Lower Lakes carbon project: the aquatic vegetation contribution to carbon pools

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Lower Lakes carbon project: the aquatic vegetation contribution to carbon pools

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Cover Photograph

Point Malcolm sites at sunset. Photographer: Leigh Sullivan.

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LIST OF ABREVIATIONS

µagg - microaggregate fraction (63–250 µm)
µClay - microaggregate-derived clay-sized fraction (heavier than 1.85 g cm^{-3}, <2 µm)
µSilt - microaggregate-derived silt-sized fraction (heavier than 1.85 g cm^{-3} 2-63 µm)
CO_2 – carbon dioxide
cPOM - coarse non-protected particulate organic matter (>250 µm)
dClay - easily dispersed clay-sized fraction (acid-soluble <2 µm)
dSilt - easily dispersed silt-sized fraction (acid-soluble 2-63 µm)
EC – electrical conductivity
H-µClay - hydrolysable microaggregate-derived clay-sized fraction (acid-soluble <2 µm)
H-µSilt - hydrolysable microaggregate-derived silt-sized fraction (acid-soluble 2-63µm)
H-dClay - hydrolysable easily dispersed clay-sized fraction (acid-soluble <2 µm)
H-dSilt - hydrolysable easily dispersed silt-sized fraction (acid-soluble 2-63 µm)
iPOM - microaggregate-protected POM (heavier than 1.85 g cm^{-3}, >63 µm in size)
LF - fine non-protected POM (lighter than 1.85 g cm^{-3}, 63–250 µm)
NATA - National Association of Testing Authorities
NH-µClay – non-hydrolysable microaggregate-derived clay-sized fraction (acid-resistant <2 µm)
NH-µSilt - non-hydrolysable microaggregate-derived silt-sized fraction (acid-resistant 2-63 µm)
NH-dClay - non-hydrolysable easily dispersed clay-sized fraction (acid-resistant <2 µm)
NH-dSilt - non-hydrolysable easily dispersed silt-sized fraction (acid-resistant 2-63 µm)
OM – organic matter
SOC – soil organic carbon
TOC – total organic carbon

Executive Summary

Vegetation has been shown to play a major role in the remediation of the Lower Lakes both during the drawdown of these lakes during the 2007-2010 drought and during their subsequent refilling. Bioremediation has produced substantial environmental benefits via the provision of alkalinity from plant roots and minimising soil erosion. Studies of the effects of bioremediation have also highlighted large differences in organic input from different bioremediating vegetation. For example, only where perennial species that survive inundation had been used for bioremediation has there been a continuation of the supply of phytogenic organic carbon to the underlying sediments since lake refilling.

Recently Sullivan *et al. (*2012a) demonstrated that bioremediation with *Schoenoplectus validus* and *Phragmites australis* revegetation has increased the storage of organic carbon in sediments considerably after only a few years of growth since lake refilling. The initial rates of organic carbon increase at these sites ranged between 670 - 903 kg C ha^{-1} yr^{-1}, rates of organic carbon increase in accord with rates typically found for revegetating wetlands. These organic carbon increases were almost totally in the relatively short-lived non-protected soil carbon pool indicating that these increases and the maintenance of the additional stored carbon under bioremediating lake vegetation is likely to be contingent on the persistence both of this vegetation (and the consequent supply of organic matter to this pool), and of constantly inundating conditions.

This project aimed to monitor the changes in carbon status in the sediments under four different vegetation types around the Lower Lakes and to examine changes in carbon status in terms of the various pools that make up total soil carbon. An ongoing supply of organic carbon to the sediments is an important consideration as organic carbon is the critical energy source necessary to drive many of the likely ongoing remediation processes. In addition, it is important to gain an adequate understanding of carbon production and cycling under additional types of vegetation and at additional sites to better assess the likely long-term effectiveness of lake revegetation strategies on carbon accumulation and sequestration in these sediments.

In particular, this project monitored the changes in carbon status in sediments at four sites around the Lower Lakes (Hunters Creek, Tolderol, Loveday Bay and Point Malcolm) under:

1) *Schoenoplectus validus* (recently established stands),
2) *Bolboschoenus* (both a mature stand and a recently established stand),
3) *Phragmites australis* (recently established stands), and
4) *Schoenoplectus pungens* (recently established stands).

The carbon status was investigated by:

1) an examination of the total carbon accumulation down to 40 cm sediment depth at each of these sites relative to a control (i.e. a nearby non-revegetated site), and
2) examining the chemical, physical, biochemical, and non-protected carbon pools of these soils consequent of bioremediation.

