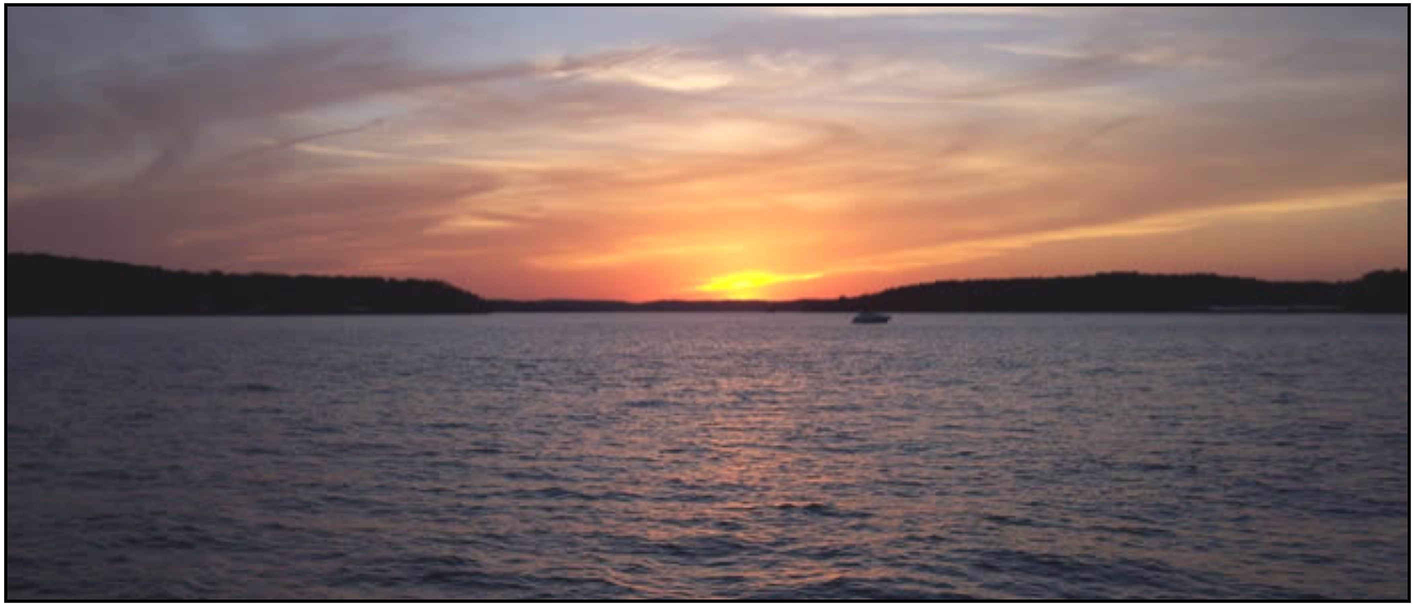
Past Freshwater Changes



Freshwater ecosystems harbor >30,000 species including 41% of all fish.

Human impact on these systems is immense and extinction rates are high – perhaps 3-4 times terrestrial rates.

These systems are especially sensitive to climate change and the impacts have important consequences for both biological diversity and human endeavors.

Freshwater Ecosystems

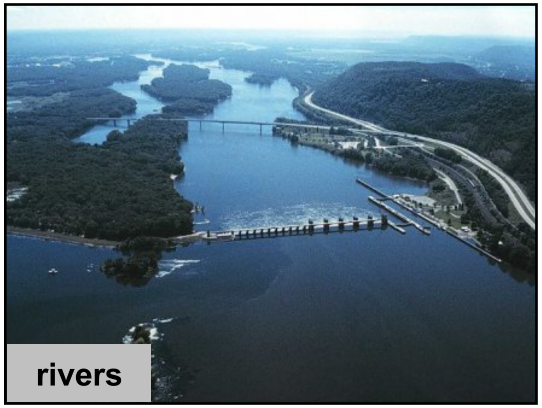

lakes


ponds


streams


swamps


marshes


rivers

Freshwater ecosystems account for less than 1/10 of 1% of earth’s surface and they are unevenly distributed.

They are ephemeral in geologic time often lasting less than 1 million and seldom more than 10 million years

Window to the Past

Lakes are a particularly good indicator of past climate changes and impacts.

Their sediments preserve abundant fossil microorganisms.

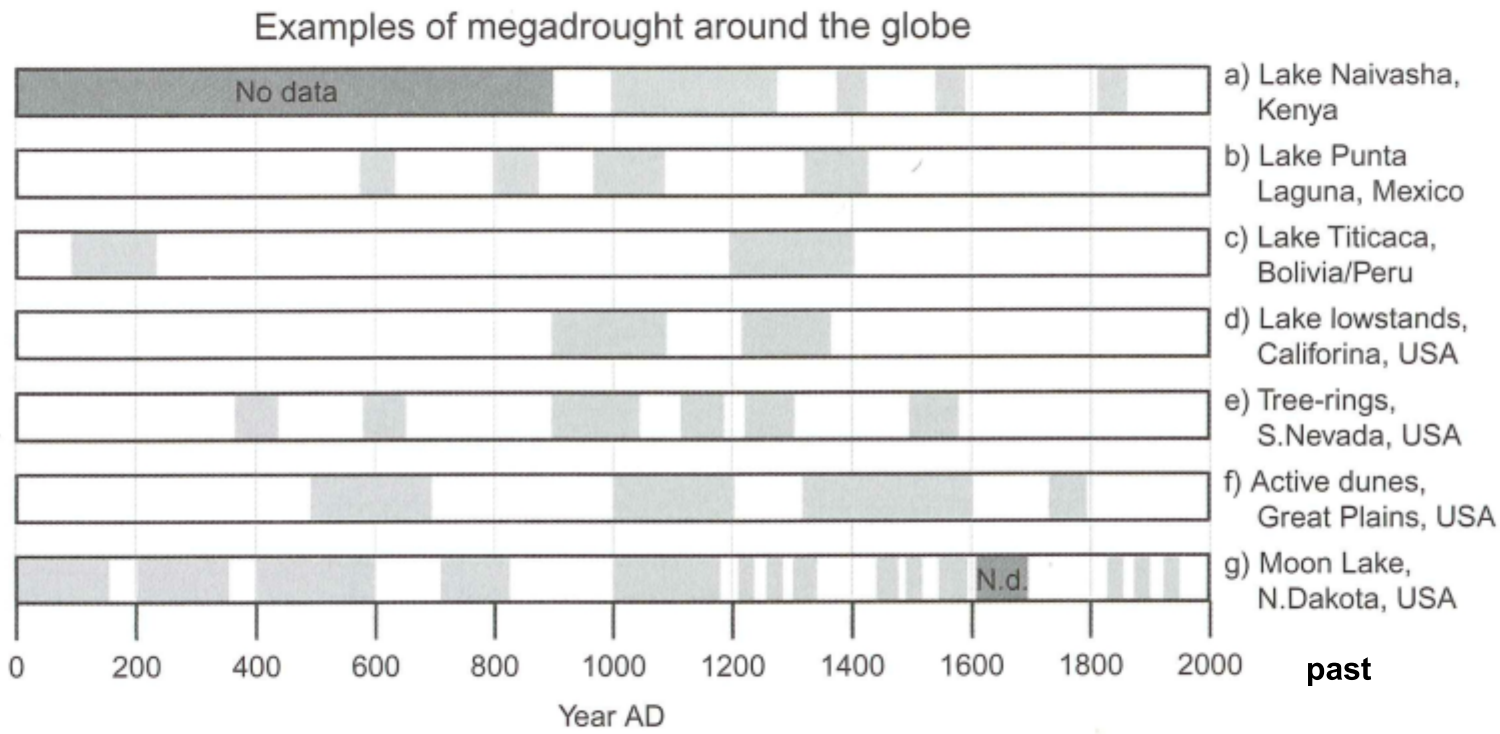
Larger organisms preserve less well but periodic catastrophic events preserve treasure troves of macro-fossils.

Lake beds are sources of pollen as well as fossils allowing inferences about conditions affecting terrestrial habitats.

Lake lowstands and highstands (period of maximum and minimum water depths) may be discernable from geochemical and biological remains.

Lake sediment remains can indicate periods of megadrought that reflect especially harsh conditions in areas.

