from Fugløya to Bear Island. The straight line is the least squares regression line ($y=77.7+29.5x$, $r^2=65\%$). (b) The average abundance of zooplankton (diamonds) and flux (squares) vs. year.



Marine mammals
Larger fish
SALINITY
TEMPERATURE
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TURBULENCE
OCEAN
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Planktivore fish
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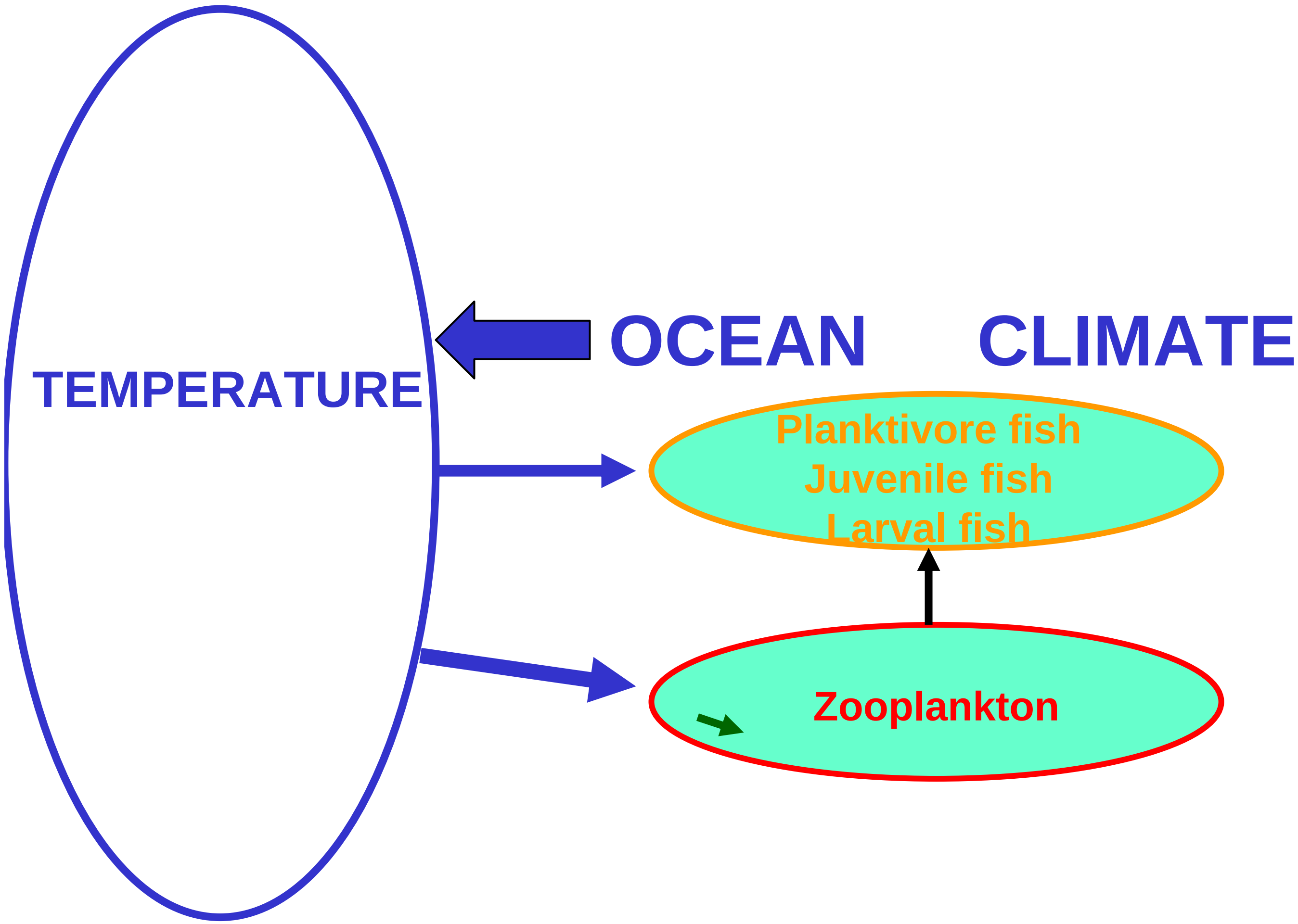
CARBON NUTRIENTS


OCEAN CLIMATE
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Planktivore fish
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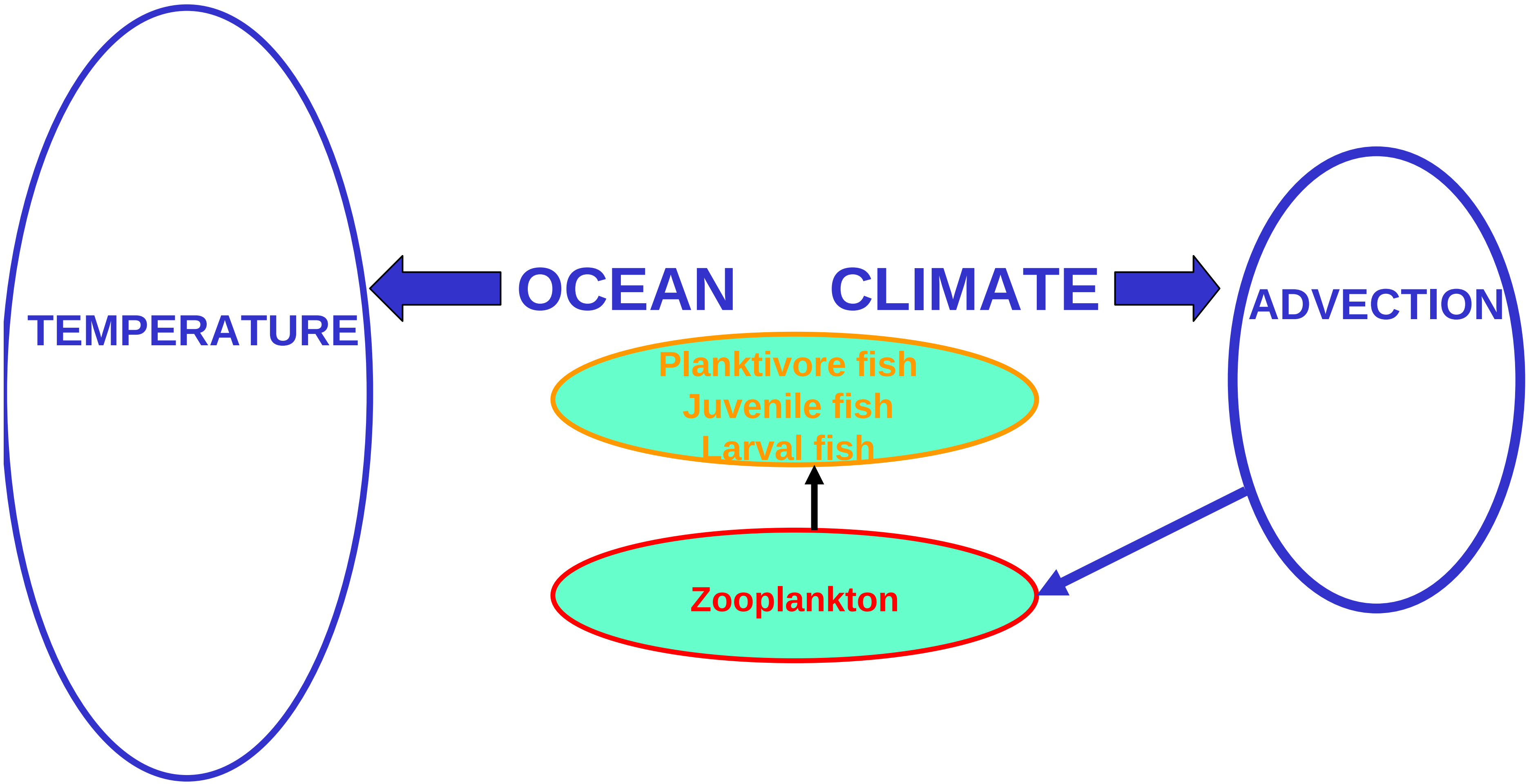

OCEAN CLIMATE
TEMPERATURE
ADVECTION
Planktivore fish
Juvenile fish
Larval fish
Zooplankton

