CHAPTER 5

SITE INTERPRETATION 2

MARC SCHALLENBERG AND ROB CADMUS

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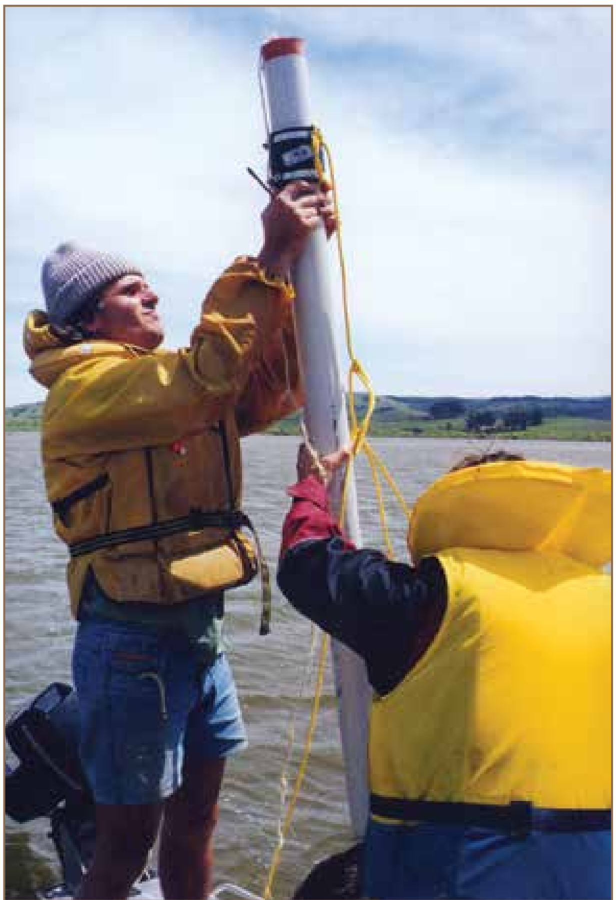
Natural and human-influenced environmental change in many aquatic ecosystems and their catchments can be inferred or reconstructed using data from fossils and subfossils. The techniques used come from the field of palaeo-ecology – the study of ancient ecology. Palaeo-ecological techniques can be used to infer changes in sediment accumulation, soil characteristics, nutrient levels, salinity, disturbance and vegetation in wetlands – all of which are useful for setting appropriate restoration goals. As many of the techniques described in this chapter require specialized equipment and considerable expertise to collect, prepare and interpret the samples, information on who can help, equipment suppliers and laboratories for analysis are included. The costs are only indicative and are based on 2010 pricing in New Zealand.

Objective historical and pre-historical information from palaeo-ecological studies complement the techniques highlighted in the previous chapter (Chapter 4 – Site interpretation 1). Used together, both techniques can provide a detailed picture of the environmental variability in wetlands over extended time periods. This knowledge is important for the long-term sustainability of restored wetlands. The case study included in this chapter demonstrates how palaeo-ecological techniques were used at two different wetland complexes, Waipori/Waihola (Otago) and Waituna (Southland).



Percussion coring is best used in shallow waters where the sediment is fine and soft and wood or vegetation are absent, such as in the middle of Lake Waihola (depth: 2 m).
Photo: Marc Schallenberg, University of Otago

Previous page: Core samples showing peat overlying marine clay. Kopuatai peat dome, Waikato. Photo: Monica Peters, NZ Landcare Trust

1 Collecting sediment/ soil cores

The first step for undertaking palaeo-ecological studies involves collecting cores. Sediment/soil coring works optimally in sites where sediment/soil accumulation is likely to have been continuous. To minimise the number of cores required, coring sites can be selected that are more representative of key, wetland-wide conditions and processes. Several methods can be used, depending on the habitat, water depth, type of sediment, and core length required. Materials from which core tubes or sleeves can be made include readily available materials such as plastic drain pipe or downspouting and aluminium irrigation tubing. However, in some habitats, specialized sediment coring devices may be needed to obtain high quality cores. These are available through some universities and government laboratories.

