Introduction to PLANT MACROFOSSILS in PALAEOECOLOGY

Lecture 2

The importance of taphonomy

The interpretation of macrofossil data using modern samples

The Interpretation of Macrofossil Data using Modern Samples

1. What questions should we ask during the interpretation of macrofossil data?

2. Modern samples from arctic and alpine regions in relation to late-glacial situations.

3. Surface sample studies relevant to interpretation of Holocene sequences.

4. Comparison of peat and lake records.

5 Questions to be Asked During Interpretation of Macrofossil Data

Individual Species

1. Does the presence of macrofossils indicate local presence of the plant?

   If not, how far away was the plant growing?

   In other words - what is the potential <u>dispersal</u> of macrofossils?

2. What do numbers of macrofossils mean in terms of the numbers of plants that produced them?

   In other words - what is the <u>representation</u> of a plant by its macrofossils?

3. Does the absence of macrofossils imply absence of the plant?

   If not, why?

   In other words - how is the fossil assemblage affected by <u>preservation</u> of the macrofossils?

Macrofossil Assemblages

4. Do modern vegetation types produce characteristic macrofossil assemblages today? (modern analogues)

   Can indicator species be used to infer vegetation type, as for pollen analysis?

5. How local are macrofossil assemblages?

   Can we use a concept of a 'seed-rain', in the same way as a 'pollen-rain', or are most macrofossil assemblages closely related in space to the vegetation that produced them?

The answers to these questions depend upon Sedimentary Environments - Taphonomy

Glacio-fluvial deposits (Pleistocene) - laid down by braided rivers. Organic lenses in gravel, etc.

Lake sediments

Deposition environment depends on:

- Size and shape
- Inflows and outflows (currents; erosion/deposition)
- Surrounding vegetation (e.g. forest, tundra)
- Marginal vegetation

Marsh or bog - sediments are produced *in situ* (peat)

Backwaters of slow rivers, oxbows, etc.

Watts (1978)

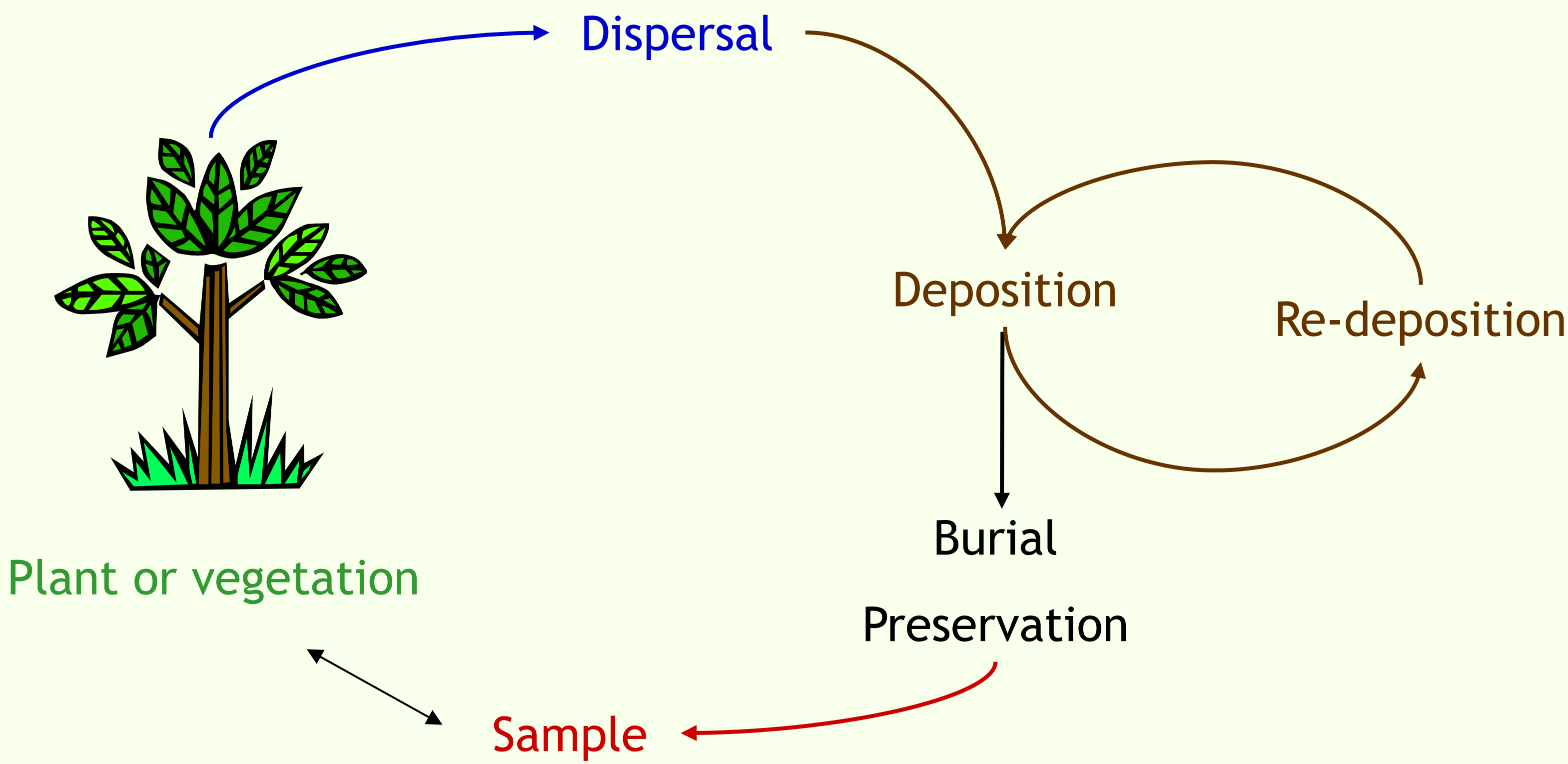
Macrofossil studies rely largely on the indicator species approach, and sometimes use the whole assemblage (analogues).

The quantitative information in a diagram is hardly used except in a broad way.

This is because we do not know how to interpret this information in any precise way.

This contrasts with pollen analysis, where attempts have been made to quantify pollen representation and to reconstruct past vegetation quantitatively

Processes



We can study the processes in the formation of an assemblage.

Or we can go from the other end – take surface samples that are the end product of all the processes, and relate them to the vegetation

- Arctic and alpine environments
- Temperate environments

Alpine and Arctic Environments

DISPERSAL

Ryvarden (1971) Seed traps in front of a glacier at Finse (summer). Seeds dispersed ≤ ca. 5 m from source.

Traps in streams. Seeds transported greater distances, probably to sites unfavourable for germination. (→ lake sediments)

Ryvarden (1975) Seed deposition on a snow bed (in winter)

Total deposition < in summer, but seeds travelled further. Distance did not seem to be affected by any adaptation to dispersal.

Savile (1972) Estimated seeds could travel 3000 km over a smooth snow-scape in tundra. (→ circum-polar flora)

Bonde (1969) Colorado. Seed dispersal on to a glacier. >30 spp.

Some of the most abundant were mosses and lichens.

Miller & Ambrose (1976) Found ca. 20 spp. of <u>moss</u> on a snowbed. They could grow, showing how cryptograms can be dispersed.

Snowbed leaf assemblage

in Alaska

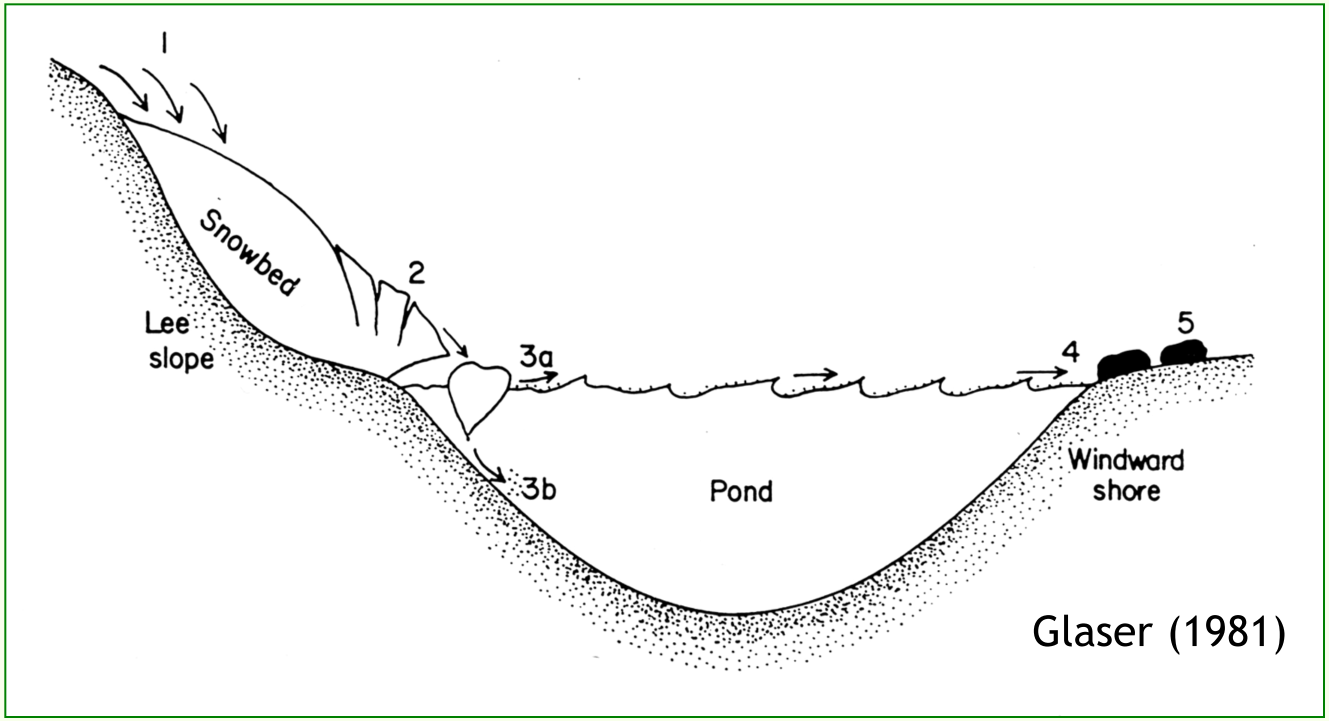
Salix herbacea leaf assemblage

in Norway

Long-distance dispersal involves many fewer propagules than local deposition. However, it is important for dispersal of the species and for colonisation of new habitats.

Local dispersal is more important in the formation of a vegetation type and for the formation of a fossil assemblage; this can be related to the local vegetation.

DEPOSITION Arctic Lakes



Schematic diagram of the transport and deposition of plant macrofossils in Mount McKinley Park, Alaska:

1. Plant debris and snow accumulate on the lee slope in winter.
2. In spring, the snowbed calves into the pond and melts.

3a. Most debris floats, and is blown to the windward shore.

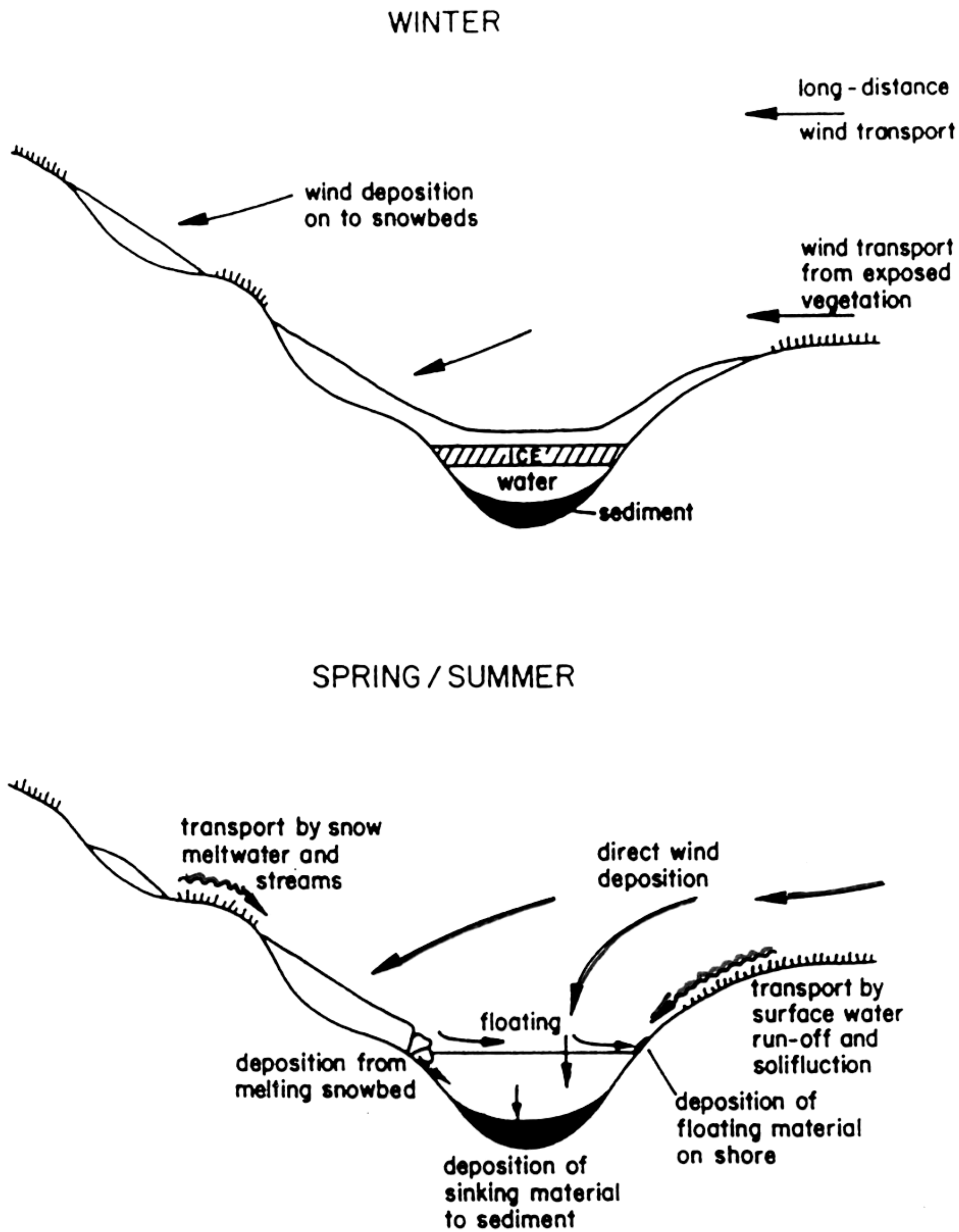
3b. Some debris sinks, and is deposited in the sediment.

4. Wave action deposits windblown debris in heaps on the beach.
5. The heaps are stranded as high water-levels recede during the summer.

Fanaråken, Norway

Arctic/alpine Taphonomy

Diagrammatic representation of processes leading to deposition of plant parts in the sediments of a small lake in the arctic or above the tree line.



Birks (1991)

How Well did the Macrofossils Represent the Local Vegetation?