The opposite effects of climate change in the arcto-boreal ecosystem of the Barents Sea and the boreal- temperate ecosystem of the North Sea

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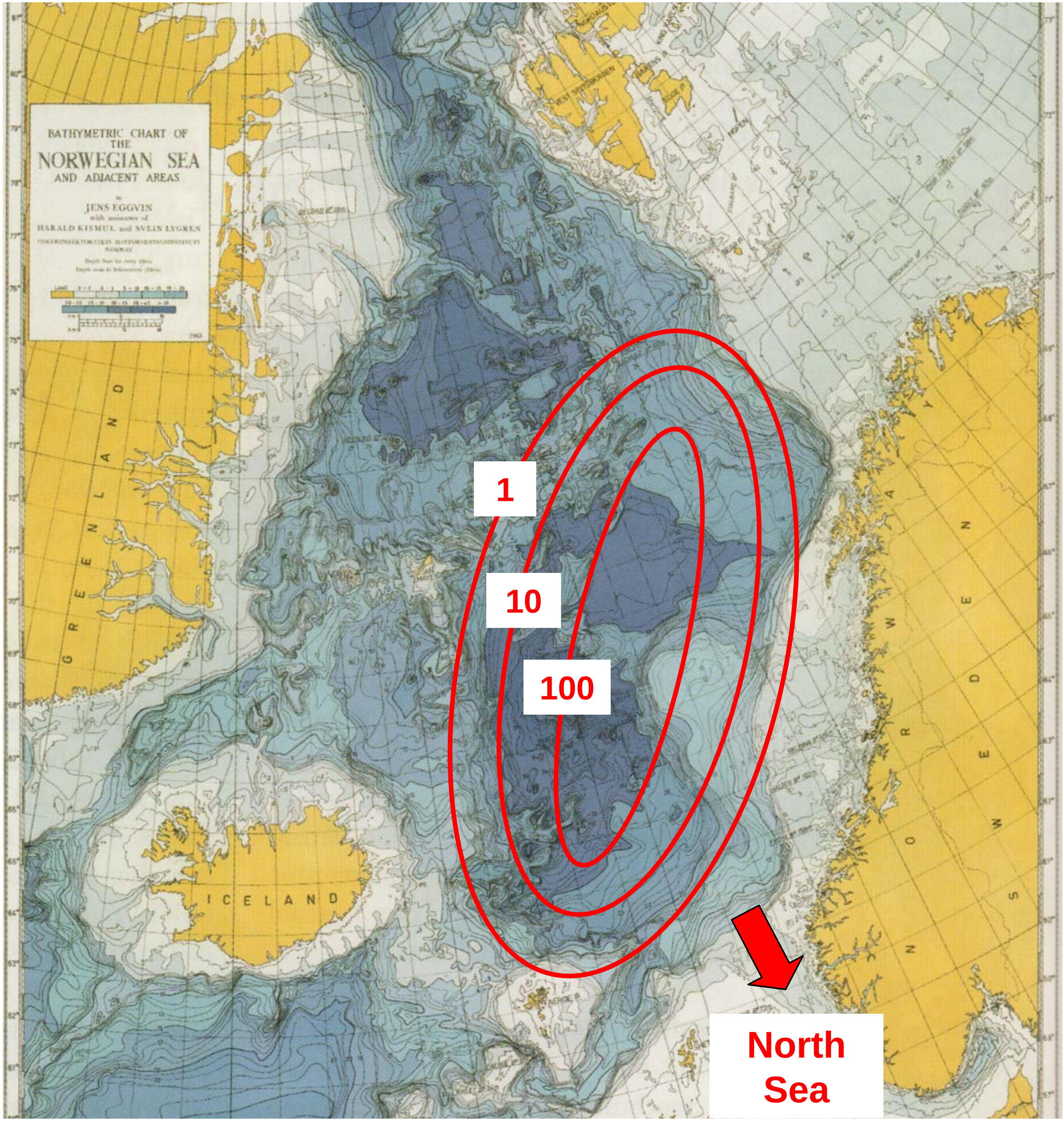