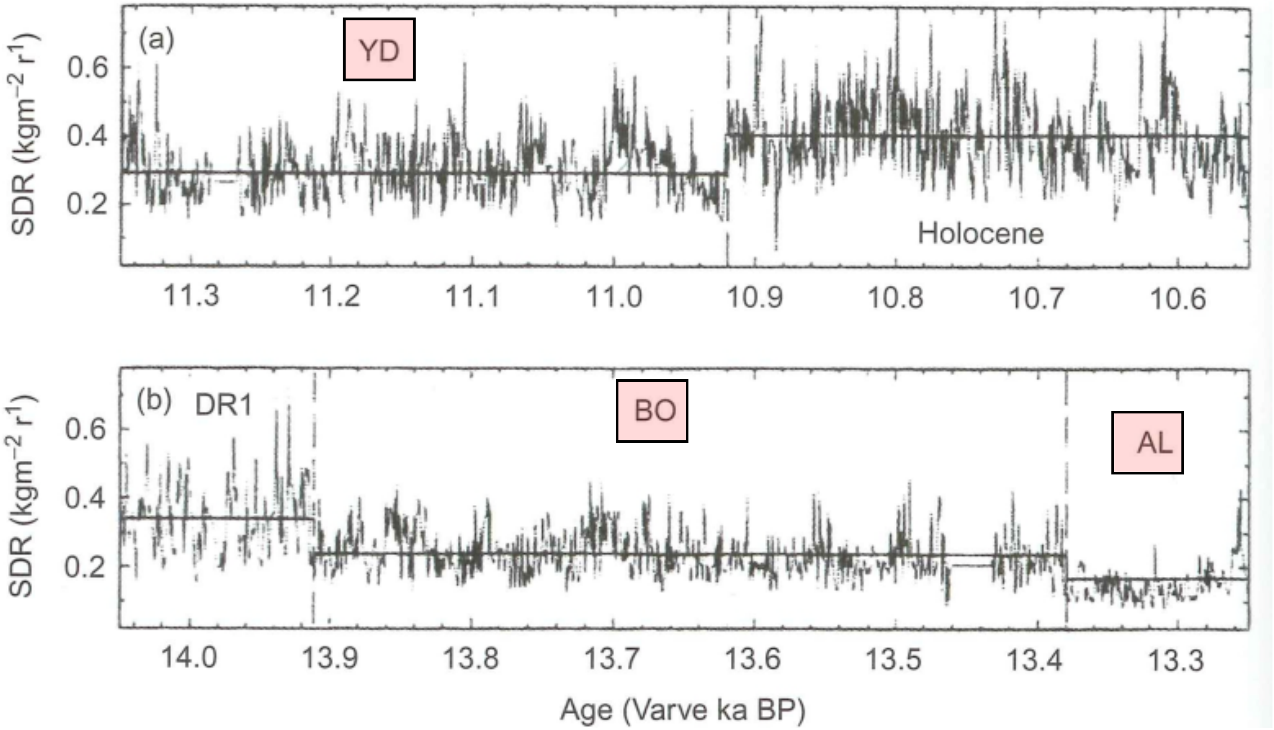
Lake Sediment Data


Examples of megadrought around the globe

There are clear regional specific patterns but also some concordances reflecting more global changes in conditions leading to droughts.

The regional patterns are especially important in unraveling past climate history and can provide more details than either the Greenland or Antarctic ice core data.

Varve Data

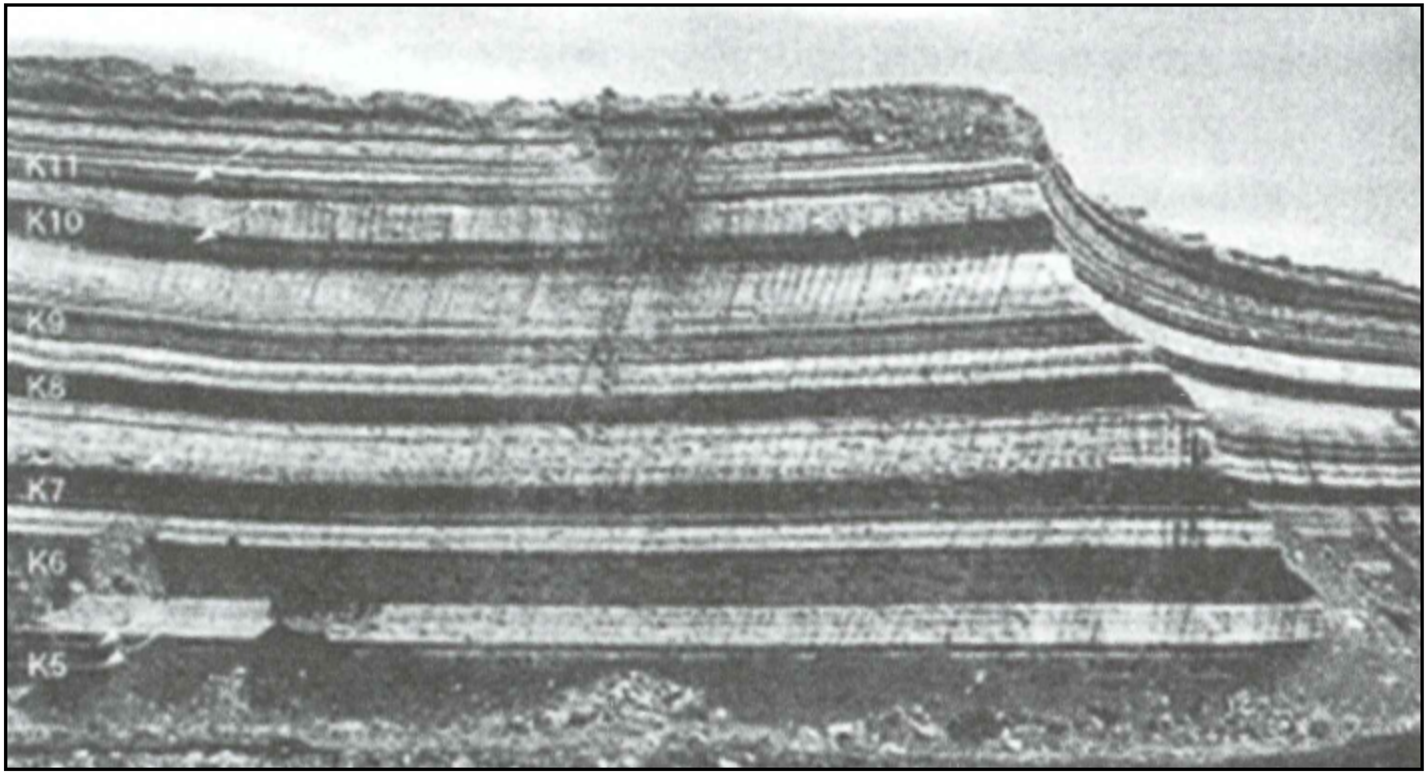


Varves are annual layers created by biological or biogeochemical processes.

Coring and examination can provide very precise indications of relatively rapid events.

This series indicates the Younger Dryas, Allerod and Bolling events.

Deeper Time Imprints



Sediment in the Ptolemais Lake region of Greece exposed along a fault line.

The alternating layers of carbonite and organic lignite display a 21,000 year pattern of Milankovitch precession cycles.

Types of Freshwater Alterations with Climate

streamflow

stream temperature

habitat fragmentation

Streamflow

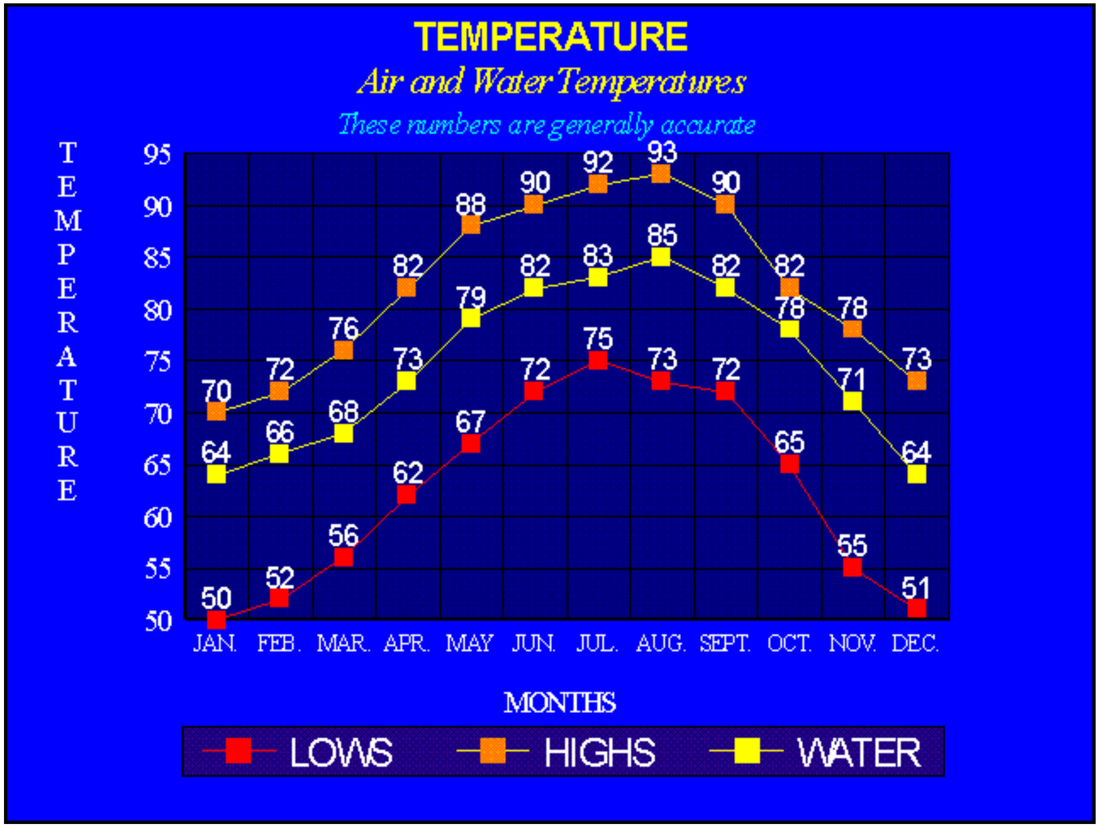
Streamflow is impacted by numerous factors including precipitation, snowmelt, temperature and evapotranspiration.

