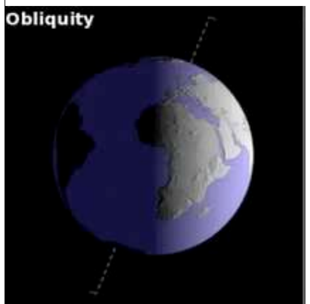
BIOGEOGRAPHIC RESPONSES TO PLEISTOCENE GLACIATIONS

MARINE EVOLUTION AND BIOGEOGRAPHY
RITA CASTILHO

outline

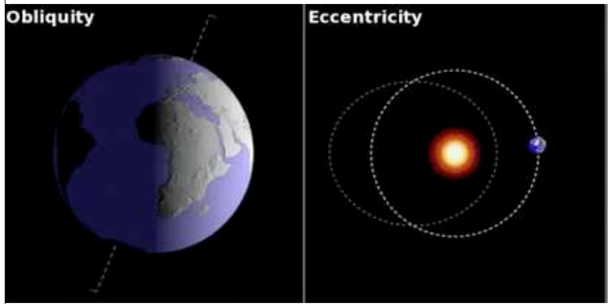
Milankovitch cycles

Biogeographic Responses to Pleistocene Glaciations



40.000 years/cycle

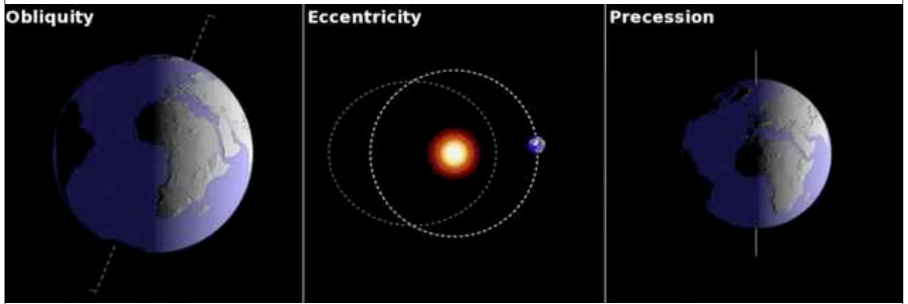
Biogeographic Responses to Pleistocene Glaciations



40.000 years/cycle

100.000 years/cycle

Biogeographic Responses to Pleistocene Glaciations

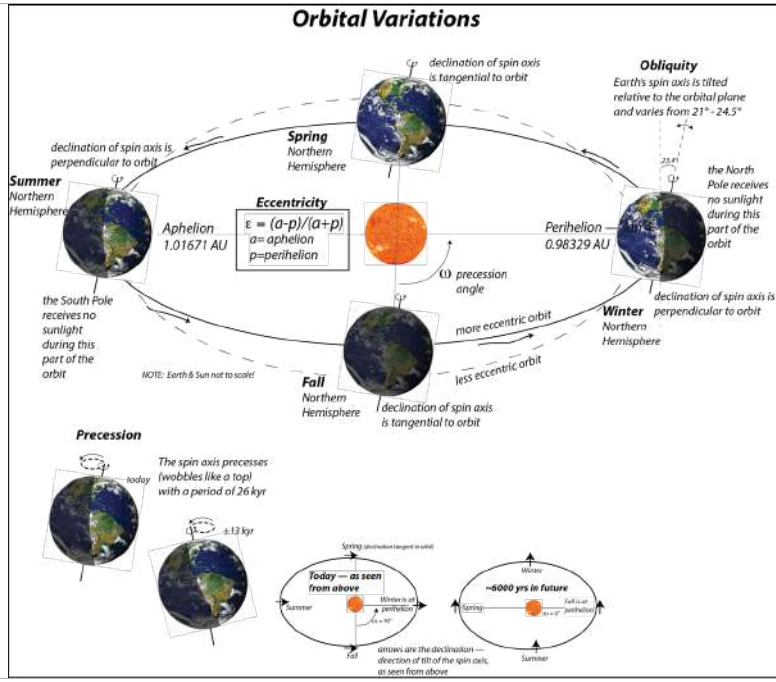


40.000 years/cycle

100.000 years/cycle

22.000 years/cycle

Milankovitch cycles



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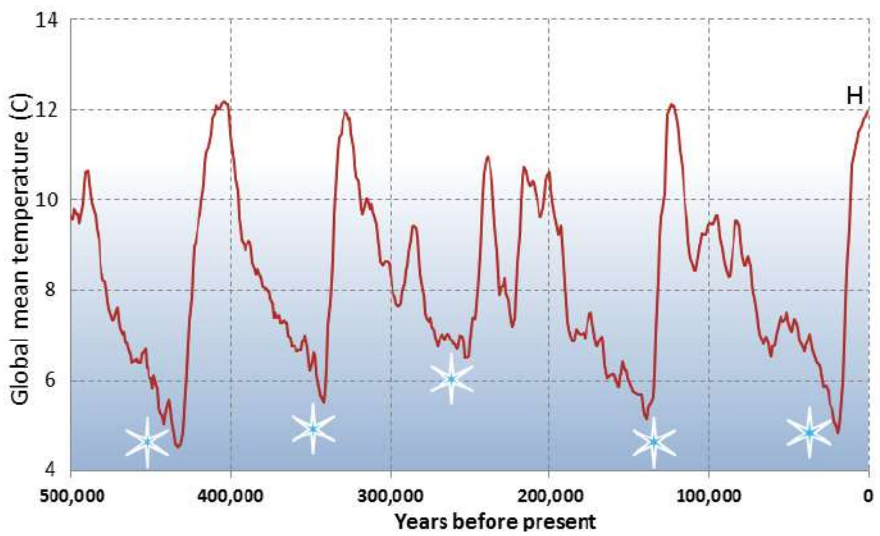

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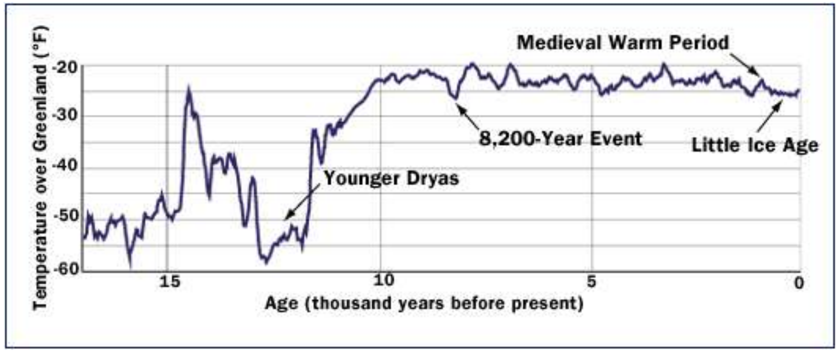
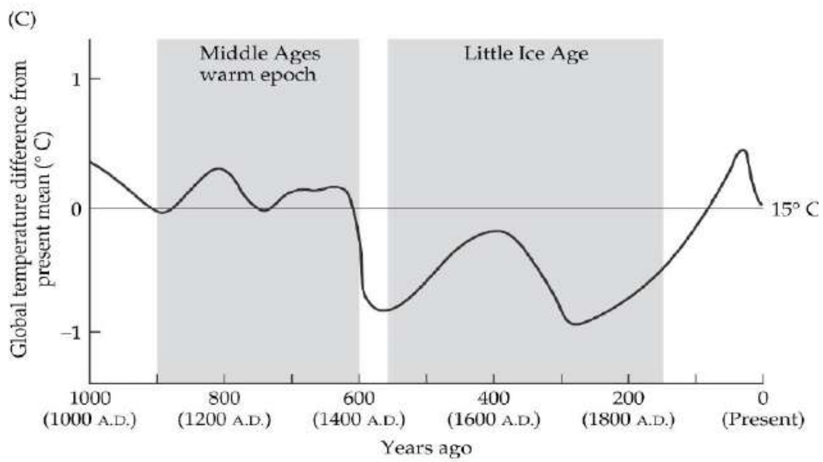


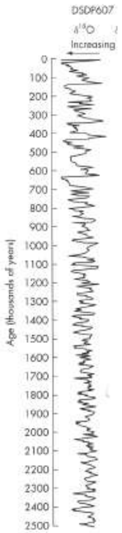
Biogeographic Responses to Pleistocene Glaciations

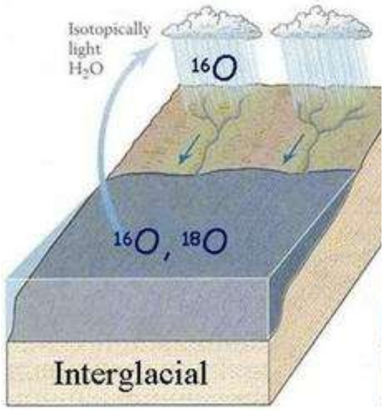
Global Temperatures



How do we measure paleotemperatures?

