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Macrofossil analyses of White Loch

Final Report to SEPA and SNH

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Executive summary

This is the final report to the Scottish Environment Protection Agency and Scottish Natural Heritage on the 'Macrofossil analyses of White Loch'. The work was conducted as a follow up to a larger palaeoecological study of seven mesotrophic lochs. The aim of the original project was to employ multi-proxy palaeoecological methods (diatoms, Cladocera, plant macrofossils) to define reference conditions and to assess ecological changes in the seven lochs over approximately the last 100-150 years and hence to provide valuable information to assist with the development of environmental improvement plans for these sites. The study sites were Tangy Loch, Loch Nan Gad, Loch a Phuill, Loch Flemington, Monk Myre, White Loch and Monzievaird. These are all sites of high conservation interest currently or having once supported the biodiversity priority species *Najas flexilis* (slender naiad) or *Potamogeton rutilus* (Shetland pondweed).

Sediment cores were collected from the lochs in January-February 2006. In the first phase of the project macrofossil analysis was carried out at only four sites to determine changes in the aquatic plant communities. At White Loch there were marked changes in the diatom and Cladocera assemblages but macrofossil analysis was not carried out. Therefore, in the present study we fill this gap and analyse plant and animal macrofossils in an undated littoral core from White Loch to further assess ecological changes, particularly in the aquatic plant community.

In summary, all of the biological elements experience marked and synchronous changes over the period represented by the White Loch cores, indicative of enrichment. The data suggest that the present day plant community has few taxa in common with those observed in the reference assemblages, having experienced the loss of *Isoetes lacustris* and a reduction in charophytes, with elodeids becoming the dominant component of the aquatic vegetation.

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Cover photograph: Piston coring at White Loch

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SPECIFICATION AND OBJECTIVES

The aim of the project was to employ macrofossil analyses to an existing littoral core from White Loch to define reference conditions and to assess ecological changes and hence to provide valuable information to assist with development of environmental improvement plans for the site. The work was conducted as a follow up to a larger multi-proxy palaeoecological study of seven mesotrophic lochs (Tangy Loch, Loch Nan Gad, Loch a Phuill, Loch Flemington, Monk Myre, White Loch and Monzievaired) (Bennion *et al.*, 2008). These are all sites of high conservation interest currently or having once supported the biodiversity priority species *Najas flexilis* (slender naiad) or *Potamogeton rutilus* (Shetland pondweed).

In the original study, diatom data indicated that White Loch formerly supported a diverse, largely non-planktonic community typical of a mesotrophic loch. However, the diatom flora underwent changes associated with enrichment, initially in ~1980 with a further phase in the late 1990s, resulting in an increase in the planktonic component. The Cladocera data indicated that plants have been abundant throughout the period represented by the core and that a diverse plant community is likely to be present today. Nonetheless, it was concluded that the shifts may reflect a change in the species composition of the submerged macrophyte flora. Macrofossil analysis was not carried out on the White Loch core in the original project and therefore the aim of the current study was to conduct analyses of plant and animal macrofossils to further assess ecological changes, particularly in the aquatic plant community.

METHODS

Core collection and extrusion

Two sediment cores were collected from White Loch using a piston corer on 30 January 2006. The open water core, WHIE1 (88 cm in length), was retrieved in 11.2 m water depth at NO 169686, 42937 and was radiometrically dated and analysed in the original project for diatoms and Cladocera (Bennion *et al.*, 2008). The littoral core, WHIE2 (98 cm in length), was retrieved in 1.64 m water depth at NO 17090, 42848 and is here analysed for macrofossils. The WHIE2 core was not dated and therefore the period represented by the macrofossil record is unknown.

The cores were extruded in the field at 1 cm intervals and any visible stratigraphic changes were noted. The percentage dry weight (%DW) which gives a measure of the water content of the sediment, and percentage loss on ignition (%LOI) which gives a measure of the organic matter content, were determined in the laboratory on alternate samples from each core by standard techniques (Dean, 1974).