The key findings of this study are:

1) The mean organic carbon increases for all four Lower Lakes' sedges were similar ranging between 580 - 1,050 kg C ha^{-1} yr^{-1} indicating that the carbon sequestration rates were relatively independent of the type of sedge growing. This is important as it indicates that the rates of carbon accumulations in the sediments of the Lower Lakes will not be markedly affected by the type of sedges that are used for revegetation.

2) The organic carbon increases at most of the recently revegetated sites and also at the well-established *Bolboschoenus* site at Hunters Creek were dominantly (i.e. ~75%) in the relatively short-lived non-protected soil carbon pool with the main contributor being the cPOM (i.e. the coarse (> 250 µm) particulate organic matter). This pool is readily available to biota and hence important for the ecology of the lakes. However, the increase and maintenance of the additional stored carbon under the bioremediating vegetation, being mainly in the relatively short-lived non-protected soil carbon pool, is likely to be to a considerable extent contingent also on the maintenance of 1) the vegetation and the consequent supply of organic matter to this pool, and 2) inundating conditions.

3) In addition, a considerable proportion of the accumulating organic carbon in the sediments were in the physically-protected pool (~15%) and to a lesser extent, the biochemically-protected carbon pool (~5%), both considered important for secure carbon sequestration in soil because of their slow turnover rates. Interestingly the well-established *Bolboschoenus* site at Hunters Creek exhibited similar patterns in the carbon pool increase (non-protected, 75%; physically-protected, 10%; biochemically-protected, 15%) suggesting the observed pattern of a considerable accumulation of carbon in these protected carbon pools will persist as the revegetating sedges mature around the Lower Lakes.

Recommendations

1) The data clearly shows that the main carbon pools that were accumulating in these sediments during these early stages of vegetation establishment were: i. the non-protected pool, a pool considered prone to removal via oxidation and ii. the physically-protected pool, a pool considered relatively resistant to decomposition in upland soils with turnover rates of ~100 years. Although the lability of these pools has been demonstrated in upland soil conditions, this has not been examined previously for lake sediments either during inundation or after drying events. We recommend that such a study be undertaken to examine the turnover rates of these carbon pools in wetland sediments in order to be able to predict fate of carbon sequestered in these sediments both under greater durations of inundation, and under re-exposure of these sediments to the atmosphere during any repeat of the drought conditions experienced during 2007-2010.

2) That further more detailed studies be undertaken of carbon pool accumulation in sediments under the vegetation occurring in wetlands along the River Murray that experience relatively frequent periodic wetting and drying cycles: a situation considerably different to that occurring in the Lower Lakes situation that was the focus of this study where drying periods only occur in exceptional circumstances such as the 2007-2010 drought.

1.0 Project Overview

A number of recent collaborative studies of the sediments of the Lower Lakes and of the effects of bioremediation with the South Australian Environmental Protection Authority (EPA) and Department of Environment, Water and Natural Resources (DEWNR) (Sullivan *et al.* 2010, 2011, 2012a, 2012b, 2013) have highlighted the high ecological importance of organic matter dynamics, sulfate reduction and associated processes during the inundation of the acidified Lower Lakes' sediments that had been exposed during the drying event from 2007-2010.

The recent studies by Sullivan *et al*. (2011, 2012b) examined several key locations around the Lower Lakes, to compare a range of revegetation treatments (in terms of both the vegetation species and timing of plantings), as well as unvegetated control sites. The results of these studies indicate that bioremediation of the exposed acidified lake sediments by revegetation produced substantial environmental benefits from a combination of vegetation-associated processes, including the provision of alkalinity from plant roots and from the vegetation minimising soil erosion and hence preventing the exposure of severely acidic subsoils that often occurred under unvegetated sites.

At the same time, these studies (Sullivan *et al.* 2011, 2012b) also highlighted the large differences in organic input from different bioremediating vegetation. Where perennial species that survived inundation (e.g. reeds such as *phragmites*) were used for bioremediation a continuation of the supply of organic carbon to the sediments is experienced for long times after lake refilling, whereas where annual or relatively short vegetation (that was covered by the inundating waters) was used (e.g. Bevy rye, rushes, natural species like *cotula*) the supply of organic carbon to the sediment was limited to that produced prior to vegetative death caused by inundation.

One of the studies last year (Sullivan *et al.* 2012a) monitored the changes in carbon status in the soils/sediments under three different vegetation types around the Lower Lake (including *Schoenoplectus validus*, *Phragmites australis,* and *Melaleuca halmaturorum*). At the constantly inundated sites containing *Schoenoplectus validus* and *Phragmites australis,* revegetation had increased the storage of organic carbon considerably within the surface layers after only a few years of growth (Sullivan *et al.* 2012a). The initial rates of organic carbon increase at these sites were 866 kg C ha^{-1} yr^{-1} for the site under *Phragmites australis*, and 670 kg C ha^{-1} yr^{-1} and 903 kg C ha-1 yr-1 for the *Schoenoplectus validus* sites. These rates of organic carbon increase accord with the rates typically found for such vegetated situations.