Note that specialized coring equipment should only be used by experienced operators. An expert in coring can also help with selecting appropriate sites, core transport, storage, opening or extruding, core logging as well as estimating coring artefacts (e.g., core shortening). Costs, constraints, and efficiencies differ among sediment corer types for a given site. Once a core has been obtained, x-raying the intact core can illustrate density variations in the sediment strata and the presence and position of shells, wood, and other macrofossils. Opening, extruding or sectioning (cutting) the core should be carefully carried out to avoid damaging, stretching or compressing the sediment record. Immediately upon opening a core, a core log should be made in which changes in sediment colour, texture, and the presence of macrofossils are recorded along with corresponding depths.

After sub-samples of the core have been taken for palaeo-ecological analyses, the core should be archived by wrapping it in plastic and storing it in a cool location, in case further analyses are required. If the core is cut lengthwise, sub-sampling should be conducted on one half of the core while the other half should be archived intact.

Where water depth is greater than c. 1.5 m, long lengths of plastic pipe can be pushed or driven into the sediment from a boat. Gravity coring in Lake Ellesmere, Canterbury.
Photo: Marc Schallenberg, University of Otago

2 Sediment analyses

2.1 Water and organic content

Water and organic content are determined by calculating changes in mass between fresh, dried and combusted samples, which can reflect changes in organic matter inputs, hydrology, vegetation, eutrophication. Water and organic content can also be useful for determining sedimentation rates and sediment compaction (dewatering).

METHOD

Samples are obtained by subsampling the core at a variety of depths to create depth profiles. Moisture content is determined after drying to constant mass at 60 degrees C. Organic content is determined after combustion of the dry sediment at 550 degrees C until all organic matter has combusted. Note: a lid is required on crucibles to avoid loss of inorganic material upon combustion. Hot samples should be cooled in a desiccator prior to weighing.

EQUIPMENT

Balance, oven, muffle furnace, desiccator, crucibles, mortar and pestle.

COST

*$5-30 per sample.

WHERE ANALYSED

Universities, other environmental institutes, and environmental consultants.

EXPERTISE

Basic laboratory skills. Some expertise required for interpreting the environmental conditions that cause changes in water and organic content.

NOTES: Interpretations can be improved if combined with sediment grain size and sediment density analyses.

2.2 Sediment grain size analysis

Sediment grain size can be used to infer changes in hydrology and sedimentation. In general, fine sediments are deposited in calm environments whereas the presence of coarse sediments indicates higher energy environments. Particle grain size analysis of wetland sediment or soil can also provide information on, e.g., soil drainage, water holding capacity, nutrient retention and cation exchange capacity.

METHOD

While x-ray densitometry and visual analysis of sediment can indicate abrupt and large changes in sediment grain size, particle grain size analysis is recommended for quantification of gradual and fine-scale patterns. Samples are obtained by subsampling the core at a variety of depths to create depth profiles.

EQUIPMENT

Simple Bouyoucos hydrometer method can be used (hydrometer, mortar & pestle, blender, glassware, stopwatch); however, laser particle size analyzers can save considerable time and are more accurate.

COST

*$70–90 per sample.

WHERE ANALYSED

Universities, other environmental institutes, and environmental consultants.

EXPERTISE

Basic laboratory skills required for sample preparation. Particle size analyzer requires specialized training. Interpretation of small changes requires an understanding of sedimentological processes.

NOTES: Interpretations can be improved if combined with sediment grain size and sediment density analyses.

2.3 Sediment density (X-ray densitometry)

Wetlands in river floodplains often experience seasonal flooding. Similarly, coastal wetlands may occasionally be influenced by high seas. In addition, land-use changes can increase erosion of soils, which can alter the composition, input rate and density of sediments. Failure to take these into consideration during restoration planning can result in over-siltation of restored or constructed wetlands and, therefore, failure to meet restoration goals. Examining the density changes in sediment cores illustrates the historical frequency of extreme sedimentation events.