The composition of the potential-macrofossil assemblage

1. Showed a close relationship between potential fossils and their abundance in the vegetation.
2. Depended upon the production of potential macrofossils (seeds/leaves).
3. Depended upon exposure to winter winds (open/under shrubs).
4. Depended upon relative bouyancy. Good floaters - flotsam (small seeds with patterned coat, leathery leaves [damaged leaves sank]).
5. Depended upon season of dispersal. Seeds travelled further in winter than in summer.

Leaves were generally better represented than seeds in his lake sediments.

Glaser (1981) Arc. Alp. Res.

Surface Samples from a Spitsbergen River

REPRESENTATION

Surface Samples from a Spitsbergen River

Braided river system in tundra environment - analogue for Pleistocene deposits.

Used 1x1m quadrats from all communities to describe vegetation present

Samples taken of detritus left on sand banks, etc. after spring meltwater flood.

Plant remains related to potential macrofossil productivity of the vegetation.

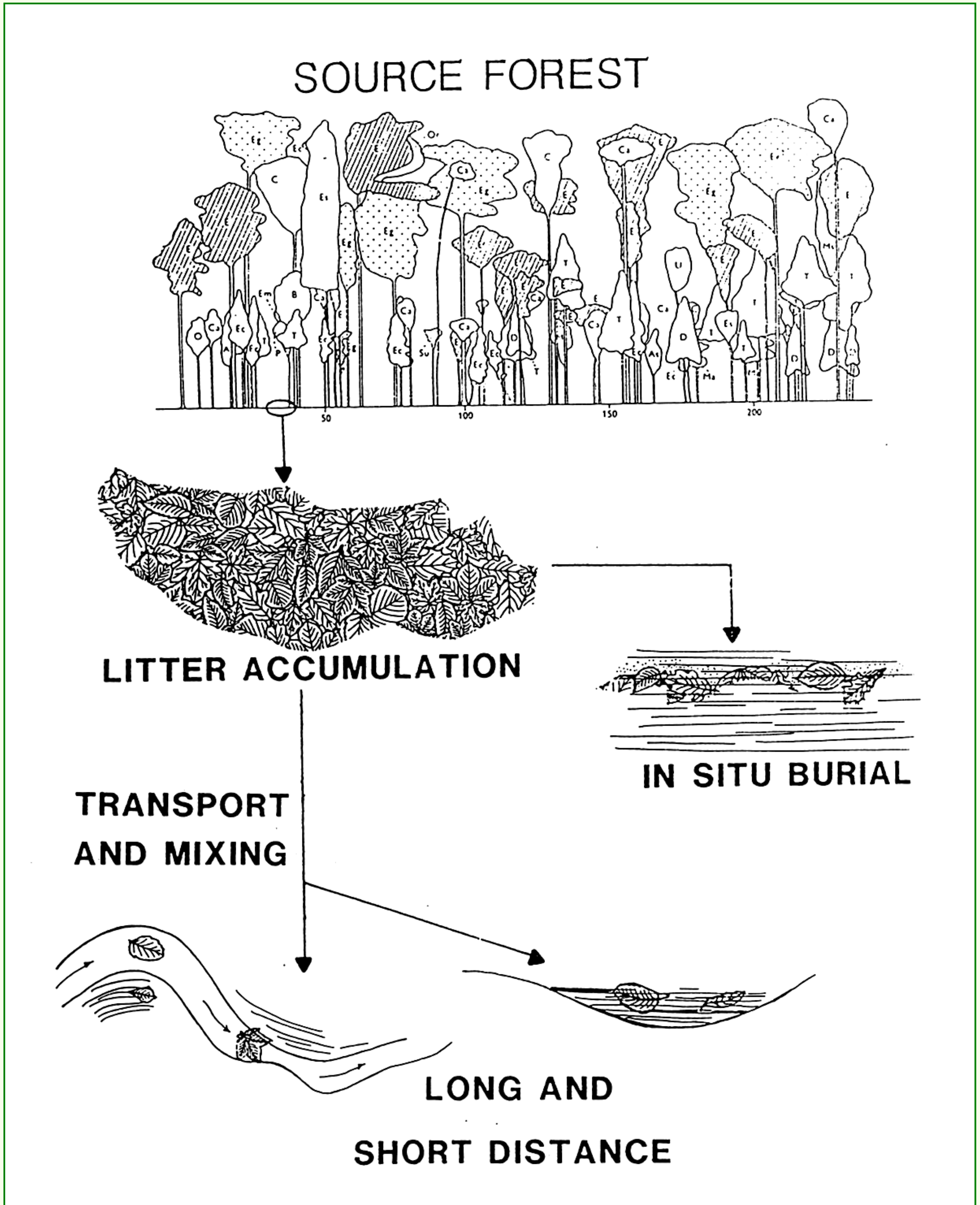
Under represented

1. Small seeds; washed away downstream.
2. Soft perishable parts.
3. Firmly attached parts; stems, twigs, etc. Parts that are not deciduous or renewed annually.
4. Species of the floodplain - remains of these washed away by initial flood.

Over represented

1. Parts that break into recognisable fragments e.g. *Dryas* leaves.
2. Plants growing in late-snow areas; only dispersed after the main melting peak is over.

Holyoak (1984)



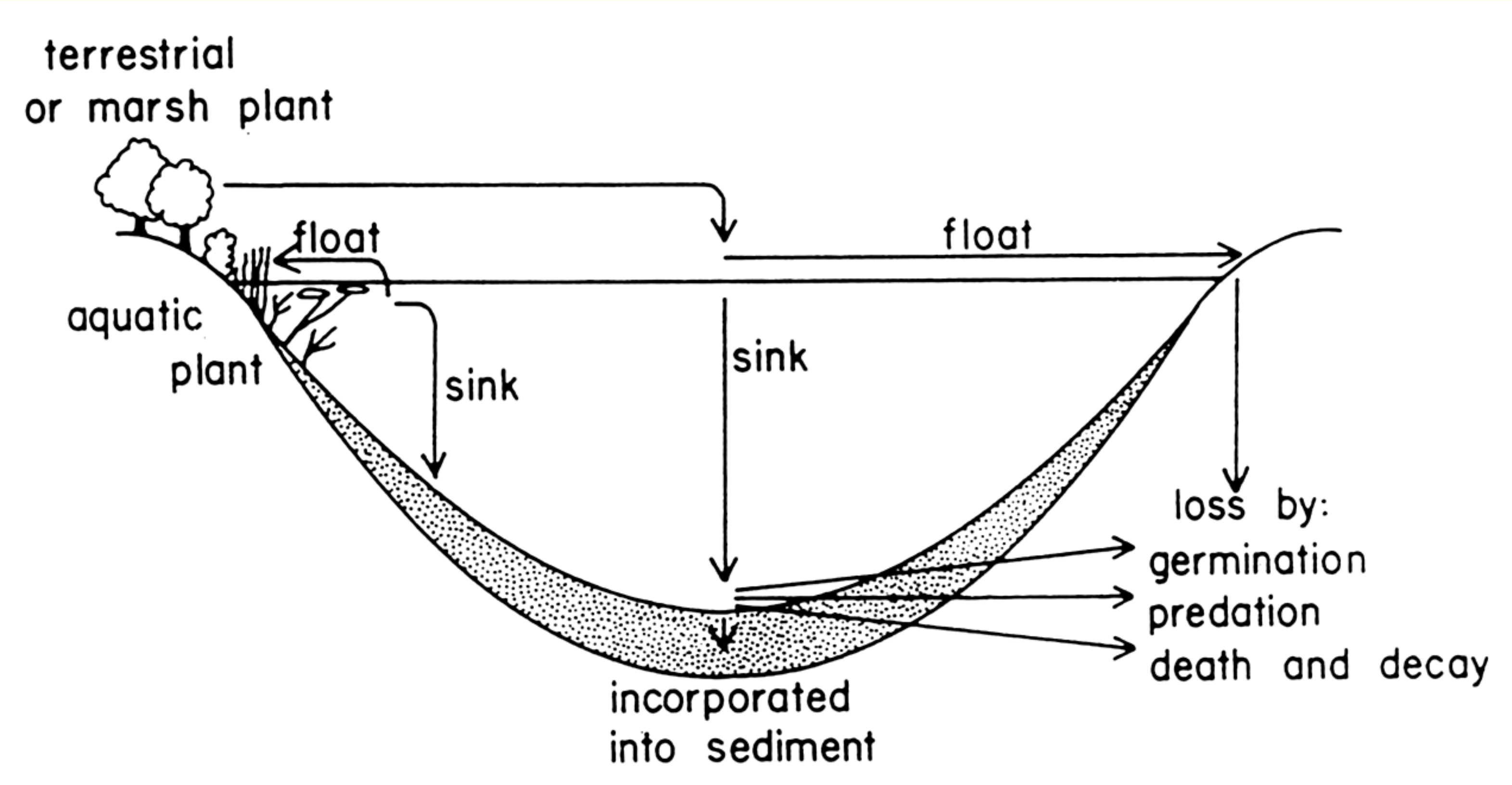
Temperate Environments

1. Leaf Assemblages

3 steps in the process of plant taphonomy. Litter accumulation in situ produces autochthonous assemblages. The amount of subsequent transport controls whether the deposits have greatest similarity to local or to regional source floras. Burial of the assemblage before degradation produces a high quality fossil flora.

e.g. Chaney (1924)

Lakes: Taphonomy



Schematic diagram of the processes affecting the incorporation of macrofossils of terrestrial and aquatic plants into lake sediments.
Birks 1980, 2007

Modern Surface-Sample Studies in lakes

McQueen (1969) New Zealand lake.

Drake & Burrows (1980) New Zealand lake.

Burrows (1980) Long-distance stream transport.

Spicer & Wolfe (1987) California, large catchment.

Wainman & Mathewes* (1990) Marion Lake, BC, Canada.

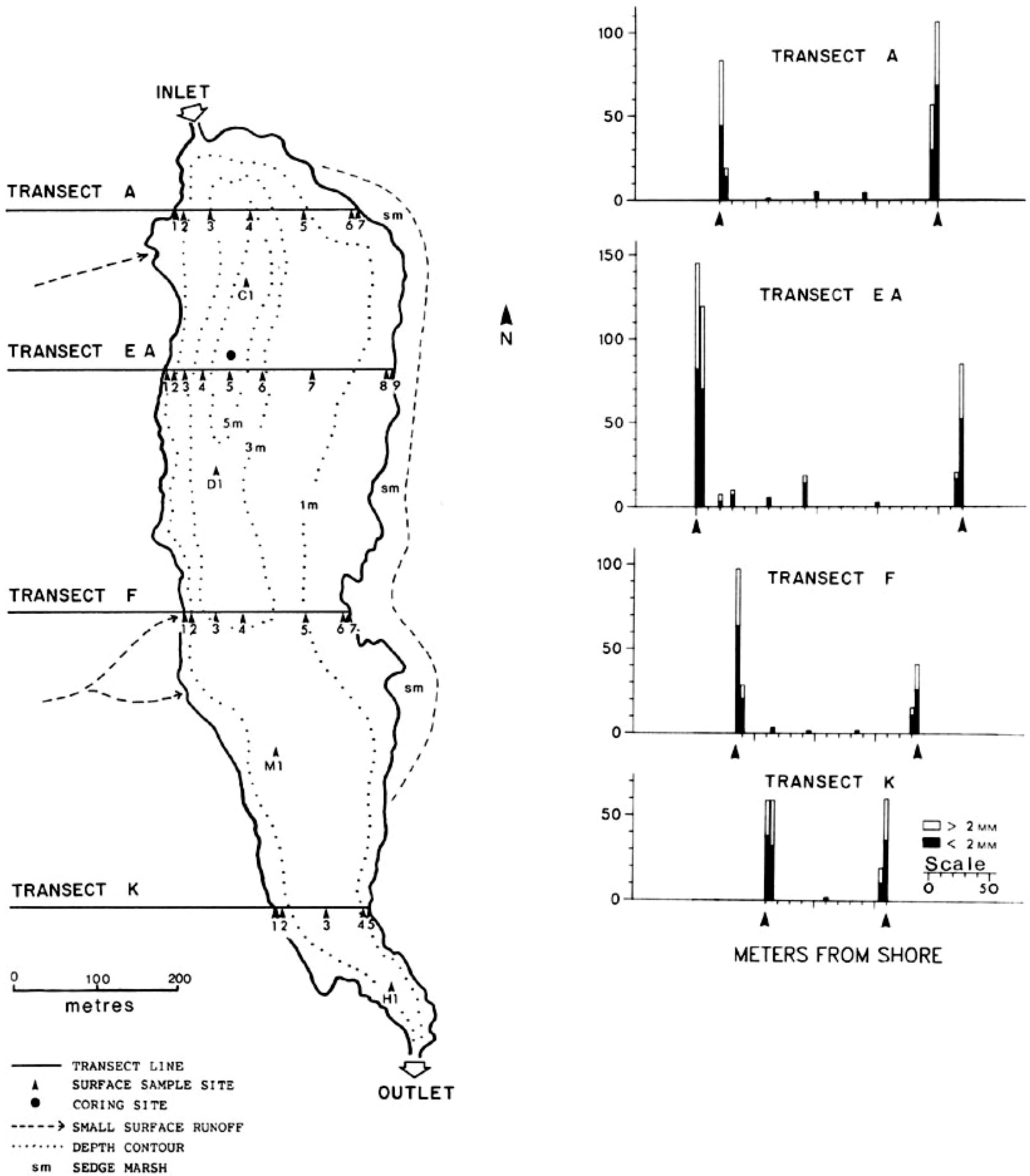
Birks (1973)* Minnesota/Dakota lakes.

Dieffenbacher-Krall & Halteman* (2000) Macros and water depth.

Dieffenbacher-Krall (2007) Lake surface samples in general

Marion Lake, southwestern British Columbia

Wainman & Mathewes (1990)



Outline of Marion Lake, plus distribution of screened residue volumes along four transects.