Macrofossil analyses

For the macrofossil analysis ten levels from WHIE2 were examined. A measured volume of sediment (~30 cm³, the exact volume was assessed using water displacement) was analysed for each level. Samples were sieved at 350 and 125 microns and the residues from each were transferred using distilled water to plastic vials for storage. The entire residue from the 350 micron sieve was examined under a stereomicroscope at magnifications of x10-40 and plant and animal macrofossils (zooplankton ephippia) were identified and enumerated. A quantitative sub-sample, approximately one fifth of the sample, from the 125 micron sieve sample was analysed for smaller remains such as leaf spines. All plant material was identified by comparison with herbarium documented reference material. It was not always possible to ascribe remains to species level, thus in some cases an aggregate group of species corresponding to the highest possible taxonomic resolution was used. For example, *Potamogeton pusillus* agg. included remains of *P. pusillus* and *P. berchtoldii*. The data are presented as numbers of remains per 100 cm³ of wet sediment.

Data analysis

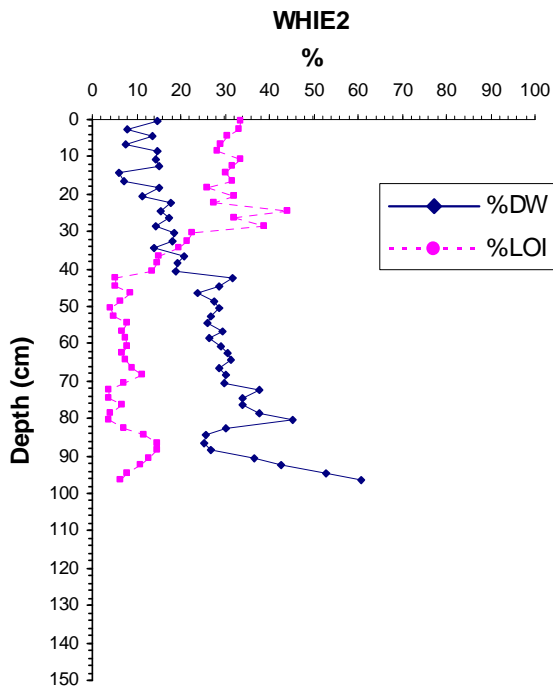
Summary statistics of the plant macrofossil data, including the number of taxa observed and the Hill's N2 diversity score (Hill & Gauch, 1980), were calculated for each sample in the core. The results of the macrofossil analyses were plotted as stratigraphic diagrams using C2 (Juggins, 2003) for the plant remains and the zooplankton ephippia. Cluster analysis was performed on the core data to identify the major zones in the macrofossil profiles using CONISS (Grimm, 1987), implemented by TGView version 2.0.2 (Grimm, 2004). CONISS is a program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. Zones are illustrated on the stratigraphic plots to facilitate description of the major compositional changes.

RESULTS

Core description

The littoral core, WHIE2, was comprised of inorganic sediments in the section below 40 cm (%LOI ~10%). There was a rapid increase in organic matter to a peak of ~40% at ~25 cm, and a subsequent decrease in organic matter to values of ~30% in the upper 25 cm of the core (Figure 1).

Figure 1 Percentage dry weight and organic matter profiles of WHIE2



Plant macrofossils

Initial screening indicated that plant macrofossils were present throughout the core. In the absence of dating, ten sub-samples were selected for analysis at 10 cm intervals from the surface to 90 cm sediment depth (Table 1). The number of taxa per sample was not especially diverse, ranging from six to ten.

Table 1 Results of the plant macrofossil analysis on WHIE2

Depth (cm)	No taxa	N2
1	6	4.57
10	8	4.80
21	8	3.91
31	10	2.70
41	8	2.55
51	6	3.59
61	6	4.27
71	10	7.24
79	6	3.69
90	6	1.15

The cluster analysis identified four major zones in the plant macrofossil record (Figure 2).

Zone 1 (90 cm sample)

Ranunculus sect. *Batrachium* and terrestrial mosses dominated the lowermost sample. *Chara* and *Nitella* oospores were also present in relatively low abundances.

Zone 2 (41-79 cm)

Nitella and *Chara* oospores dominated the aquatic macrophyte assemblage in this zone, with *Isoetes lacustris* also prevalent. The occurrence of terrestrial mosses declined, whilst *Juncus* and *Carex* seeds were abundant (data not shown).