METHOD

By x-raying whole sediment cores, photographic prints can be made from the x-ray negatives revealing stratigraphic structures, including the presence of shells, gravel, peat, etc. X-rays are also useful for determining whether bivalve shells are articulated and in living position, which is important for determining if the bivalves inhabited the site or if their shells were washed in from the sea. Sediment density is related to the organic and water content, sediment grain size, the level of compaction (de-watering). Stratigraphic patterns from flooding or other changes in hydrology and other sedimentation changes can therefore be observed in x-rays. X-rays can be used for the quantitative analysis of variation of sediment density.

EQUIPMENT

Medical x-ray scanner or dedicated sediment core scanner.

COST

*$10-100 per metre of sediment core. Additional costs for photographs. Minimal time is required for x-ray densitometry.

WHERE ANALYSED

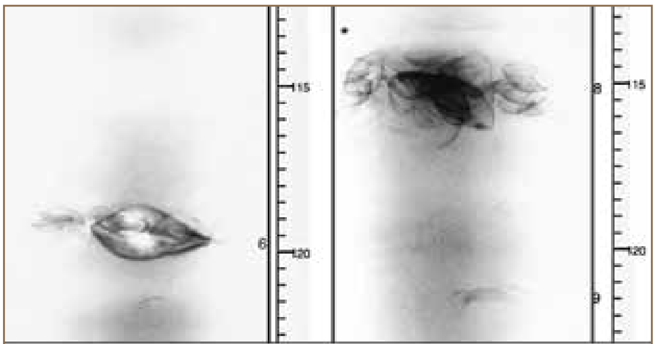
Hospital radiology departments or geosciences laboratories in universities or other research institutes.

EXPERTISE

Interpretation of abrupt changes in density and the presence of shells and other macro-fossils is straightforward, but some expertise in sedimentology allows for more density variations to be interpreted.

NOTES: X-ray densitometry is complementary to sediment grain size and organic and water content analysis, and can substitute for these methods when funds are limited and quantitative data are not required. Interpretations can be improved if combined with sediment grain size and sediment density analyses.

*Unit costs are usually dependent on sample number. The costings here are rough estimates based on a run of 30 samples.



Positive renderings of x-rays of a cockle (*Austrovenus stuchburyi*) from c. 1200 mm below the sediment–water interface in Lake Waihola, Otago. Shells were carbon 14 dated as c. 4000 years old.
Image: Marc Schallenberg, University of Otago

3 Methods for dating sediments

3.1 Caesium-137 (^{137}Cs)

Caesium-137 is a radioactive isotope, globally distributed as a result of the atmospheric testing of thermonuclear weapons. ^{137}Cs can be used to identify sediment strata deposited during the period of elevated atmospheric fallout.

TIMESCALE

Detects ^{137}Cs fallout from atmospheric thermonuclear bomb testing which peaked in the Southern Hemisphere c. 1959–1964.

METHOD

Gamma particle counting.

MATERIAL

Bulk dry sediment.

COST

c. $100-250 per sample, but may be analysed in conjunction with 210Pb. A number of samples should be analysed to determine the peak.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Interpretation is relatively straightforward but can be complicated by bioturbation, translocation of ^{137}Cs rich soil from upstream erosional areas.

3.2 Lead-210 (^{210}Pb)

The method is based on inferring changes in atmospheric and background ^{210}Pb levels in relation to its degree of equilibrium with other isotopes in the uranium decay series.

TIMESCALE

Present to c. 1850s.

METHOD

Alpha or gamma particle counting.

MATERIAL

Bulk dry sediment.

COST

$100-250 per sample, however ^{210}Pb analysis may sometimes be carried out in conjunction with ^{137}Cs analysis. Usually 10 to 20 samples are required to obtain reliable ^{210}Pb dates and estimates of sedimentation rates.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Data interpretation requires statistical analyses and an understanding of radiochemistry.