BATHYMETRIC CHART OF THE NORWEGIAN SEA AND ADJACENT AREAS
JENS EGGVIN
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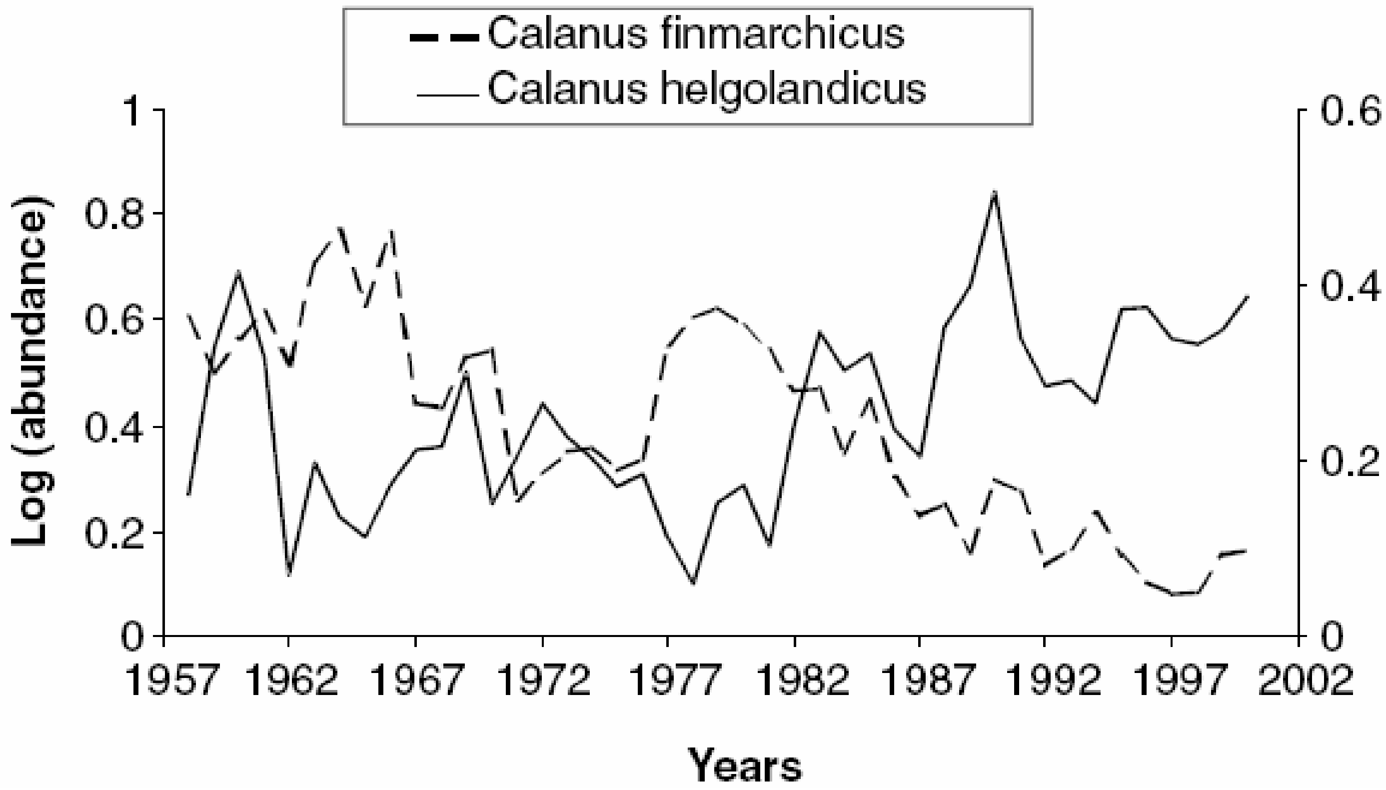
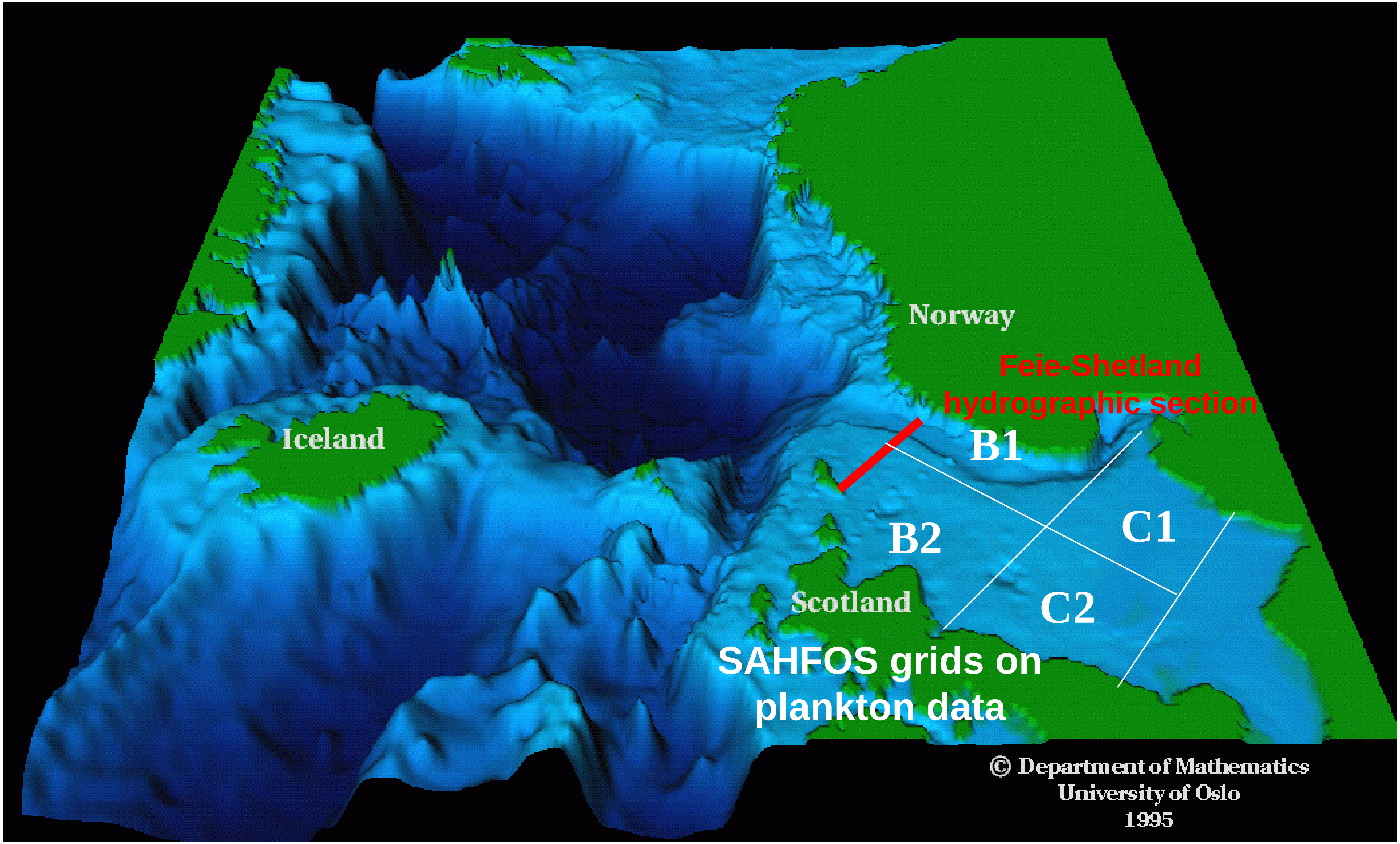
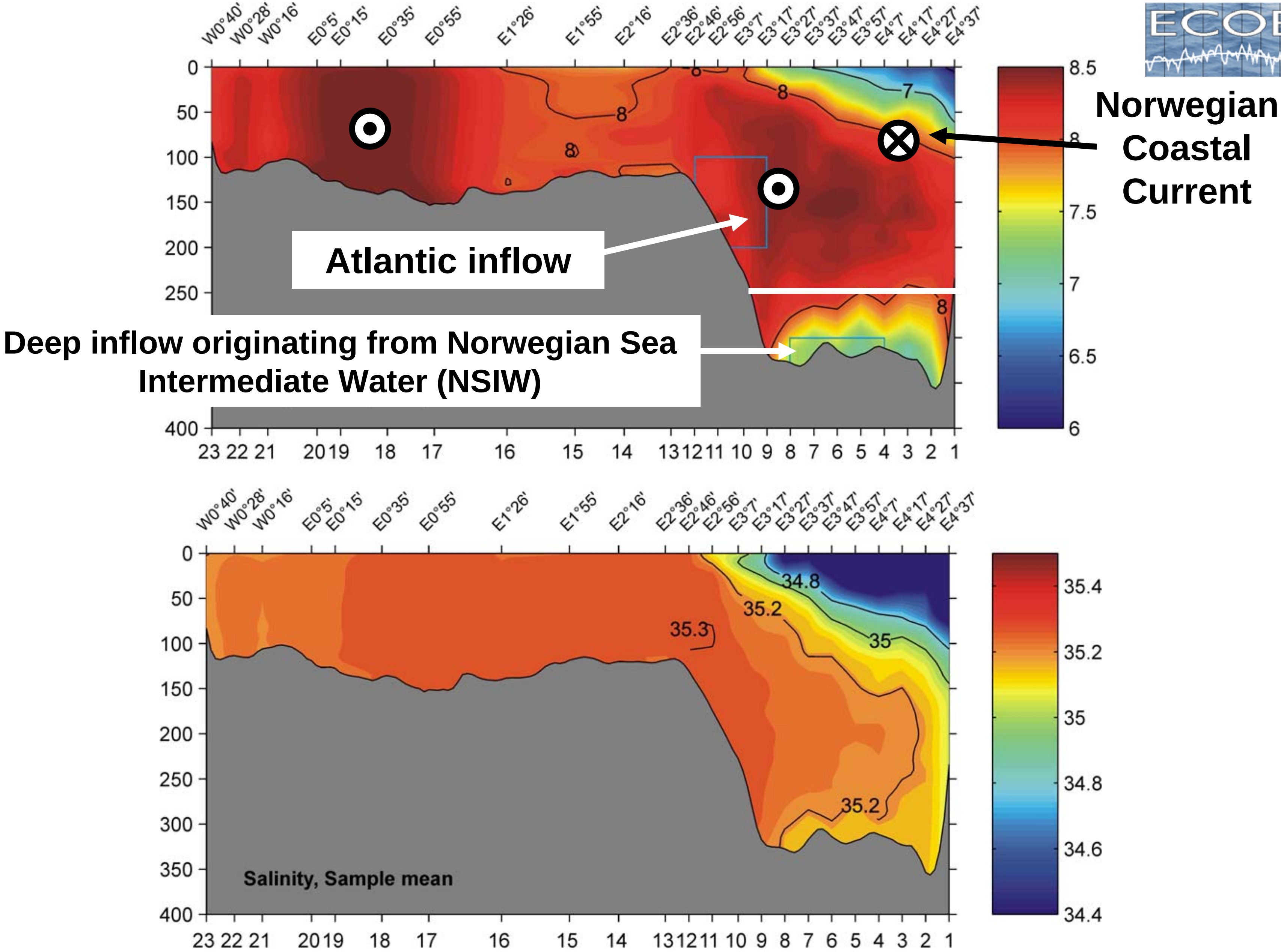
ICELAND
NORWEGEN
1
10
100
North Sea

