

# Influence of climate change on POP dynamics

using Kings Bay (Svalbard) as a model fjord, representing a mini climatic scenario.

Funded by ConocoPhillips

Geir Wing Gabrielsen – Norwegian Polar Institute  
Katrine Borgå – Norwegian institute for Water Research



# Background for project

- Persistent Organic Pollutants (POPs)
  - Sources and properties
  - Why of interest in the Arctic?
- Uptake in marine food webs
  - Bioconcentration/biomagnification
  - Food web structure
- Relevance of climate change for exposure and food web accumulation of POPs
  - Present Project
    - Objective 1: Exposure
    - Objective 2: Biological pathways
    - Objective 3: Combine 1&2 to scenarios.
  - Project status

# PERSISTENT ORGANIC POLLUTANTS

- anthropogenic chemicals
- persistent (half life criteria, e.g., air  $t_{1/2} > 2$  days or found in remote locations far from source)
- bioaccumulative (criteria; BCF  $> 5000$ )
- toxic

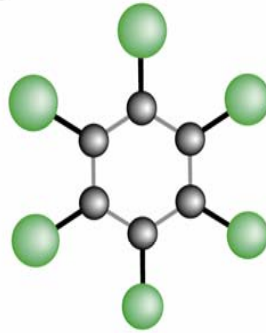
## UNECE "dirty 16" Persistent Organic Pollutants (POPs)

Chemicals (important Arctic contaminants in Red):

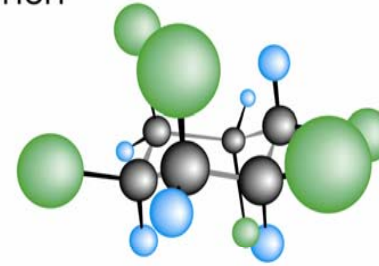
Aldrin	➔ Chlordane	Chlordecone
➔ DDT/DDE	Dieldrin	Endrin
➔ HCH / lindane	Heptachlor	Hexabromobiphenyl
➔ Hexachlorobenzene	Mirex	PAHs
➔ PCBs	PCDDs	PCDFs
toxaphene		

# HCB

HCB



$\alpha$ -HCH



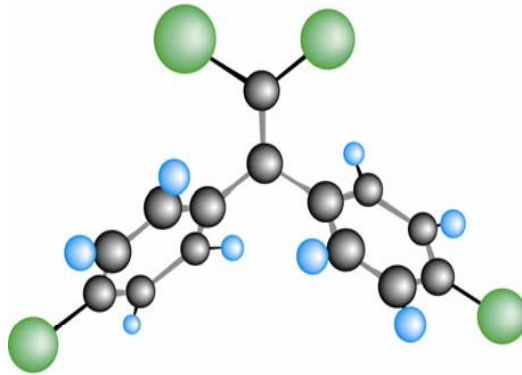
# HCHs

- $\alpha$ -HCH
- $\beta$ -HCH
- $\gamma$ -HCH

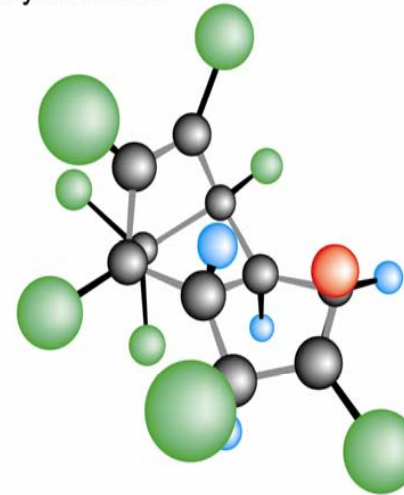
# DDTs

- p,p'*-DDE
- p,p'*-DDT
- p,p'*-DDD

*p,p'*-DDE



oxychlordanes



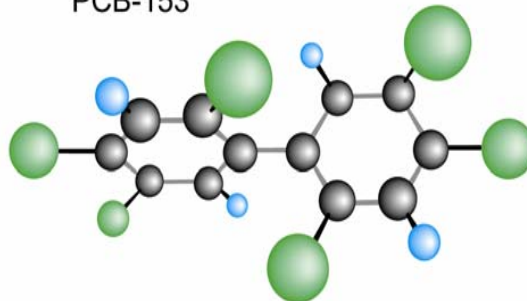
# Chlordanes

- cis*-chlordanes
- trans*-chlordanes
- trans*-nonachlor
- oxychlordanes

# PCBs

30 congeners

PCB-153



- Hydrogen
- Carbon
- Oxygen
- Chlorine

Lipid soluble  
Toxic  
Persistent  
Mobile

**Are there additional chemicals that should be added?  
What criteria should be used?**

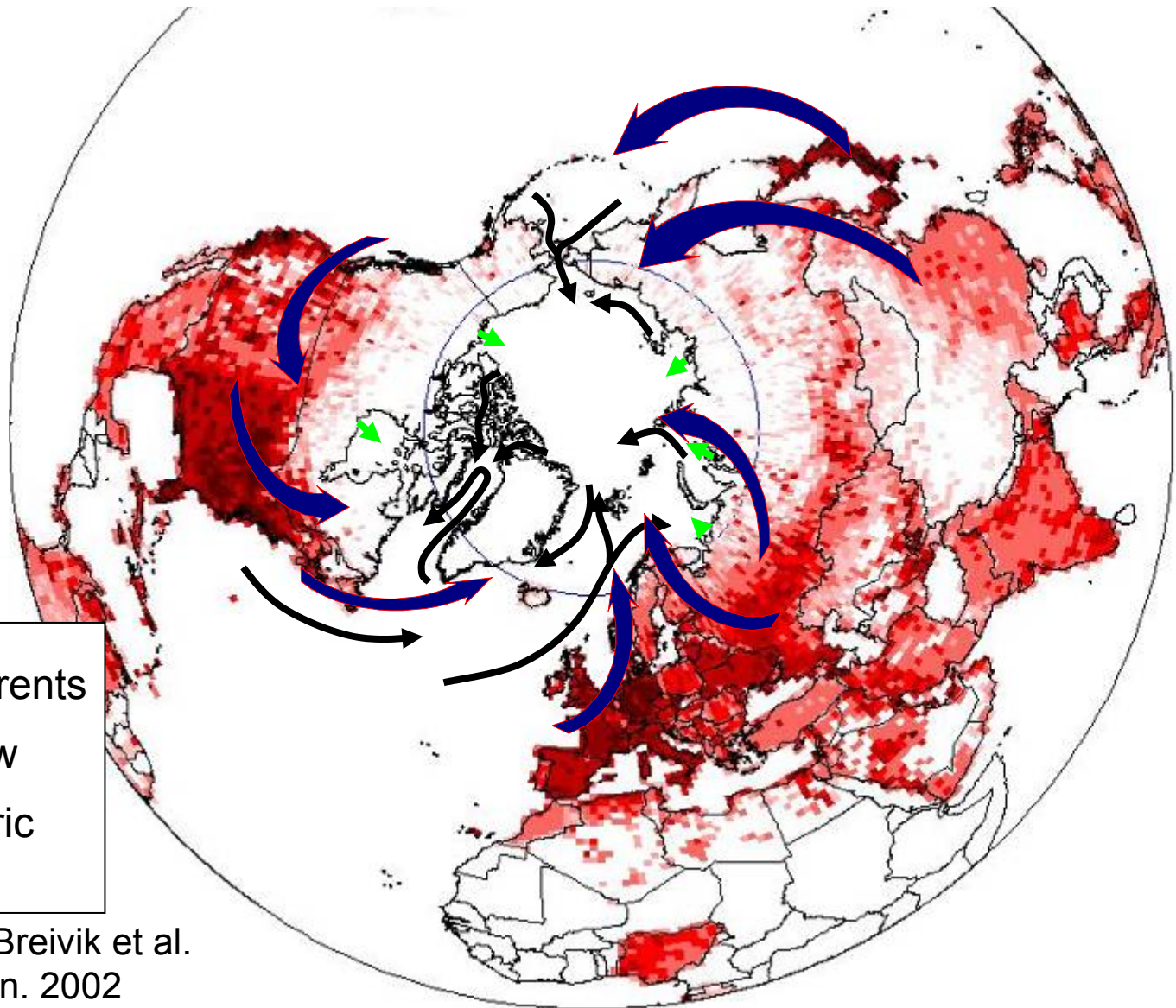
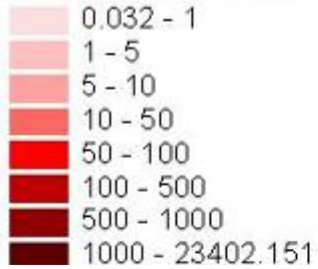


Smithsonian National Museum of American History in Washington DC.