Main results of Wainman & Mathewes

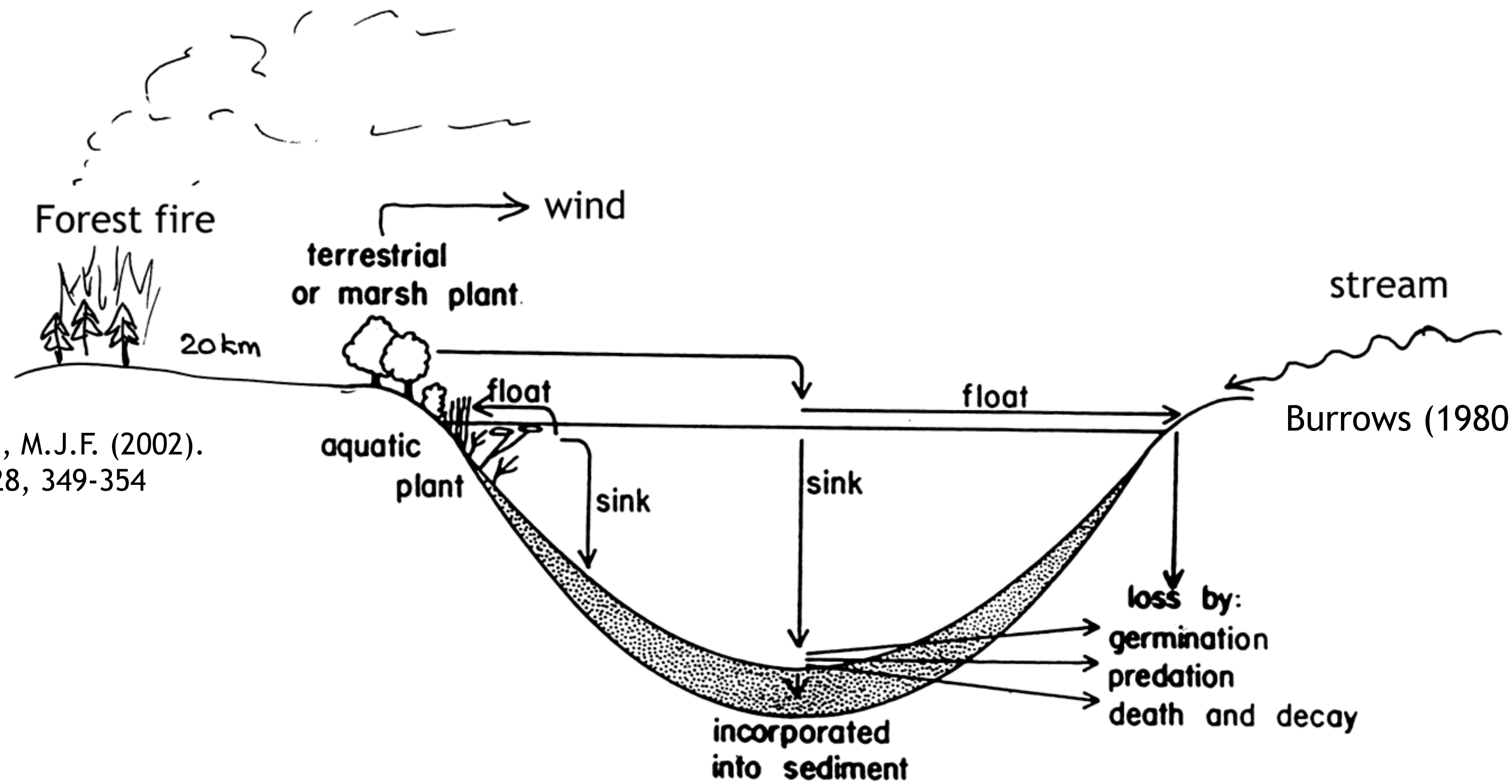
Where forest margin came directly to the lake, good representation of forest species.

Presence of a marsh filtered the terrestrial species. But marsh and aquatic taxa were found that could be identified to species, in contrast to pollen.

Upland taxa found mainly in deeper water, plus taxa growing along the inflow stream (e.g. *Alnus rubra*).

The representation of some important conifer taxa, (e.g. *Thuja plicata*) could be evaluated that cannot be separated by pollen.

Long-Distance Transport



Pisaric, M.J.F. (2002).
JOPL 28, 349-354

Burrows (1980)

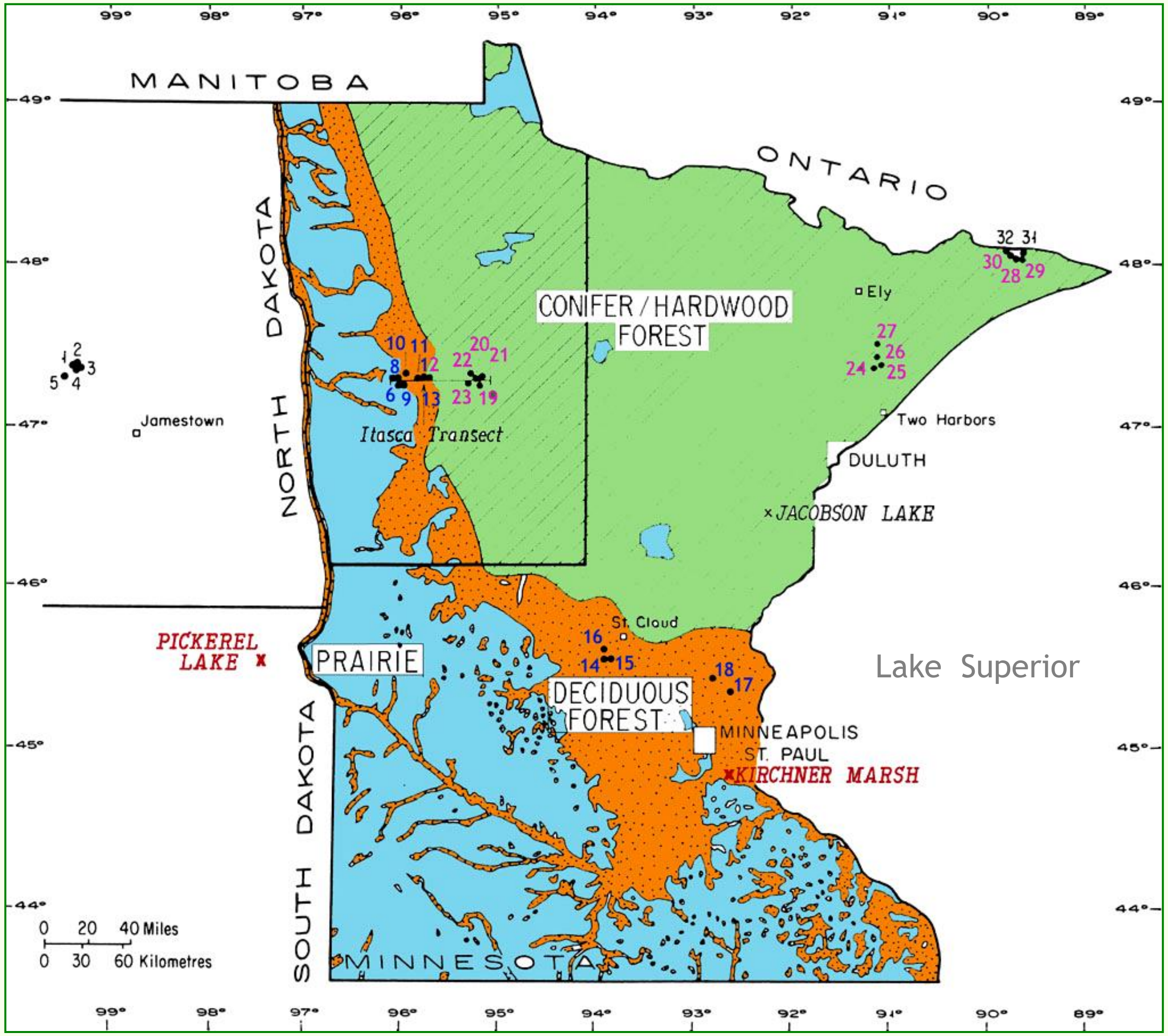
Glacio-fluvial Environments

Beetley gravel pit, S. England

Last Glacial Maximum

Tanana River – modern braided river in Alaska

Modern Assemblages in Minnesota Lakes



Birks (1973)

Map of Minnesota and North Dakota showing the locations of the lakes, numbered 1-32, used for modern surface samples, in relation to the major vegetation types.

Prairie Lakes

Woodworth Prairie ponds
North Dakota

Deciduous Forest Lakes

Missouri Pond

Beckman Lake

Coniferous Forest Lakes

Twin Lake A, Itasca

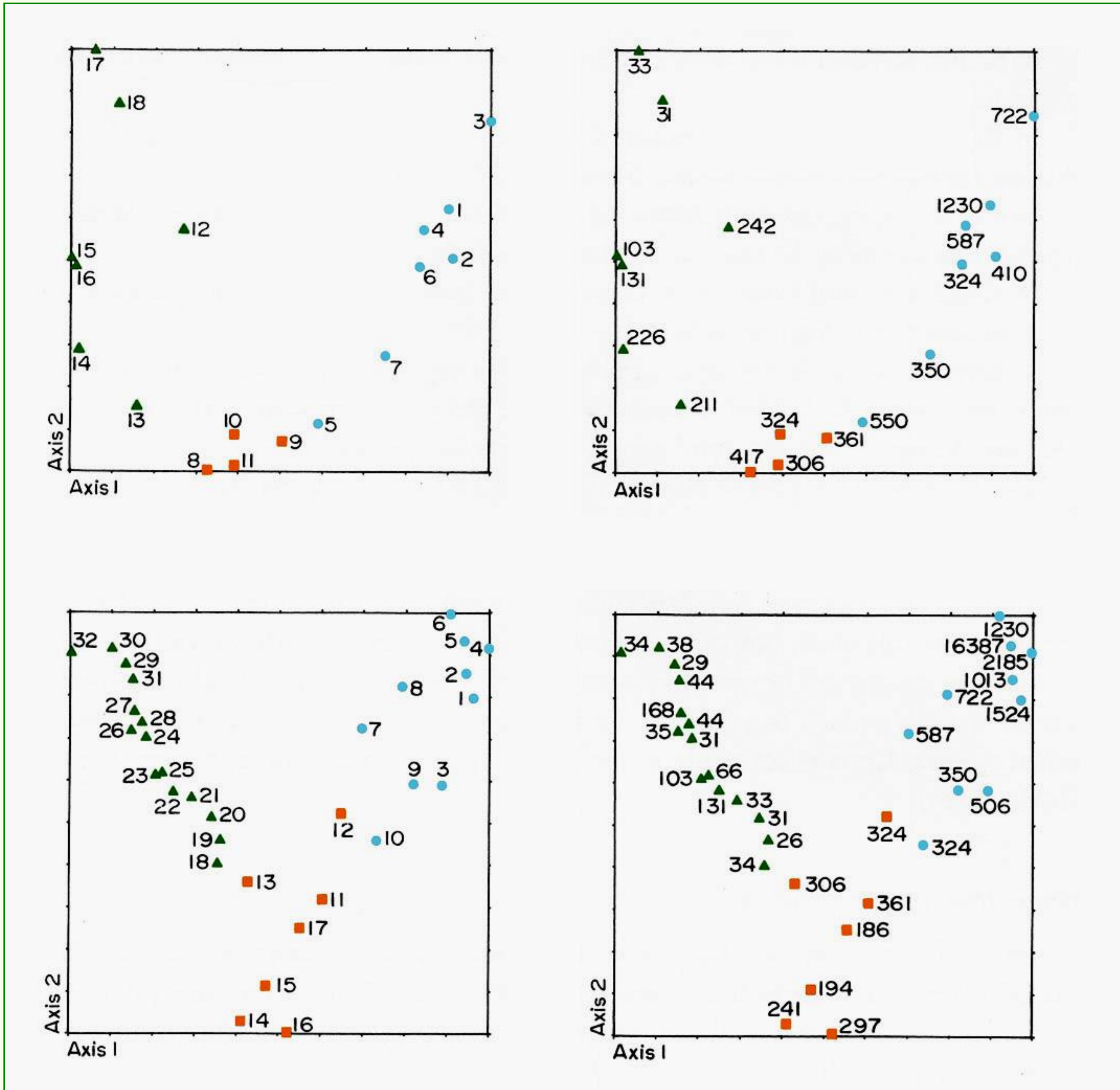
Clearwater Lake

Ordination of lakes on present flora (Itasca only)

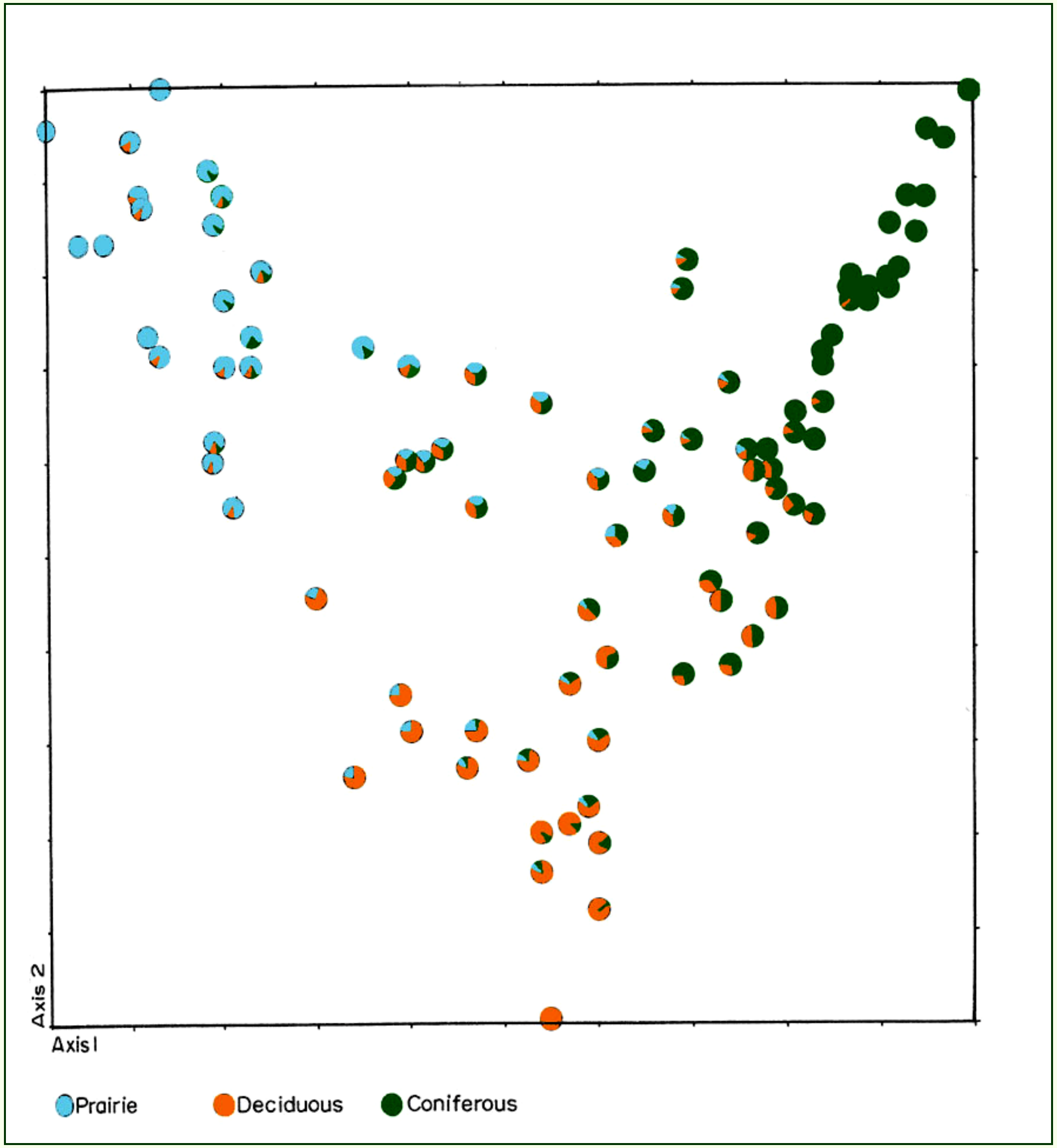
Conductivity of the lakes (Itasca)

Ordination of lakes on ‘macrofossil’ flora (32)