Zone 3 (21-31 cm)

Isoetes lacustris almost disappeared from the record, whilst *Chara* and *Nitella* oospores declined markedly although remained present at lower abundances. *Callitriche* seeds initially appeared in the macrofossil record at 31cm, as did *Potamogeton pusillus* agg. leaf tips and *Potamogeton* spp. seeds. *Ranunculus* sect. *Batrachium* reappeared at low abundance. Remains from terrestrial species such as *Larix*, *Betula* and *Fagus* were also found (data not shown).

Zone 4 (1-10 cm)

The species assemblage in the upper part of the core was dominated by *Callitriche* with presence of *Potamogeton obtusifolius* in reasonably high amounts. Remains of the marginal species *Epilobium* sp. were found, but no grass or sedge seeds were recorded.

Zooplankton ephippia

The cluster analysis identified two major zones in the zooplankton ephippia record (Figure 3). Ephippial remains were scarce below 41 cm (Zone 1) with only a small number of *Daphnia hyalina* agg. present. Above this depth (Zone 2) the remains of *Daphnia hyalina* agg. increased in abundance as did those of *Ceriodaphnia* spp., although remains of the latter were not present in the 10 cm sample. *Daphnia pulex* first occurred in the record at 21 cm and increased in abundance towards the surface, as did *Simocephalus* spp., a large-bodied species associated with plant beds.

DISCUSSION

The macrofossil data indicate that White Loch formerly supported a plant community typical of a relatively nutrient-poor loch with presence of *Isoetes lacustris* and several Charophytes (*Chara* and *Nitella* spp). This period coincides with the inorganic section of the core when organic matter content was less than 10%. Zooplankton ephippia were sparse in this lower section. The major shift in all groups occurred at ~40 cm in the core, the point at which the sediment becomes notably more organic. The remains of *Isoetes lacustris* disappear and the Characeae oospores decline in abundance above this depth. Conversely, *Potamogeton* and *Callitriche* taxa increase, and are particularly abundant in the two uppermost samples. This shift from isoetids and charophytes to larger canopy-forming elodeids reflects enrichment of the loch (e.g. Blindow, 1992). The changes in the plant community are synchronous with those in the zooplankton ephippia where a large increase in *Daphnia* (*hyalina* and *pulex*) and *Ceriodaphnia* occurs in the upper 40 cm, and the plant associated *Alona* spp and *Simocephalus* spp. both appear in the upper two samples.

The shifts in the macrofossil record accord well with the changes observed in the diatom and Cladocera data from the open water core (Bennion *et al.*, 2008). The diatom data indicated that White Loch formerly supported a diverse, largely non-planktonic diatom community typical of a mesotrophic loch (Figure 4). However, the diatom flora underwent changes indicative of enrichment with an increase in several planktonic taxa typically found in more

productive waters from ~1980, followed by a further change in the late 1990s indicating a second phase of enrichment to more eutrophic conditions which appear to have prevailed for the last decade. The *Daphnia ephippia* data are in agreement with this, suggesting an increase in pelagic productivity reflecting more eutrophic conditions (Vadeboncoeur *et al.*, 2003). The Cladocera assemblages of White Loch (chitinous remains) also experienced shifts, the timing of which was coincident with those in the diatom record (Figure 5). Most notably there was a shift to larger bodied pelagic species such as *Bosmina coregoni* in ~1980, and from ~1990 several plant-associated species increased suggesting an increase in plant biomass. Hence, the inferred enrichment and changes in plant abundance reported by Bennion *et al.* (2008) are here supported by the macrofossil data. The addition of plant macrofossil analyses to the palaeoecological dataset has confirmed that there have been marked changes in the composition of the aquatic plant community of White Loch.