20. October 2006 Conoco Phillips Kick Off

Katrine Borgå, NIVA

# Circumpolar perspective on the historical use of PCBs provides an insight into sources and pathways of other industrial chemicals to the Arctic



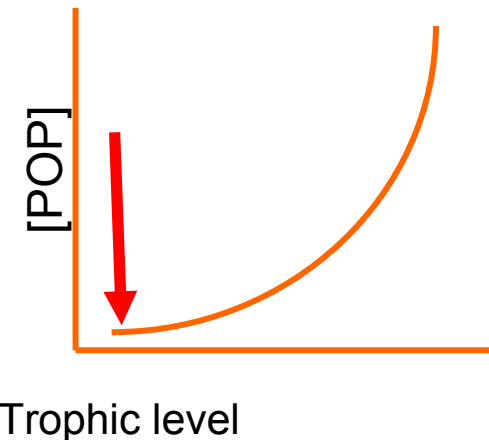
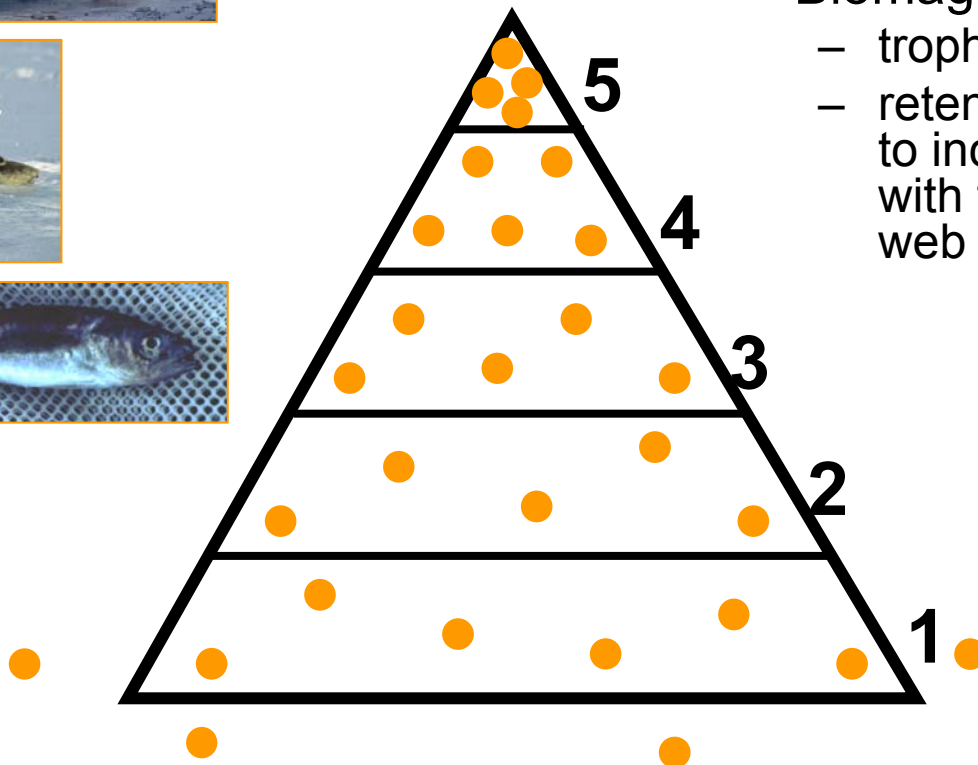
- ← Ocean currents
- ← River inflow
- ← Atmospheric circulation

Adapted from Breivik et al.  
Sci Tot. Environ. 2002

# Bioaccumulation/Biomagnification



- Bioaccumulation:
  - the net process of contaminant uptake and elimination by an organism.
- Biomagnification:
  - trophic transfer
  - retention of chemicals leading to increasing concentrations with trophic level in the food web

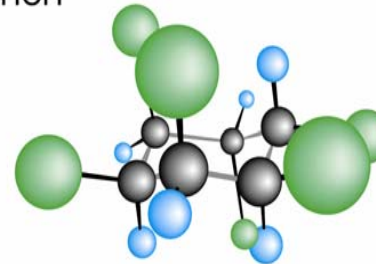


# Bioaccumulation/Biomagnification

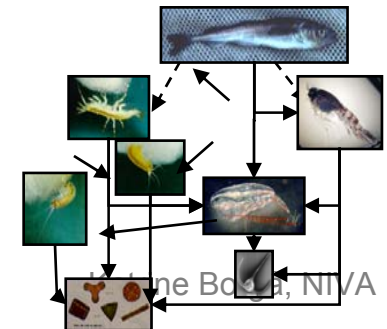
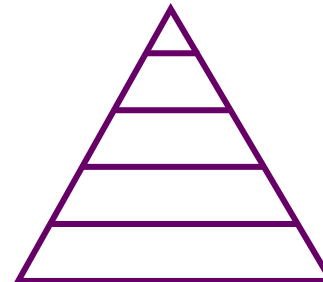
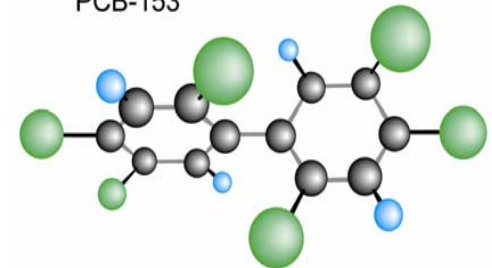
- Organismal properties
  - Feeding ecology
  - Physiology
- Chemical's properties
  - Lipid solubility
  - Persistence
- Food web properties
  - Food chain length
  - Transfer rate



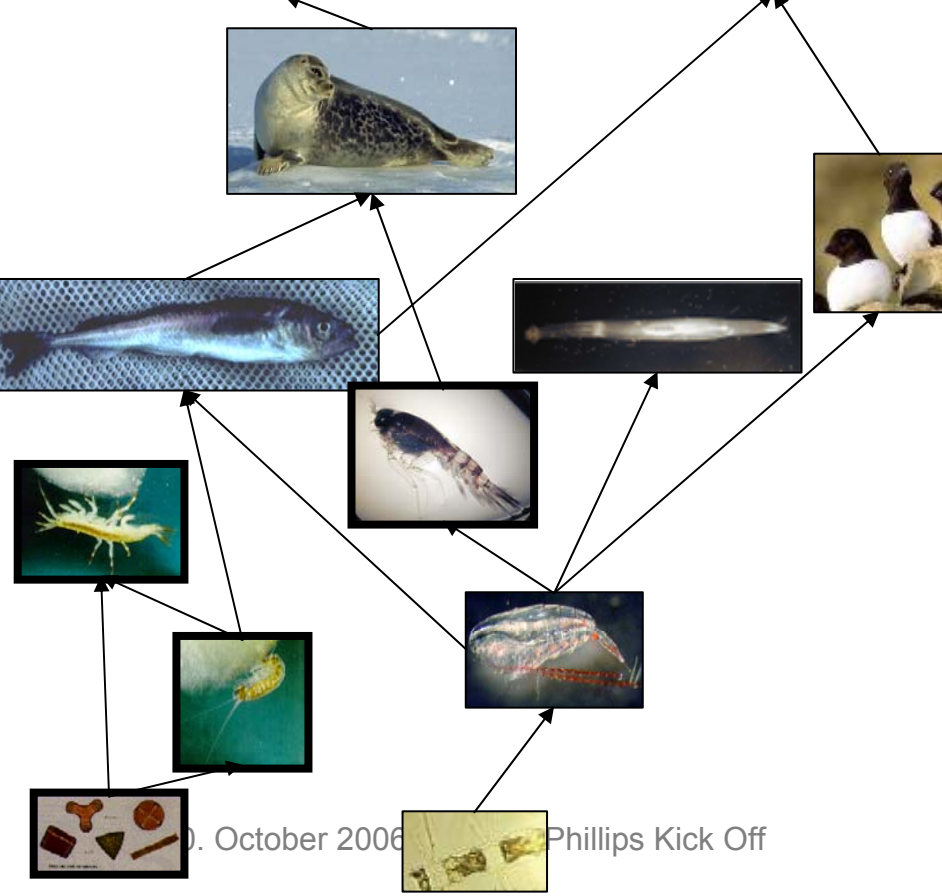
$\alpha$ -HCH



PCB-153

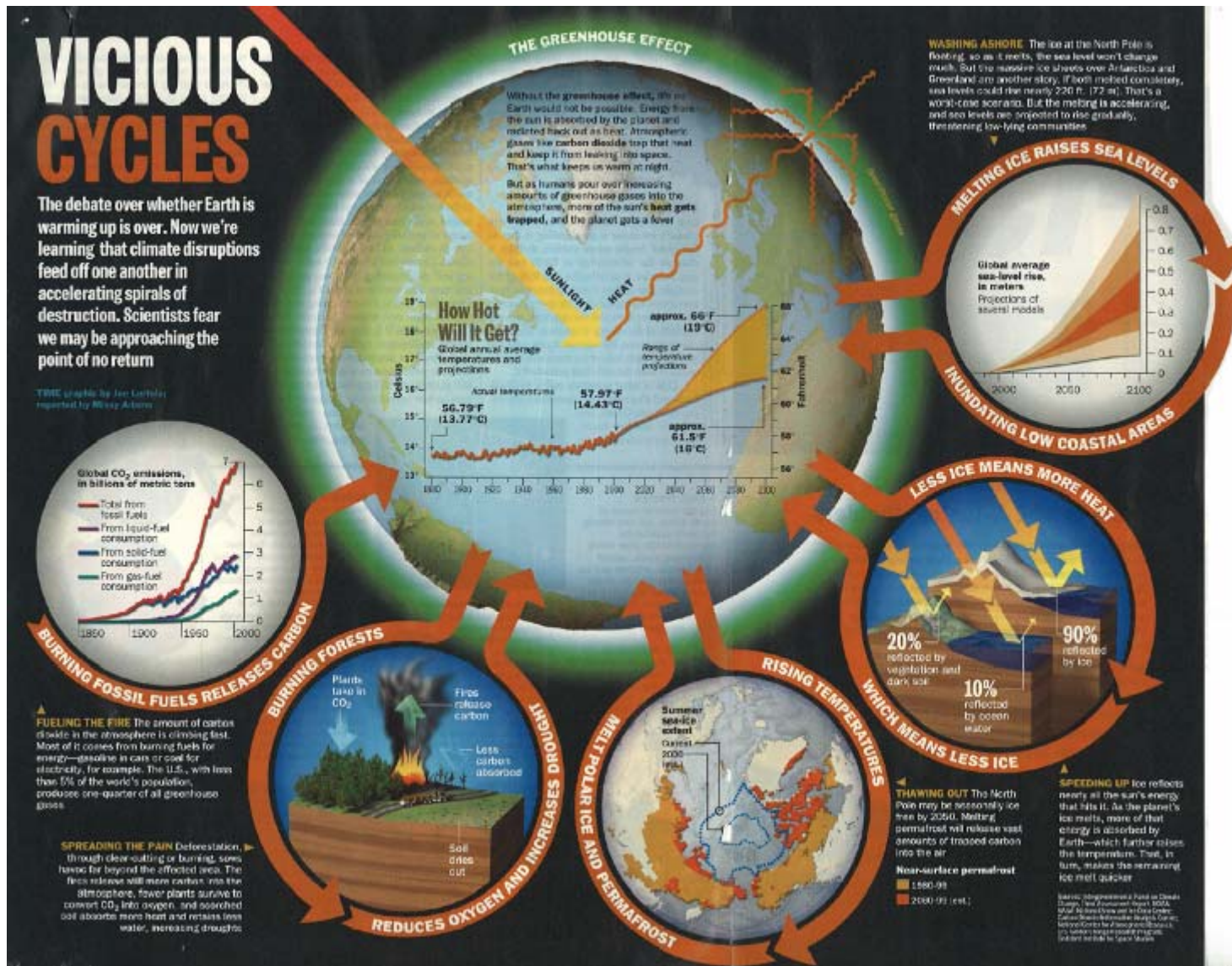


# Arctic Marine Food Web



- Young ecosystem → few species → **simple food webs**
- **Lipid** dependent, lipid rich diet
- **Long** food webs → risk top predators
- **Minor regional influence** → well suited to study underlying processes
- **Comparable** across Arctic regions
- Important for **traditional food** and international **fishing**
- **"Watch dog"** for UNEP - Stockholm convention (distant locations)