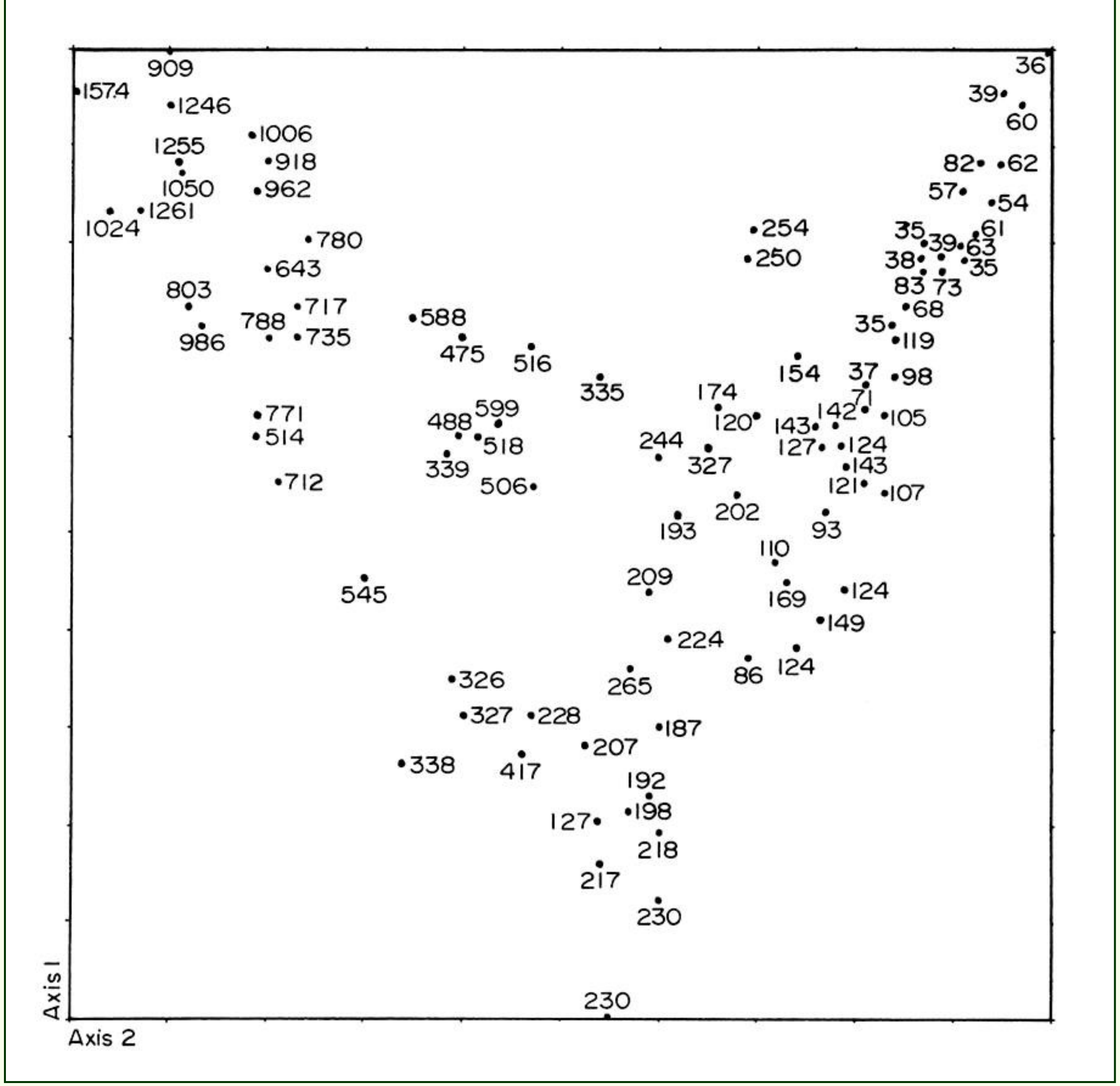
Conductivity values of the lakes (32)



▲ Coniferous lakes ■ Deciduous lakes ● Prairie lakes



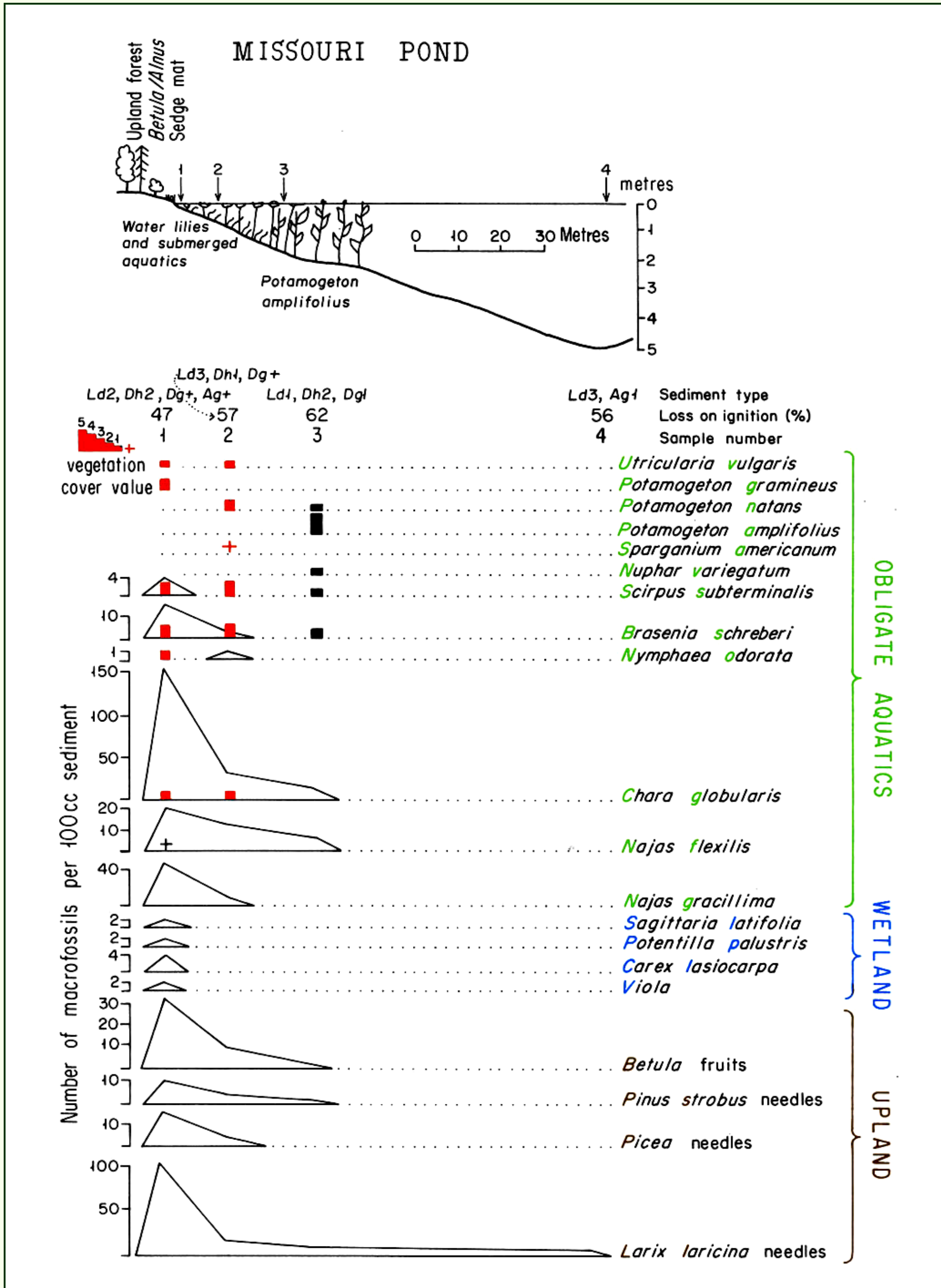
Ordination plot of macrofossil taxa in surface samples, ordinated on the basis of their occurrence in lakes. The distribution of each taxon within the range of lakes is shown by 'clockfaces'.



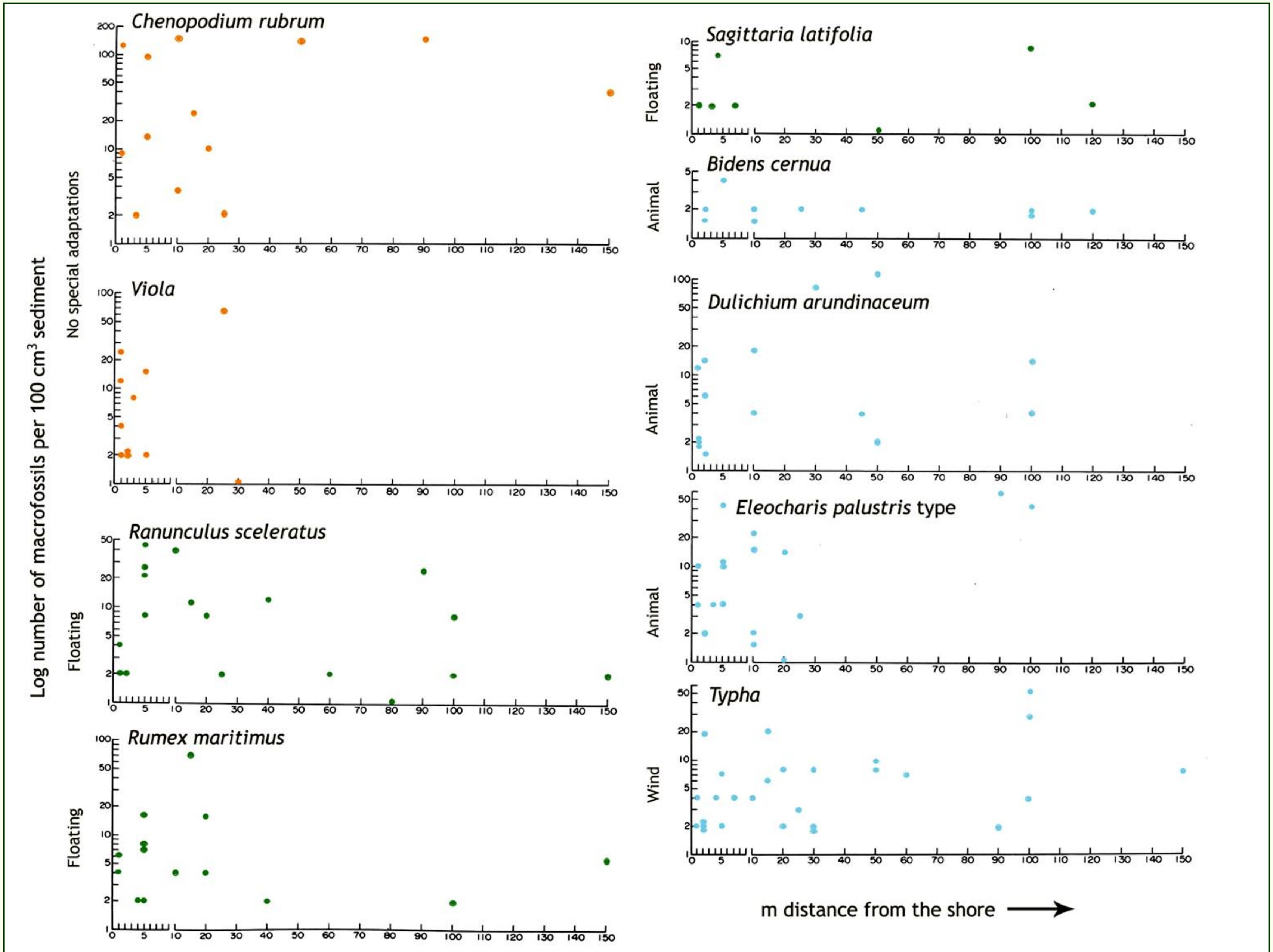
Mean conductivity values (μmhos at 25ºC) for the macrofossil taxa. The mean value was calculated from the values of all the lakes in which each macrofossil taxon was found.

The pattern of macro-fossil deposition in Missouri Pond.

The vertical bars denote the cover value of the plant in the vegetation plots; the silhouettes denote the number of macro-fossils per 100 cm^3 sediment.



Dispersal: Terrestrial and Marsh Plants (increasing distance from shore)