Many of these are correlated and vary in consort annually.

The impact of interest to past and future climate change are inter-annual differences and patterned changes in streamflow.

Because rapidly flowing water cuts into channels and banks it also results in sedimentation in basins and lakes.

Stream Temperature



Stream temperatures track air temperatures.

The correspondence improves as the stream becomes more shallow.

Streams that draw more of their water from surface run-off rather than springs and aquifers are also more influenced by air temperatures.

Stream depending on high mountain snow melt are less influenced by air temperature

Streams that are normally cold and support cold-water fauna such as trout will be more impacted by changes in air temperature.

Habitat Fragmentation and Change

Removing the trees from riparian habitat exposes streams to exacerbated effects of climate change.

The treeless shores of even parts of streams increases water temperature and evaporation.

The latter increases the chance of lowering water levels throughout the watershed.

The absence of vegetation along stream boundaries also increases sedimentation.

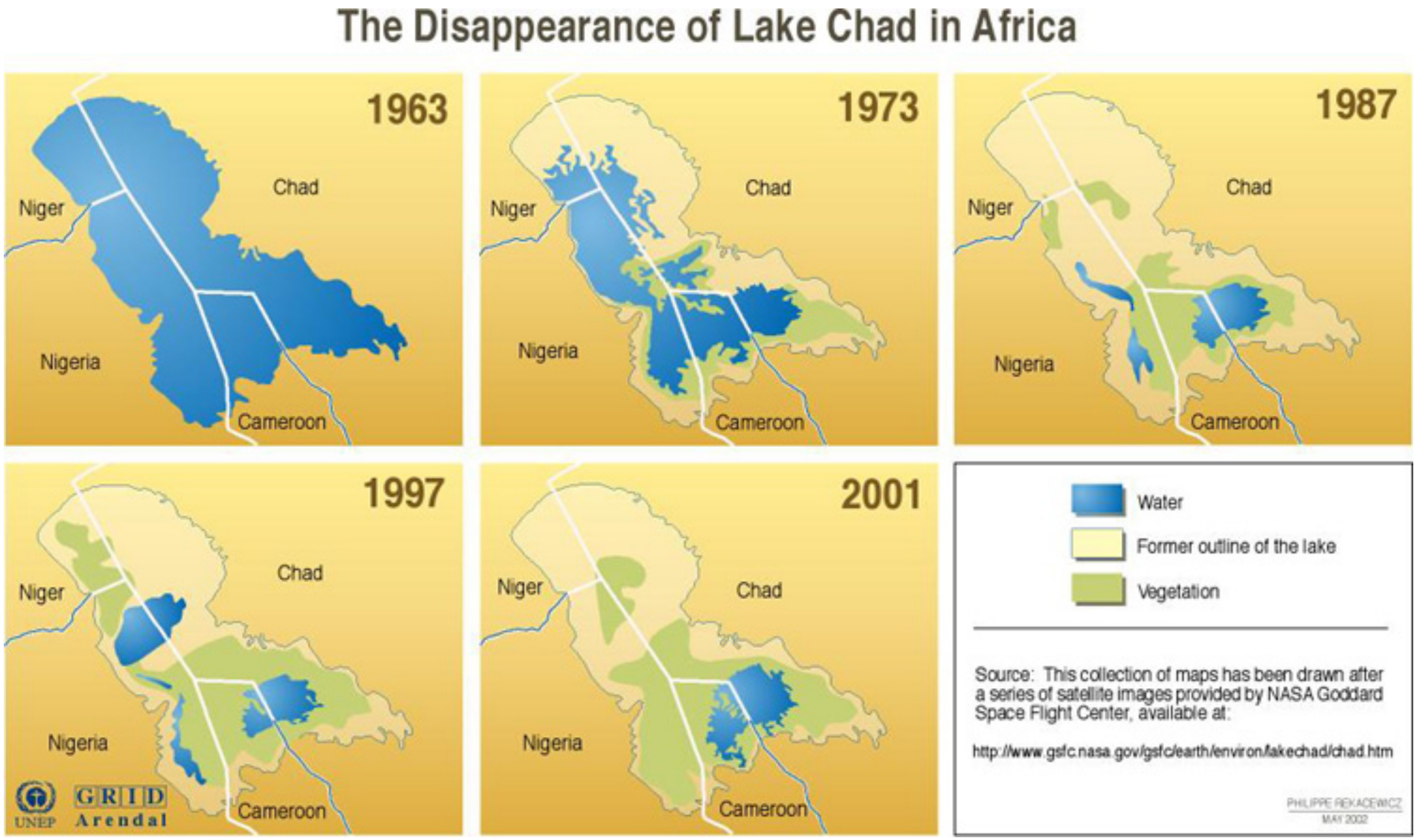
Habitat Fragmentation and Change

The combined effects of overconsumption of water and climate change leads to lakes drying up.

This has happened during deep historically as a sole function of past climate change.

The appearance and disappearance of lakes is a natural process and the sediment left behind can be examined to reconstruct local climate.

Habitat Fragmentation and Change



The Disappearance of Lake Chad in Africa

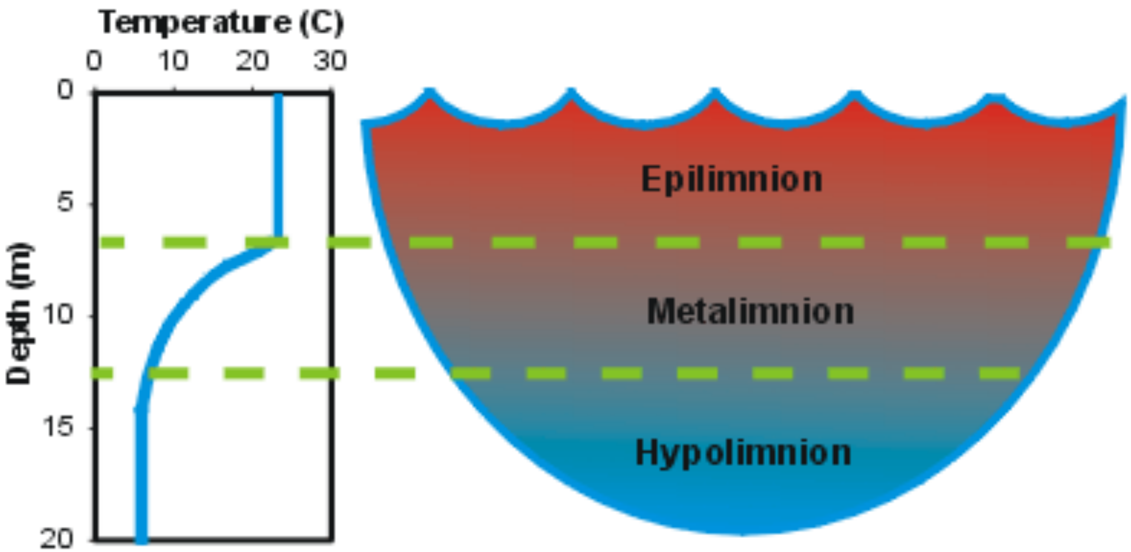
Source: This collection of maps has been drawn after a series of satellite images provided by NASA Goddard Space Flight Center, available at:

http://www.gsfc.nasa.gov/gsfc/earth/environ/lakechad/chad.htm

PHILIPPE REKACEWICZ
MAY 2002

The basins of lakes can be detected even after totally gone and sediments can still be used to reconstruct local climate change.