# POPs in relation to climate change?



# PROJECT 2006-2009: Overall objective

**Determine how climatic changes will influence the dynamics of persistent organic pollutant (POPs) in marine ecosystems**

Objective 1. Changes in exposure to the ecosystem

Objective 2. Changes in pathways within the ecosystem

Objective 3. Combining knowledge from WP1 and WP2

# Who we are

Dr. Geir Wing Gabrielsen, Norwegian Polar Institute

Dr. Katrine Borgå, Norwegian Institute for Water Research

PhD-student NN

In close collaboration and co-ordination with:

- MariClim: Marine ecosystem consequences of climate induced changes in water masses off West-Spitsbergen. Norwegian Research Council funded project on links between climate and marine ecology
- COPOL-WP1: Contaminants in Polar Regions. International Polar Year (if funded). Norwegian Research Council
- ARCTOS: Arctic marine ecosystem research network
- UNIS: University Studies on Svalbard



**Space for time:  
Kongsfjorden as a model fjord,  
representing a mini climatic scenario.**

Arctic water/Atlantic water

Arctic and Atlantic species assemblage

Air currents – different origins



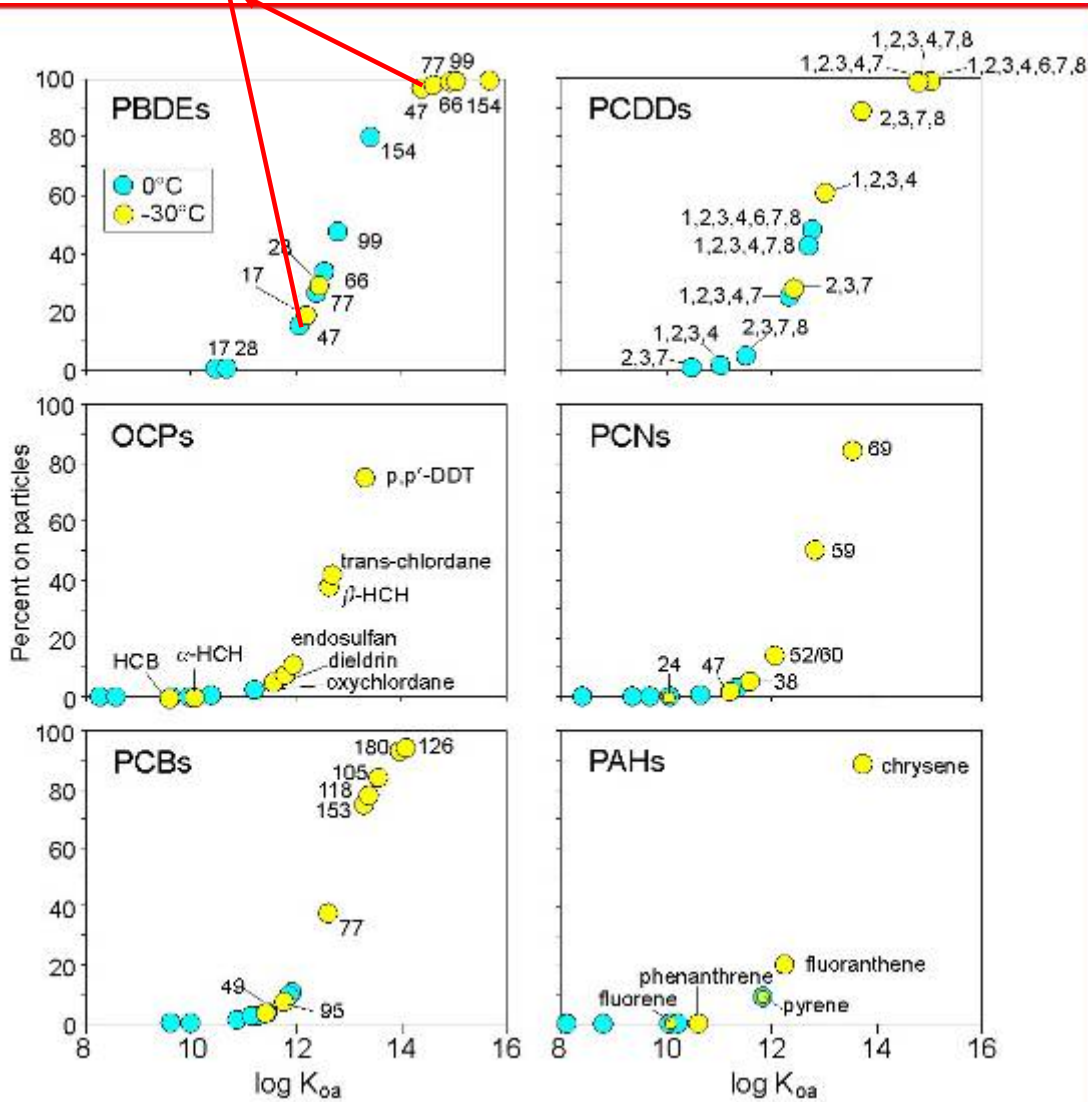
**Kongsfjorden, Svalbard**

# Components of Change

- Physical system (thermodynamics, temperature, hydrological cycle, gas-particle, winds, currents, ice cover...) – Objective 1
- Organic carbon system (organic carbon production, transport and destruction) – Objective 2
- Ecosystem (structure, lipid dynamics (Arctic-temperate), prey selection, migration, exotic species...) – Objective 2

# Temperature and POPs Partitioning

## BDE-47



**Chemicals with  $\log K \sim 11-14$  will be the most sensitive to changes in T**

**Altered ability to get to the Arctic and, once there, to stay in the Arctic**

# NAO and Atmospheric PCB Distribution

- The effect of climate on atmospheric PCB was highest in the Arctic and northern Europe in winter and spring.
- The most evident changes in POP levels due to CC are expected to be demonstrated at the northernmost monitoring stations such as the Zeppelin monitoring station in Kongsfjorden on Svalbard.

*MacLeod et al., 2005*

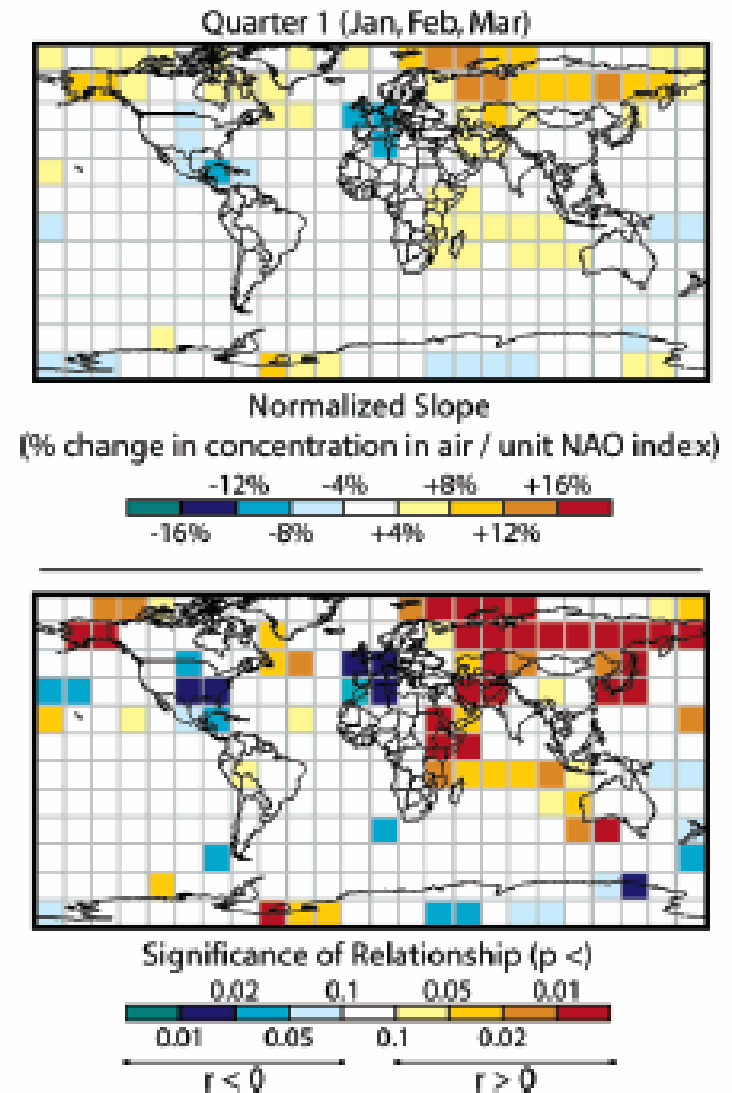
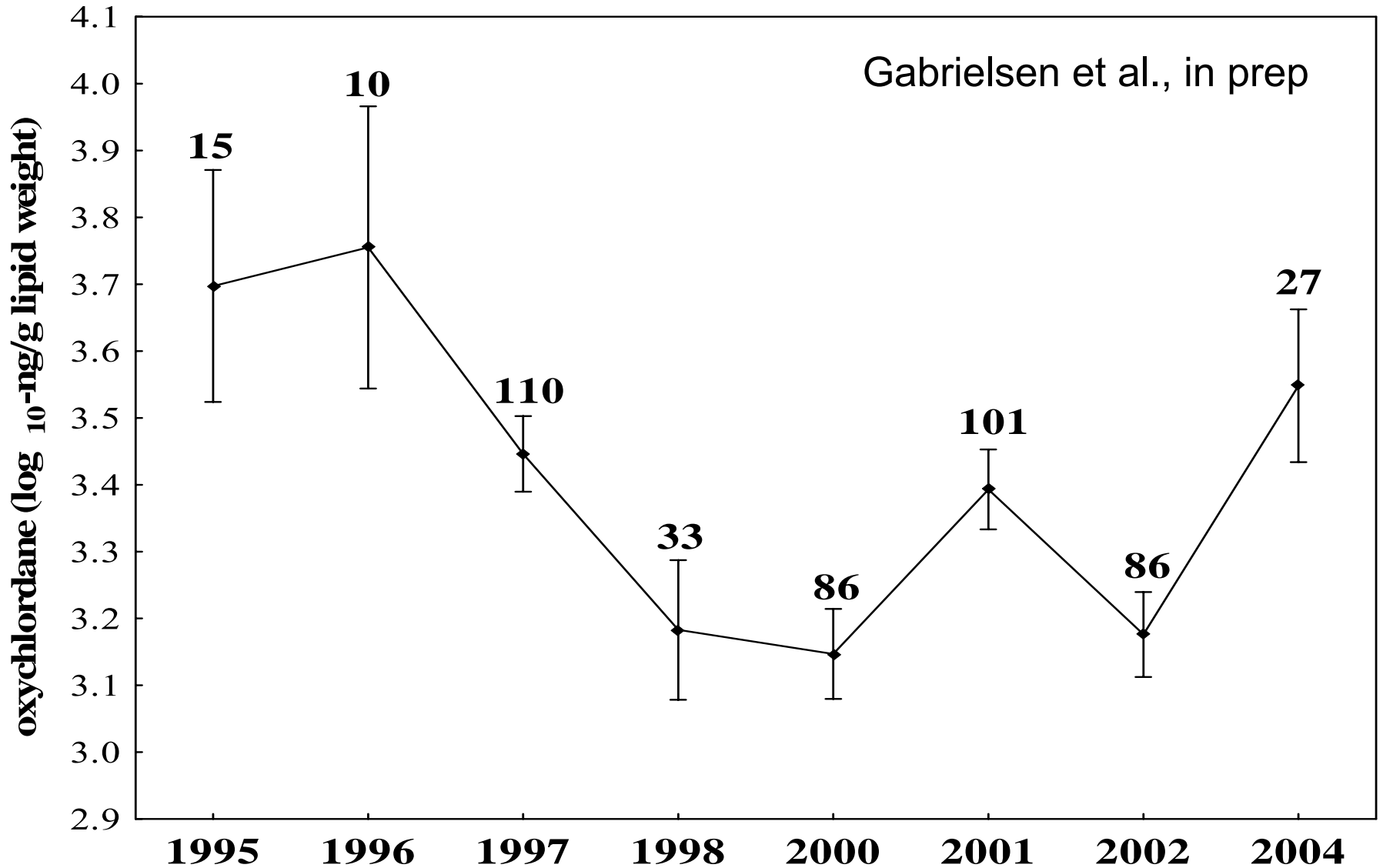