Figure 2. Graphs of the log abundance of C. *finmarchicus* (solid line) and C. *helgolandicus* (dashed line) averaged for the North Sea over the period 1958–2000.



Reid *et al.* (2002)


Norway
Feie-Shetland
hydrographic section
B1
Iceland
C1
B2
Scotland
C2
SAHFOS grids on
plankton data
© Department of Mathematics
University of Oslo
1995



FEIE - SHETLAND section.1980-1999, Week 2-6.

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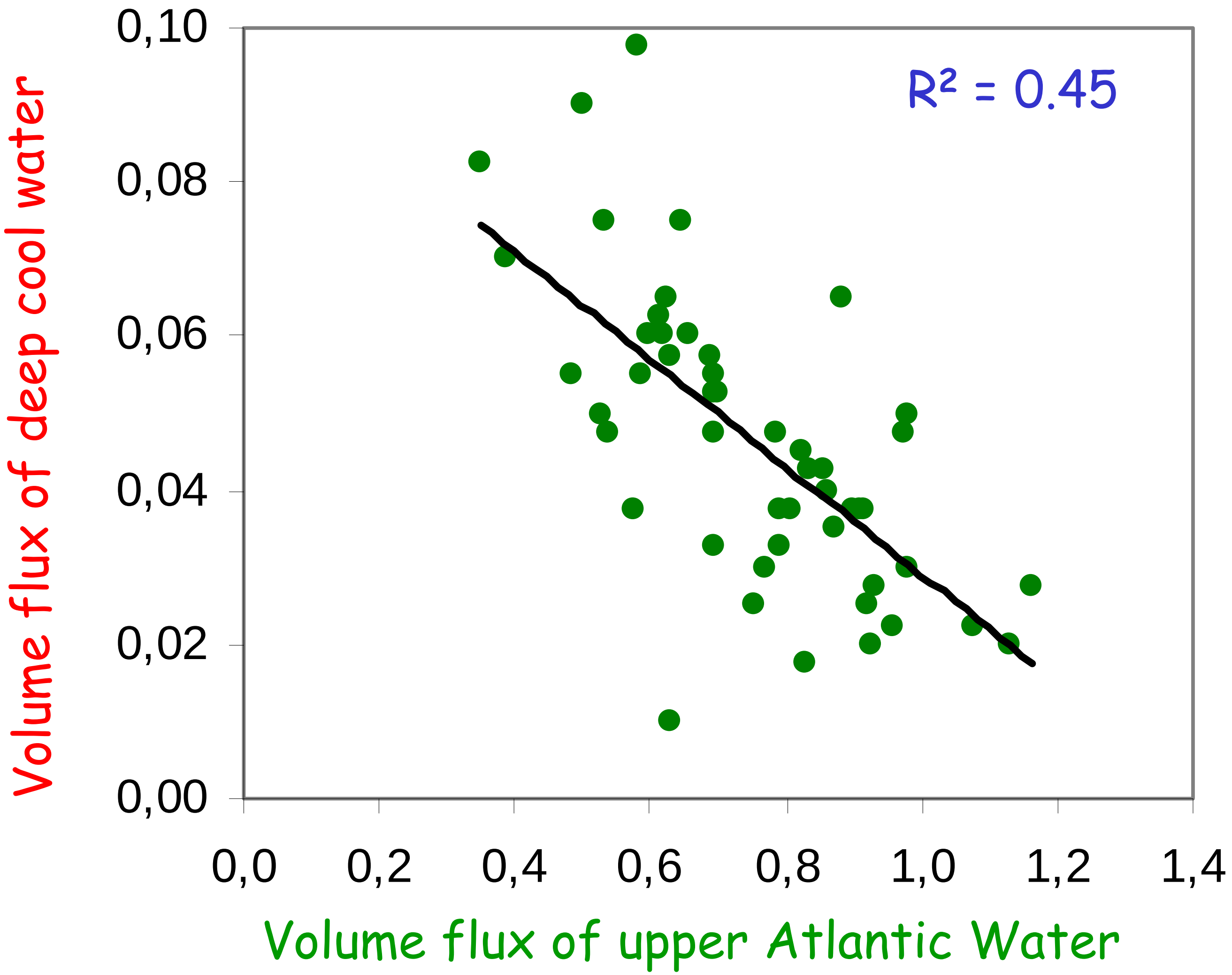
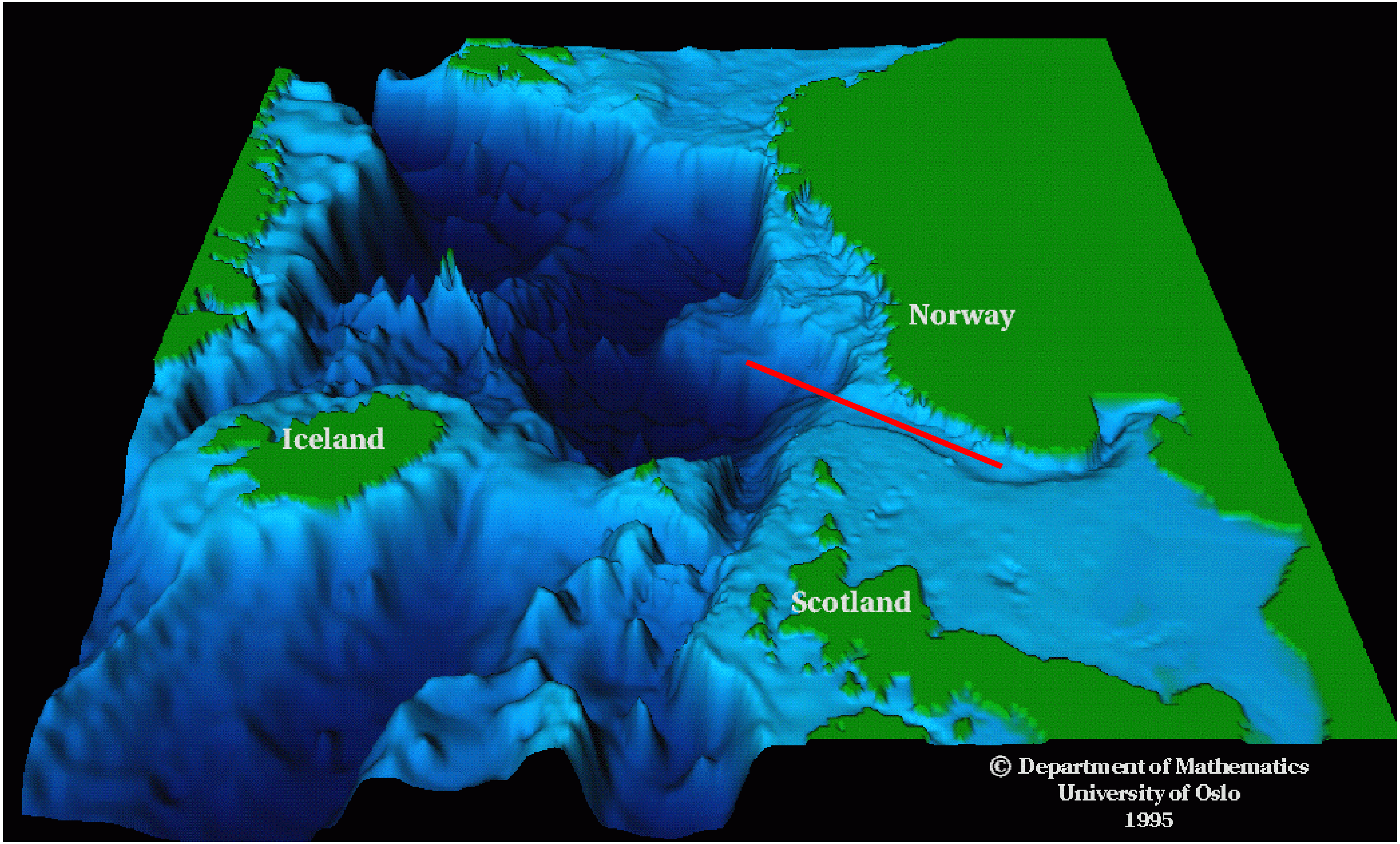
Inflow through the Norwegian Trench into the North Sea