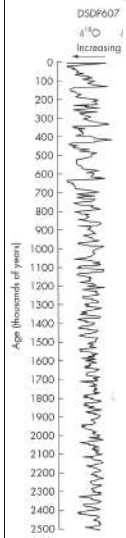
Biogeographic Responses to Pleistocene Glaciations

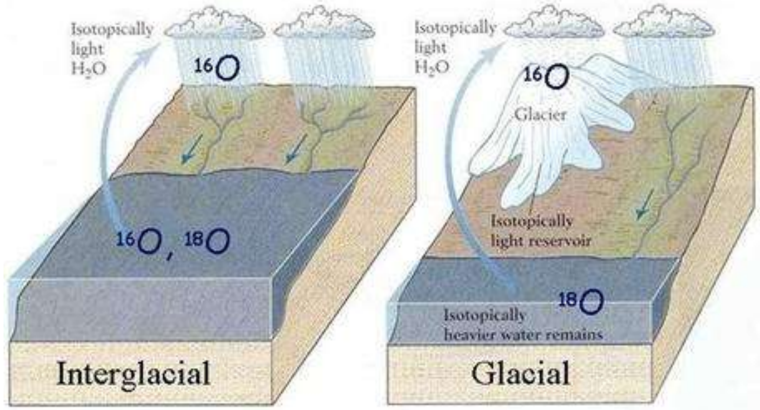




Isotopically light water evaporates from the ocean and returns via rivers: the system is in balance.

Biogeographic Responses to Pleistocene Glaciations





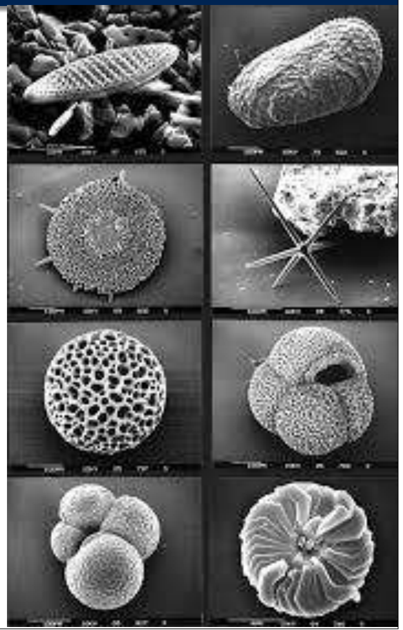
Isotopically light water evaporates from the ocean and returns via rivers: the system is in balance.

Glaciers expand, forming a new reservoir of isotopically light water on the land: sea level drops and the ocean becomes isotopically heavy.

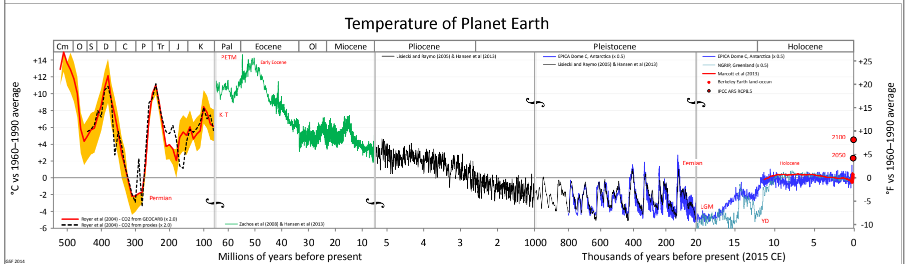
Biogeographic Responses to Pleistocene Glaciations

Microfossil shells

Shells are made of calcite ($CaCO_3$)



Biogeographic Responses to Pleistocene Glaciations



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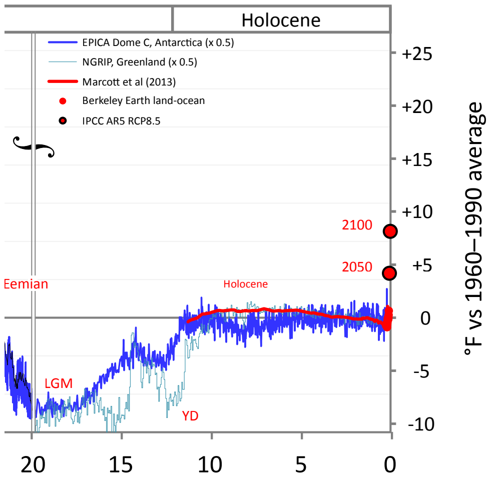
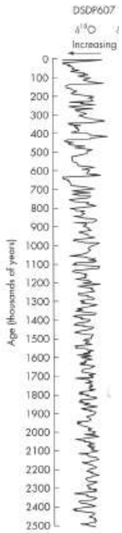
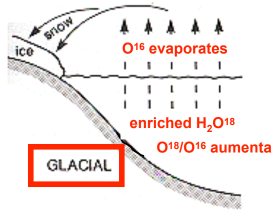


Biogeographic Responses to Pleistocene Glaciations



Measuring temperature

Relative abundance of O^{18}/O^{16} varies with evaporation, precipitation and water storage in the poles.



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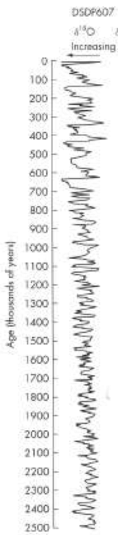

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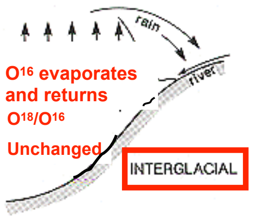

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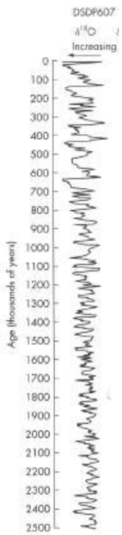

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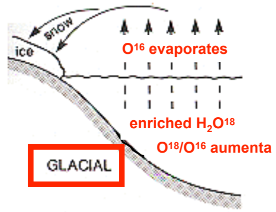
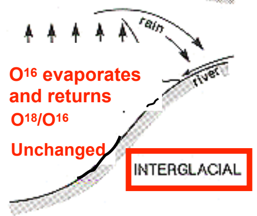
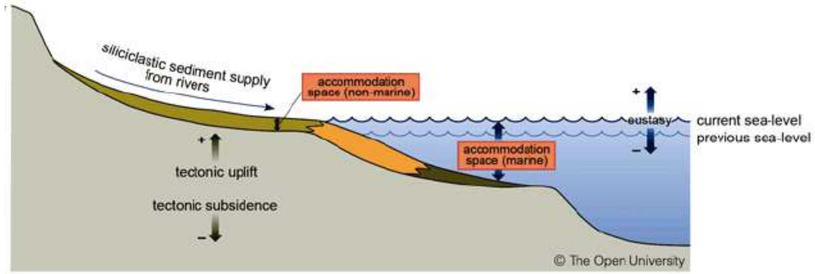




European phylogeography

Biogeographic Responses to Pleistocene Glaciations

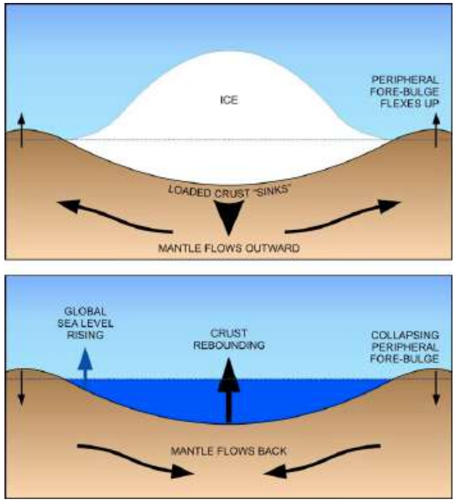
Sea Level Variation



volume of water in the oceans

Biogeographic Responses to Pleistocene Glaciations

Sea Level Variation



loading of the crust of the earth

Biogeographic Responses to Pleistocene Glaciations

Sea Level Variation

During an ice age
isostatic change: build up of ice on the land.
(As water is stored on the land in glaciers, the weight of the land increases and the land sinks slightly, causing the sea level to rise slightly. This is referred to as compression.)