FIGURE 4. Modeled relationship between average concentration of PCB28 in lower air and NAO index during Q1 (January, February, and March) under the primary emission scenario.

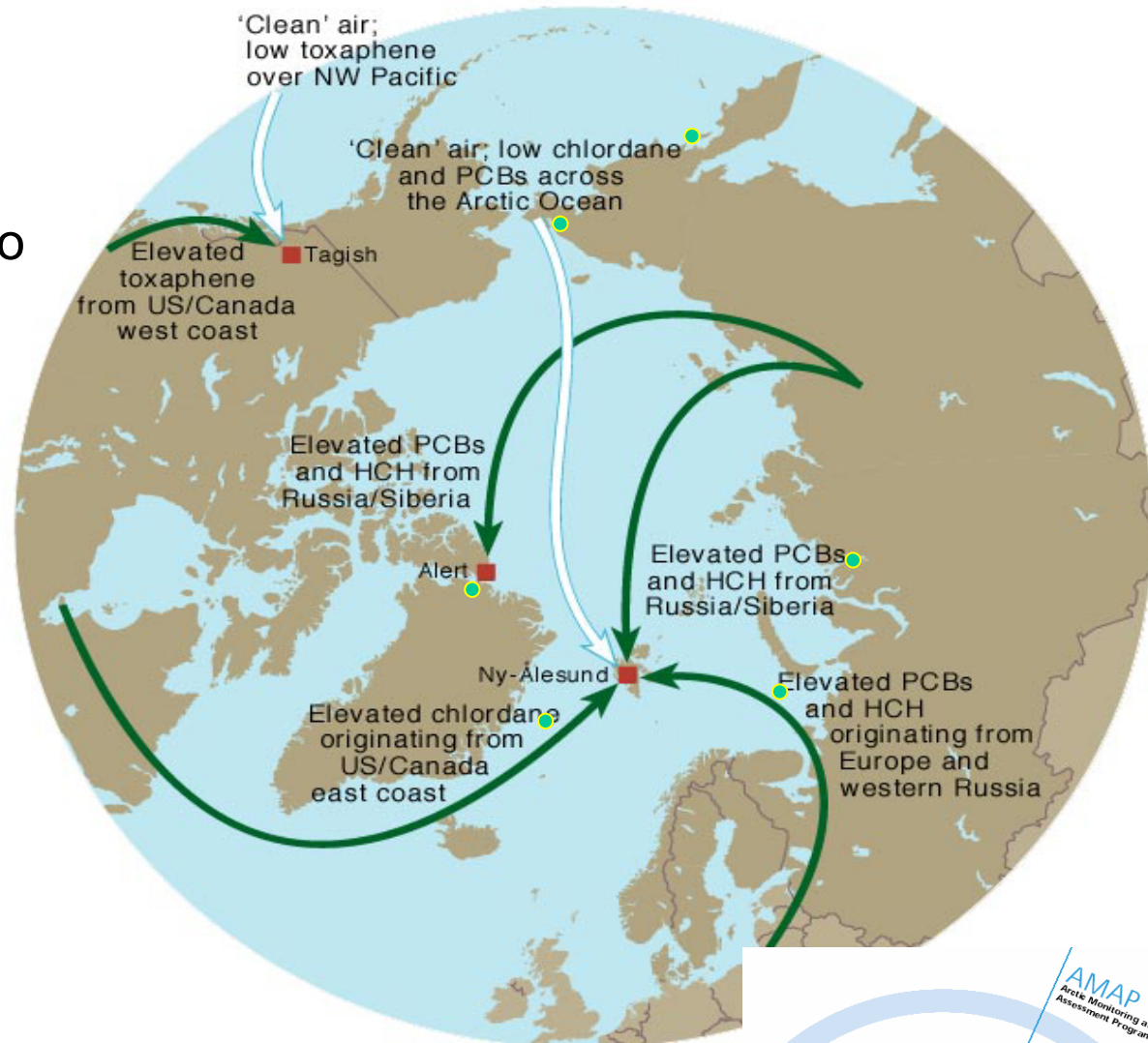
# Signals in atmosphere → biota



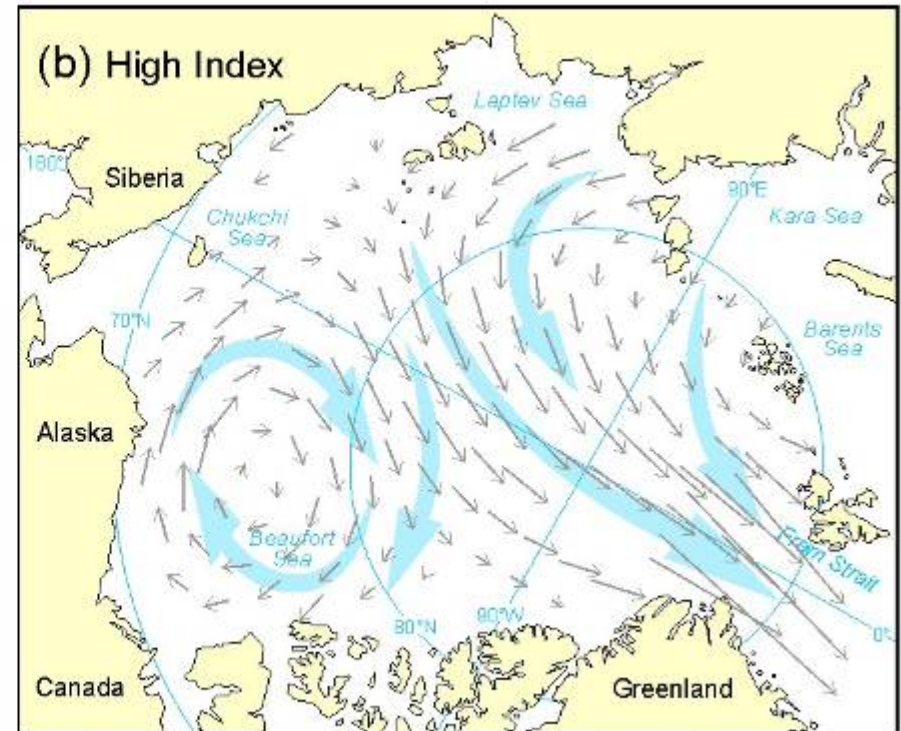
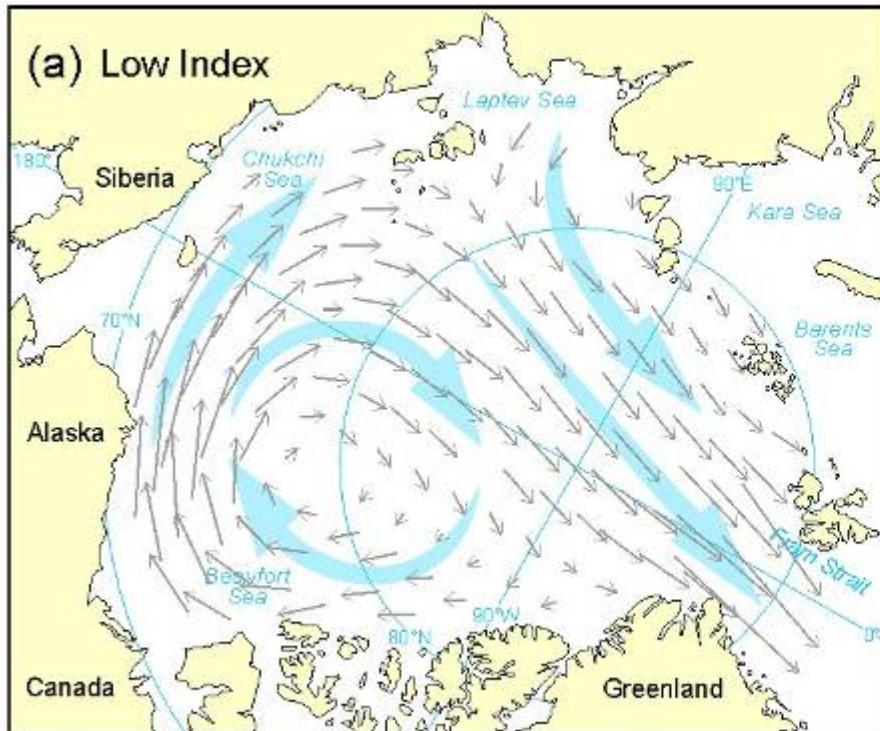
# Long-range atmospheric transport