Norway
Iceland
Scotland
© Department of Mathematics
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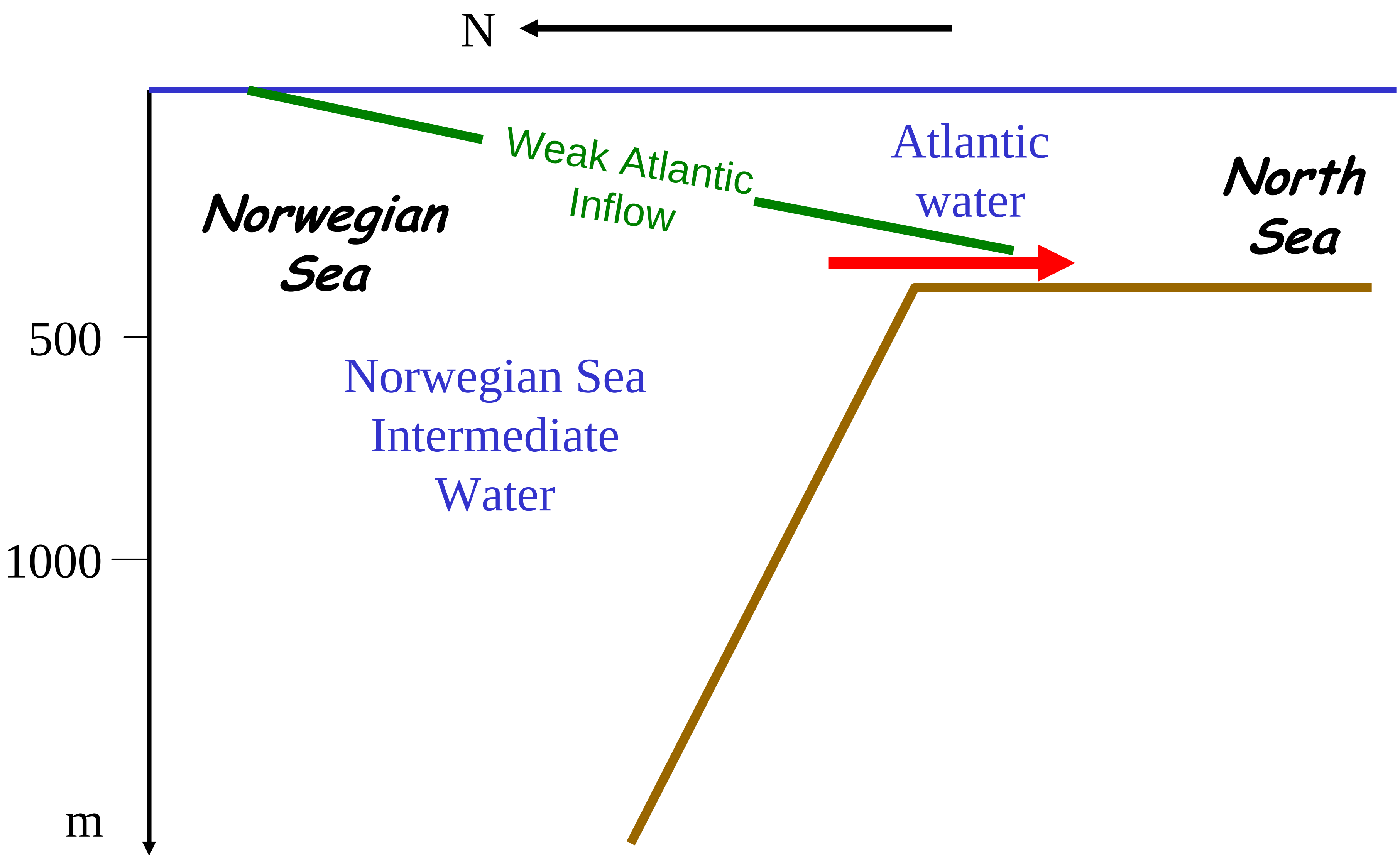
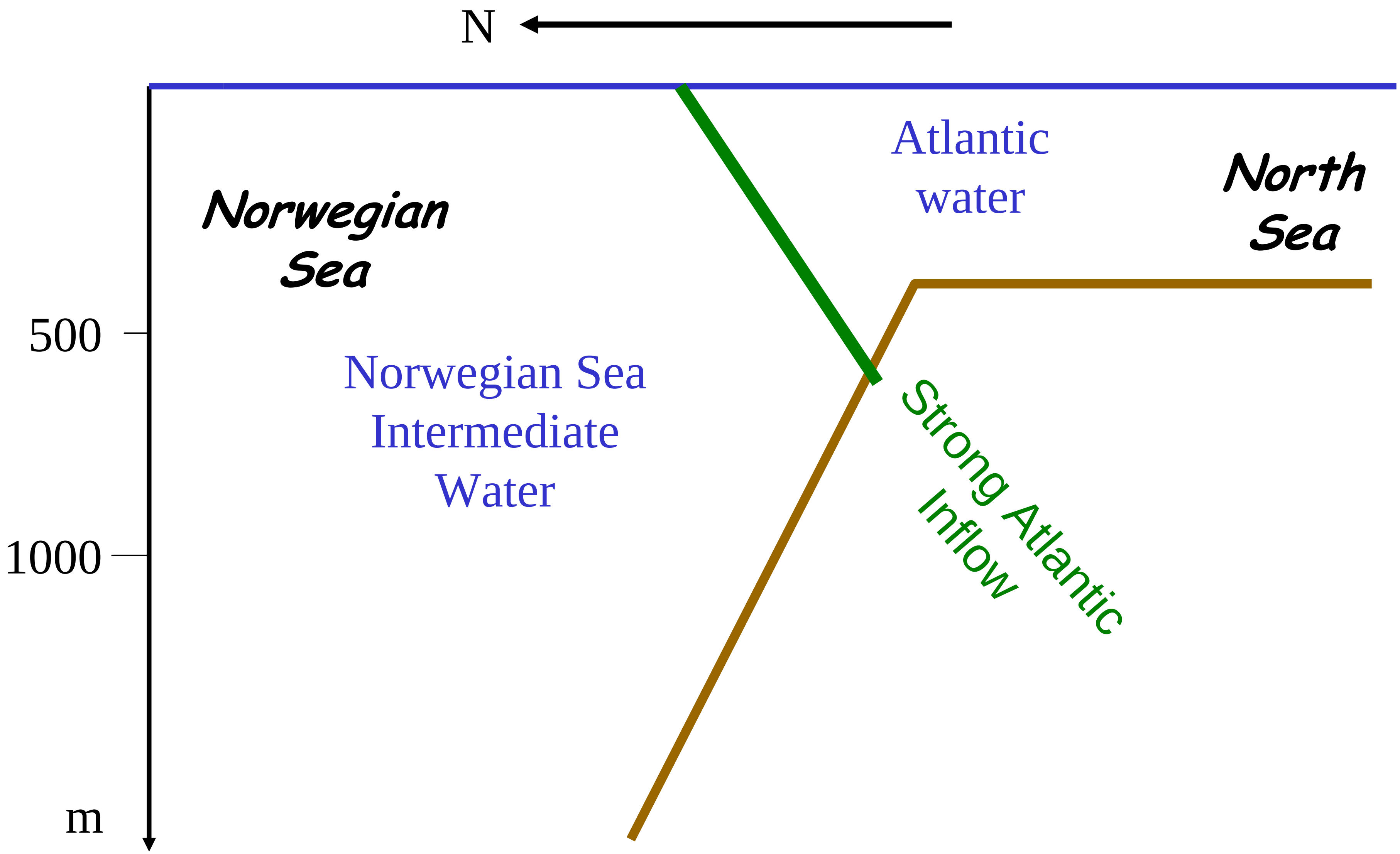
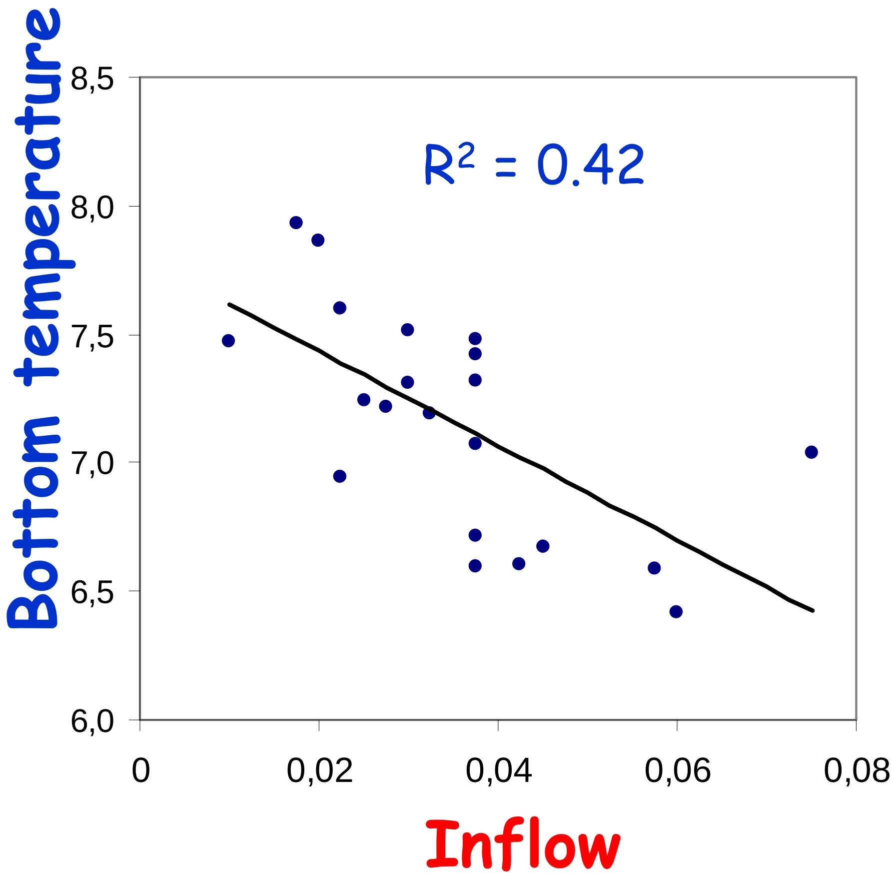
1995