During inter-glaciers
isostatic change: the ice melts, the land begins to rise up again and the sea level falls.
(This is referred to decompression or isostatic rebound. Isostatic rebound takes place incredibly slowly and to this day, isostatic rebounding is still taking place from the last ice age.)

Sea Level Variation

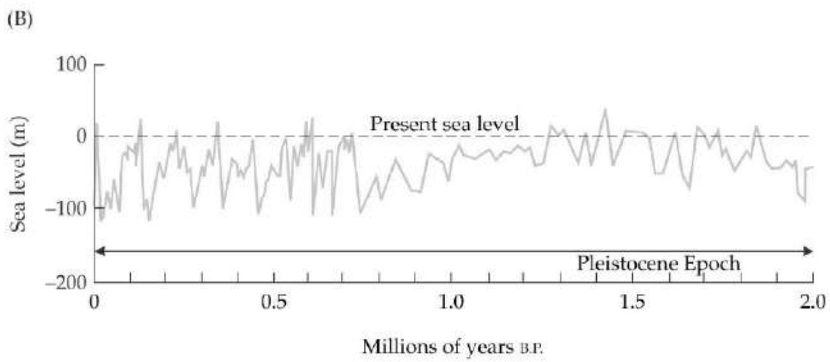
Isostatic change is a **local** sea level change.
Eustatic change is a **global** sea level change.

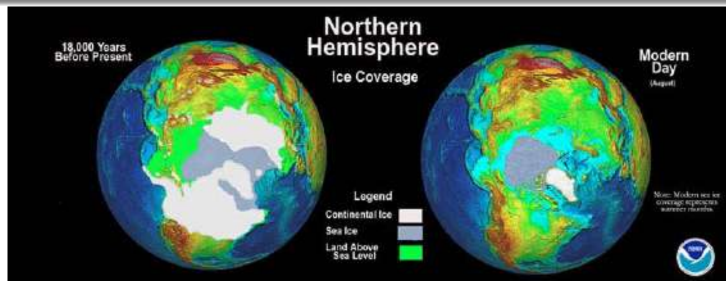
"Both eustatic and isostatic changes during the Pleistocene (and Holocene) strongly influenced the distributions and diversity of biotas."

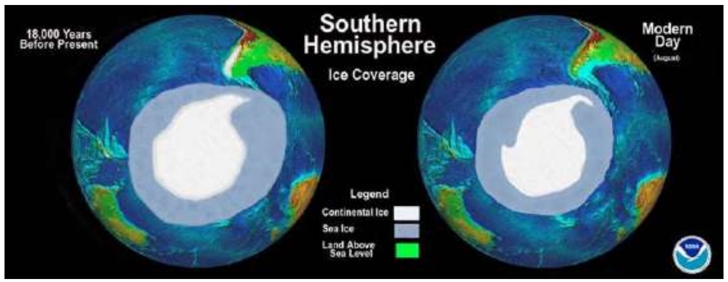
Lomolino et al. 2006. p. 284.

Sea Level Lowering at the LGM

Global Sea Level Variation



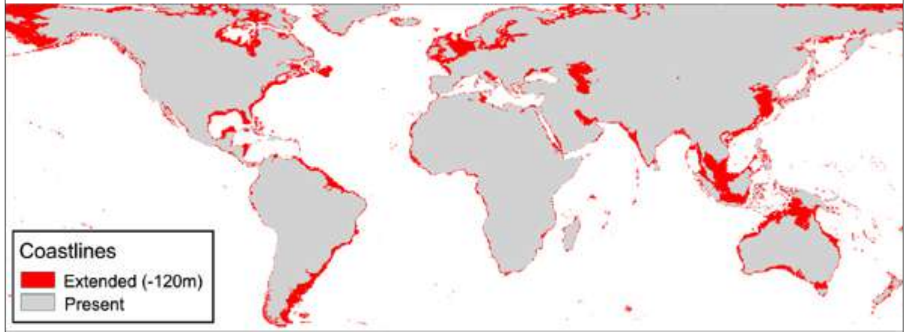




Mark McCaffrey , NGDC/NOAA Source: http://www.ncdc.noaa.gov/paleo/slides/slideset/11/11_178_slide.html

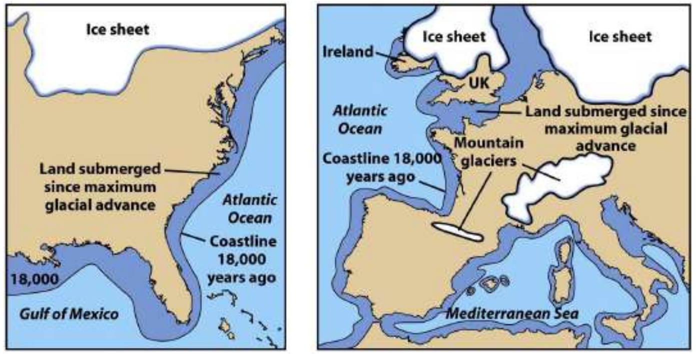
Global Sea Level Variation

LGM extended coastlines (sea-level drop 120m) computed from global bathymetry (Smith and Sandwell, 1997)



Ray, N. and J. M. Adams. 2001. *Internet Archaeology 11* (http://intarch.ac.uk/journal/issue11/rayadams_toc

Global Sea Level Variation



Global Sea Level Variation

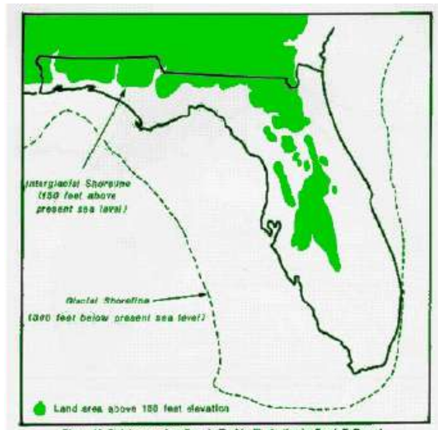
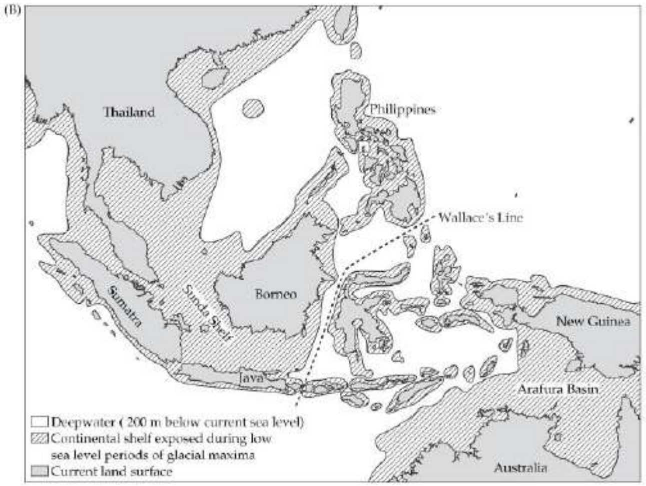


Figure 16. Pleistocene shorelines in Florida. Illustration by Frank R. Rupert.