## Persistent organic pollutants (POPs)

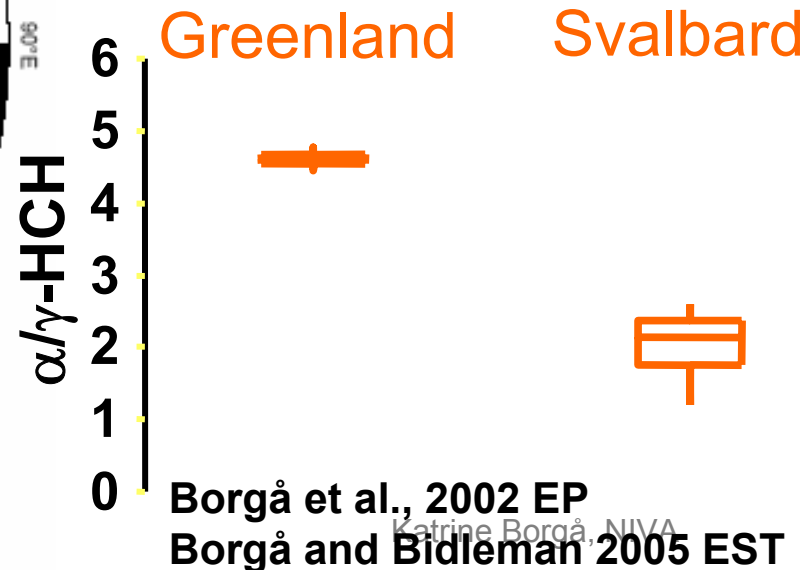
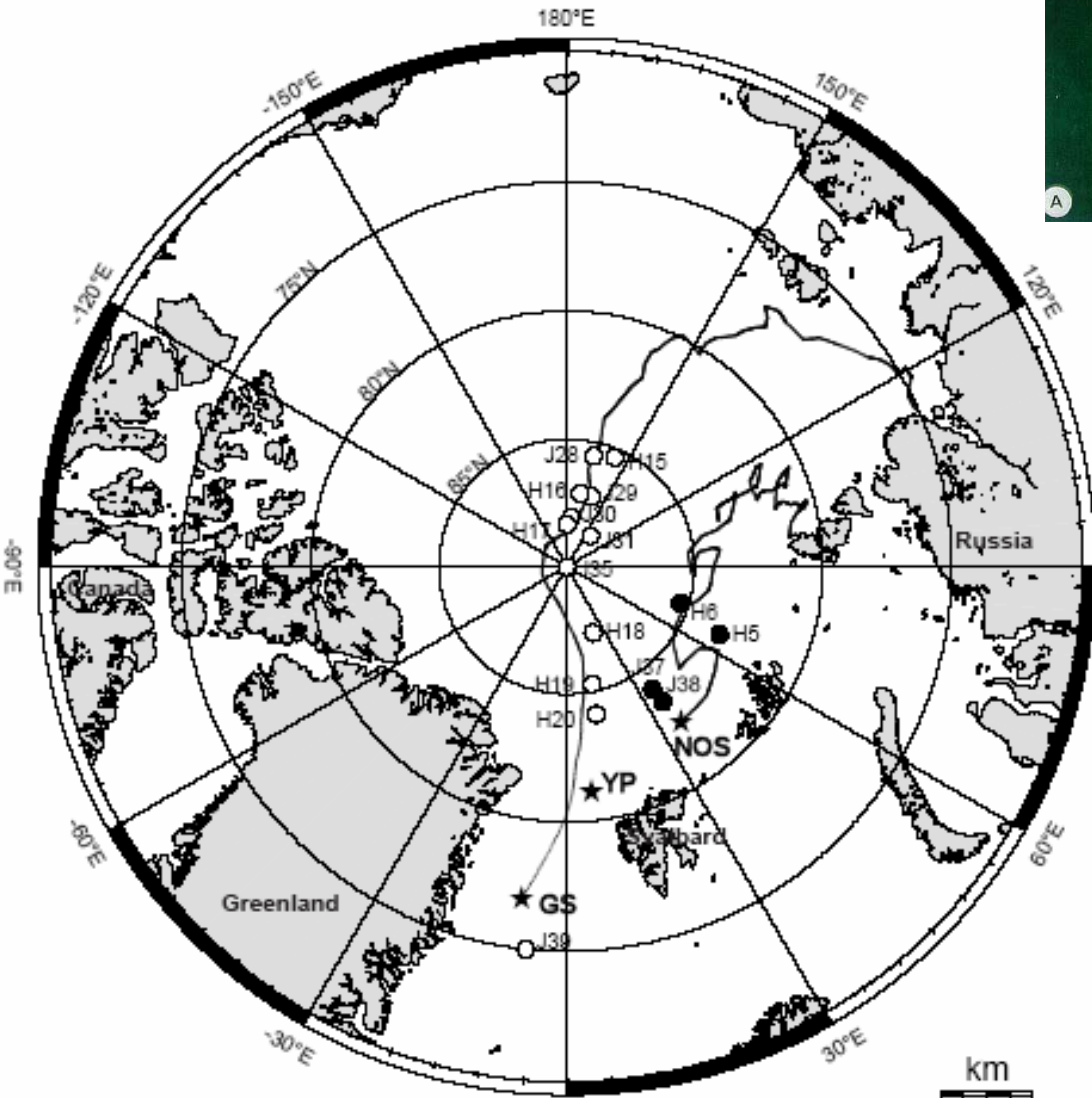
Mainly due to LRT, but also due to regional use and release of pesticides and industrial chemicals (e.g. PCBs and HCB)



# Ice Drift Trajectories – AO<sup>-</sup> vs AO<sup>+</sup>



# Ice drift and POP accumulation



Katrine Borgå, NIVA

# Changing Water Masses

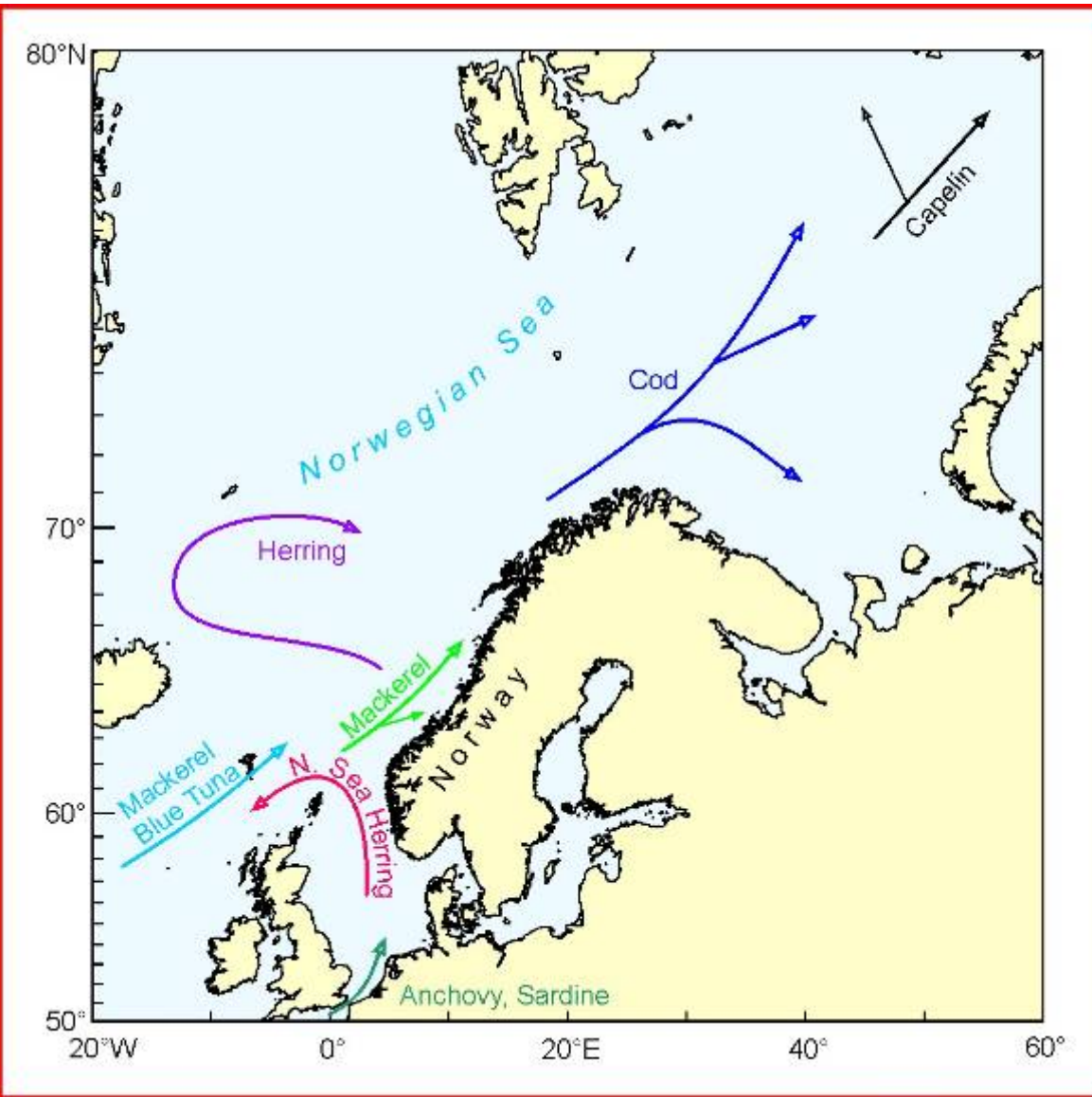
- Arctic Oscillation and the connection between Atlantic and Arctic (Swift et al., 1997; Rigor et al., 2002; Serreze et al., 2000; Gobeil et al., 2000).
- Svalbard; AW remnants found on the shelf provide evidence of irreversible exchange across the front between AW and ArW (Saloranta & Svendsen 2001, Svendsen 2002)
- Different water masses carry different phyto- and zooplankton assemblages