Lake Depth and Stratification



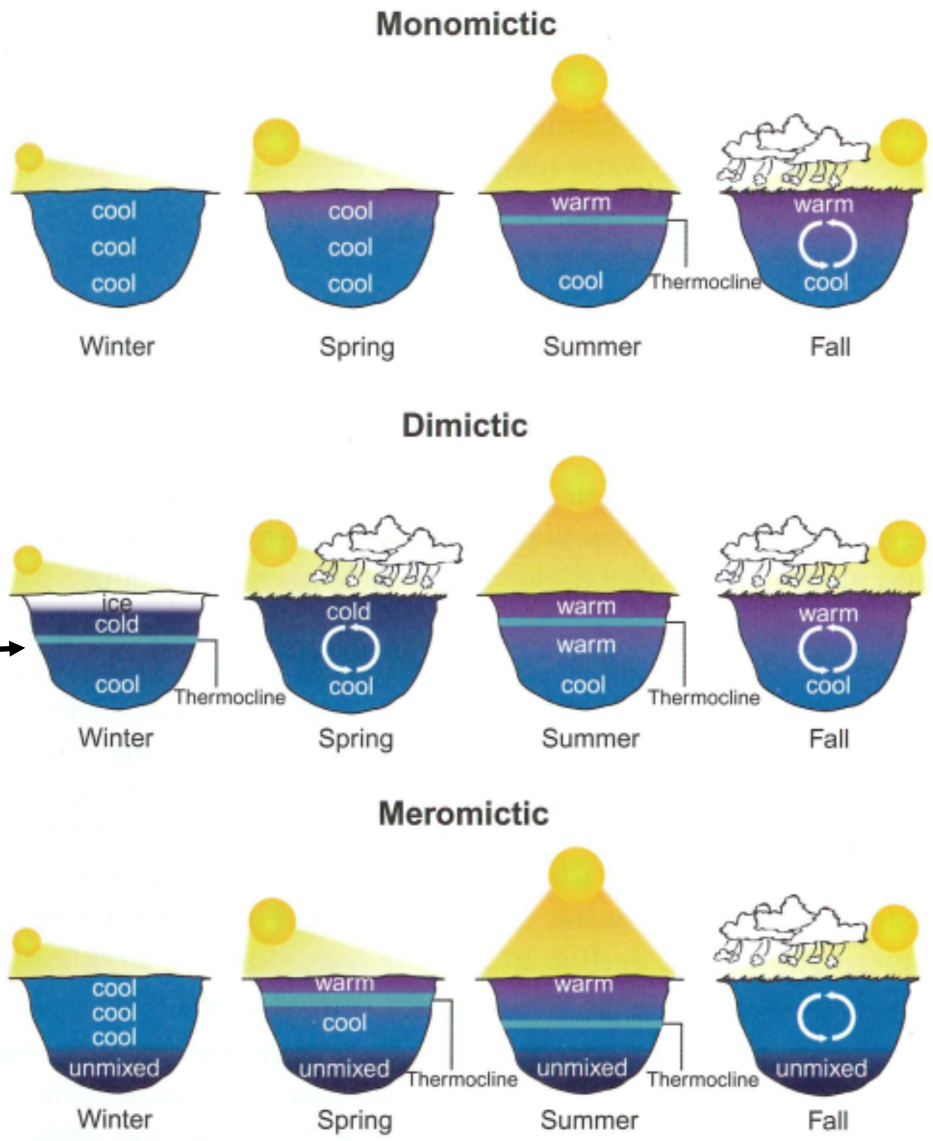
Heat causes the upper layer to float on colder, deeper water.

Stratification occurs when wind mixing is not sufficient to offset the buoyancy.

Thickness and steepness of the thermocline (metalimnion) depends on temperature difference.

The epilimnion is well oxygenated and productive while the hypolimnion is heterotrophic only.