Kahikatea pollen. Studying fossilized pollen can reveal historical vegetation patterns, and imply changes in land use, climate, and disturbance regimes. Photo: Marc Schallenberg, University of Otago

Pine pollen. Both the pine (introduced) and kahikatea (native) pollen samples are stained with carbol fuchsin dye. Photo: Marc Schallenberg, University of Otago

3.3 Indicator pollen

Vegetation changes can be used to infer changes in land use, climate, and disturbance regimes. Pollen is separated from the sediment, stained and identified microscopically. Where known vegetation changes are described in historical records, indicator pollen can be used to date sediment. Useful indicator pollen for wetlands and their catchments include pine (*Pinus radiata*), kahikatea (*Dacrycarpus dacrydioides*), bracken fern (*Pteridium esculentum*). Note that pollen may be rare in coarse sediments from high-energy environments.

TIMESCALE

Decades to millennia before present. Usefulness depends on preservation of the pollen in the sediments.

METHOD

Light or electron microscopy.

MATERIAL

Bulk fresh sediment. Pre-treatment is necessary.

COST

c. $170 per sample for preparation of pollen slides and $250 per sample for the pollen identification.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Pollen identification and interpretation requires strong botanical and palynology skills.

3.4 Carbon-14 (^{14}C)

Radioactive isotope of carbon. By analyzing the different isotopes of carbon, objects (e.g., shells, wood) can be dated back thousands of years with relatively high accuracy. With care, this method can be used to infer sediment ages and sedimentation rates.

TIMESCALE

c. 1,000 – 25,000 years before present.

METHOD

Beta particle counting or accelerator mass spectrometry. Marine/freshwater/terrestrial calibration required.

MATERIAL

Macrofossils (e.g., wood, shells) and bulk sediment. Sample pre-treatment necessary.

COST

Standard beta particle emission analysis costs c. $310–400. With small sample sizes, accelerator mass spectrometry may be required and this costs c. $800 per sample.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Expertise and experience essential.

Bracken is a key indicator of human-induced environmental change: as a valuable food source, early Maori cleared land by burning to encourage its growth. Photo: Monica Peters NZ Landcare Trust

CASE STUDY

WAIPORI/WAIHOLA & WAITUNA WETLANDS: DIGGING EVEN DEEPER INTO THE PAST

Palaeo-ecological techniques were used at both the Waipori/Waihola Lake-Wetland Complex (Otago) and the Waituna Lagoon wetland complex (Southland). The techniques yielded important ecological information on the effects of past saline intrusions and sea level rise on the systems. This information is of great relevance to setting appropriate restoration goals for these tidal ecosystems. See previous chapter – Site interpretation 1 for further information on the two wetland complexes profiled.

Date	Determination	Findings	Methods used
Waituna Lagoon			
> c. 7000 ybp	Wetland formation	• Post-glacial formation due to mid-Holocene sea level rise	• ^{14}C dating • Grain size analysis • Organic matter analysis • X-ray densitometry
Waipori/Waihola Lake-Wetland Complex			
> c. 5000 ybp to present	Long-term state of lake/wetland system	• Continued presence of standing water in lakes surrounded by wetlands that were inundated at times	• ^{14}C dating • Grain size analysis • Organic matter analysis • X-ray densitometry
Waituna Lagoon and Waipori/Waihola Lake-Wetland Complex			
c. 7000 ybp to c. 1860	Wetland state prior to significant anthropogenic impact	• Wetland consisted of a large area of standing water (lagoon/ lake) surrounded by temporally stable, vegetated wetland • Minimal marine influence • Low sediment accumulation rate in open waters • Established dominant native vegetation	• Radio-isotopic dating (^{14}C, ^{210}Pb, ^{137}Cs) • Grain size analysis • Organic matter analysis • X-ray densitometry • Pollen analysis and dating • Reference site analysis • Historical research
c. 1860 to present	Anthropogenic effects	• Increased in marine influence • Vegetation changes (local and in catchment) • Increased sediment accumulation rate • Increased hydrological throughout and energy • Reduced hydrological buffering	• Radio-isotopic dating (^{210}Pb, ^{137}Cs) • Grain size analysis • Organic matter analysis • Pollen analysis • X-ray densitometry • Site evaluation/interpretation • Historical research
Present to future	Environmental constraints for restoration	• Shift to estuarine conditions • High hydraulic energy and sediment accumulation rates • Determine appropriate restoration goals	• Palaeo-limnological interpretation • Literature research • Site evaluation/interpretation • Reference site analysis

– Marc Schallenberg

4 Biological indicators/ proxies

These are specialist methods best employed in collaboration with experts from universities or environmental research laboratories. As such, no cost estimates are provided.