# Objective 1.

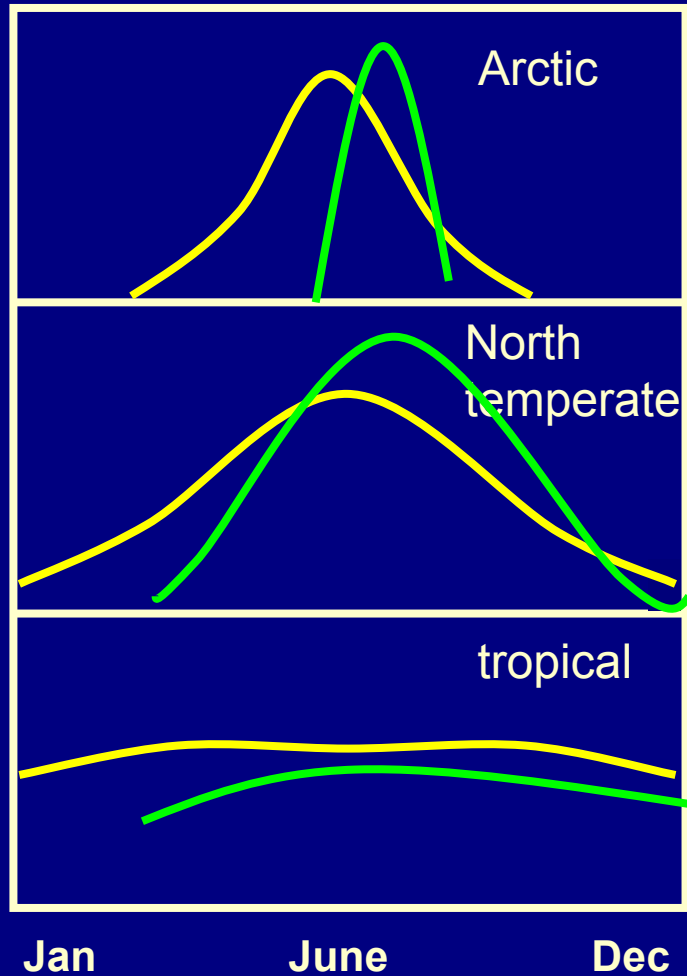
## Changes in exposure to the ecosystem

- In Kongsfjorden:
  - Atlantic water
  - Arctic water
- Dissolved fraction
- Particulate fraction
- Particulate matter
- Contaminant levels and profile

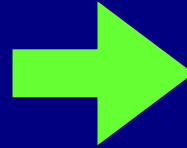
# Projected Changes in Species Distribution Due to Warming



# Strong Seasonal Amplitude and Dependence

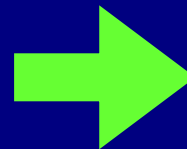


primary production



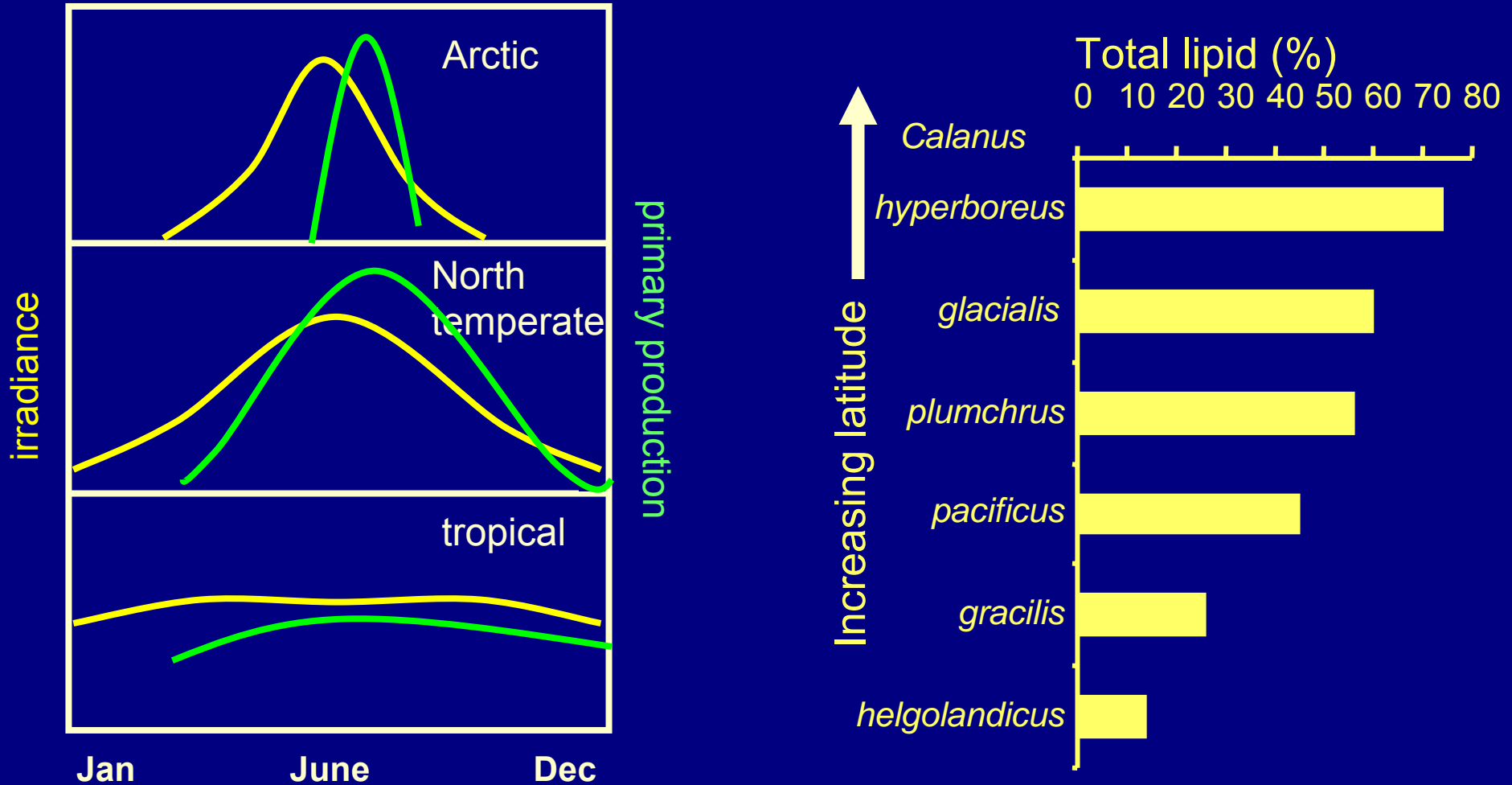
- maintenance
- growth
- reproduction
- storage

Neutral lipids:  
energy density



- maintenance
- growth
- reproduction
- storage

# Strong Seasonal Amplitude and Dependence



# Selection for the Richest Prey?

- Few studies on prey selectivity
- Fatty tissue - advantageous

**Polar bear prefers the blubber of seals**



**Gulls feed on left-overs from polarbear kill**



# Selection versus Opportunity

- Many predators are opportunistic
  - Large seasonal and spatial variations in diet composition
  - Dependent on availability
- Possible selectivity:
  - Harp and ringed seal: polar cod (*Wathne et al., 2000*)
  - Minke whale: capelin, krill (*Lindstrøm, 2001*)
  - Little auk: Arctic calanoid copepods (*Weslawski et al., 1999*)
- Reasons for prey choice:
  - Energy content

Little auk: Arctic calanoid copepods rather than Atlantic species



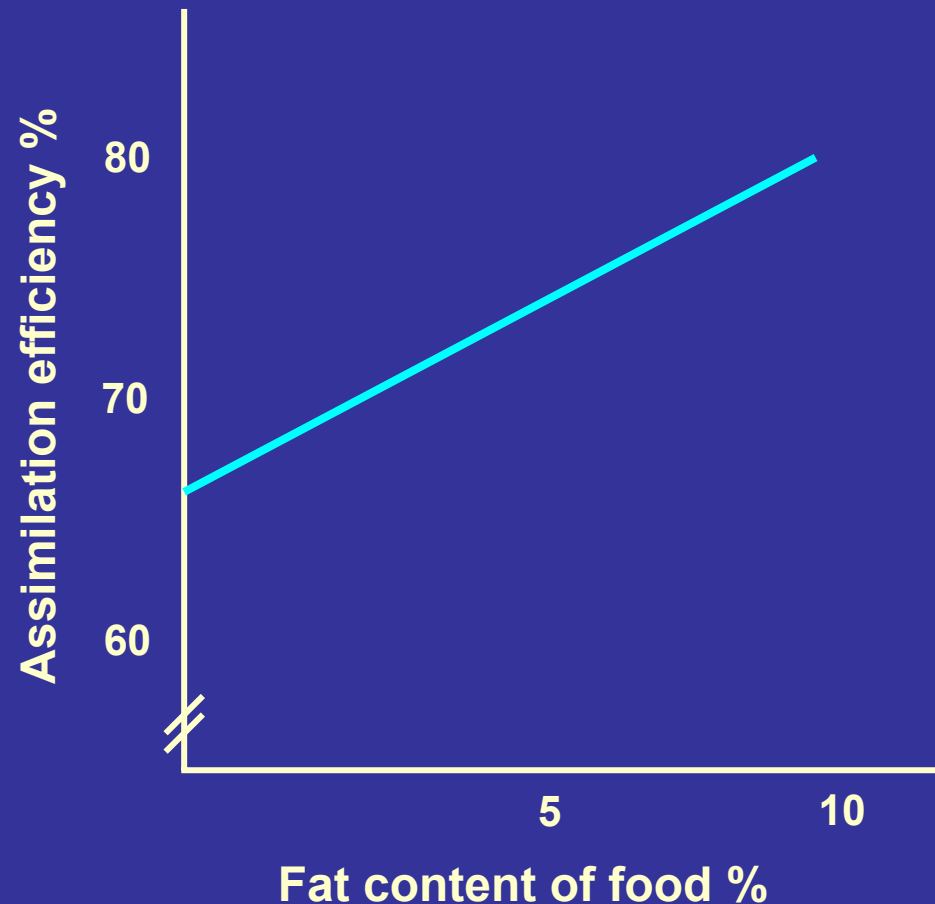
# Food Quality

Lower lipid content, less energy for predators

- Must feed more as assimilation of proteins is less efficient than that of lipids
  - lean capelin vs fat polar cod fed to kittiwake and Brünnich's guillemot