Patterns and Mixing of Deep Lakes



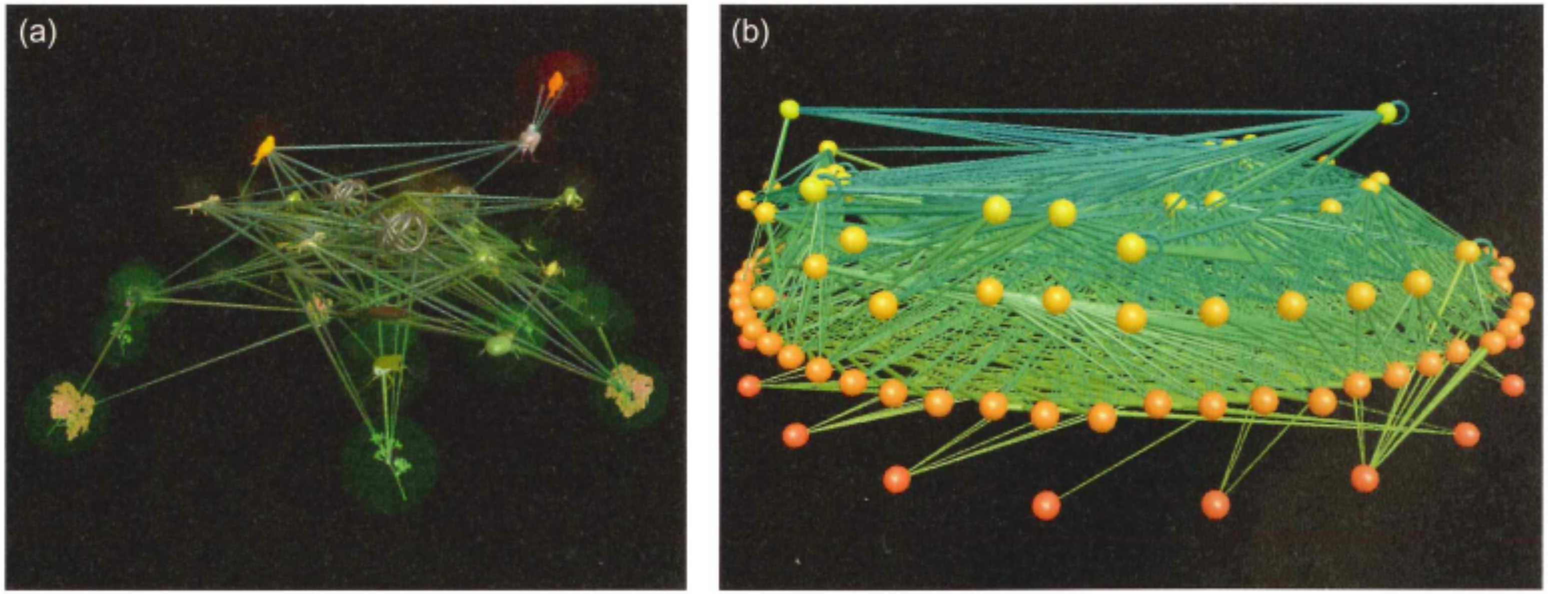
Monomictic

Dimictic

Meromictic

reversed stratification

Freshwater Biotas, Habitats and Food Webs



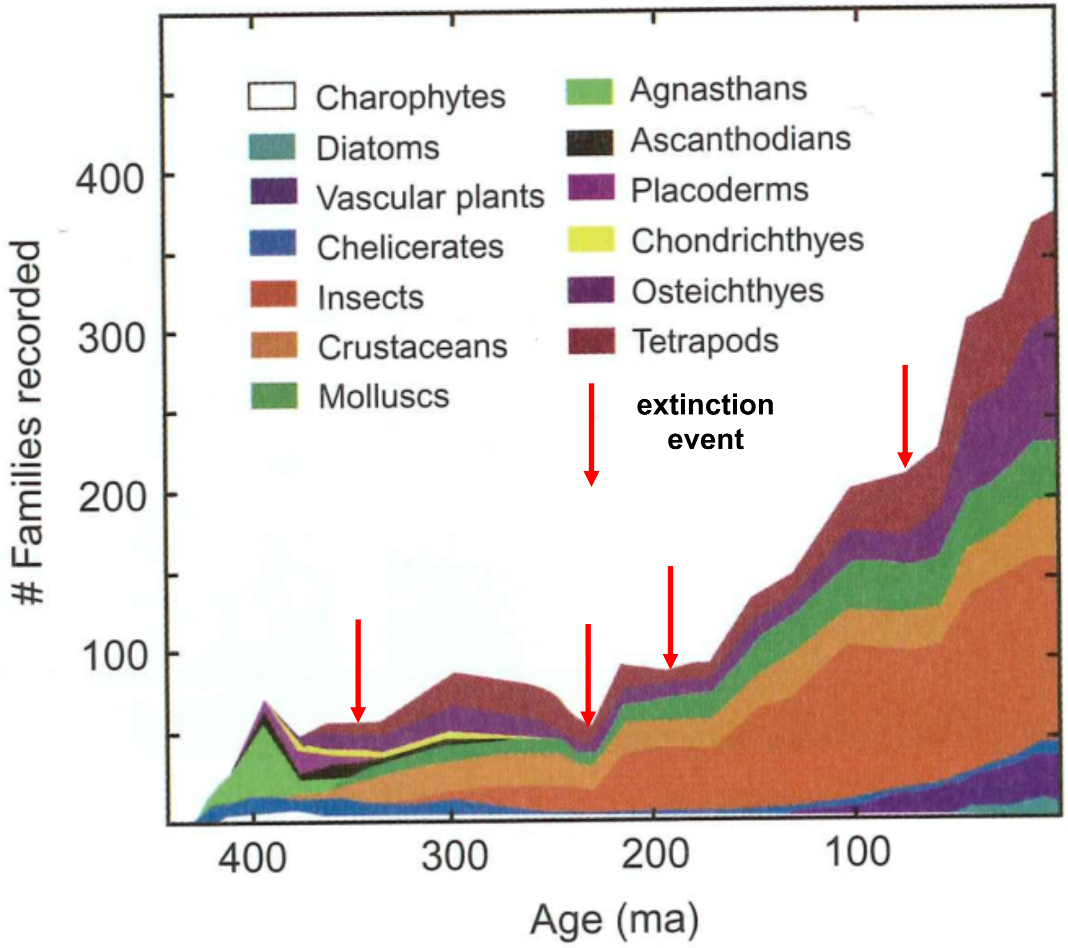
The base producers of most freshwater ecosystems are microscopic as are many of the primary consumers (herbivores).

The diversity of these mid-level species is much higher than that of producers and of the top end carnivores.

As a consequence, we see that both for trophic guilds (left) and for species (right) the interconnections in this abstracted food web are highest in the middle.

In permanently stratified lakes there are often separate food webs in the epilimnion and hypolimnion.

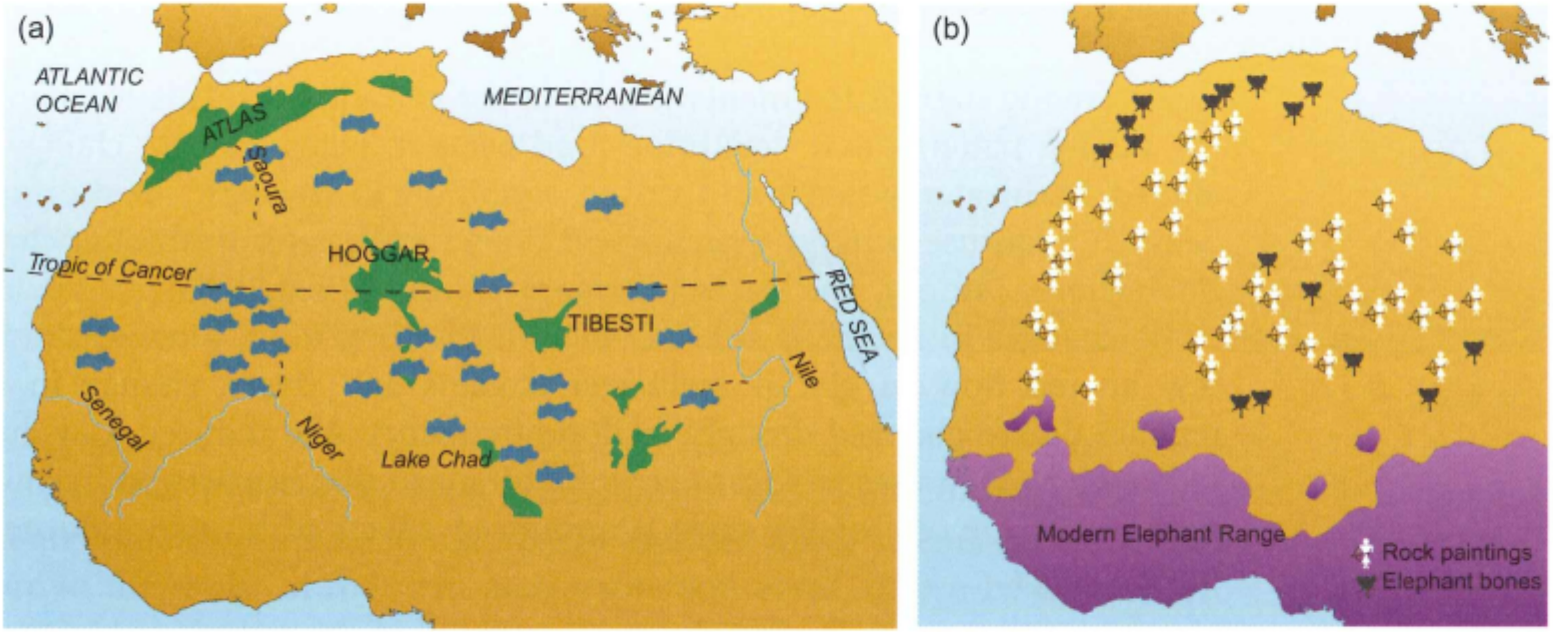
Deep Time: Pace of Evolution and Species Accumulation



The number of species in freshwater ecosystems has increased steadily despite extinctions.

Diversification began later than in marine or terrestrial systems due to a shortage of phosphorus that had eroded from the land and collected in marine systems.

Tertiary and Pleistocene Records of Change



One of the most biologically important events was global cooling 34 mya that eliminated many tropical species from mid-latitude lakes.

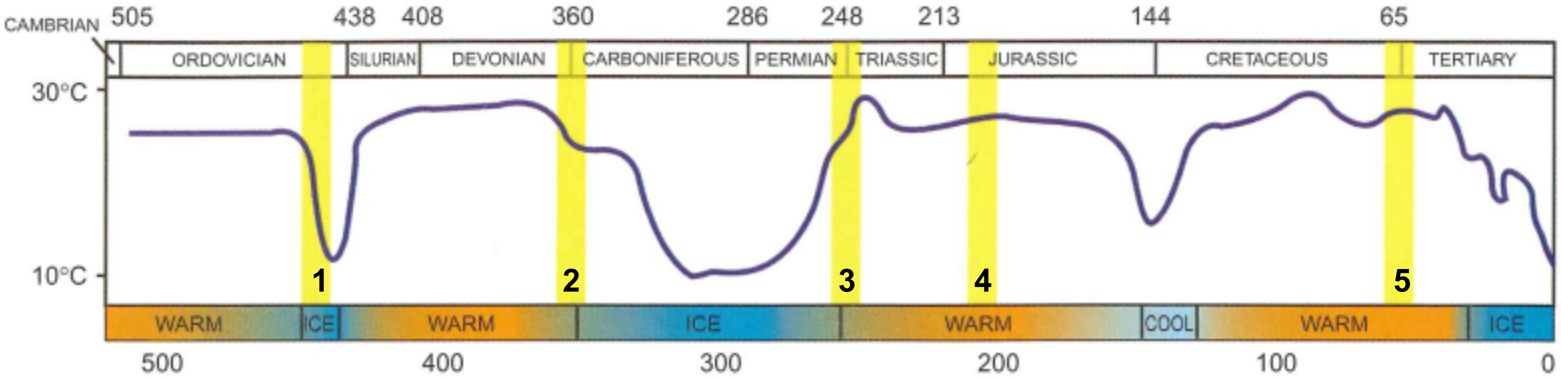
Ice ages have had a major effect because retreating glaciers left a large number of lakes and connections.

As ice sheets melted and reformed, sea levels rose and fell isolating lakes and leading to allopatric speciation and then extinction.