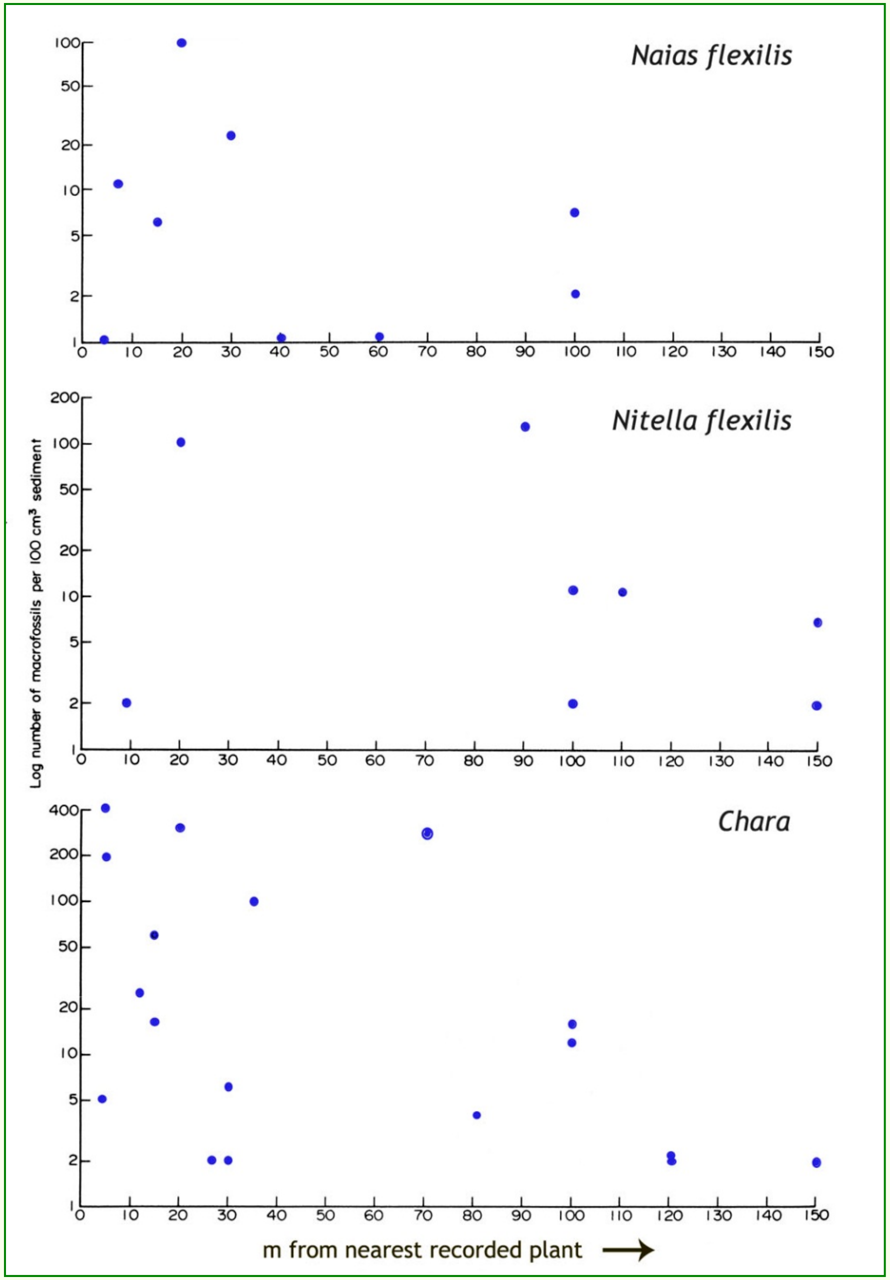


Dispersal: Aquatic Plants

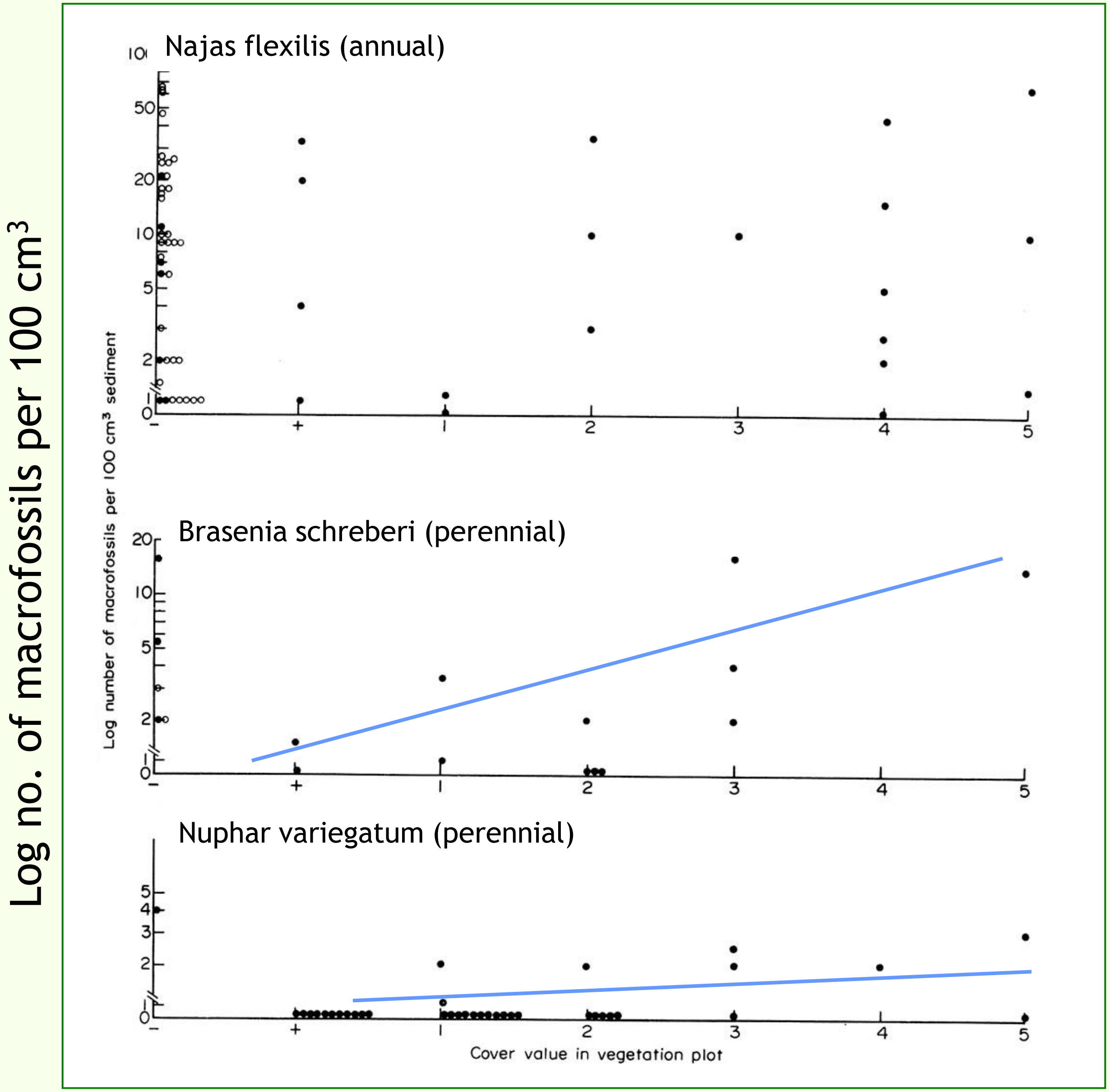
Dispersal:

distance from nearest recorded plant (aquatics that produce abundant propagules)

Most other aquatics are not dispersed very far from the parent plant.

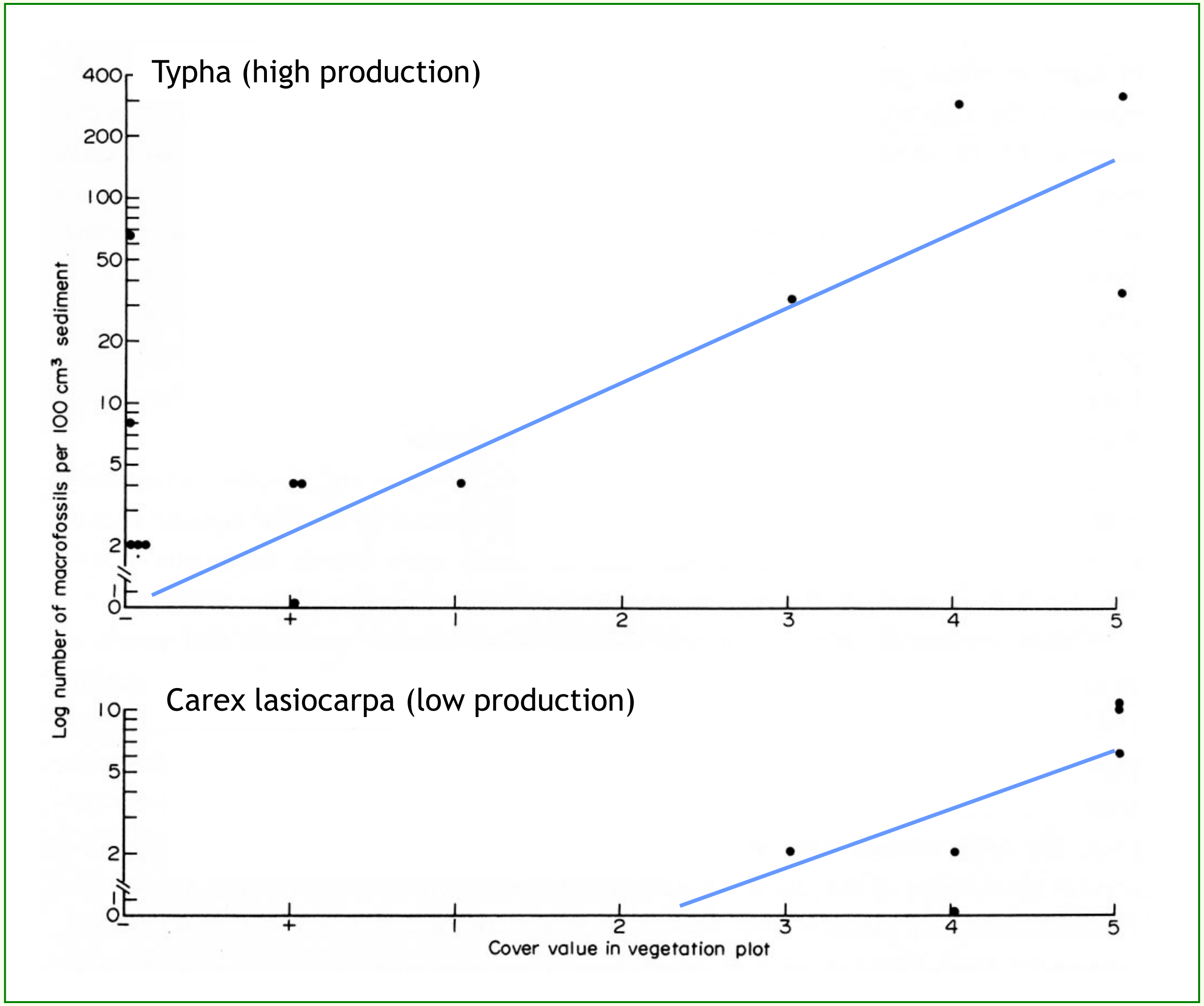


Representation: aquatics



Cover value of plant

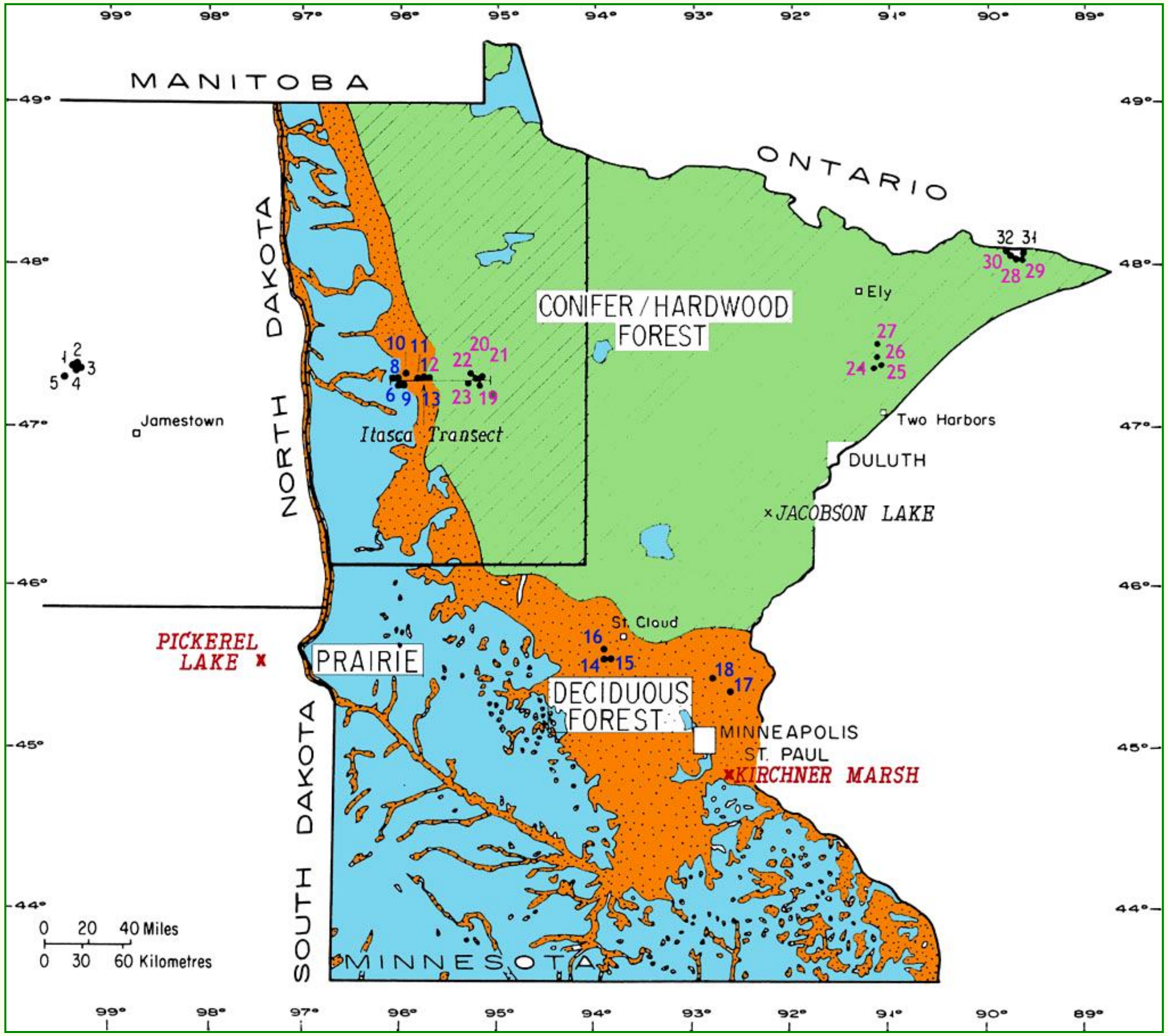
Representation: wetland



Log no. of macrofossils per 100 cm³

Cover value of plant

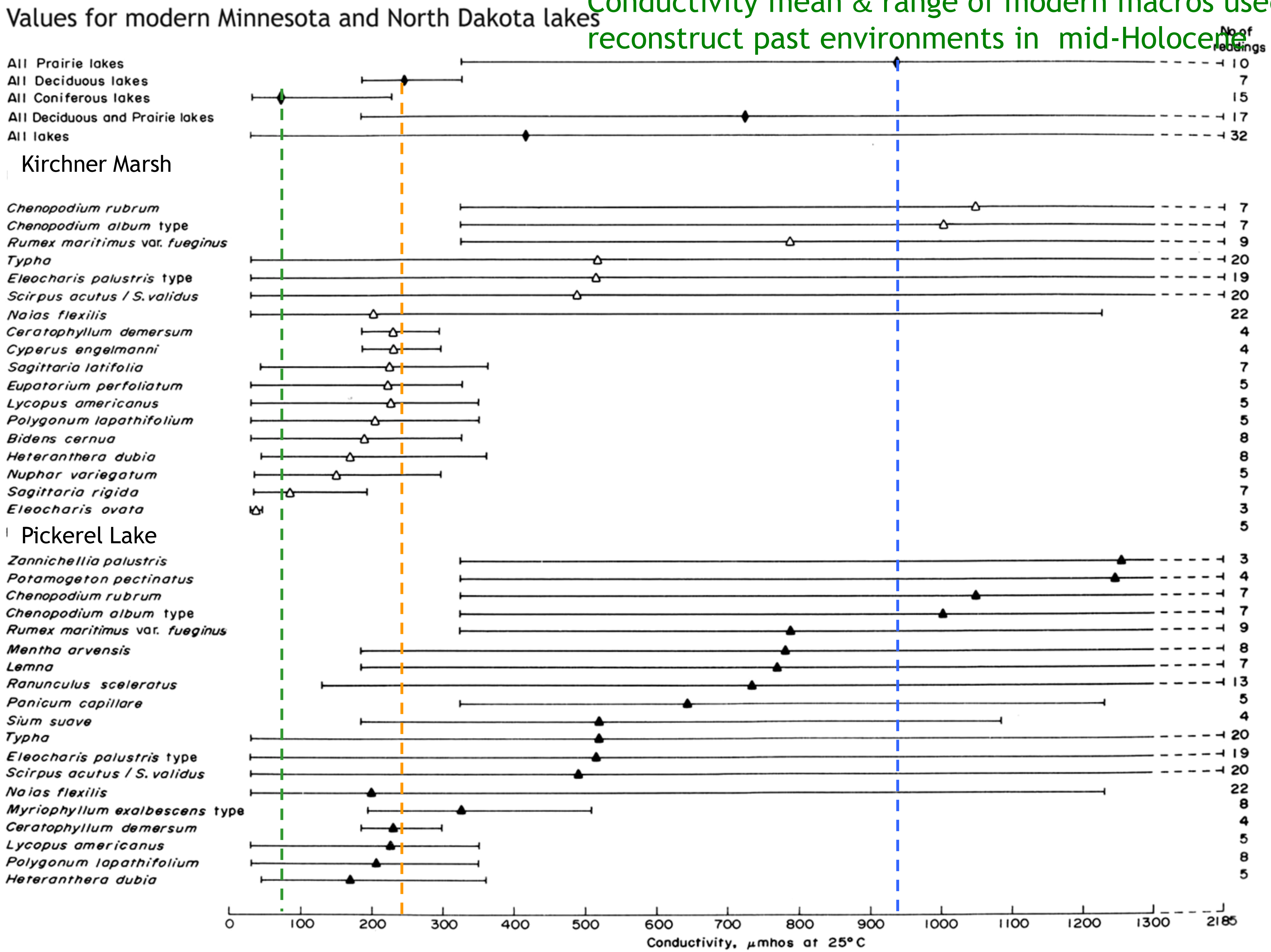
Relate modern assemblages to fossil assemblages at Pickerel Lake and Kirchner Marsh