## Triple bonus with lipids:

- Higher energy density
- More efficient assimilation
- Less time is needed to feed



From: Brekke & Gabrielsen, 1994

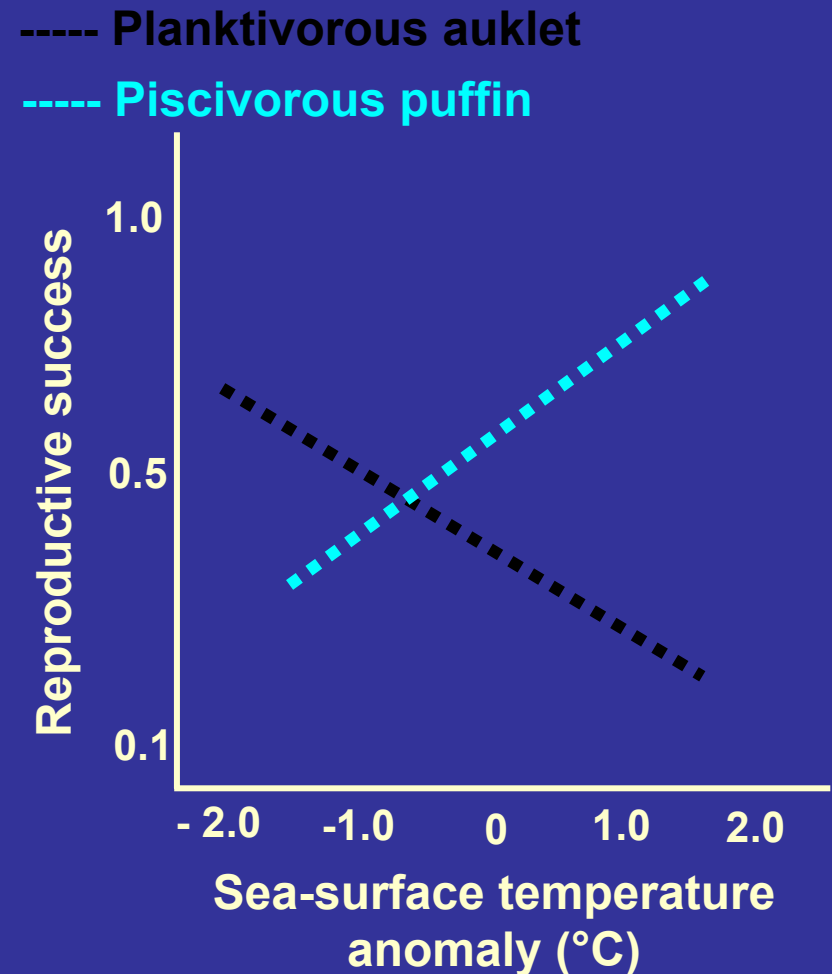
# Regime Shifts – the Pacific Arctic

## Cold years:

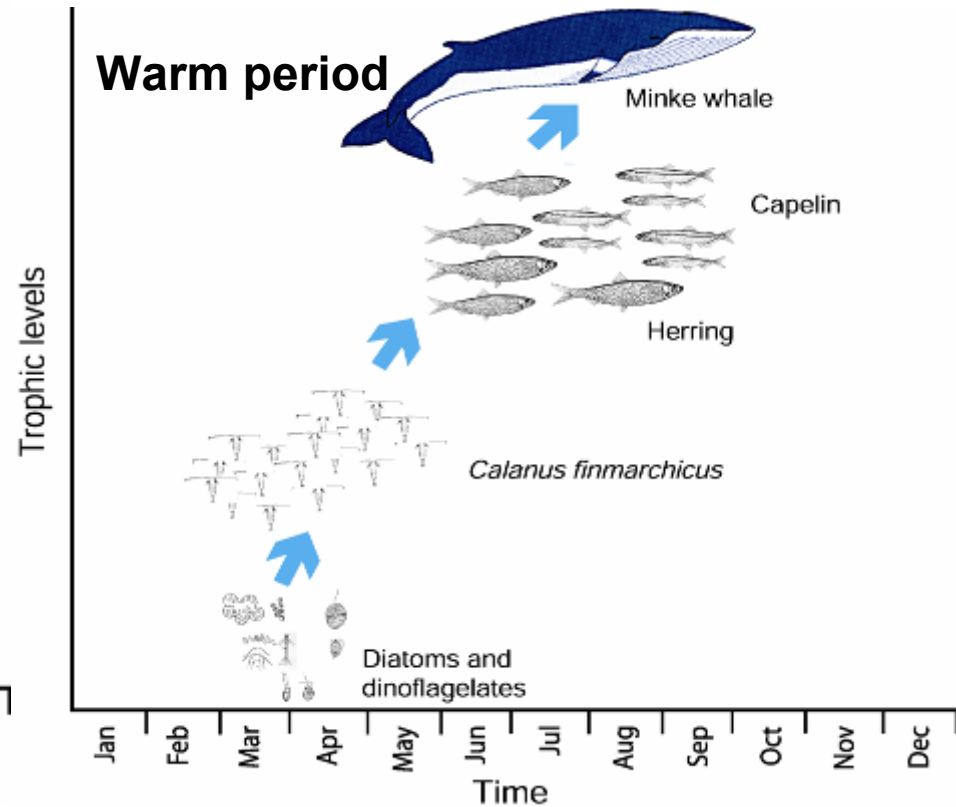
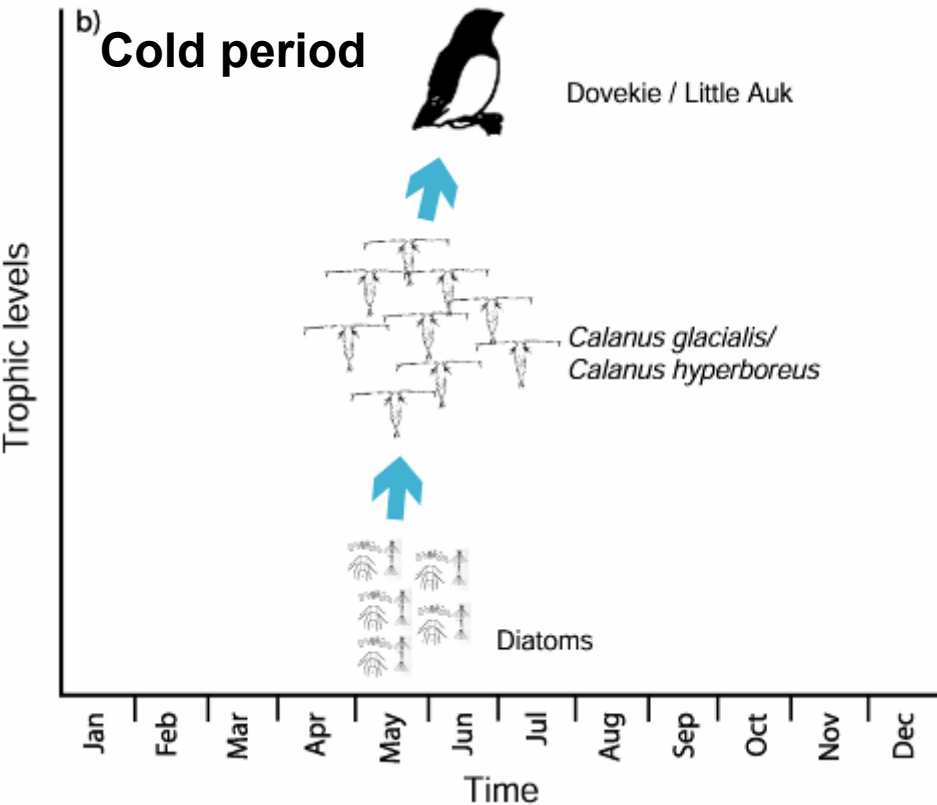
- Macrozooplankton  $\Rightarrow$  planktivorous auklets

## Warm years:

- Decreased macrozooplankton and increased mesozooplankton
- Auklets don't change their diet
- Mesozooplankton  $\Rightarrow$  juvenile pelagic fish  $\Rightarrow$  piscivorous puffin.
- Puffins are flexible in their diet