Extinction


WILDLIFE IN DANGER
THE MOST THREATENED SPECIES
1
2
3
4
5
6
7
8
9
10
That's one more creature we can remove from the endangered species list.
It's become extinct.
Chris Madden
www.chrismadden.co.uk

Mass Extinctions and Climate



The 5 major mass extinctions:

1. End Ordovician, 439 mya
60% of marine invertebrate genera go extinct.

2. Late Devonian, 367 mya
57% of marine invertebrate genera go extinct.

3. End Permian, 245 mya
82% of marine invertebrate genera go extinct.

4. End Triassic, 208 mya
53% of marine invertebrate genera go extinct.

5. End Cretaceous, 65 mya
47% of marine invertebrate genera go extinct.

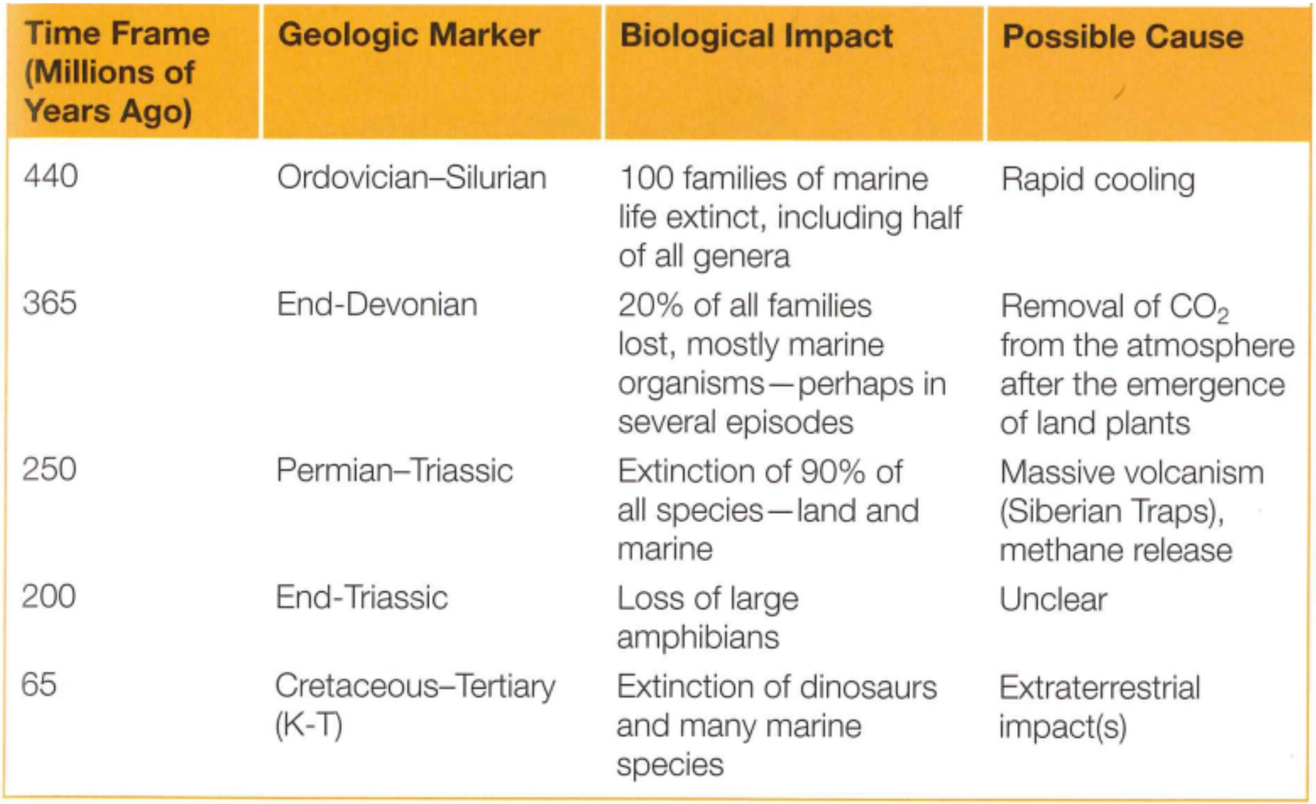
mya = million years ago

Mass extinctions were seen across all flora and fauna.[1]

The were best reflected in the loss of marine invertebrates since those sediments are our best records.

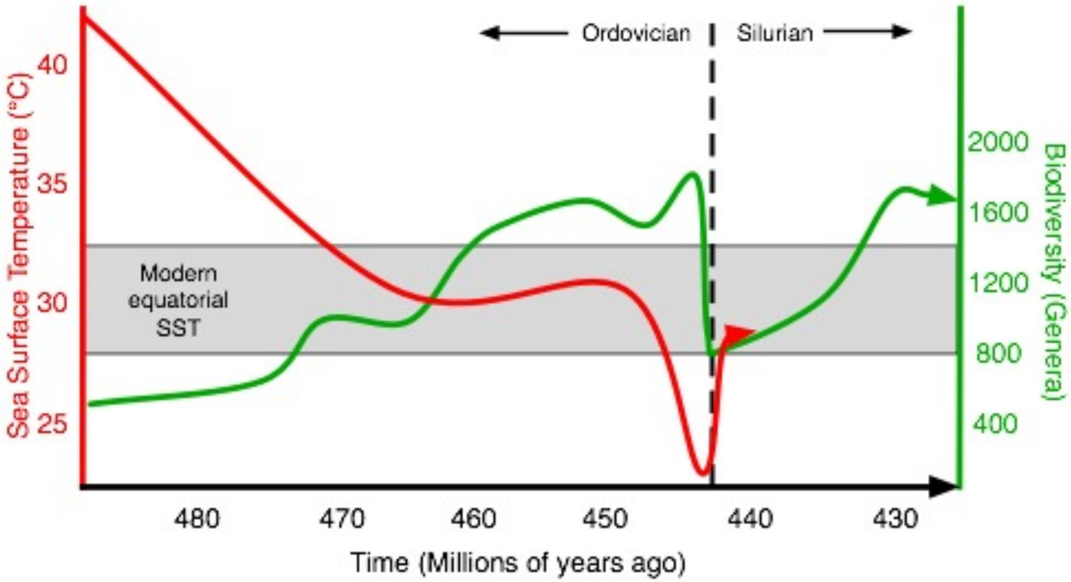
It is clear there is no simple relationship between mass extinctions and climate

Mass Extinctions



Time Frame (Millions of Years Ago)	Geologic Marker	Biological Impact	Possible Cause
440	Ordovician–Silurian	100 families of marine life extinct, including half of all genera	Rapid cooling
365	End-Devonian	20% of all families lost, mostly marine organisms—perhaps in several episodes	Removal of CO_2 from the atmosphere after the emergence of land plants
250	Permian–Triassic	Extinction of 90% of all species—land and marine	Massive volcanism (Siberian Traps), methane release
200	End-Triassic	Loss of large amphibians	Unclear
65	Cretaceous–Tertiary (K-T)	Extinction of dinosaurs and many marine species	Extraterrestrial impact(s)

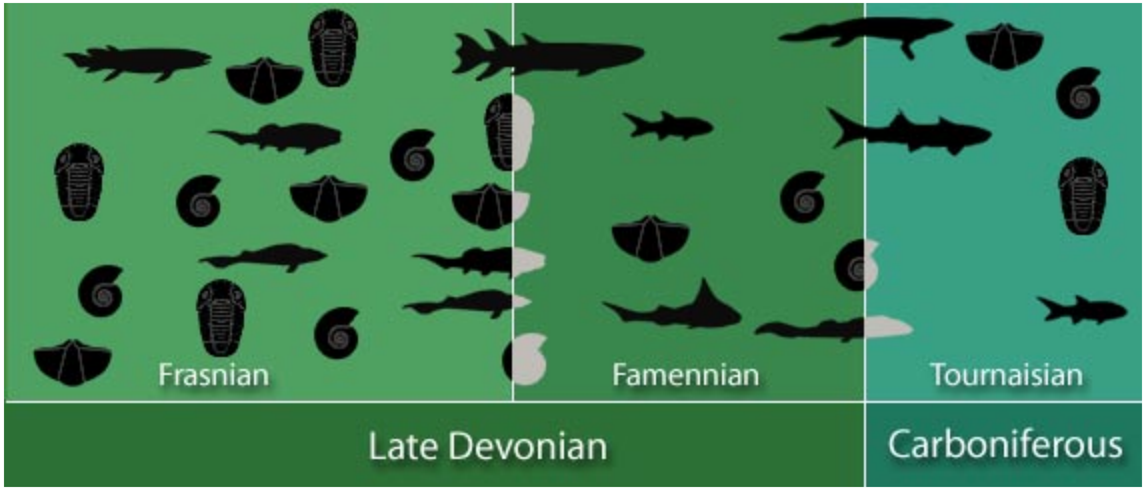
Ordovician-Silurian Event – 440 mya



The first mass extinction for which we have records was the result of a shift from greenhouse to icehouse conditions.

Most of life at this time was marine invertebrates and more than 100 families including 50% of identifiable genera went extinct.