Eustatic sea level change: fluctuations driven by changes in ice volume

Global Sea Level Variation

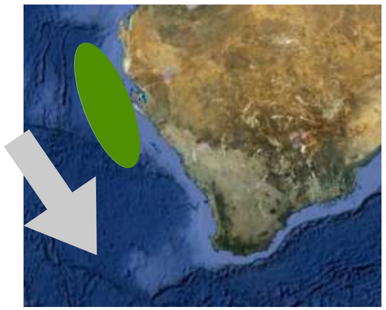


Range shifts of marine organisms

Shift in geographic distribution

Cooling trend

Warming trend

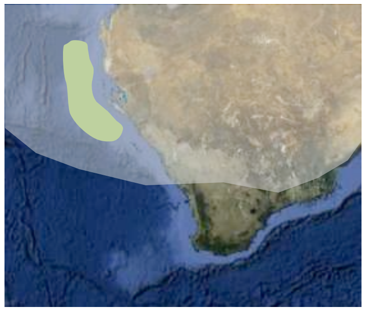


No range contraction

adapted from Grant and Waples (2000)

Shift in geographic distribution

Cooling trend



Warming trend

Range contraction

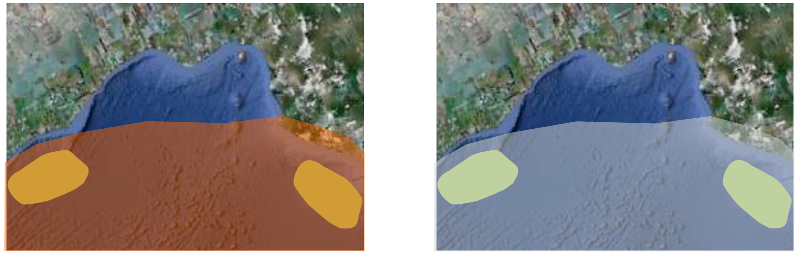
Shift in geographic distribution

Range contraction and possible extinction: warming or cooling

adapted from Grant and Waples (2000)

Shift in geographic distribution

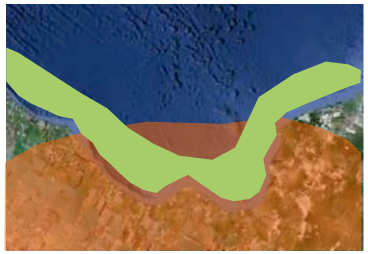
Warm or cooling trend



Range contraction and mixing

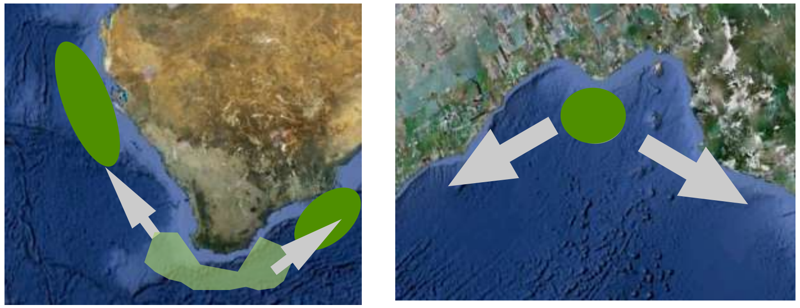
Shift in geographic distribution

Warm or cooling trend



Range expansion

Shift in geographic distribution



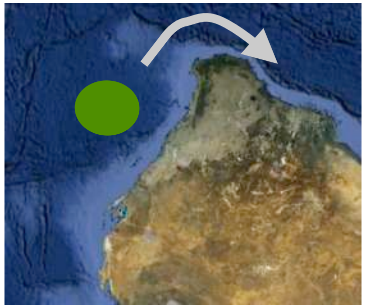
Population subdivision: warming or cooling

adapted from Grant and Waples (2000)

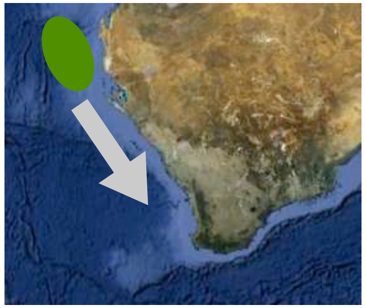
The models

Shift in geographic distribution

Polar warming

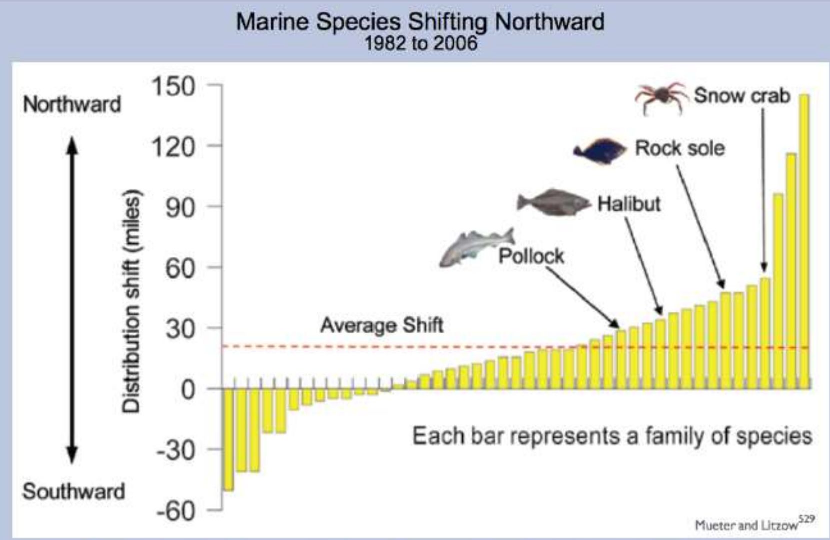


Tropical cooling



Dispersal across relaxed temperature barriers

Range shifts



As air and water temperatures rise, marine species are moving northward, affecting fisheries, ecosystems, and coastal communities that depend on the food source. On average, by 2006, the center of the range for the examined species moved 19 miles north of their 1982 locations.

http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

Biogeographic Responses to Glaciation-Deglaciation

Biogeographic Responses to Pleistocene Glaciations

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- Changes in the location, extent, and configuration of prime habitats

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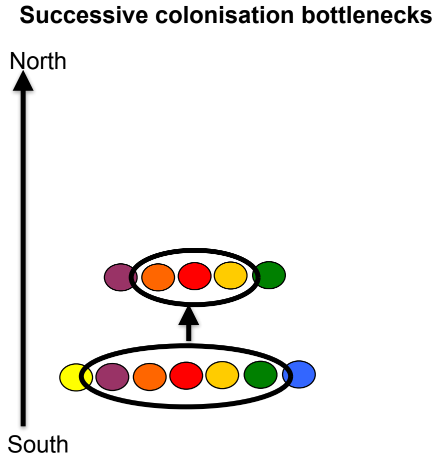
Biogeographic Responses to Glaciation-Deglaciation

- Changes in the location, extent, and configuration of prime habitats
- Changes in the nature and location of climatic and environmental zones
- Formation and dissolution of dispersal routes
- Some species move with optimal habitat
- Other species persist and adapted
- Other species ranges were reduced, and some became extinct

How do range shifts of affect the **genetics** marine organisms?

What happens to the genetic architecture of leading-edge populations?

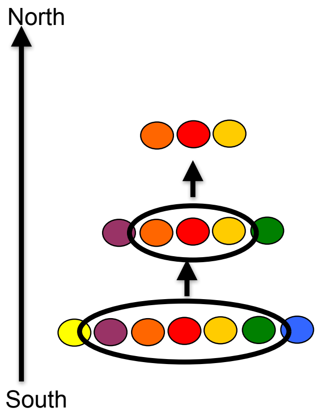
Colonisation leads to erosion of diversity



Biogeographic Responses to Pleistocene Glaciations

Colonisation leads to erosion of diversity

Successive colonisation bottlenecks



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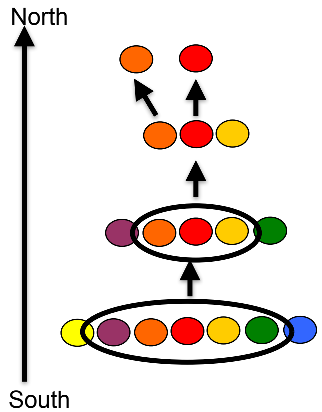


reduction of diversity
(64.2% of studies)

reproductive isolation
(70.2% of studies)

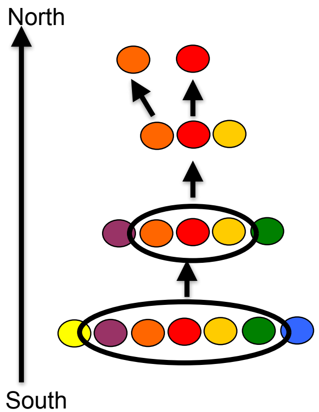
A common hypothesis:
Bottlenecks
Decrease in neutral genetic diversity
Reduced adaptive potential

[Eckert et al. 2008, Mol Ecol]

Biogeographic Responses to Pleistocene Glaciations

Colonisation leads to erosion of diversity

Successive colonisation bottlenecks



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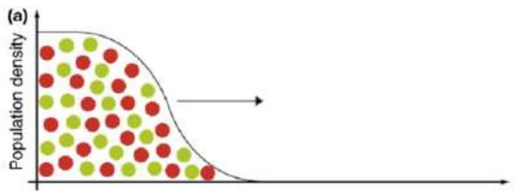
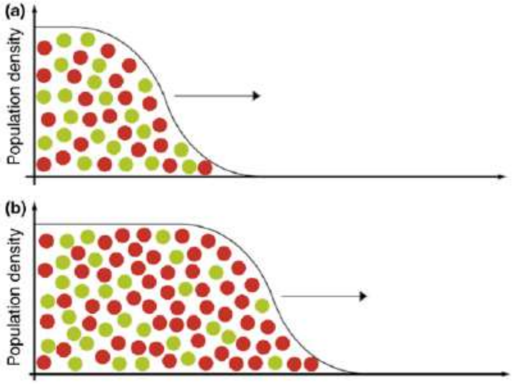


Excoffier and Ray 2008. TREE 23:347–351.