Najas flexilis, the biodiversity priority species for White Loch, was last recorded in 1882. The species was absent from a snorkel survey carried out in 1999 (Wingfield *et al.*, 2004). However, it was recorded again in low abundance in June 2008 in one area on the southern side of the loch during a grapnel survey by Nick Stewart (N. Stewart, pers. comm.). Given the high inter-annual variation of the plant community and the unstable state of the loch, with occurrence of extensive algal blooms in some years, it may be difficult to find *Najas flexilis* using standard plant survey methods. Indeed in years when *Chara rudis* is abundant, there may be little suitable habitat for *Najas flexilis* (N. Stewart, pers. comm.). The remains of *Najas flexilis* were not found in the sediment core. This could be because the core does not extend back as far as the late 1800s when the species was last recorded although dating is required in order to establish this. Alternatively, *Najas flexilis* may have been rare in the past. Given that *Najas flexilis* is an annual, seeds are likely to be found in the sediment if the plant was frequently present in the loch.

Several taxa observed in recent plant surveys were captured in the uppermost part of the sediment record. For example, *Callitriche hermaphroditica* has been recorded regularly since 1997 (Nick Stewart, pers. comm.) and it is therefore likely that the *Callitriche* seeds found in our core are from this species. *Potamogeton obtusifolius* has been recorded in several years and its remains, both seeds and leaves, were found in the macrofossil record. Several other *Potamogeton* taxa have been recorded in surveys since 1997 including *P. crispus*, *P. x nitens* and *P. pusillus* but remains of these species were not found in the sediments. The plant surveys of SEPA (2005) and Nick Stewart (2003-2008) indicate that charophytes are still present in White Loch with several species recorded in recent years including *C. rudis*, *C. aspera*, *C. contraria*, *C. virgata* and *Nitella* spp. Whilst *Chara* and *Nitella* oospores were observed in the upper zone of our core, the palaeoecological data suggest that there has been a decline in charophyte abundance. Unfortunately *Elodea canadensis* is also present in the loch and is abundant in some years. This species does not produce viable remains and is therefore not recorded in the macrofossil data.

In summary, all of the biological elements experience marked and synchronous changes over the period represented by the cores, indicative of enrichment. The data suggest that the present day plant community has few taxa in common with those observed in the reference assemblages, having experienced the loss of *Isoetes lacustris* and a reduction in charophytes, with elodeids becoming the dominant component of the aquatic vegetation.

Figure 2 Summary plant microfossil diagram for WHIE2
 (Note variable scaling on the x axis)