Birks (1973)

Map of Minnesota and North Dakota showing the locations of the 32 lakes, used for modern surface samples, the major vegetation types, **Kirchner Marsh and Pickerel Lake.**

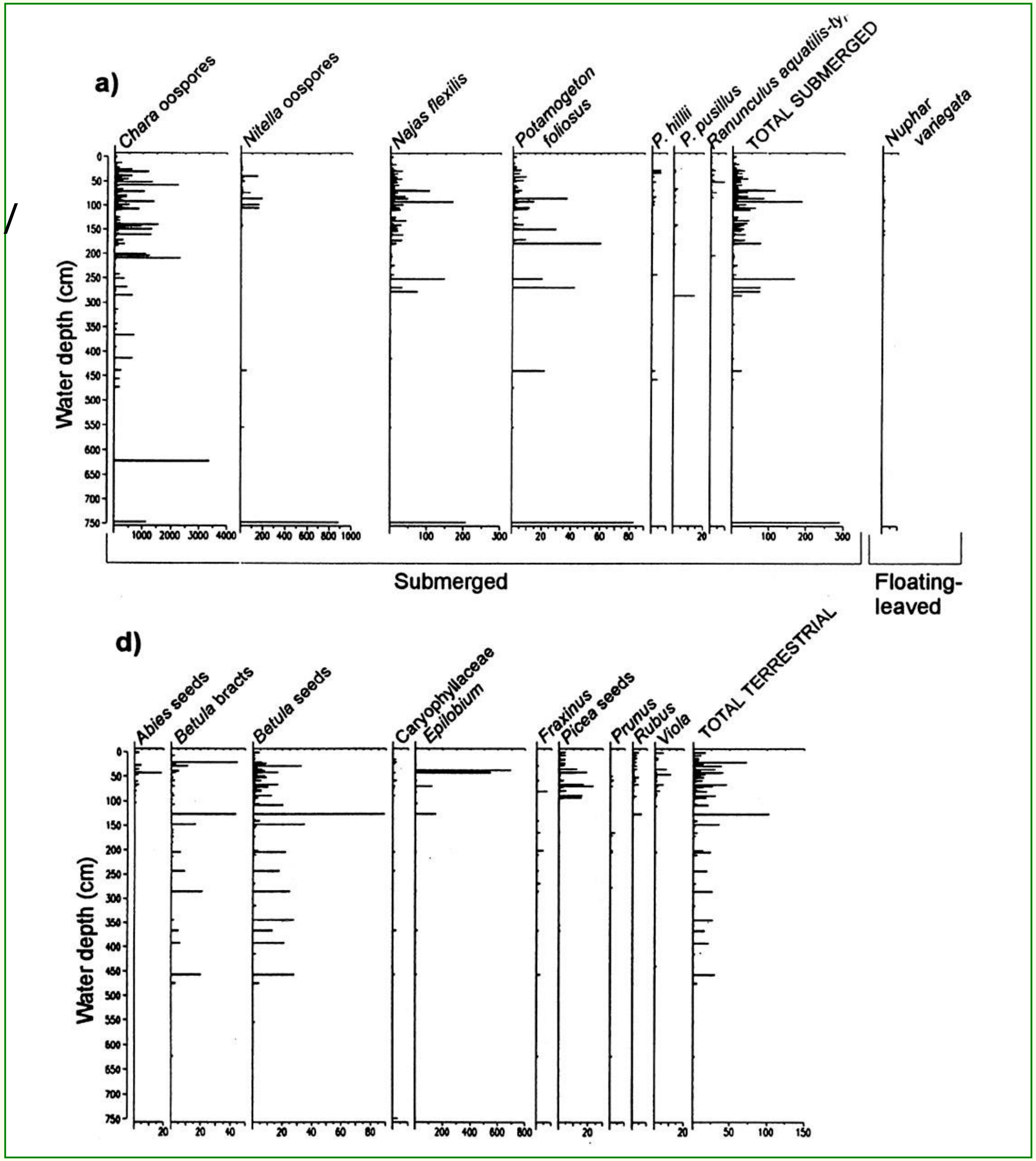
Conductivity mean & range of modern macros used to reconstruct past environments in mid-Holocene



Macro-remains in relation to water depth

Submerged/ floating

Terrestrial

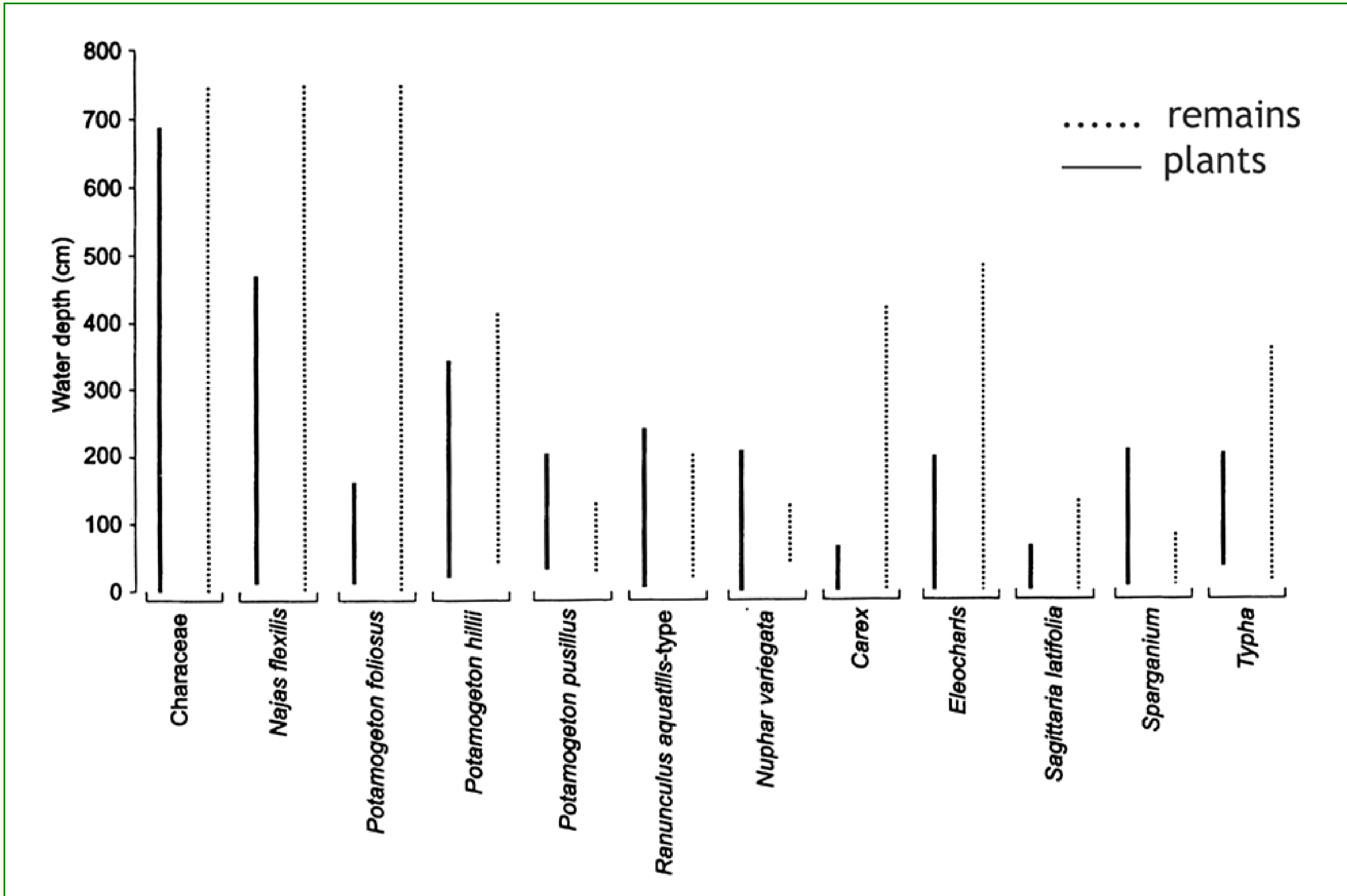


Can the water-depth range of macro-remains be used to reconstruct past water depth?

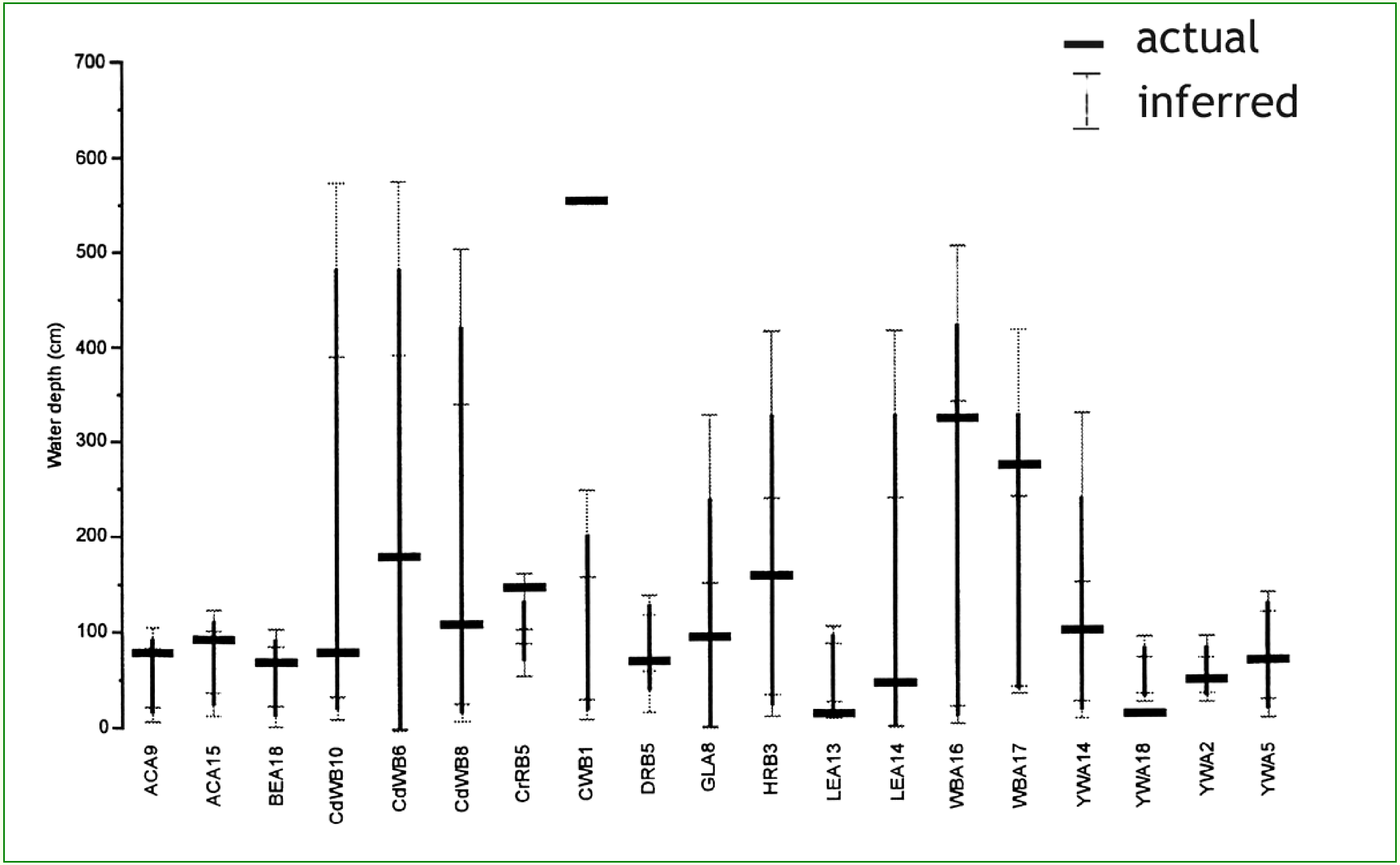
170 surface samples in transects from shallow to deep water

Dieffenbacher-Krall & Halteman (2000)

Plant Depth Range Compared with Remains Depth Range

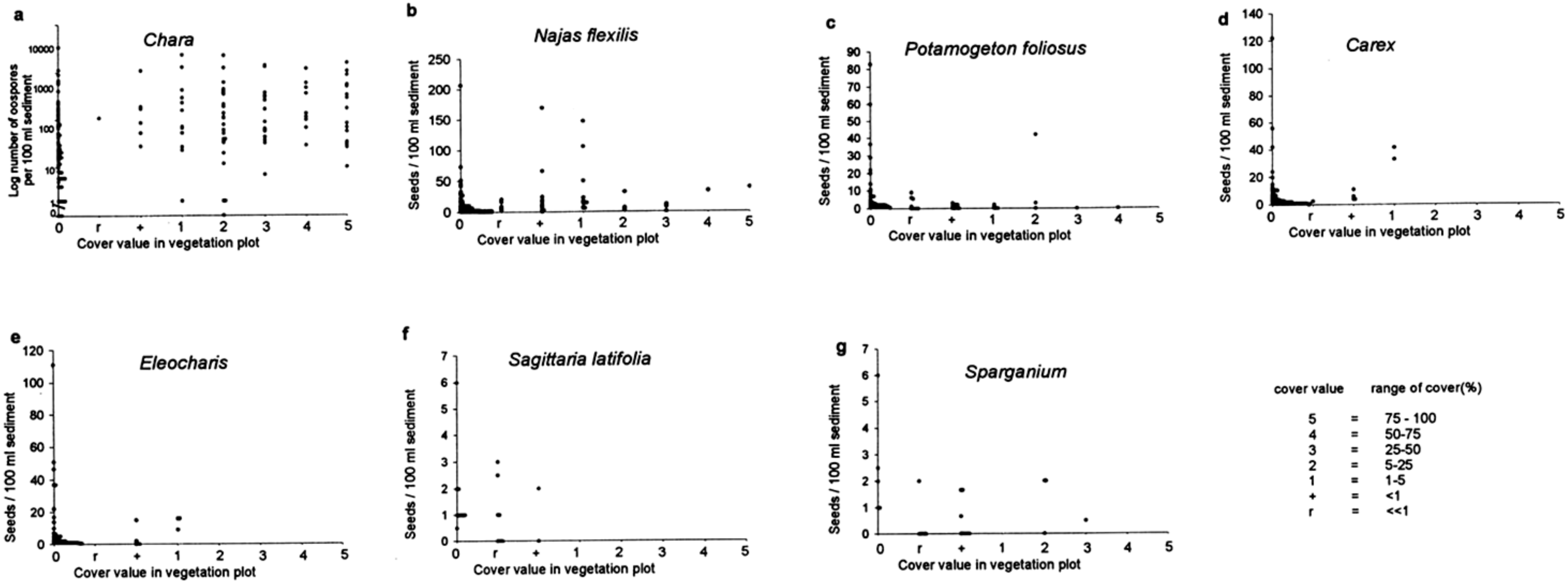


19 Test Samples used to Reconstruct Water Depths



'Mutual water-depth range' method

Representation of Taxa



Abundance of plant remains found in sediment samples relative to cover value in vegetation plots for all aquatic species that occurred as plants in a minimum of 5 vegetation plots.