Biogeographic Responses to Pleistocene Glaciations



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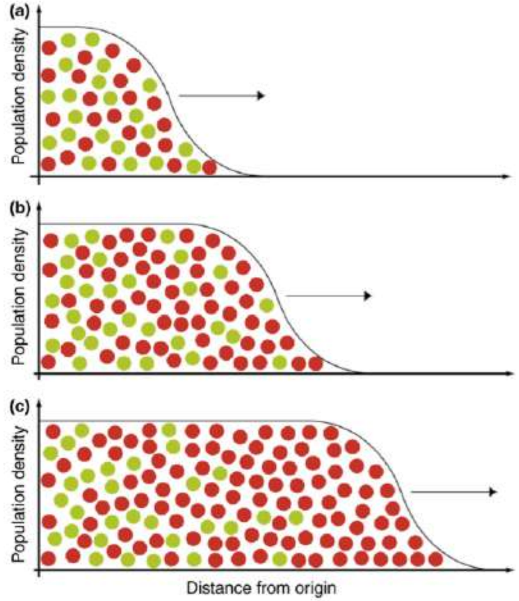


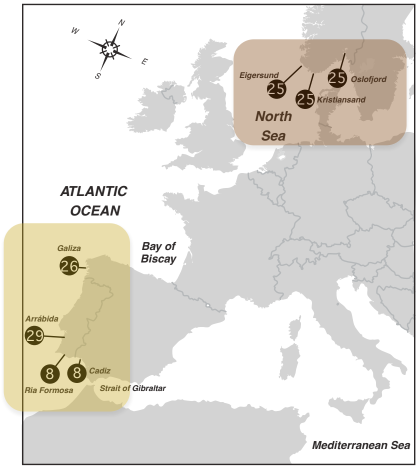
Excoffier and Ray 2008. TREE 23:347–351.

Examples

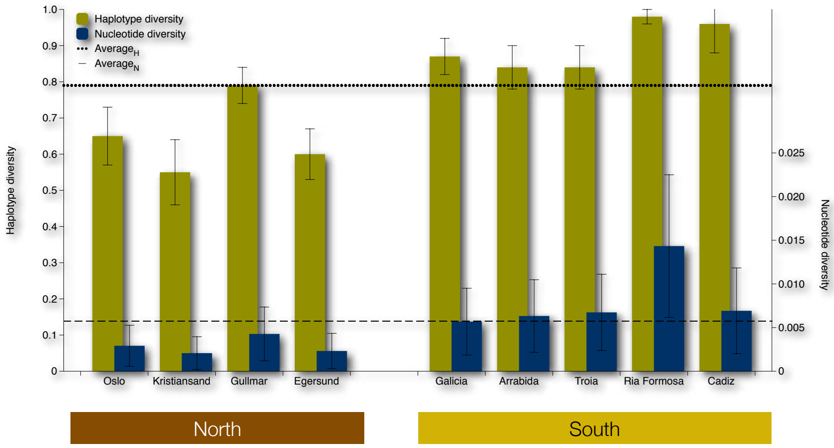
Gobius niger: so far away and yet so close

a tale of the North and South

Sampling locations and sampling size

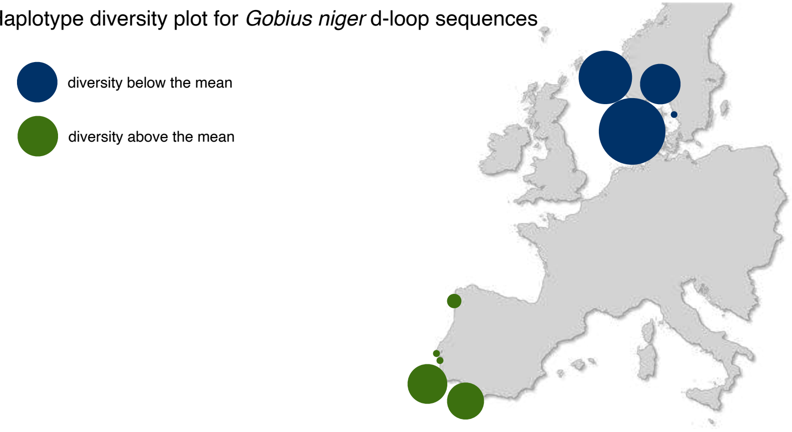


Diversity estimates



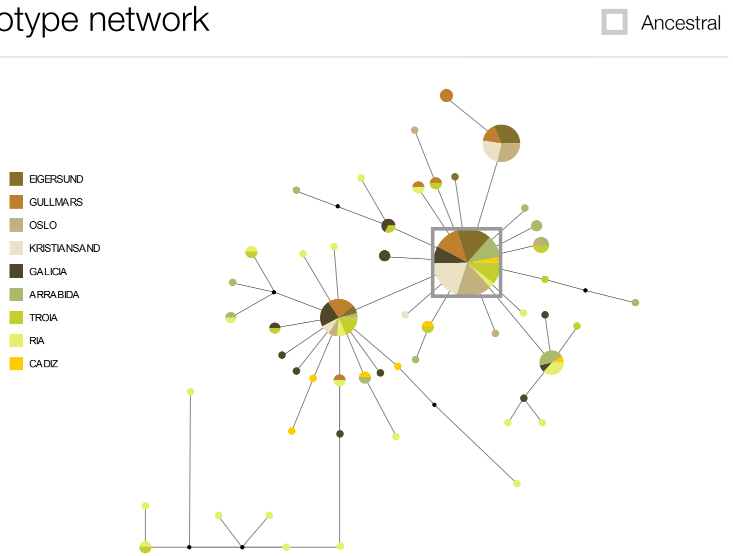
Diversity estimates

Haplotype diversity plot for *Gobius niger* d-loop sequences

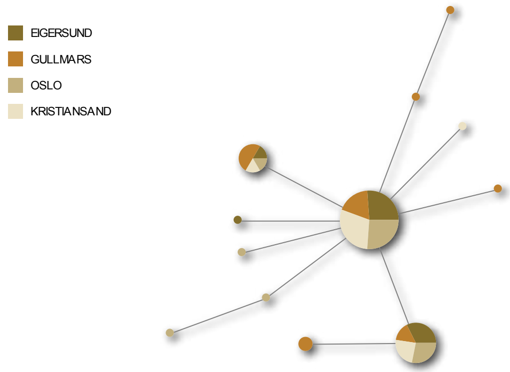


The least diverse sample is indicated by the largest blue circle and the most diverse sample by the largest green circle.