The ongoing supply of organic carbon to the sediments is a critical consideration for the likely ongoing remediation processes in these sediments such as sulfate reduction, as organic carbon is the main energy source and primary constraint to many of the essential microbial processes. It is thus critical to gain an adequate understanding of the carbon production and cycling under different types of vegetation and across all lake conditions to better gauge the likely effectiveness of such vegetation on long term bioremediation, as well as on the effect of these vegetation types on carbon accumulation and sequestration in these sediments and soils.

2.0 Aim

This project aims to gain a better understanding of the carbon production and cycling under bioremediating and non-bioremediating vegetation. The study will also gauge the effect of four different vegetation types on carbon accumulation and sequestration in the sediments within the riparian zone of the Lower Lakes. The carbon status was examined in the following vegetation types:

1) *Bolboschoenus* (Hunters Creek and Point Malcolm),
2) *Phragmites australis* (Tolderol, Loveday Bay and Point Malcolm),
3) *Schoenoplectus validus* (Loveday Bay and Point Malcolm), and
4) *Schoenoplectus pungens* (Loveday Bay and Point Malcolm).

The carbon status was investigated by examining the chemical, physical, biochemical, and non-protected carbon pools of these sediments.

3.0 Introduction

3.1 Background on soil organic carbon

3.1.1. General

Worldwide soils are an important store for carbon, storing approximately three times the amount of carbon found in plants (Schlesinger 1990). Soil organic carbon (SOC) constitutes a large pool in the global carbon cycle, and represents a dynamic balance between carbon inputs (through photosynthesis and deposition) and losses (via respiration, erosion and leaching) (Stewart *et al.* 2007). The preservation of organic carbon within the soil is vital as it improves soil structure, soil fertility, crop production, and ensures long-term sustainability of agriculture (Denef *et al.* 2004). Increasing SOC also has the added benefit of reducing carbon dioxide (CO_2) emissions into the atmosphere (Gulde *et al.* 2008).

In the early development of ecosystems, the accumulation of organic matter is essential to supply biota with a reliable supply of nutrients and water (Bechtold and Nainman 2009). As the plant communities develop, soils undergo a period of organic matter increase. This eventually levels off as organic debris production comes into equilibrium with its decomposition (Bechtold and Nainman 2009). The time scales over which these changes occur vary greatly among different ecosystems (Walker and del Moral 2003).

While it is well known that climate and the amounts and chemical composition of organic matter added to the soil strongly influence both carbon and nutrient cycling, the soil texture is also known to be an important controlling factor (e.g. Six *et al.* 2002; Bechtold and Nainman 2009). For example, organic matter is less prone to leaching and decomposition when adsorbed to silt and clay particles or when physically protected by aggregates (Six *et al.* 2002). These factors may significantly influence turnover times of organic carbon within the soil, which for organic matter encapsulated in aggregates may range from 10s to 100s of years and for clay-adsorbed organic matter in temperate ecosystems can range from 100s to 1000s years (Trumbore 1993; Gaudinski *et al.* 2000).

The following subsections outline the organic carbon fractions commonly observed within the soil (Section 3.1.2), the concept of SOC saturation (Section 3.1.3), modelling SOC dynamics (Section 3.1.4), and soil carbon pool dynamics in both restored wetlands (Section 3.1.5) and salt marshes (Section 3.1.6).

3.1.2. Soil organic carbon fractions

The organic carbon within the soil is commonly separated into two fractions known as *labile* (active/unprotected) and *stable* (passive/protected) pools (Parton *et al.* 1987; Six *et al.* 2002). The labile SOC pools are rapidly turned over in the soil and are sensitive to both land management and environmental conditions. Labile SOC pools play an important role in the short-term cycling of both carbon and nitrogen within the soil (Schlesinger 1990). The most commonly isolated labile pools are the light fraction (LF) and particulate organic matter (POM) (Gulde *et al.* 2008). These labile fractions consist mostly of mineral-free, partly-decomposed plant residues but also contain seeds and microbial debris such as fungal hyphae and spores (Six *et al.* 2002).