- *Chara* and *Nitella* oospores ubiquitous. Do not indicate proximity of the plants.
- Submerged: Remains often present where no plants, Always present when plants are present.
- Emergent: Abundance of remains tends to reflect plant cover. Many remains can be found with no plants. i.e. good dispersal within a lake.
- Terrestrial: Frequent remains in the lake when plant grows at the shore. Depends on abundance of production. e.g. *Betula* (bracts more local than fruits). Conifers generally well represented by needles.

Conclusions

Relationship between plant water depth and seed water depth generally good; best at less than 3 m.

Quite wide variation; could be used to detect depth changes more than 2 m.

Presence is a better indicator than abundance.

Comparison of Plant Macrofossils in Peat and Lake Sediments

How do macrofossils represent the vegetation round the site?

Peat	Blato Mire
	Keldonk Fen
Lake	Kirchner Marsh

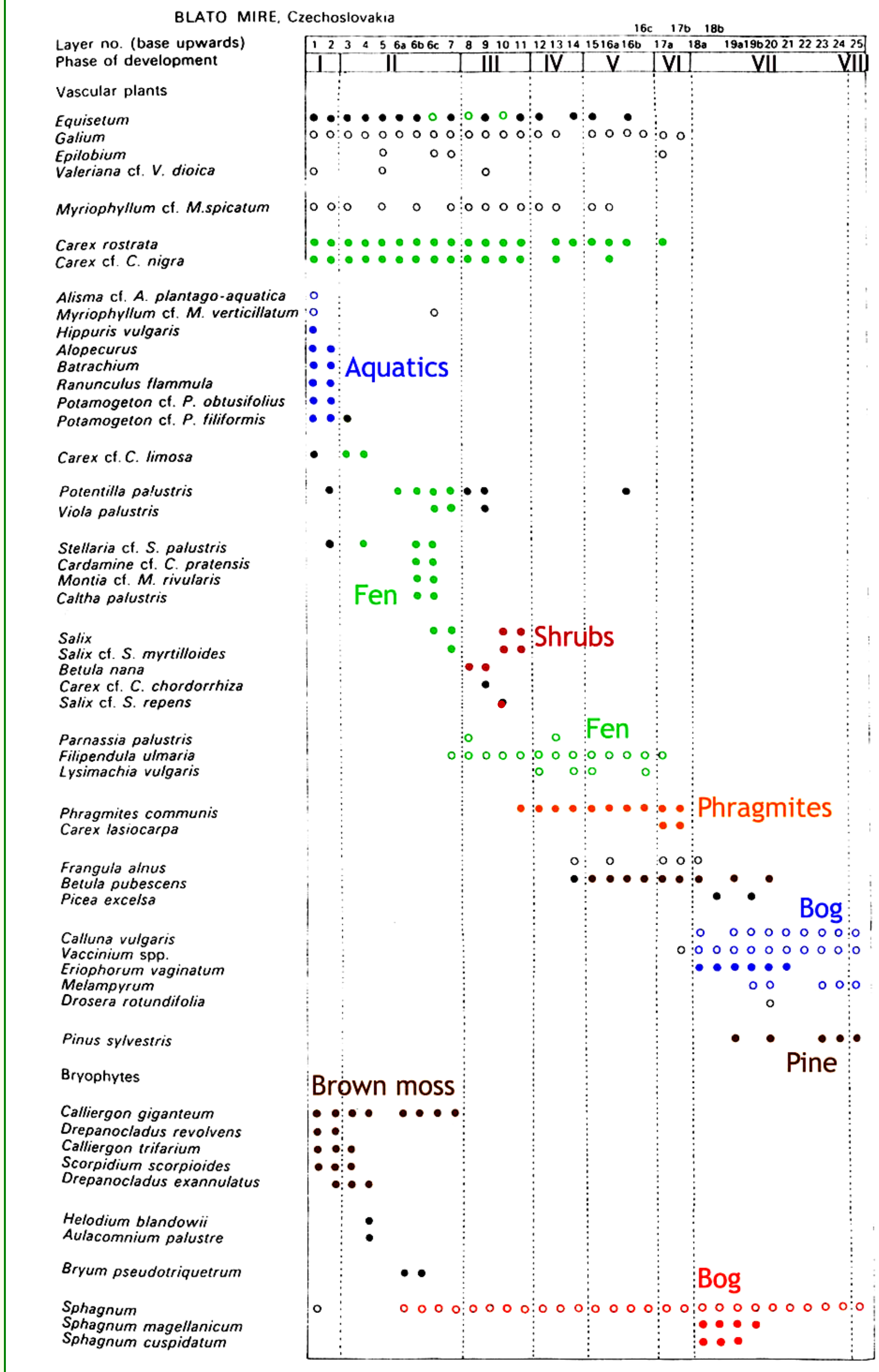
(Birks & Birks, 1980)

Macrofossils from a Peat Deposit (local deposition)

Blato Mire,
Czech Republic

Distribution of plant macrofossils and pollen, with taxa arranged in the order of similar occurrence.

Vegetation phases

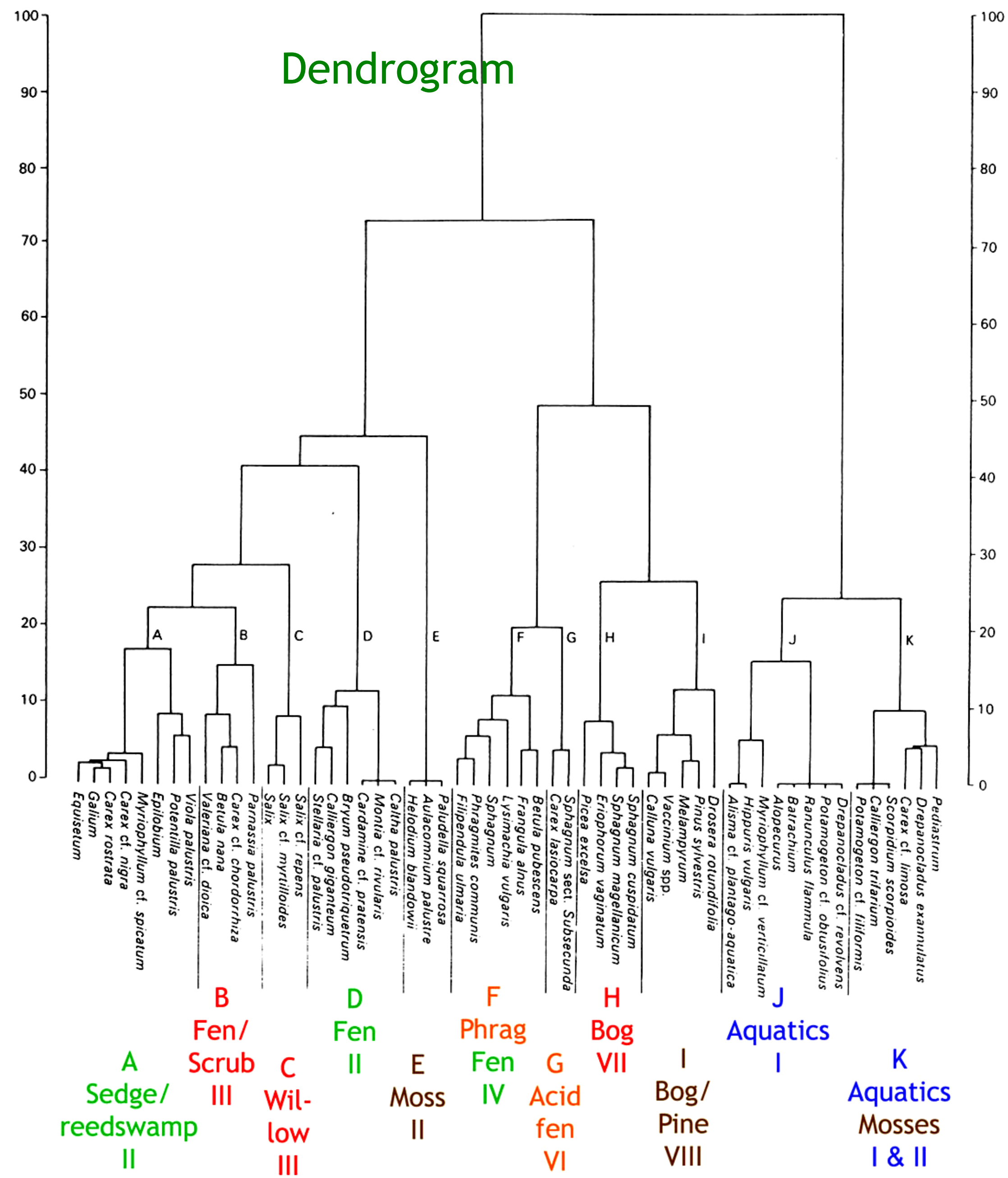


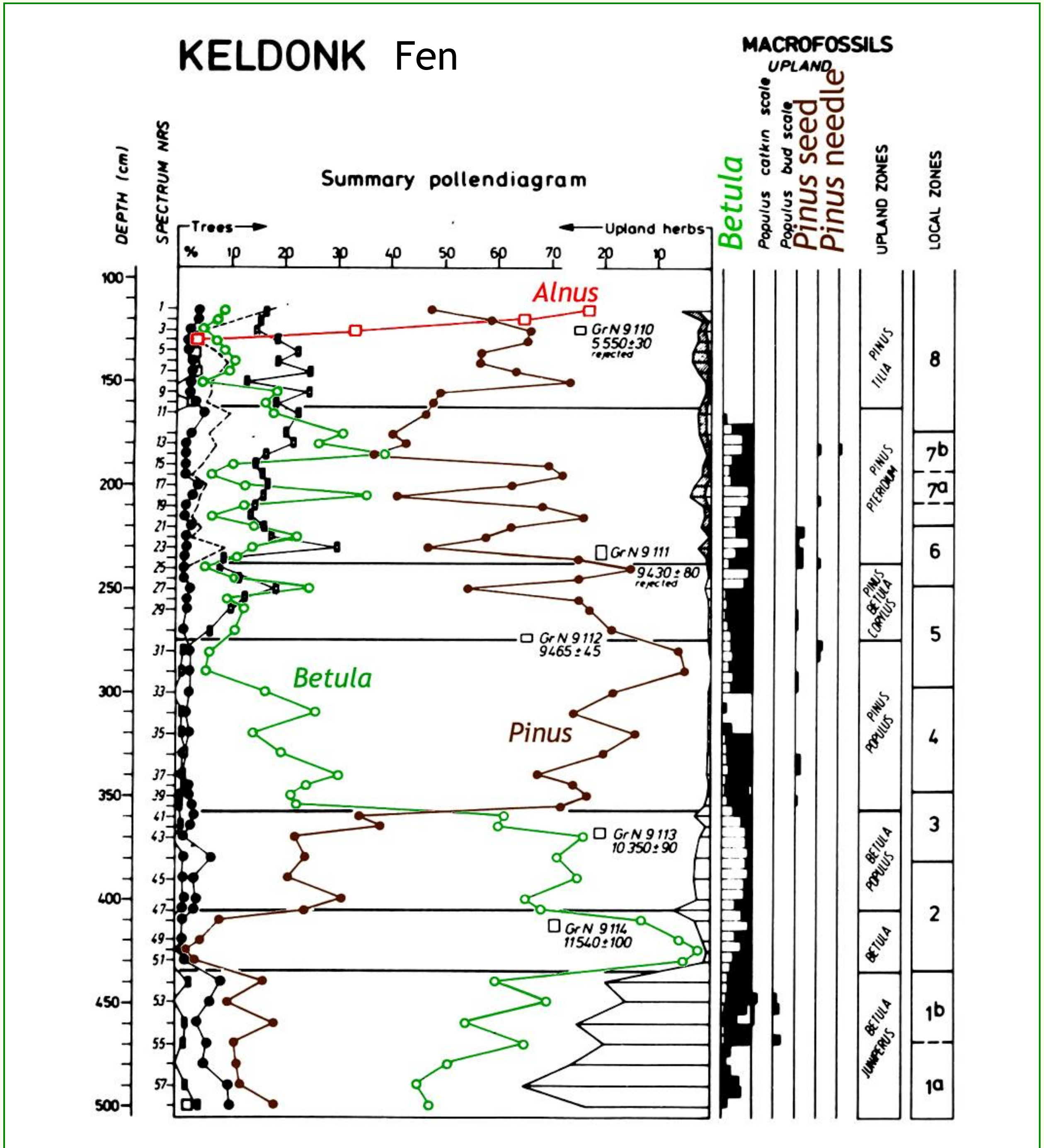
Birks & Birks (1980)

Question: are these phytosociological groups really there, or do we interpret them from our previous knowledge of vegetation?