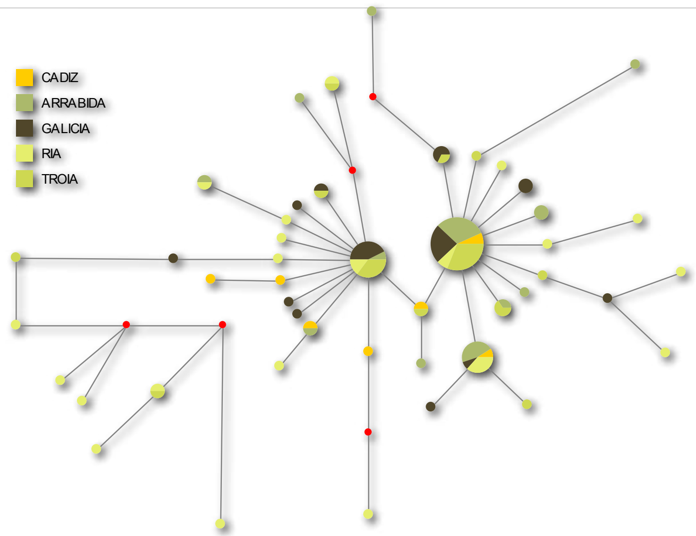
Haplotype network



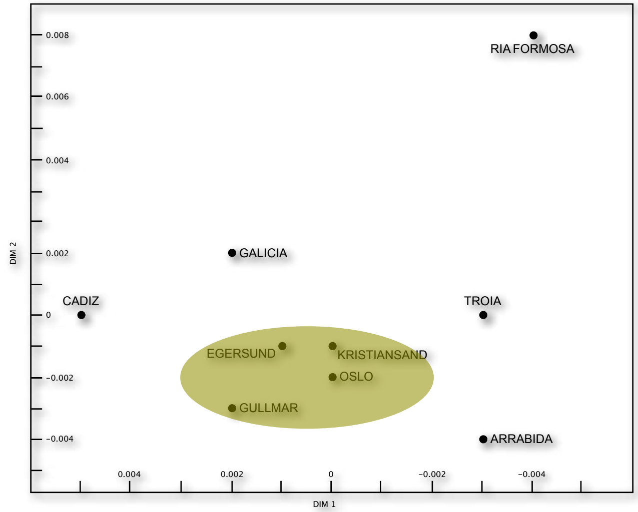
NORTH



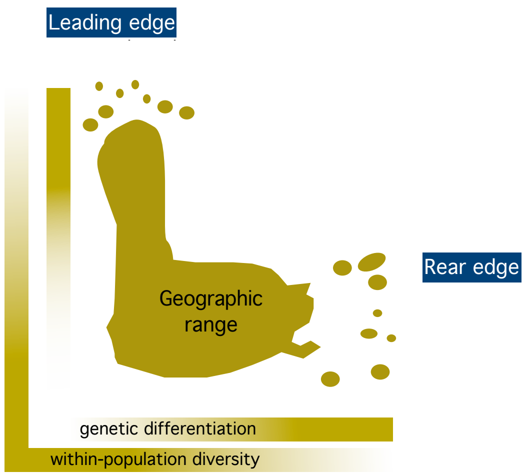
CENTRAL



MDS (corrected genetic distances)



Edge effect



Adapted from Hampe and Petit. Conserving biodiversity under climate change: the rear edge matters. Ecol Letters (2005) vol. 8 (5): 461-467.

Examples

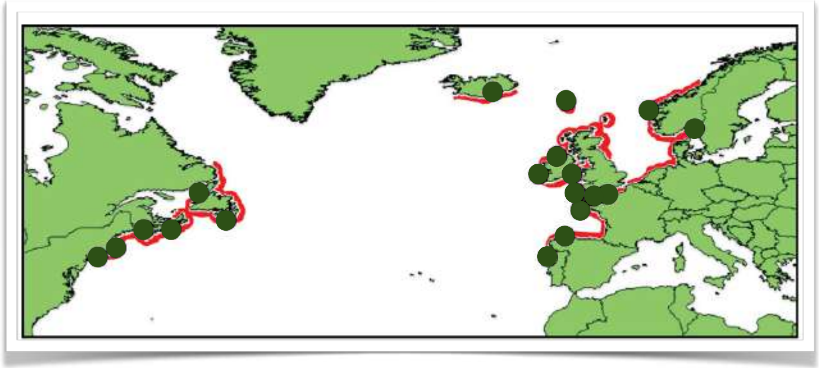

PROCEEDINGS OF THE ROYAL SOCIETY B
FirstCite e-publishing
Proc. R. Soc. B
doi:10.1098/rspb.2011.0536
Published online

Unique genetic variation at a species's rear edge is under threat from global climate change

Jim Provan* and Christine A. Maggs

Chondrus crispus

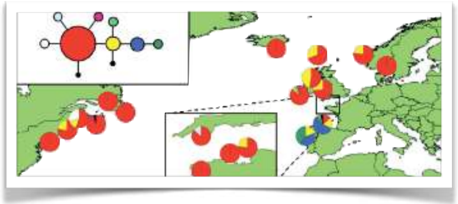
Examples



Present distribution

Provan & Maggs 2011. PRSL

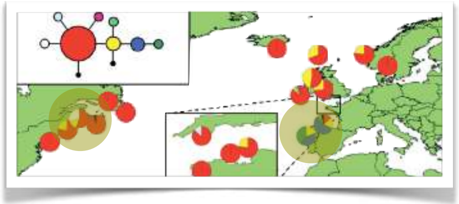
Examples



Mitochondrial SNP (trnI intron)

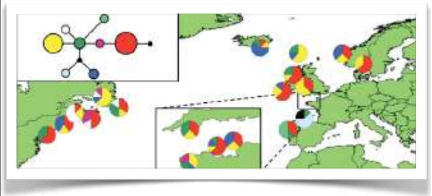
Provan & Maggs 2011. PRSL

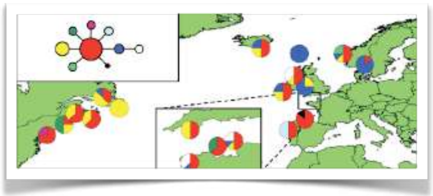
Examples



Mitochondrial SNP (trnI intron)

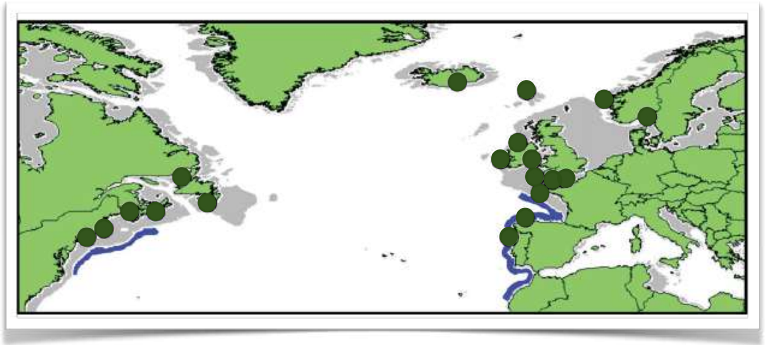
Sequencing of two single-copy nuclear loci