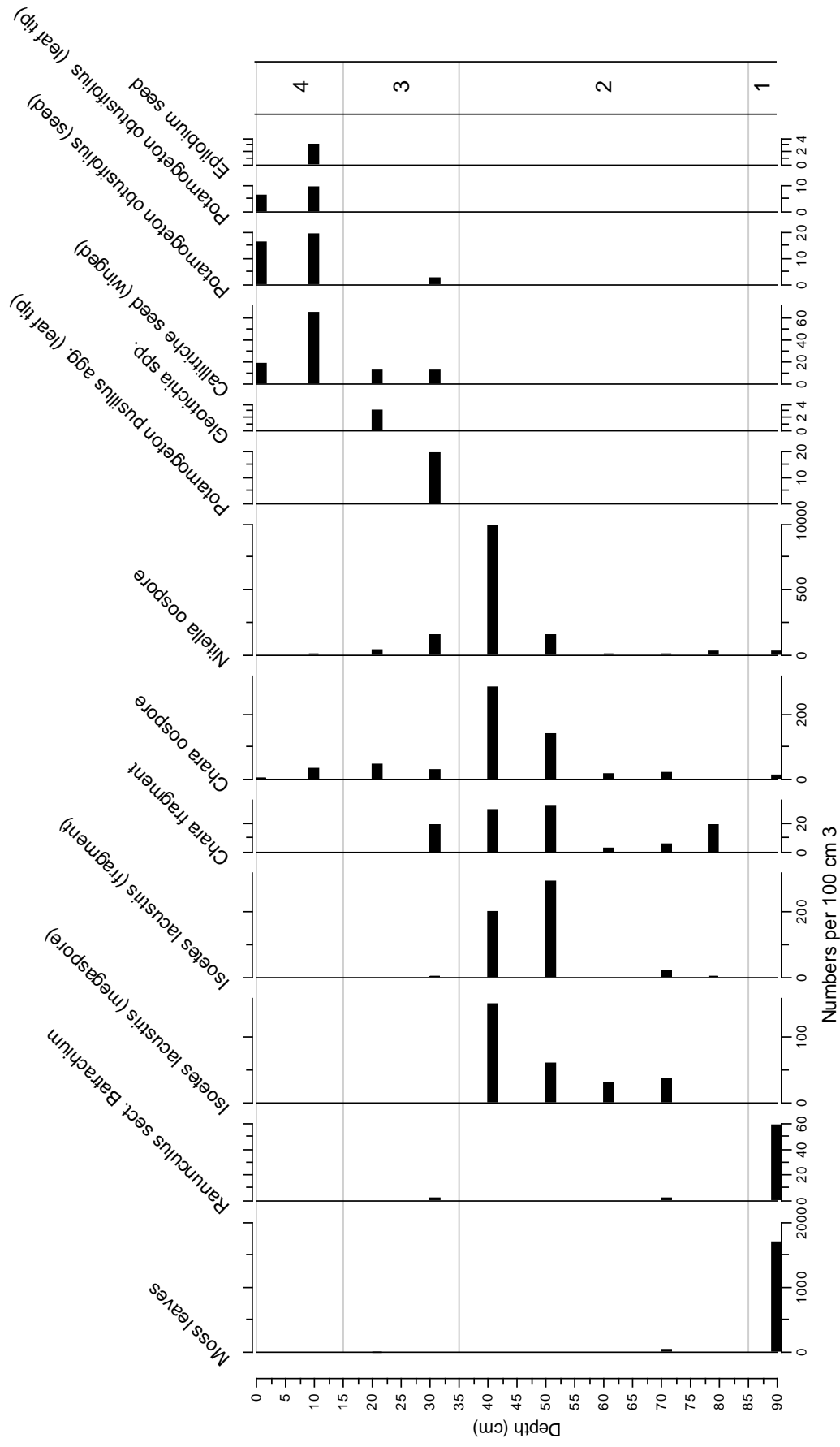


Figure 3 Summary zooplankton ephippia diagram for WHIE2
 (Note variable scaling on the x axis)