Late Devonian Event – 365 mya



This was a protracted extinction event extending over several million years.

By this time land plants had developed and had greatly reduced atmospheric CO_2.

A reduction in greenhouse gas would lower temperatures and this is thought to have had a partial role.

There is some evidence of a meteor strikes that would have also contributed to a temperature reduction.

Corals and other marine invertebrates were especially impacted.

Permian-Triassic Event – 250 mya

Massive volcanic activity in what is now Siberia injected millions of tons of CO_2 into the atmosphere.

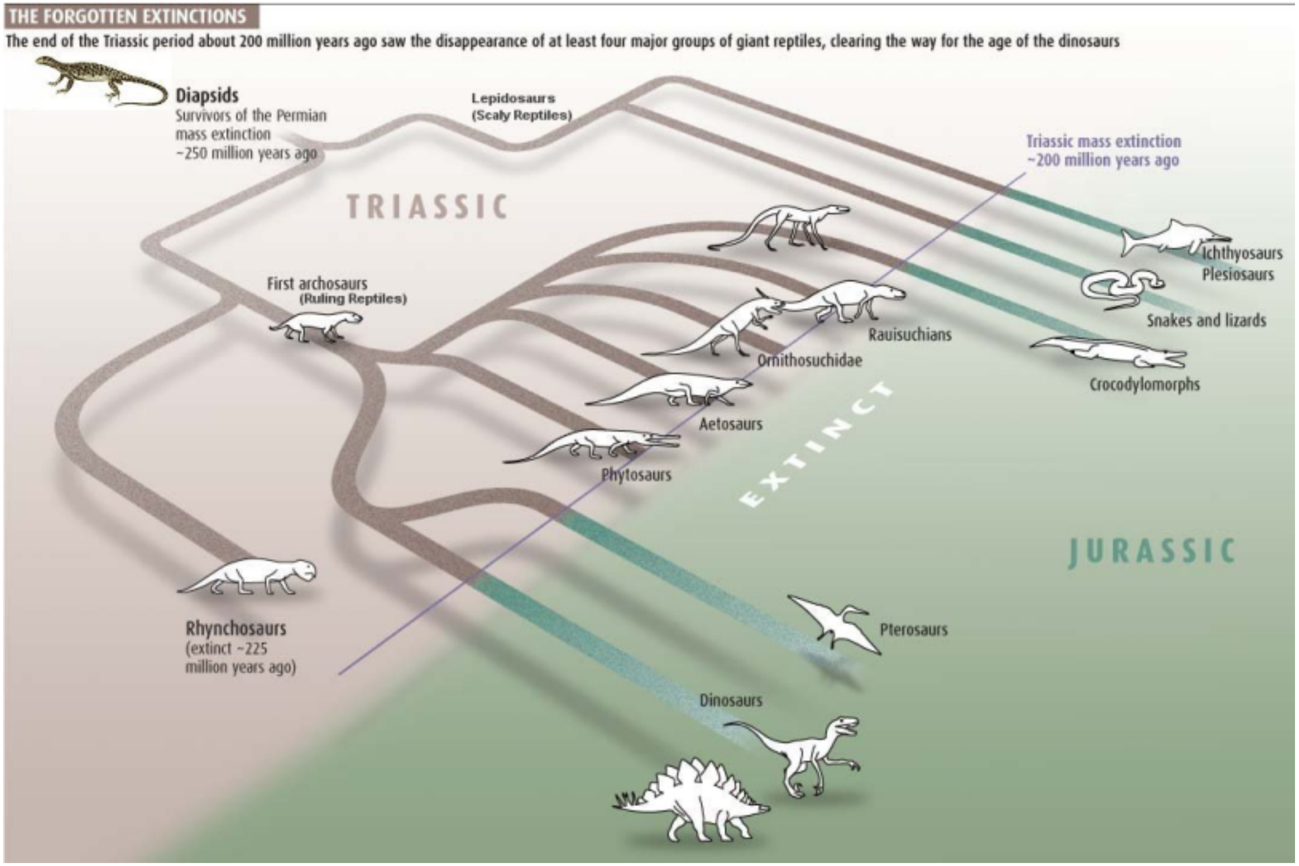
This resulted in an increase in acidity of seawater and the death of most marine critters dependent on calcium carbonate.

The volcanic activity may have been triggered by a massive asteroid strike

Changes in marine flora and fauna had impacts on terrestrial forms that were also being impacted by massive clouds of dust and accumulation of greenhouse gases including methane.

90% of all species were wiped out in the largest of the 3 mass extinction events.

Late Triassic Event – 200 mya



THE FORGOTTEN EXTINCTIONS

The end of the Triassic period about 200 million years ago saw the disappearance of at least four major groups of giant reptiles, clearing the way for the age of the dinosaurs

This event eliminated a number of large terrestrial animals and paved the way for the success of the dinosaurs.

Cretaceous-Tertiary Event – 65 mya

A 180km diameter asteroid is thought to have struck and formed the Chicxulub crater on the coast of Yucatán, Mexico.

The initial heat followed by ash and cooling brought an end to the age of dinosaurs and allowed mammals to proliferate.

C was already used for Carboniferous and the German word for Cretaceous is Kreidezeit – thus the K

The K-T event is now called the Cretaceous–Paleogene event.

Climate as a Common Factor in Major Extinctions

Both volcanoes and asteroid strikes can cause local heat increases followed by globally distributed ash.

The ash and particulates can block solar insolation and light needed for photosynthesis.

Volcanic activity can be triggered by asteroid strikes and can add massive amounts of greenhouse gases to the atmosphere.

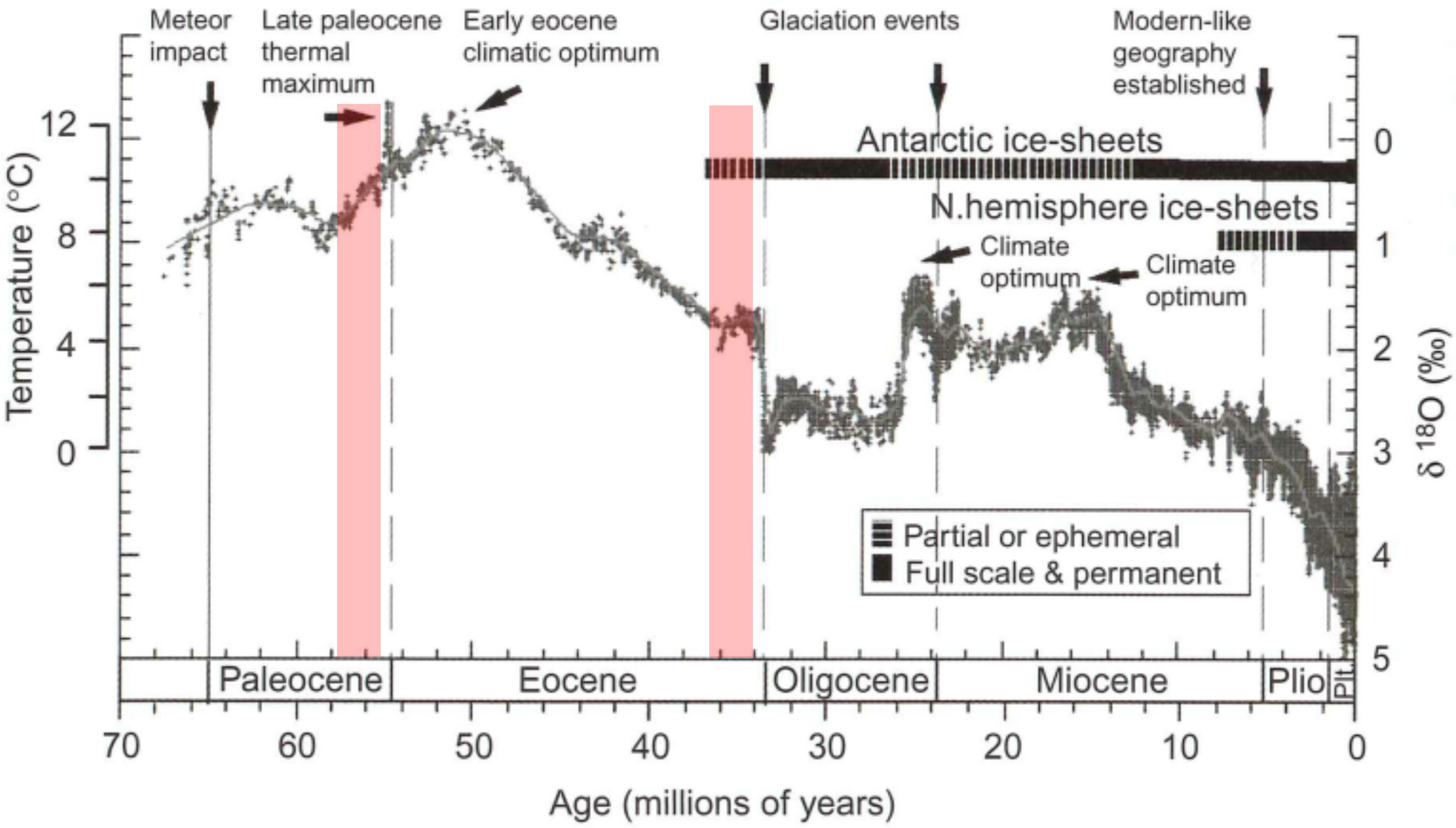
While the relation of mass extinctions and temperature is not straightforward, there are certainly suspected climate links to all of them.