Provan & Maggs 2011. PRSL

Examples

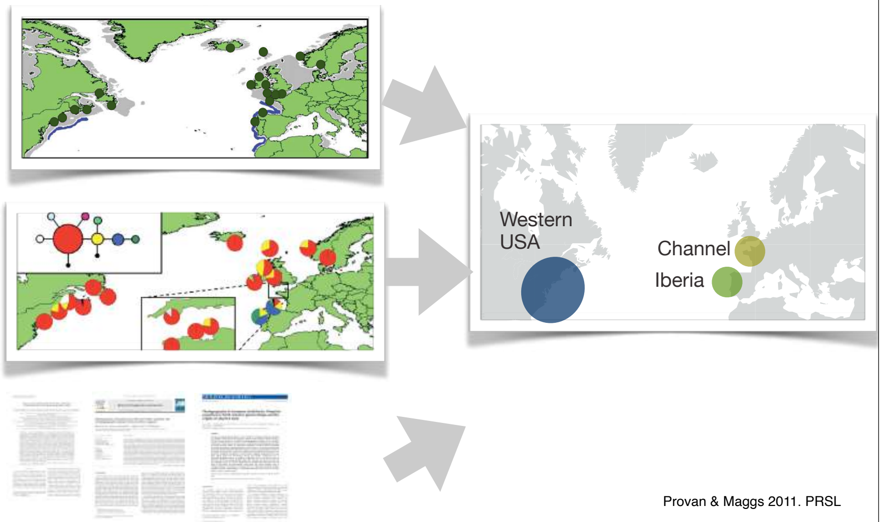


Dry land at the LGM

Putative refugial areas

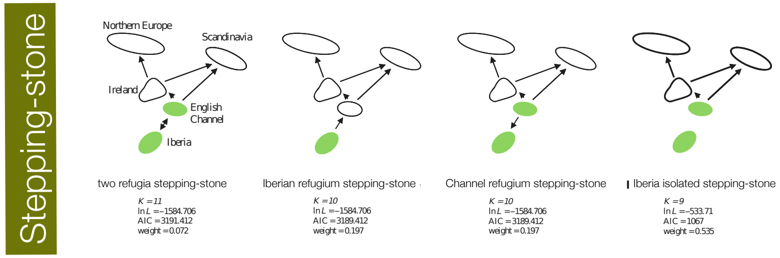
Provan & Maggs 2011. PRSL

Examples



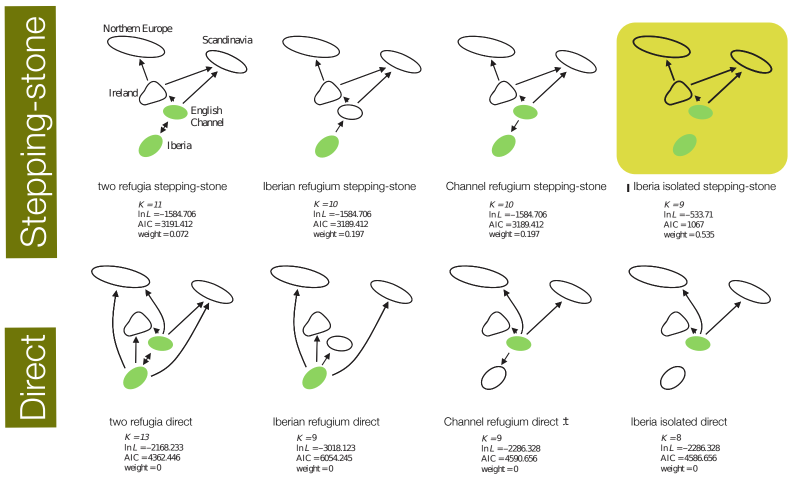
Provan & Maggs 2011. PRSL

Examples



Provan & Maggs 2011. PRSL

Examples



Provan & Maggs 2011. PRSL

Biogeographic Responses to Pleistocene Glaciations

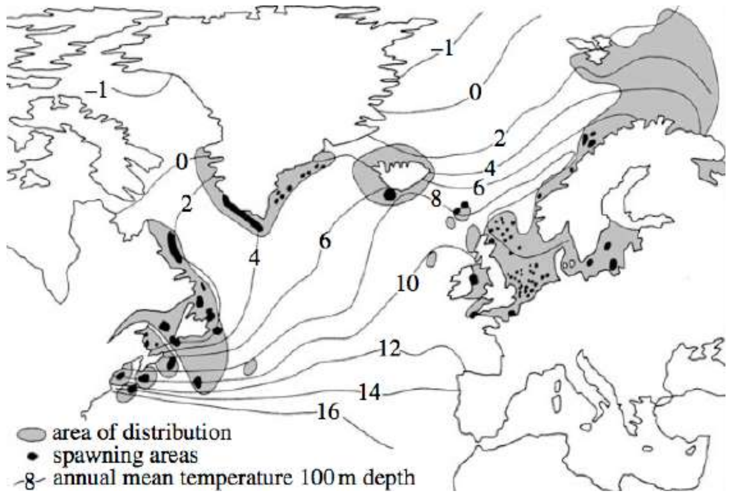
Climate change consequences

Biogeographic Responses to Pleistocene Glaciations

outline

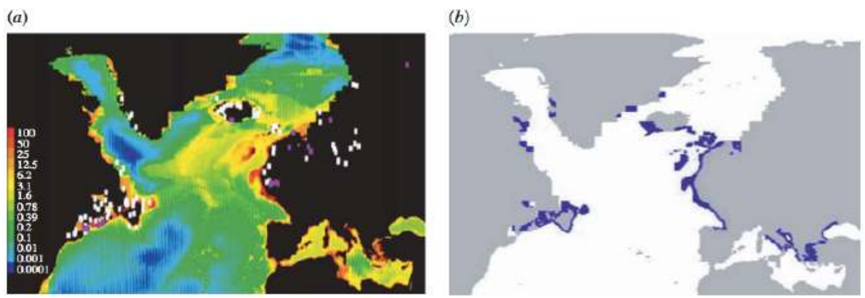
- MILANKOVITCH CYCLES
- MEASURING PALEOTEMPERATURES
- GLACIERS
- ISOSTATIC / EUSTATIC SEA LEVELS
- LOWER SEA LEVELS IN THE PAST
- BIOGEOGRAPHIC RESPONSES
- CASE STUDy