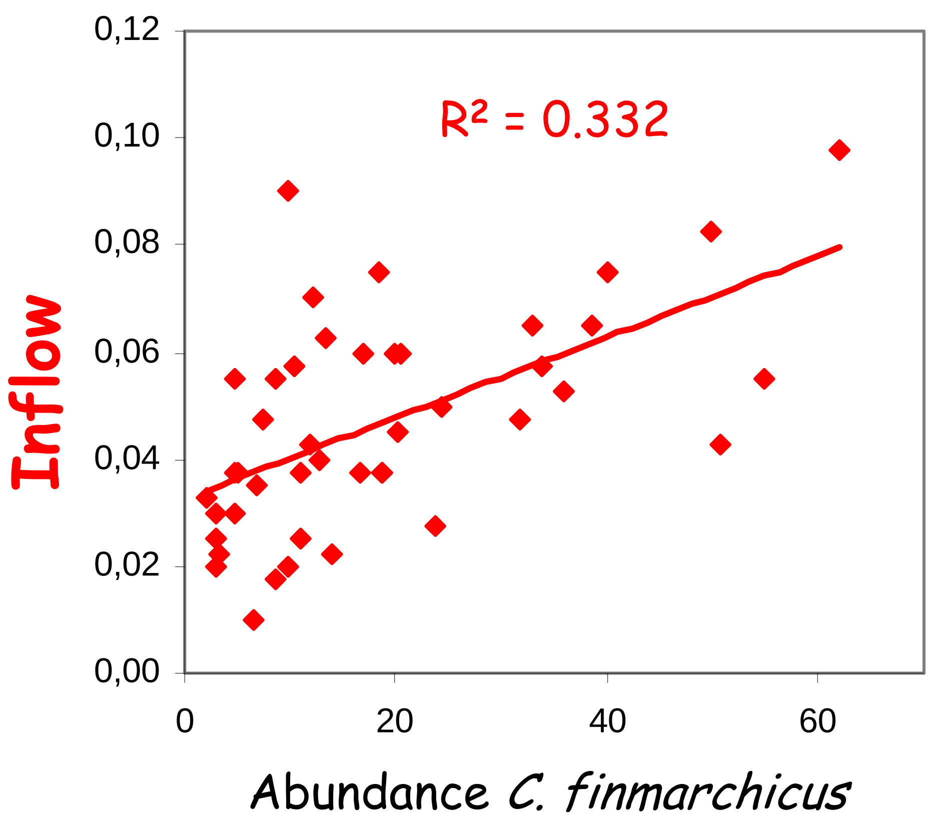

N
Weak Atlantic
Inflow
Atlantic
water
Norwegian
Sea
North
Sea
500
1000
m
Norwegian Sea
Intermediate
Water

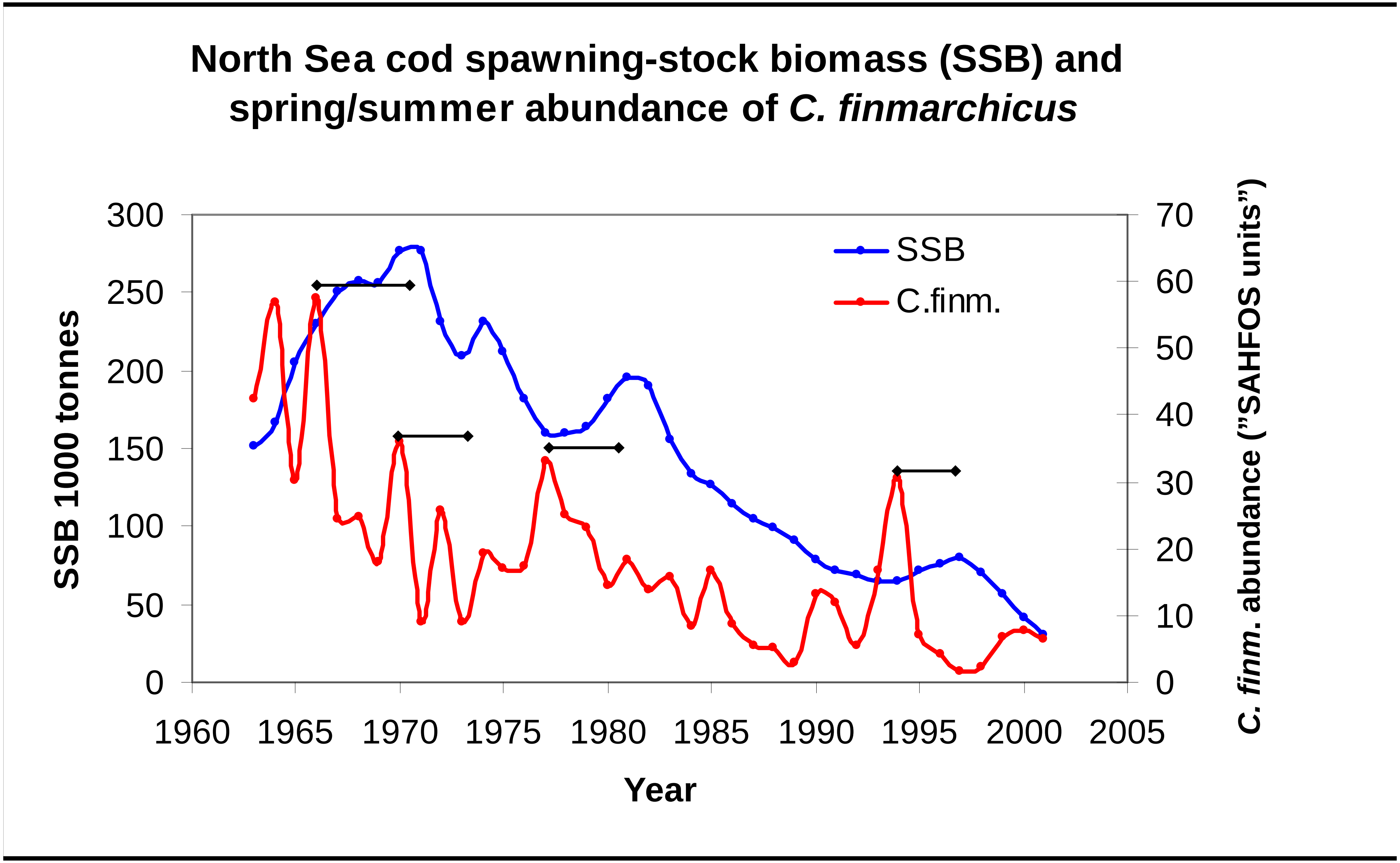

N
Norwegian Sea
Atlantic water
North Sea
500
1000
m
Norwegian Sea Intermediate Water
Strong Atlantic Inflow

Modelled inflow of deep water from the Norwegian Sea into the North Sea during winter
and
observed bottom temperature of the Norwegian Trench