Heat generated by strikes or eruptions would have more impact on larger terrestrial fauna and plants and that seems to be the pattern.

Following the heat event, ash would result in climate cooling and this would have disproportionate impact on cold blooded fauna like the dinosaurs.

The only lineage to survive the K-T event was birds – and they were/became warm blooded.

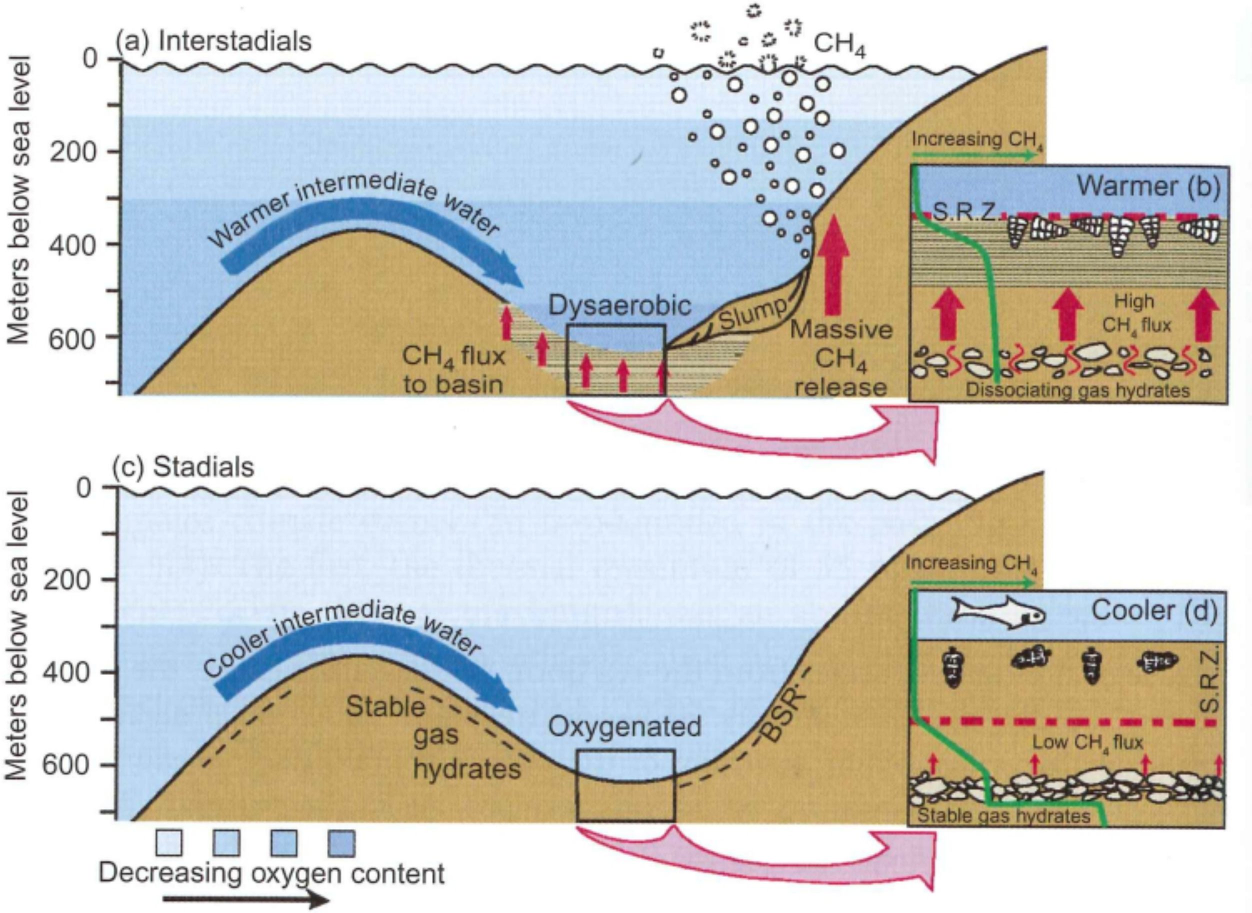
The Past 65 Million Years



Paleo-eocene thermal maximum likely resulted from release of large amounts of methane that added to volcanic-based greenhouse gases. 50% foraminifera were lost.

The Oligocene chill down again led to extinction of marine and terrestrial plants and animals.

Methane Release



Methane released from sea floor clathrates during short warm periods adds to greenhouse gases and general warming.

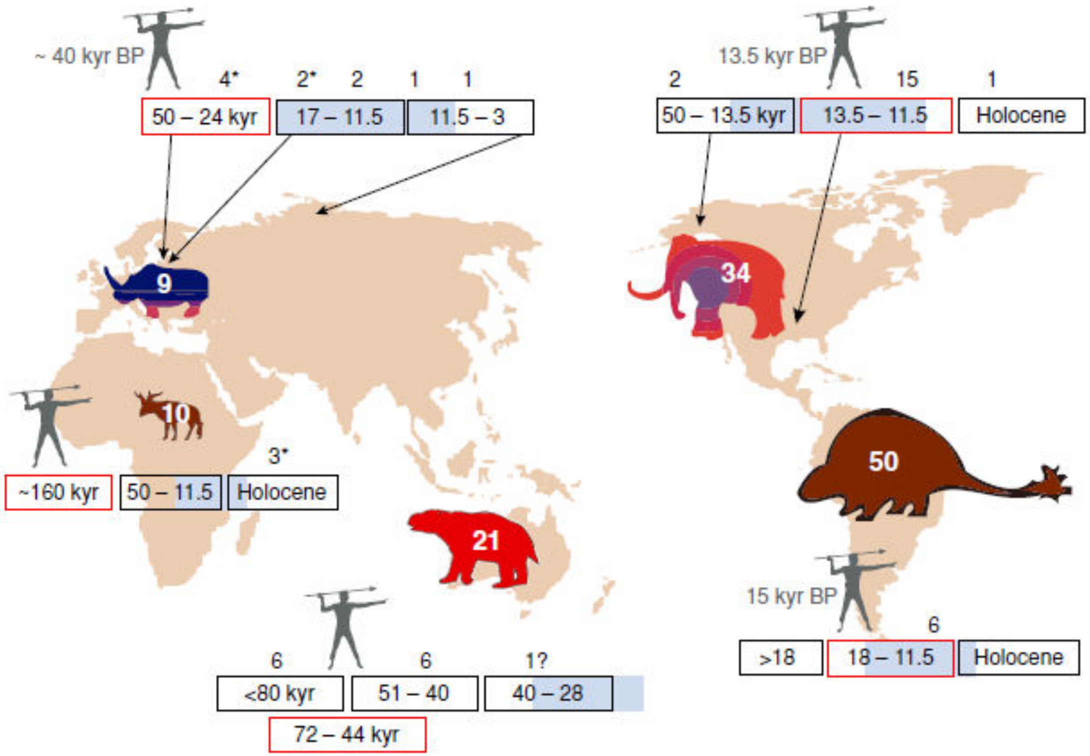
Late Pleistocene (Quaternary) Extinctions

The onset of the ice age 2 mya led to extinction of taxa adapted to warmer conditions.

The extinctions near the end of the Pleistocene, as the ice sheets retreated were more related to man.

The human population grew and harvested increasingly, targeting large and slow reproducing species.

Late Pleistocene (Quaternary) Extinctions



Causes of extinction

- 🟥 Humans
- 🟦 Climate
- 🟫 Insufficient data

Relative size of extinct-taxon icon corresponds to relative magnitude of extinction. Number of extinct genera is listed on each icon.

Correlations in time

- ☐ Humans arrive
- ▨ Climatic change

Numbers indicate how many genera have robust dating control evidence except as indicated:

- • Provisional evidence
- ? Needs more work