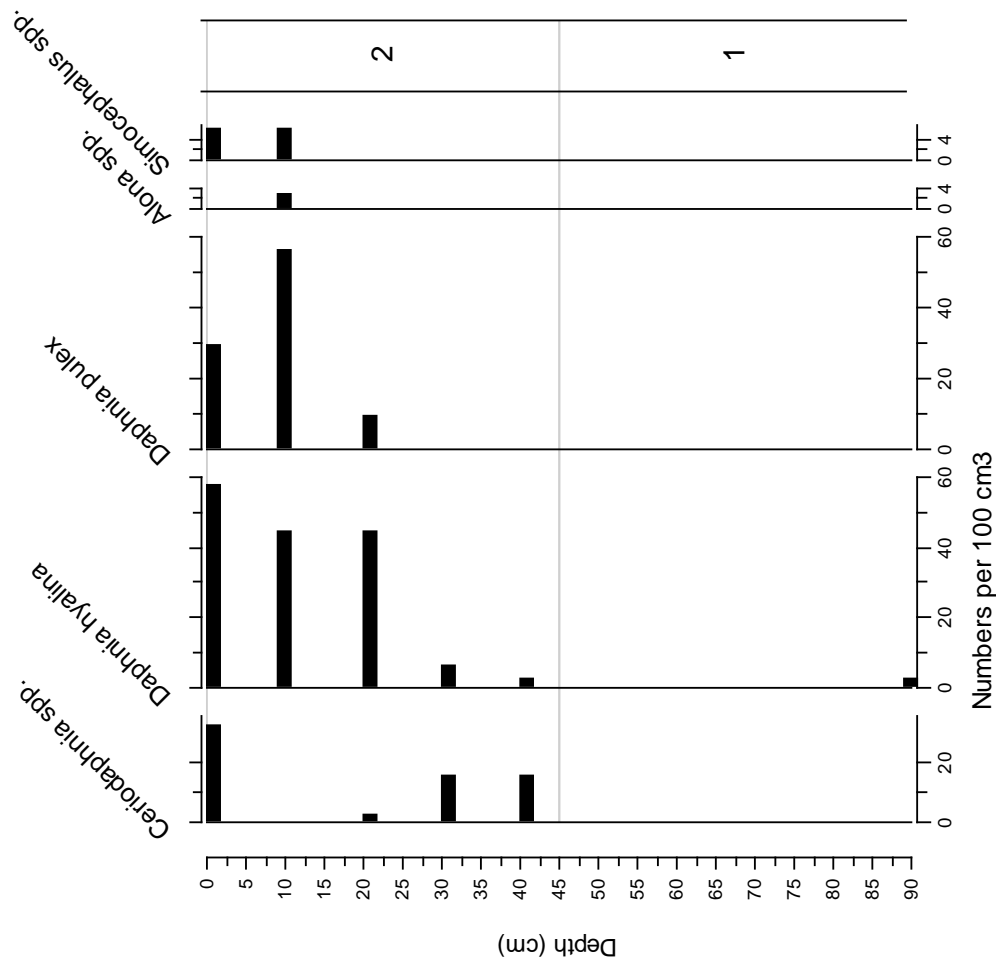


Figure 4 Summary diatom diagram of WHIE1
(from Bennion et al., 2008)