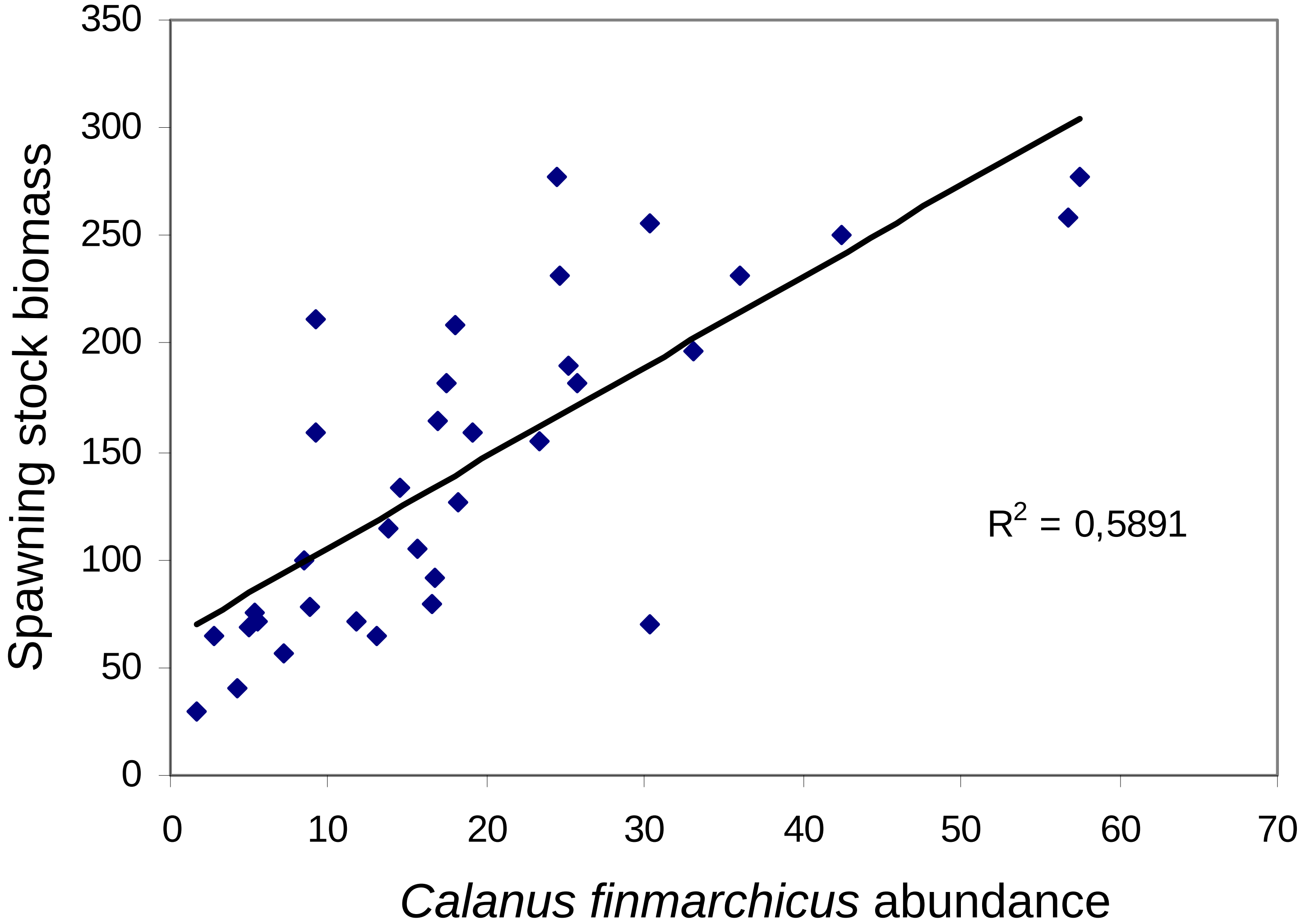
Observed abundance of *C. finmarchicus* in Northern North Sea during spring/summer
and
modelled inflow of deep water from the Norwegian Sea into the North Sea during winter