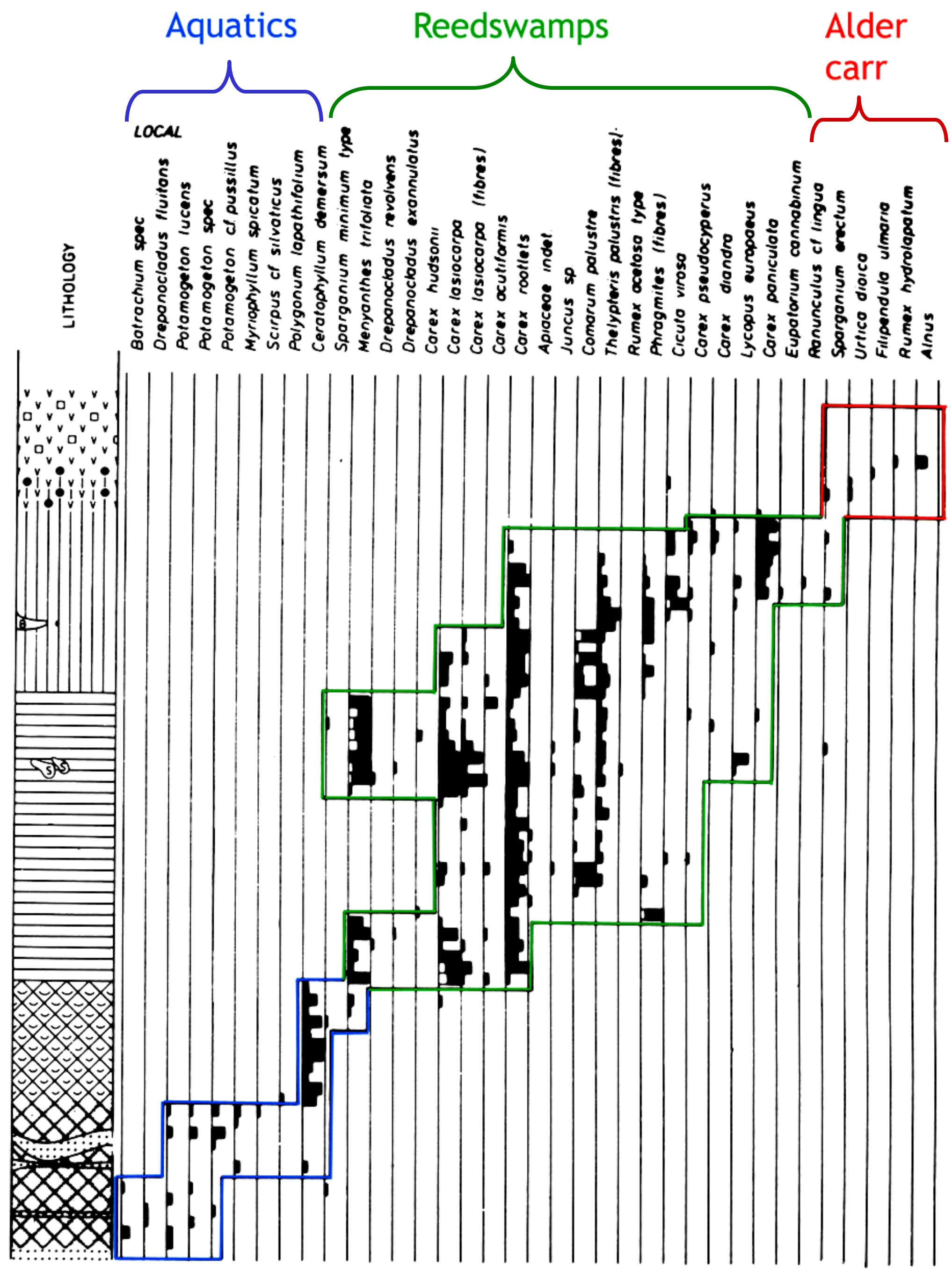
Do an objective numerical analysis (cluster analysis) to find unbiased 'recurrent groups'

Blato Mire Cluster Analysis



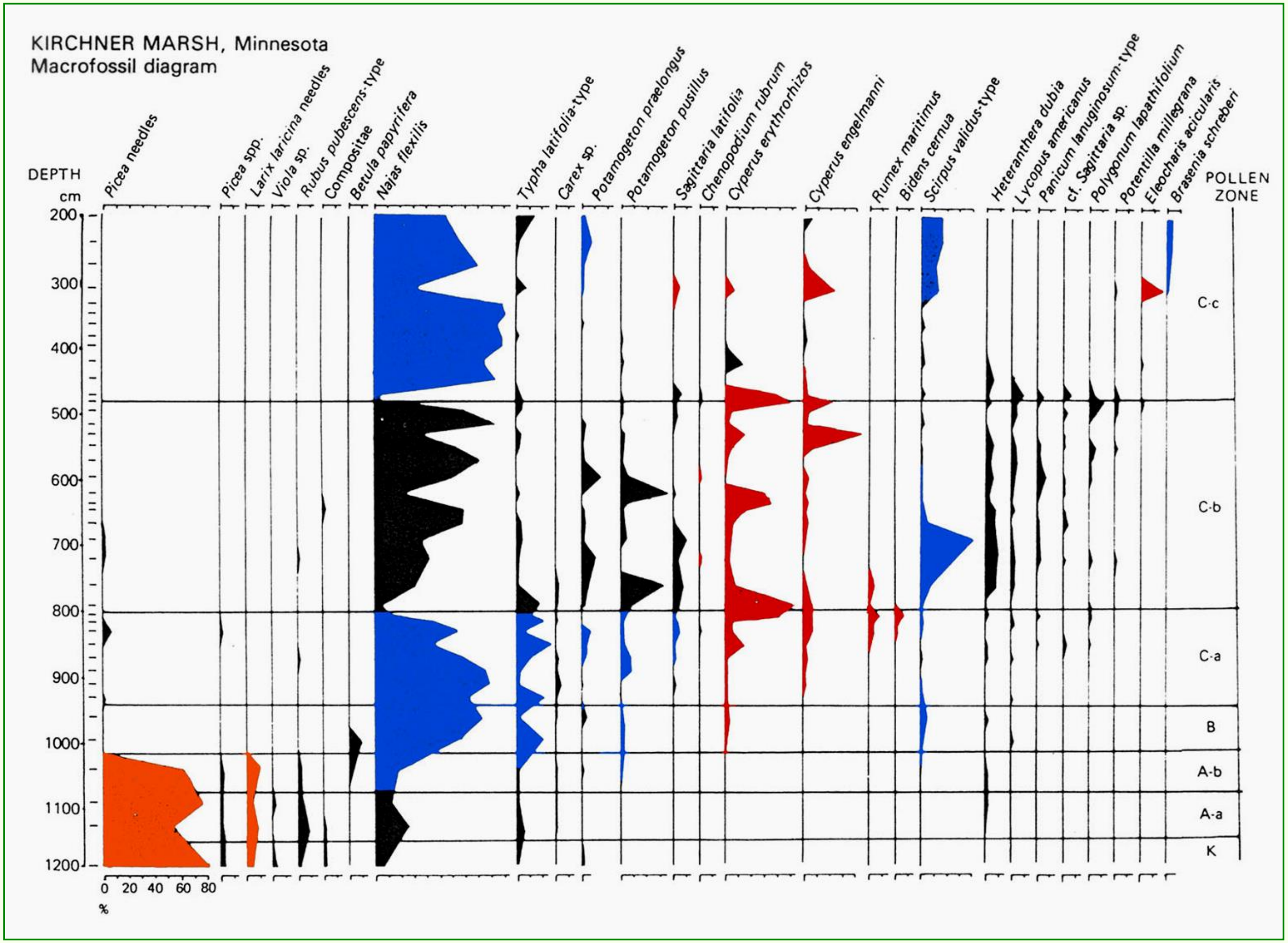


Macrofossil diagram from Keldonk, Netherlands, combined with a shortened pollen diagram. Bars for individual species, arranged according to their appearance, show the local succession from open-water communities, through reedswamps to alder woods (next slide). (from Leeuwarden, 1982 in Wasylikowa, 1986).



Wasylikowa (1986)

Macrofossils in Lake Sediments



Present

Oak savanna

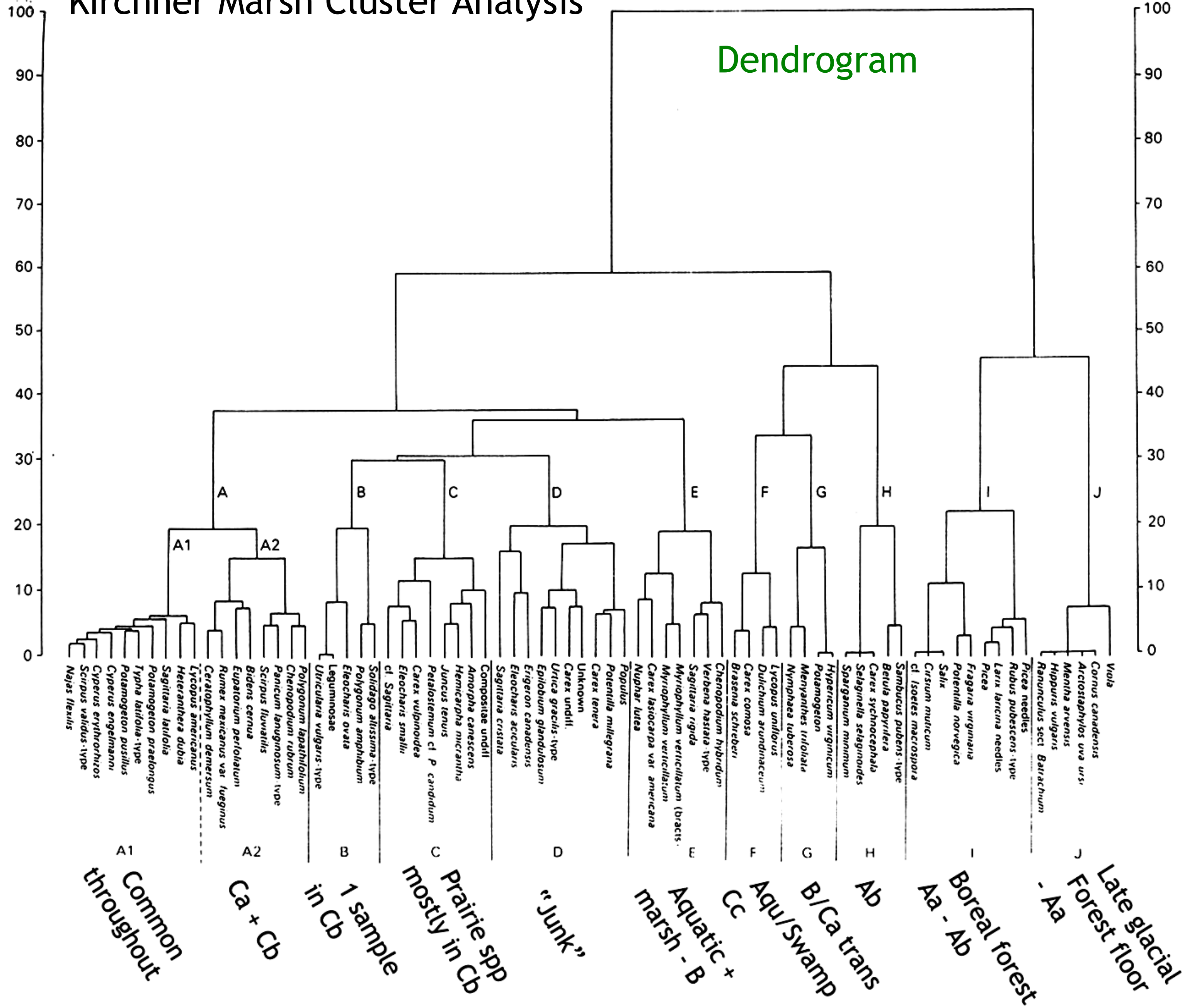
Prairie period 'draw-down'

Oak savanna

13,000 BP

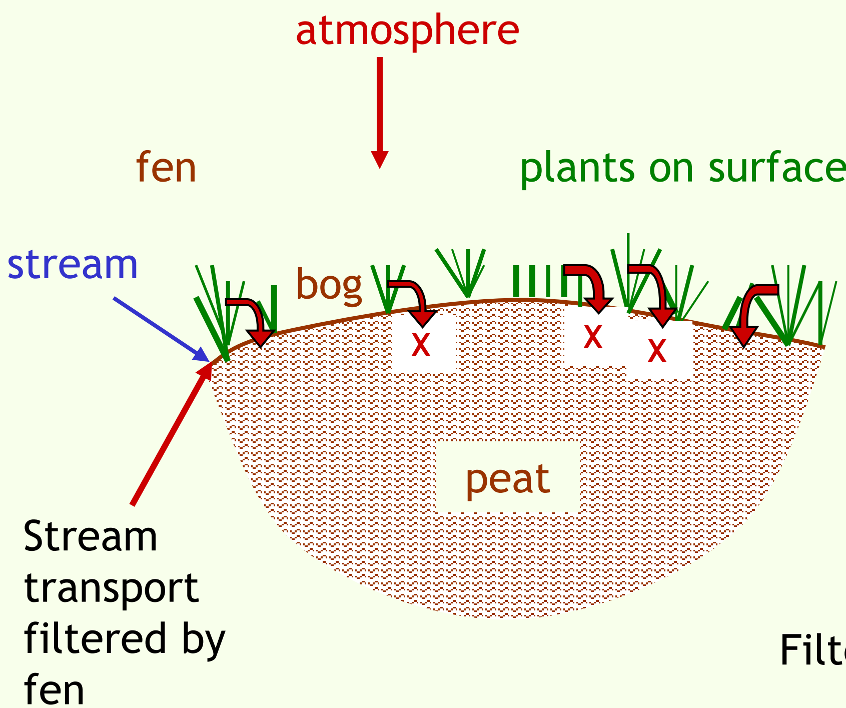
Plant macrofossil diagram from Kirchner Marsh, Minnesota, showing selected macrofossils only. All values are expressed as percentages of the total macrofossils shown, and all the curves are drawn to the same scale. The pollen zones are shown. (After Watts & Winter, 1966)

Kirchner Marsh Cluster Analysis



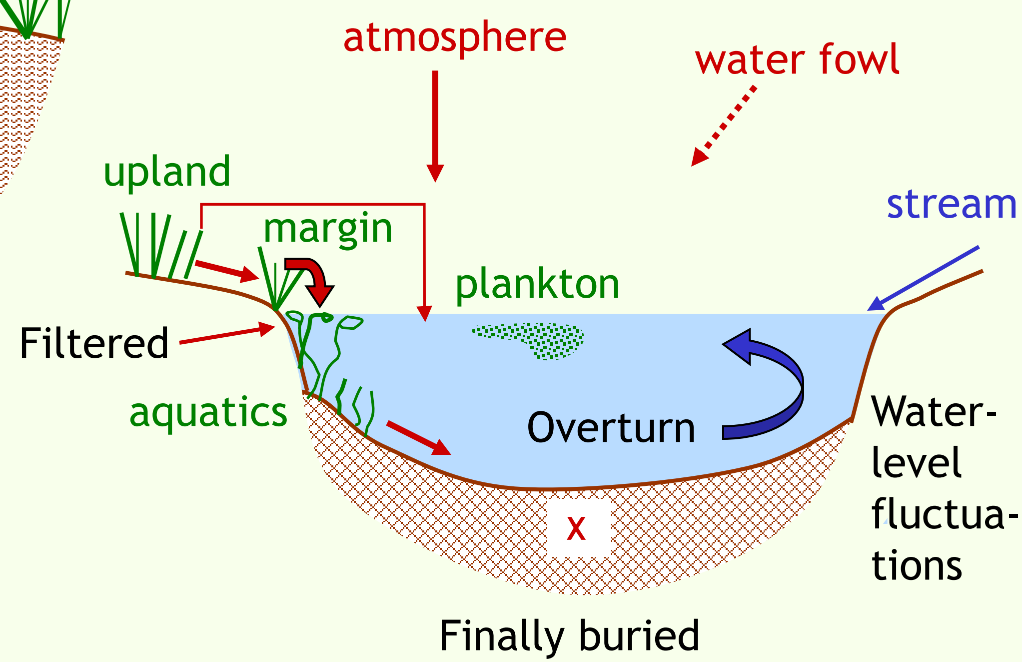
BOG

Autochthonous



LAKE

Allochthonous



Conclusion

Macrofossil assemblages from peat deposits (composed of the vegetation growing at the surface) are local and represent the types of vegetation that formed them.

Macrofossil assemblages from lake deposits have a mixture of origins; aquatic, marsh, local terrestrial, distant terrestrial. Production, dispersal, and taphonomy are important factors in the representation of taxa in a lake assemblage.