# Bottom-up Change, and Foodwebs

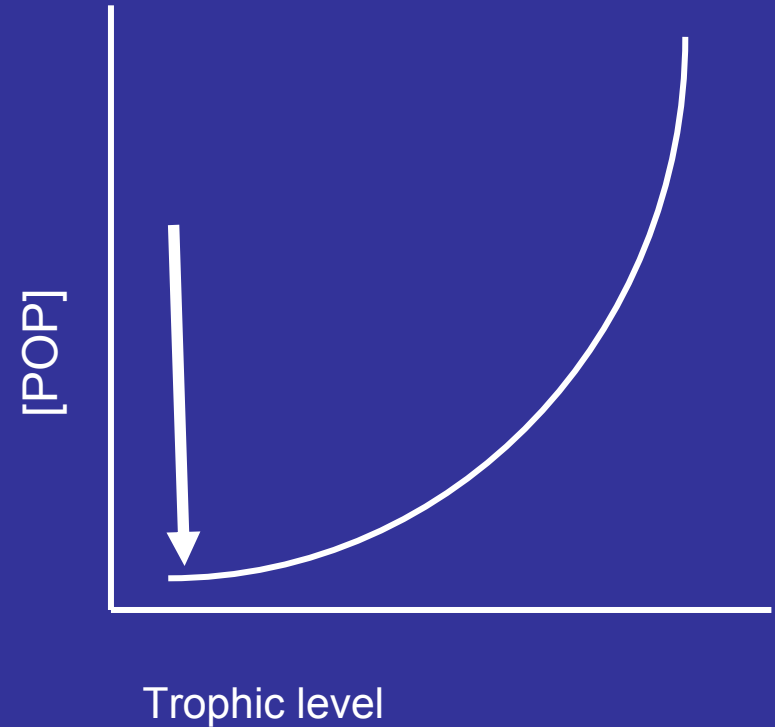
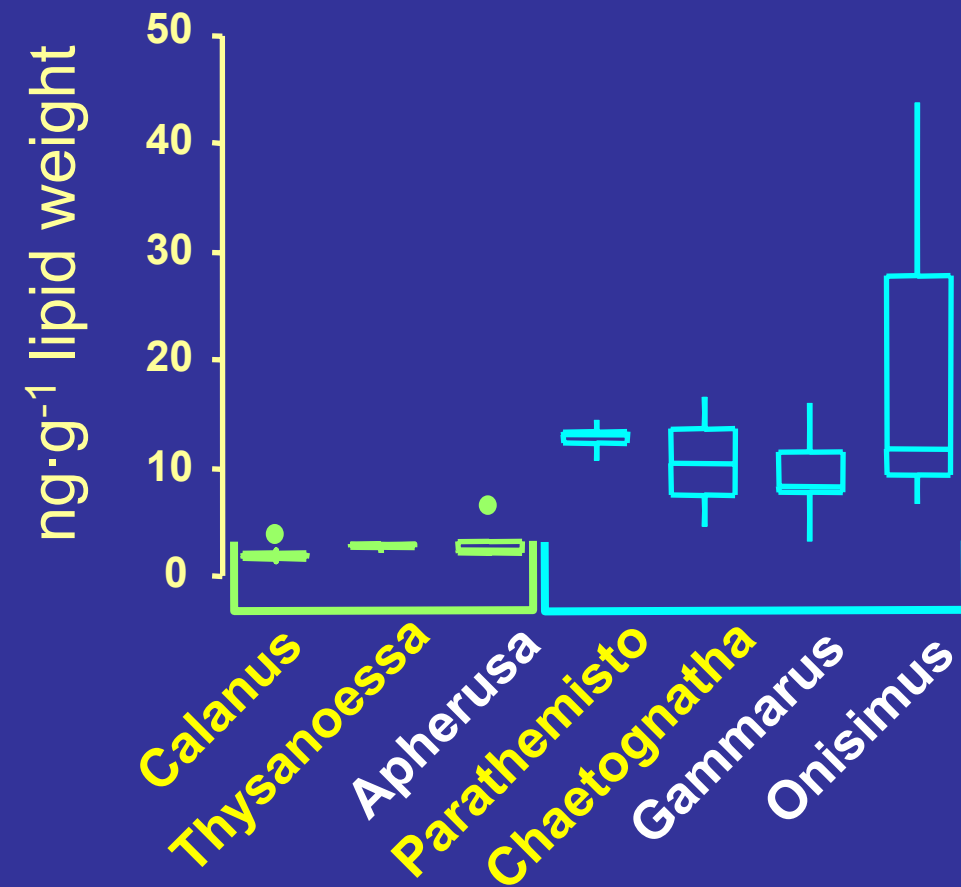


Favor Arctic species: *C. glacialis*  
 Storage buffer  
 Sufficient energy for little auk

Favor Atlantic species: *C. finmarchicus*  
 Small and less lipids-rich  $\Rightarrow$  No little auk  
 Increase in planktivorous fish and in piscivorous minkewhale

# Zooplankton and Ice fauna

## PCB-153: effect of diet

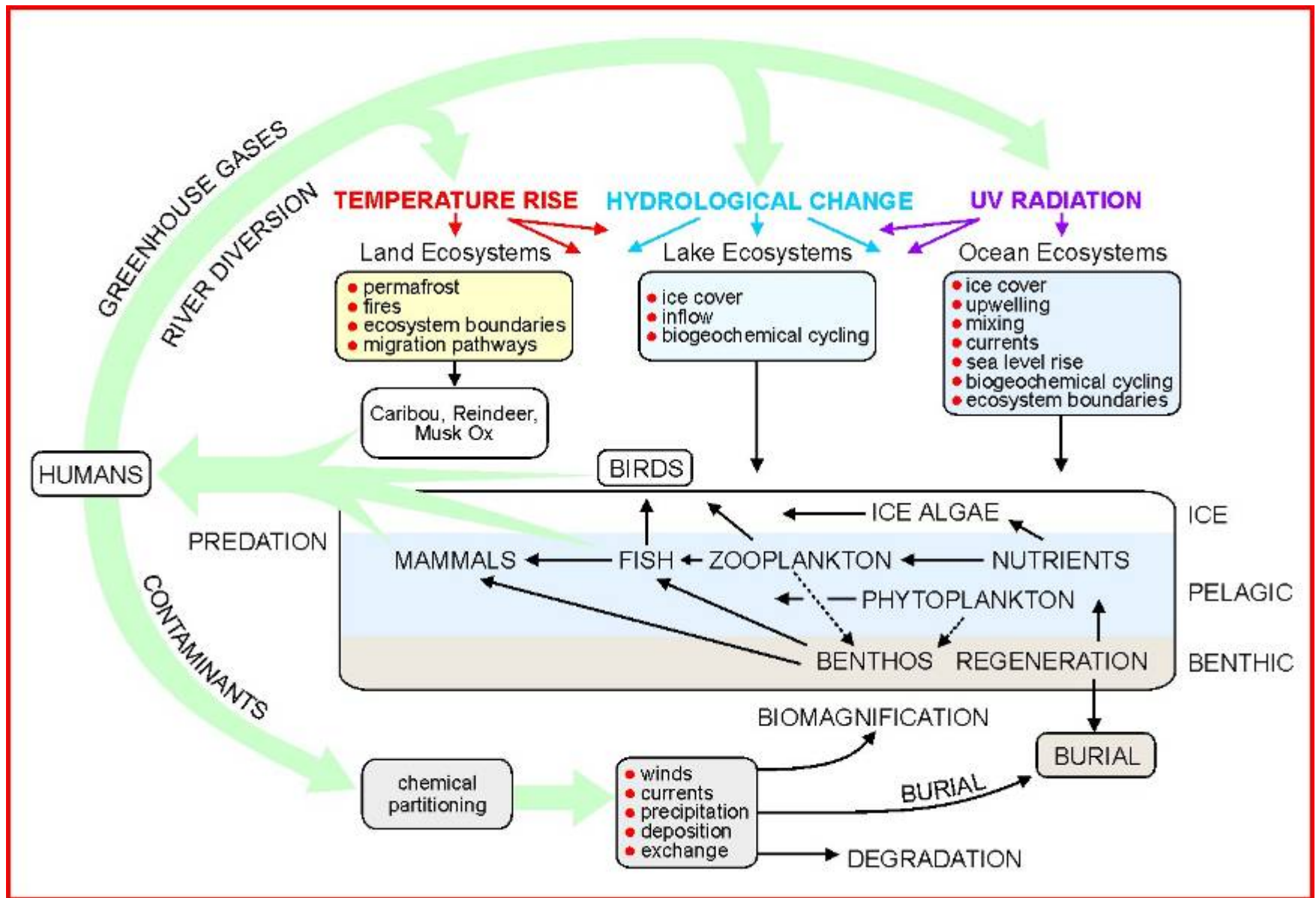


# Objective 2.

## Changes in pathways within the ecosystem

- Biota:
  - Zooplankton (net hauls): sieves to separate size classes, pick out large zooplankton (krill and amphipods) (3 pr species pr cruise)
  - Fish: pelagic trawls
  - Seabirds: kittiwake and little auk samples obtained from the seabird crew
- In collaboration with MariClim:
  - food web structure and its relation to contaminant flux
- Participation on cruises:
  - 2007-2008, spring, summer and autumn

# Pathways and Change



# Objective 3.

## Combine Exposure and Structure

### Warm scenario

#### Water

Atlantic water (AW)  
Higher POP exposure  
High DOC → Low Dissolved/Particulate  
Low respiratory availability

#### Air

Increased temperature  
Higher precipitation  
Higher POP exposure

#### Biota

Atlantic zooplankton species  
High POP → High food web POP exposure  
Low lipid content → Less efficient transfer  
Predators high or low?  
Less energy → Eat more → More exposed

### Cold scenario

#### Water

Arctic water (ArW)  
Low POP exposure  
Low DOC → High Dissolved/Particulate  
High respiratory availability

#### Air

Low temperature  
Low precipitation  
Lower POP exposure

#### Biota

Arctic zooplankton species  
Low POP → Low food web POP exposure  
High lipid content → Efficient transfer  
Predators high or low?  
More energy → Eat less → Less exposed

## COLD:

Low POP, high lipid,  
eat less, lower  
contaminated food  
with good quality,  
lower POP levels in  
seabirds

## WARM:

High POP, low lipid,  
eat more of higher  
contaminated food  
with poor quality,  
higher POP levels in  
seabirds

PHYTOPLANKTON  
Diatoms, *Phaeocystis* sp.

### ARCTIC ZOOPLANKTON

*Calanus glacialis*

*Calanus hyperboreus*

*Themisto libellula*

### ATLANTIC ZOOPLANKTON

*Calanus finmarchicus*

*Thysanoessa* spp. (Krill)

Capelin, Polar cod

Little auk

Kittiwake

Little auk

Kittiwake

# Project status

- Recently signed the contract
- In the process of finding and hiring a PhD-student
- Planning and preparing field work for 2007  
March, June and August

- Contact information:
  - [geir.wing.gabrielsen@npolar.no](mailto:geir.wing.gabrielsen@npolar.no)
  - [katrine.borga@niva.no](mailto:katrine.borga@niva.no)

• Thank you for your attention!