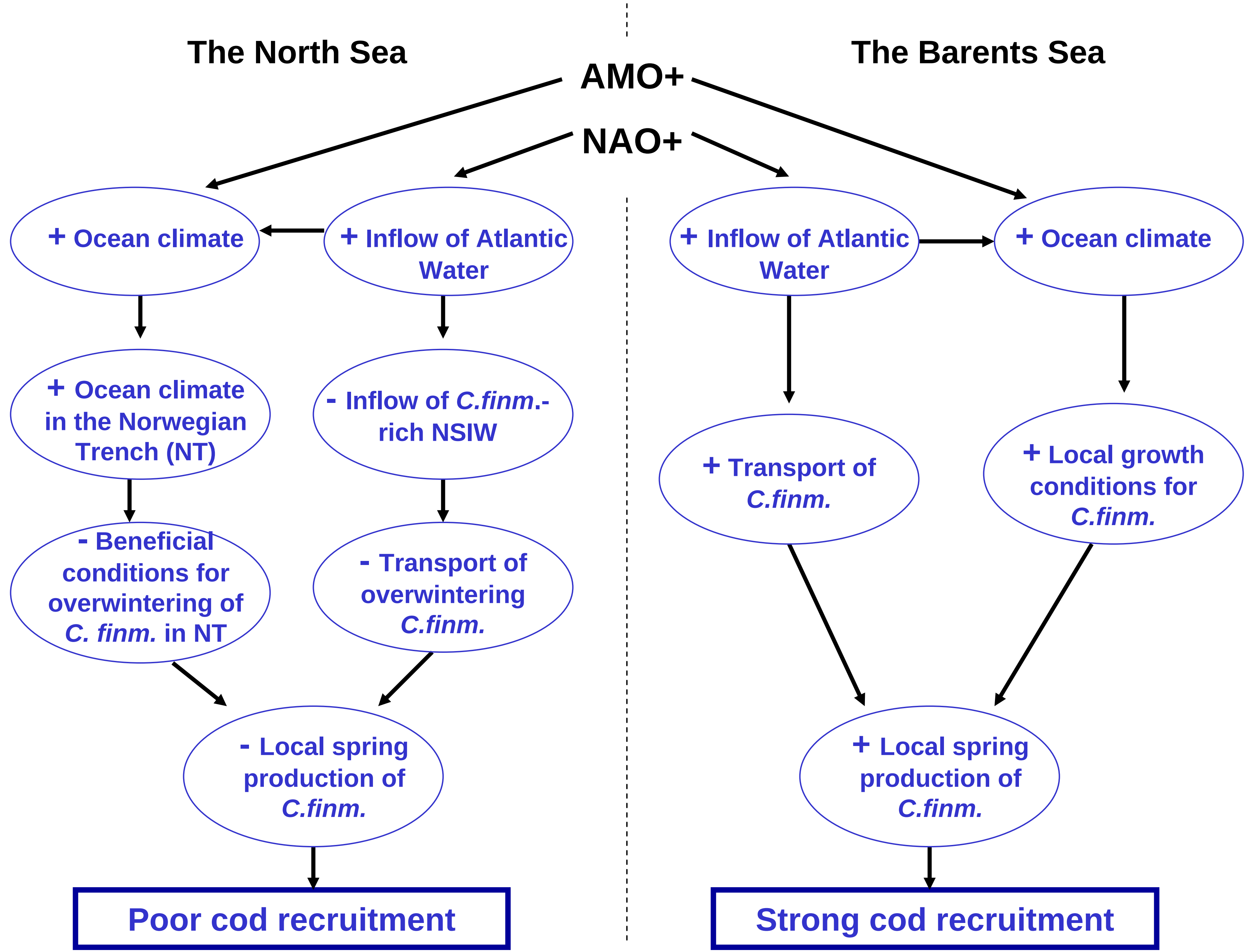




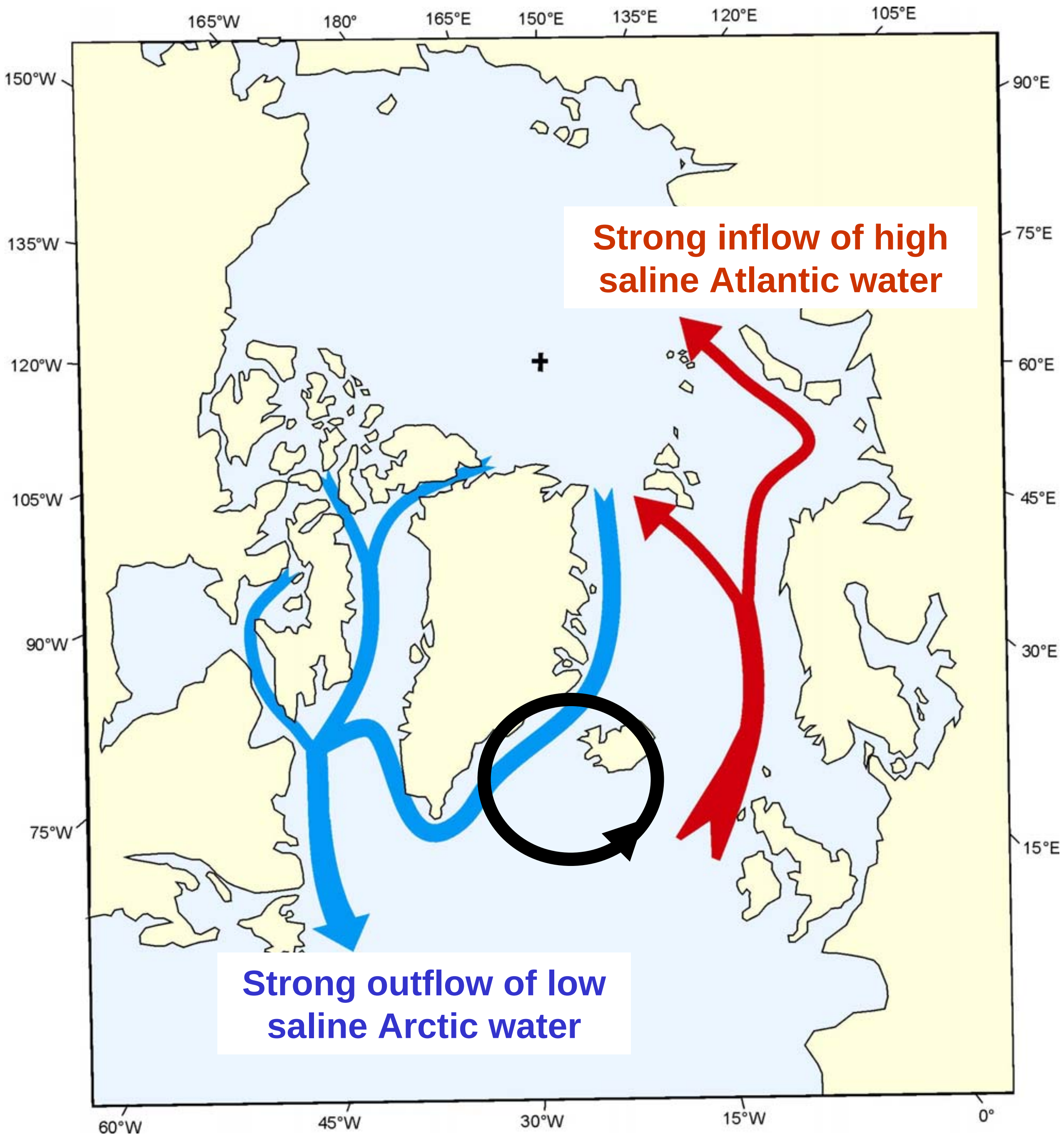
North Sea cod spawning-stock biomass (SSB) and spring/summer abundance of C. finmarchicus
SSB 1000 tonnes
300
250
200
150
100
50
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
70
60
50
40
30
20
10
0
C. finm. abundance ("SAHFOS units")
SSB
C.finm.

Abundance of *C. finmarchicus* in the northern North Sea (SAHFOS data) vs. the SSB of North Sea cod 4 years later



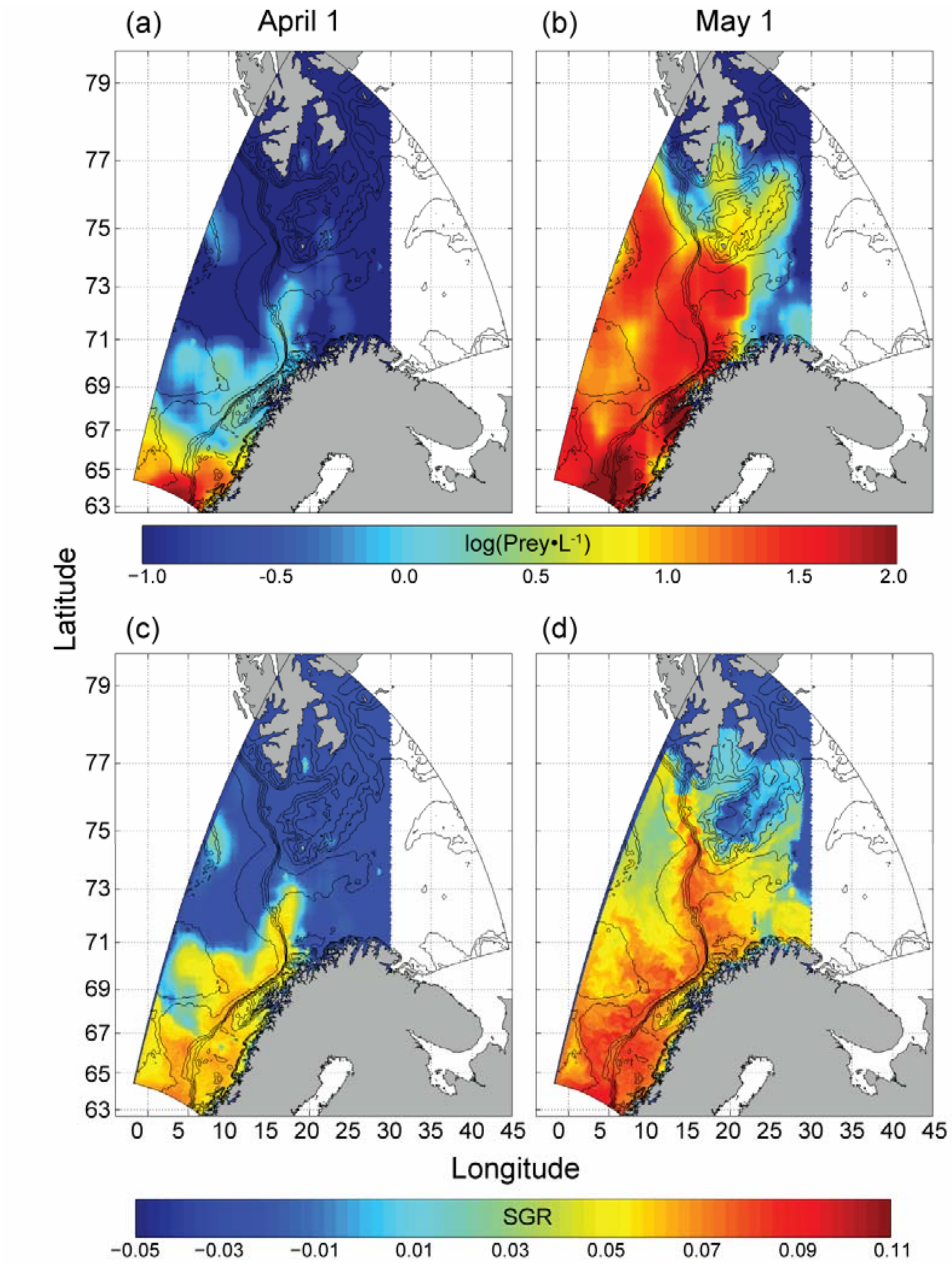


The North Sea
The Barents Sea
AMO+
NAO+
+ Ocean climate
+ Inflow of Atlantic Water
+ Inflow of Atlantic Water
+ Ocean climate
+ Ocean climate in the Norwegian Trench (NT)
- Inflow of C.finm.-rich NSIW
+ Transport of C.finm.
+ Local growth conditions for C.finm.
- Beneficial conditions for overwintering of C. finm. in NT
- Transport of overwintering C.finm.
- Local spring production of C.finm.
+ Local spring production of C.finm.
Poor cod recruitment
Strong cod recruitment



Sundby and Drinkwater (2007)

Coupled IBM+ROMS+zooplankton model



Prey distribution from zooplankton model

Growth of 5mm larvae

Questions

- Is the concept of <u>spatial</u> match-mismatch between larval and juvenile fish more important than the concept of <u>temporal</u> match-mismatch (synchrony)?

- Is recruitment variability in the Atlantic driven by the zooplankton level and not from the bottom?

Conclusions

• Climate have strong influences on marine ecosystems on interannual scale and on multidecadal scale

• Quantifying flux variability across the north Atlantic is key issue in understanding ocean climate influence on marine ecosystems

• IBM models must be forced by basin-scale hydrodynamic models of high resolution

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