Examples

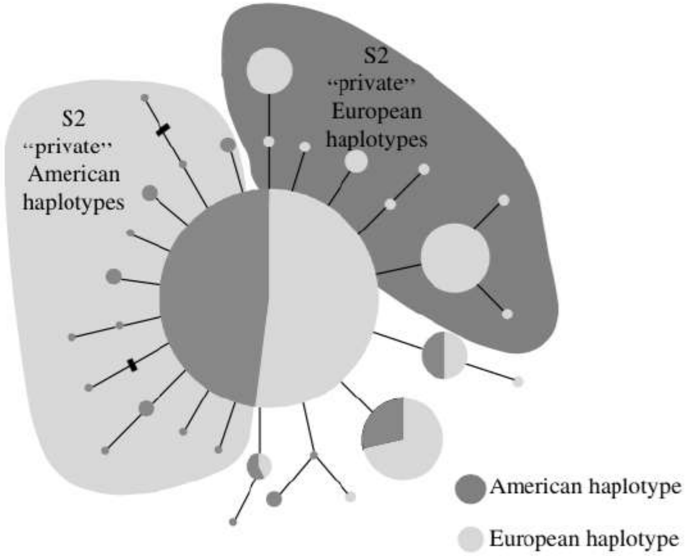


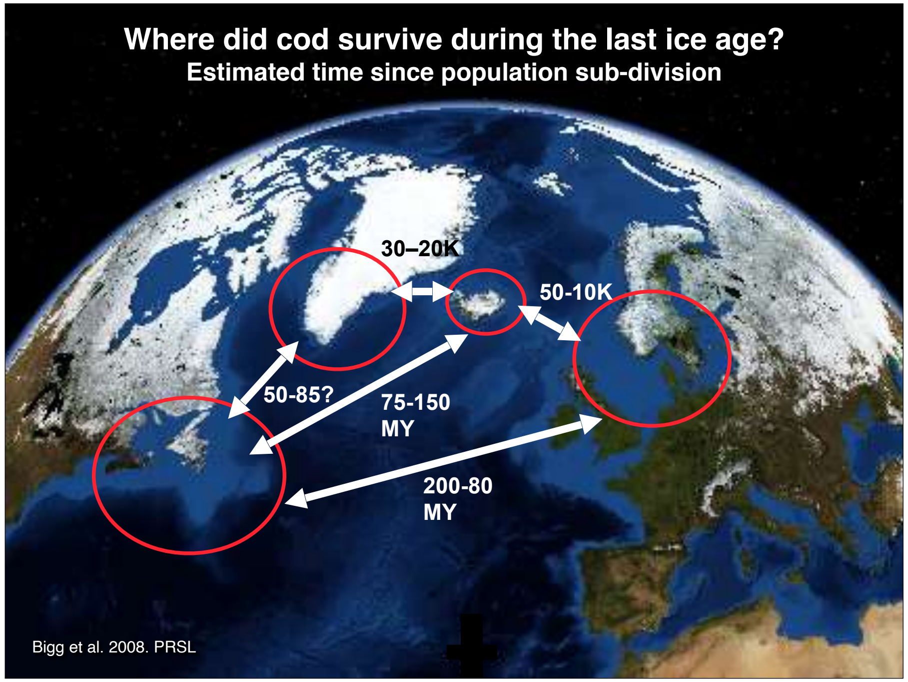
Bigg et al. 2007. PRSL

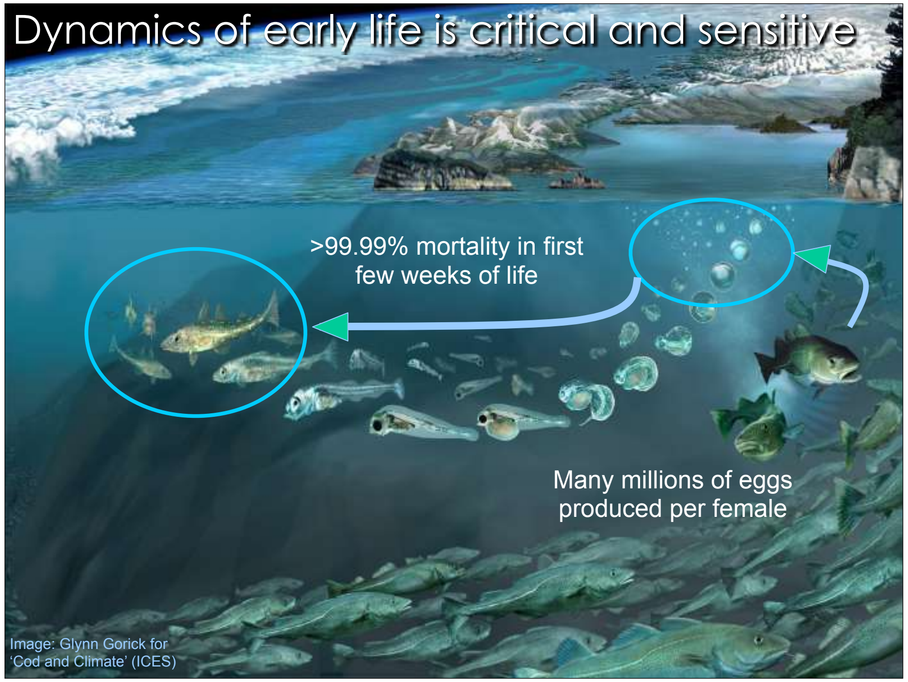
Examples

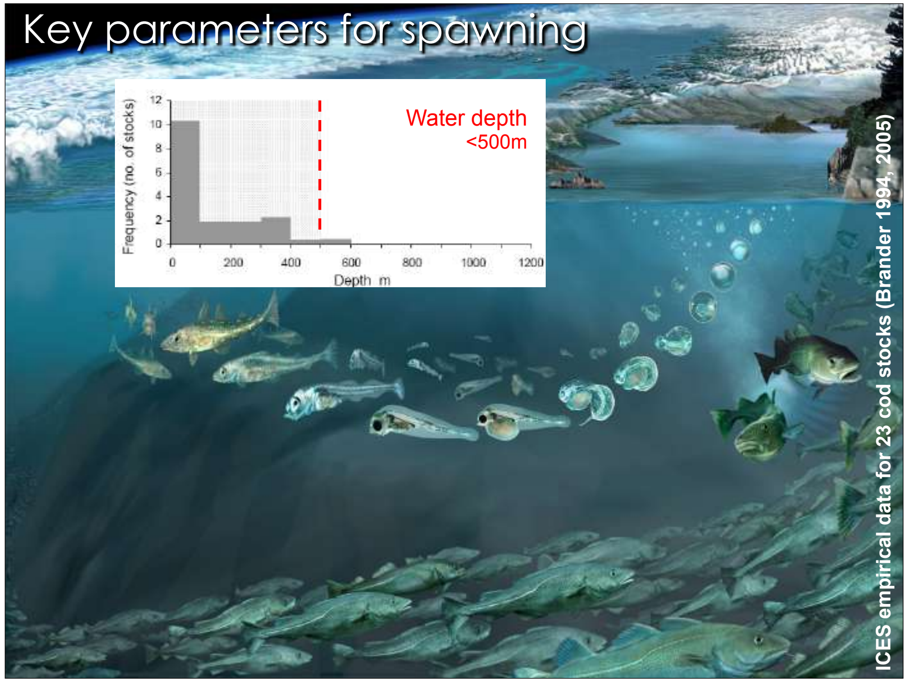


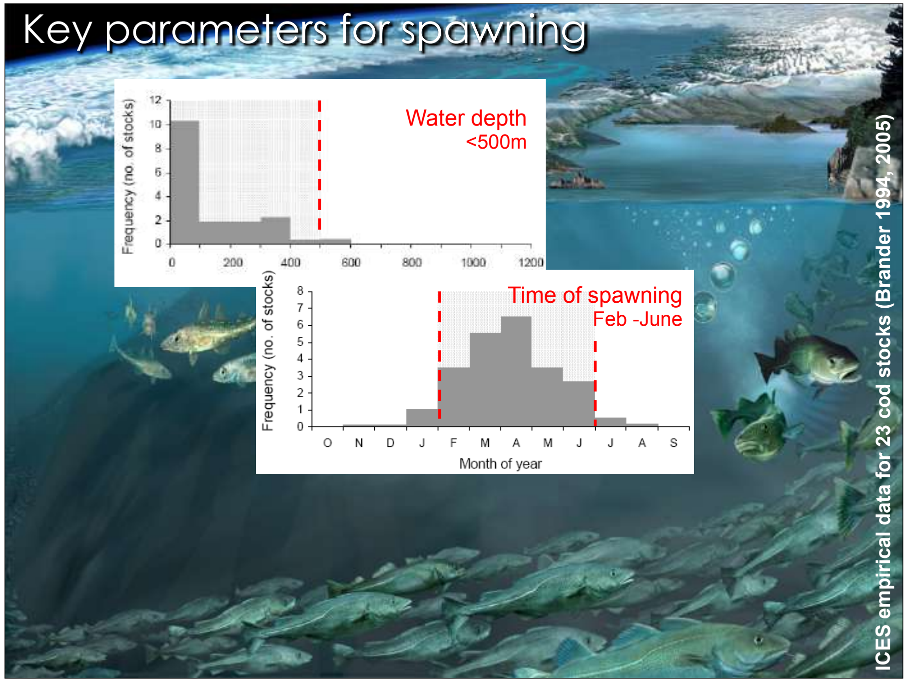
Examples

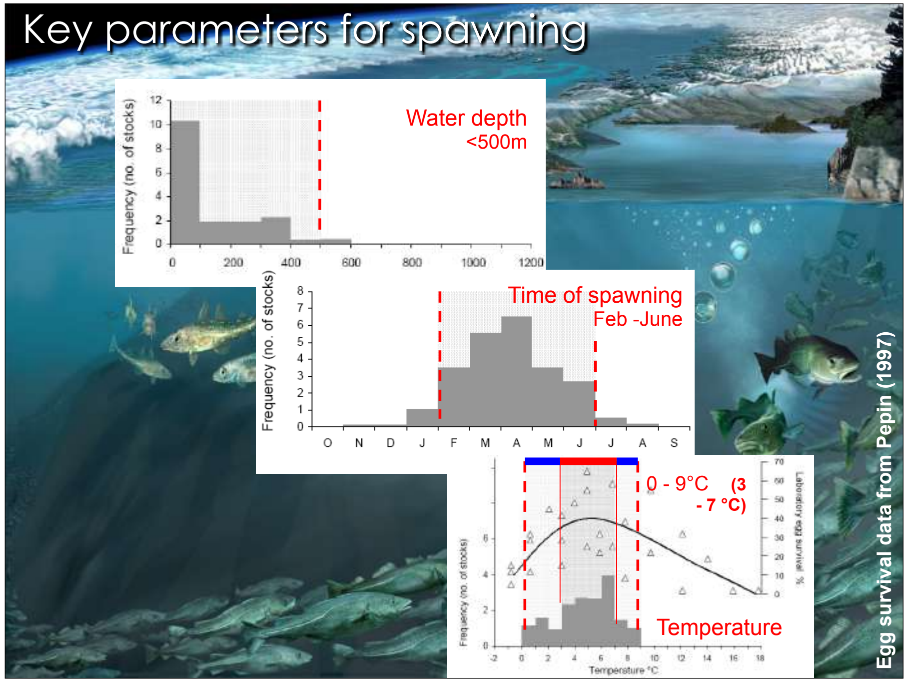



Where did cod survive during the last ice age?
Estimated time since population sub-division
30–20K
50-10K
50-85?
75-150
MY
200-80
MY
Bigg et al. 2008. PRSL


Dynamics of early life is critical and sensitive
>99.99% mortality in first
few weeks of life
Many millions of eggs
produced per female
Image: Glynn Gorick for
'Cod and Climate' (ICES)


Key parameters for spawning
Water depth
<500m
Frequency (no. of stocks)
Depth m
ICES empirical data for 23 cod stocks (Brander 1994, 2005)


Key parameters for spawning
Water depth
<500m
Frequency (no. of stocks)
Time of spawning
Feb -June
Frequency (no. of stocks)
O N D J F M A M J J A S
Month of year
ICES empirical data for 23 cod stocks (Brander 1994, 2005)



Climate change consequences