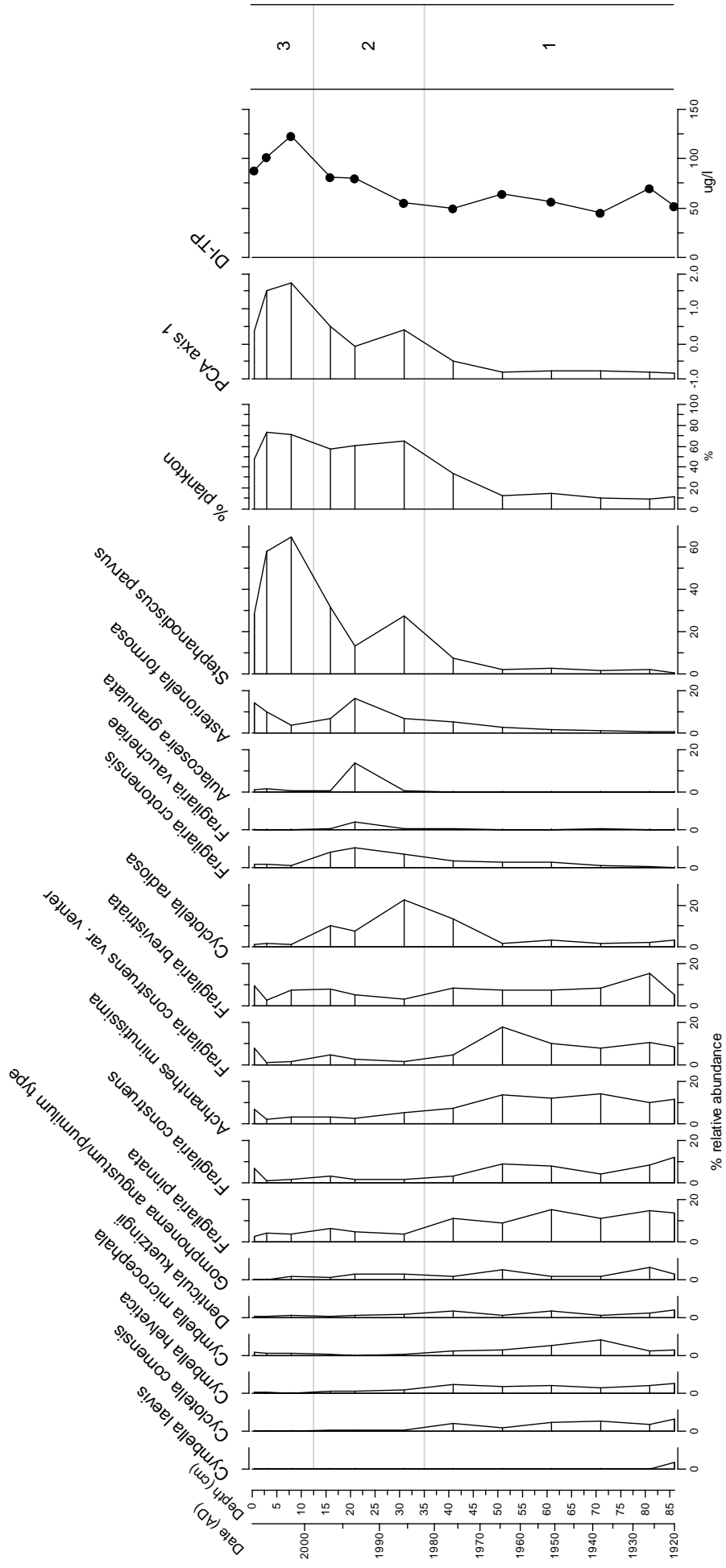
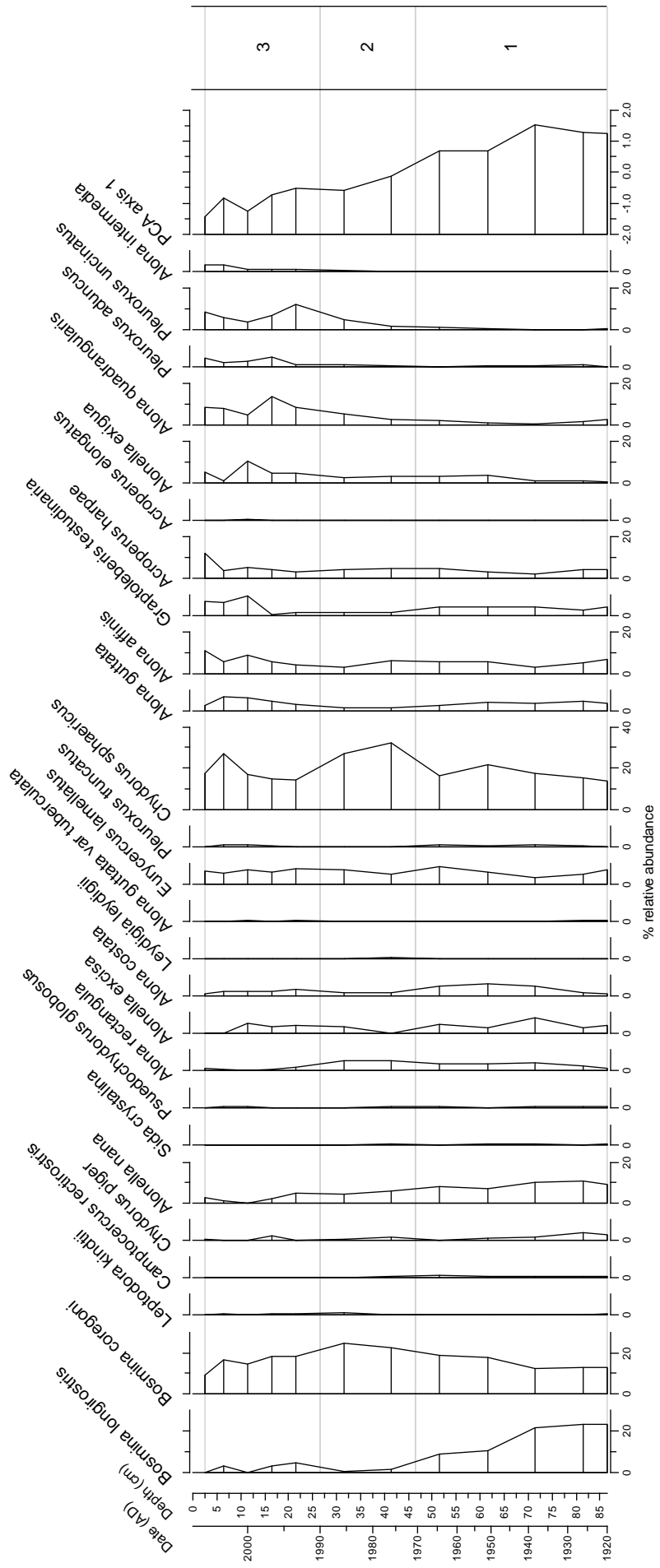


Figure 5 Summary Cladocera diagram for WHIE1
 (from Bennion et al., 2008)



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