4.1 Macrofossil plant and animal remains

These include leaves, seeds, shells and wood. These indicators are commonly found in sieved wetland sediment samples and are useful in providing information about plants and animals which lived in and around wetlands. With the help of skilled specialists, past physico-chemical conditions can be inferred from the types of organisms that inhabited the wetland.

METHOD

1. Identify species present in sediment strata; 2. Confirm that the species that produced the macrofossils were likely to have been living at the site; 3. Research present types of environments (e.g., salinity, hydrology, etc.) in which the species live; 4. Infer similar conditions existed in the past at the site

EQUIPMENT

Sieves, chemicals and a laboratory for sample preparations, microscope.

SAMPLE COLLECTED FROM

Various aquatic environments.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Microscopy, taxonomy.

4.2 Microfossil plant and animal remains

These include diatom frustrules (the silicate shells of microscopic algae known as diatoms), chironomid head capsules (from aquatic midge larvae), phytoliths (inorganic crystals produced in some terrestrial plants), foraminifera shells (from small marine animals called foraminiferans), planktonic crustaceans (zooplankton) and the pollen and spores of wetland plants.

METHOD

1. Identify species present in sediment strata; 2. Confirm that the species that produced the macrofossils were likely to have been living at the site; 3. Research present types of environments (e.g., salinity, hydrology, etc.) in which the species live; 4. Infer similar conditions existed in the past at the site.

EQUIPMENT

Sieves, chemicals and a laboratory for sample preparations, microscope.

SAMPLE COLLECTED FROM

Diatoms, phytoliths and pollen can be collected from most wetland sediments and soils. Chironomids and zooplankton can be collected from sediments underlying open water in lakes, ponds, wetlands and lagoons. Foraminifera can be collected from aquatic sediments which have had some marine influence.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Microscopy, taxonomy, statistical skills.

4.3 Charcoal

Charcoal grains are indicators of fire in the catchments and are useful for reconstructing fire histories.

METHOD

Microscopic identification and quantification of charcoal grains.

EQUIPMENT

Sieves, chemicals and a laboratory for sample preparations, microscope.

SAMPLE COLLECTED FROM

Sediments, soils.

WHERE ANALYSED

Specialist laboratories in universities and other environmental research institutes.

EXPERTISE

Microscopy.

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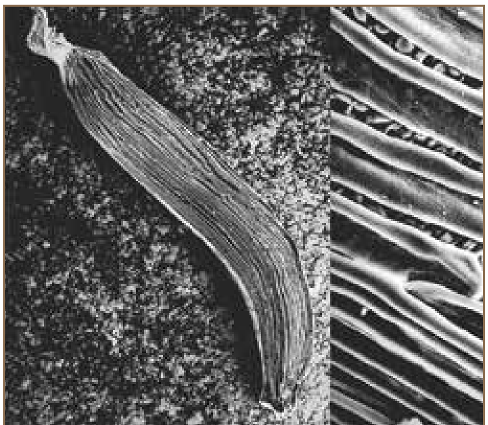

Manuka seed enlarged x30 and x300.
Photo: Colin Webb, Landcare Research

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5.1 Useful websites

National Radiation Laboratory

www.nrl.moh.govt.nz/

University of Waikato Radiocarbon Dating Laboratory

www.radiocarbondating.com/

Note that many of the resources above are available as hard copy from the respective organisations. There is also a CD containing all above hyperlinks at the back of this Handbook. If you are using the online version of the Handbook and having problems with the hyperlinks above, try copying and pasting the web address into your browser search bar.