For soils to act as a carbon sink it is necessary for soil organic carbon to be stabilised in protected soil carbon pools. Organic carbon within the soil can be protected from decomposition and stabilised in soils by three potential mechanisms including: (i) physical protection by occlusion within aggregates, (ii) chemical protection by association with mineral surfaces, and (iii) biochemical protection by recalcitrance (Six *et al.* 2002; Plante *et al.* 2006b). A conceptual model showing SOC dynamics and the measurable organic carbon pools is presented in Figure 3-1; *silt- and clay-associated soil C* is also commonly referred to as the chemically protected carbon pool.

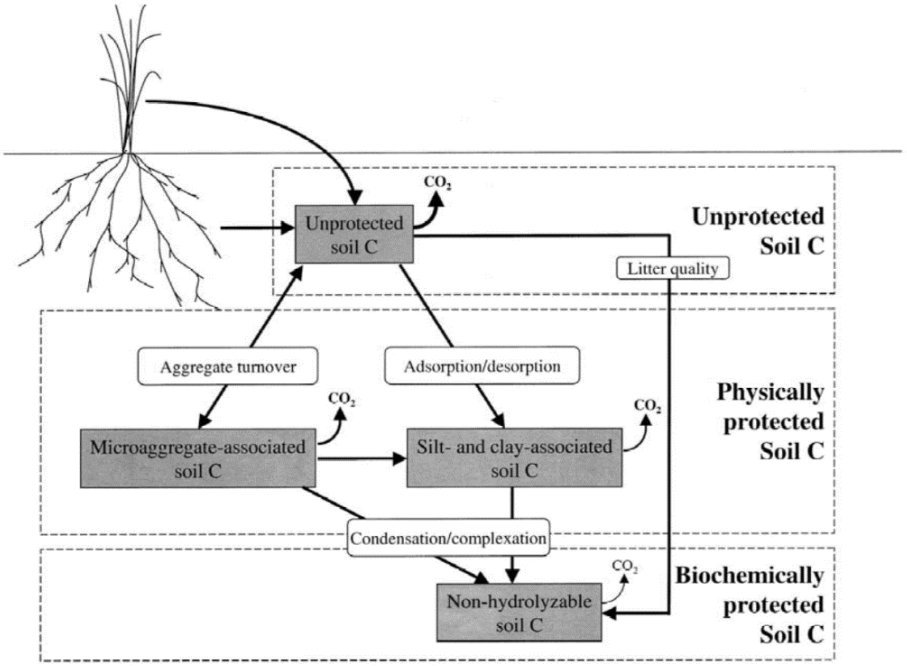

Figure 3-1. Conceptual model of soil organic carbon dynamics (Source: Six *et al.* 2002).

The inclusion of organic materials within soil aggregates is known to reduce their decomposition rate (Elliott and Coleman 1988). Aggregates physically protect organic matter within the soil by forming physical barriers between the microbes and enzymes and their substrates (Elliott and Coleman 1988). In addition, aggregates also physically protect organic matter by reducing oxygen diffusion into the aggregates (leading to reduced activity within the aggregates), and separate microbial biomass from microbial grazers (Six *et al.* 2002). The soil texture is widely known to influence aggregation and increased clay contents have been associated with increased aggregation or aggregate stability (Plante *et al.* 2006b).

The chemical protection of SOC results from the chemical or physicochemical binding between organic matter and minerals (i.e. clay and silt particles) within the soil (Six *et al*. 2002). The adsorption of organics to clay and silt particles is an important determinant of the stability of organic matter in soils (Hassink 1997). Finer soil particle-size fractions protect organic matter within the soil due to the reactivity of their surfaces (Plante *et al.* 2006a). Labile organic material that may have decomposed quickly may become protected from decomposition by close association with clay and silt particles (Sørensen 1972). In addition to the clay content, the type of clay (i.e. 2:1, 1:1 and allophonic clay minerals) may also influence the stabilisation of organic carbon (Sørensen 1972). Soils dominated by clays with a high specific surface area are expected to adsorb more humic substances than soils dominated by soils with low specific surface areas (Tate and Theng 1980), although this relationship is not always clear. For example, Hassink (1997) did not find a relationship between the dominant clay type and the amount of carbon associated with the clay and silt fraction.

The chemical composition of SOC (e.g. recalcitrant compounds such as lignin and polyphenols) provides biochemical protection, although this may also occur through chemical complexing processes within the soil (Six *et al*. 2002). Biochemically resistant carbon is defined as organic carbon that is resistant to acid hydrolysis (Leavitt *et al.* 1996). Previous research has shown that this non-hydrolysable biochemically protected carbon fraction may be substantially older (i.e. 1300 to 1800 years) than other carbon fractions within the soil (Leavitt *et al.* 1996; Paul *et al.* 1997, 2001). It has been assumed that as SOC decreases the proportion of biological resistant SOC increases, however, Plante *et al.* (2006a) have shown this is not always observed.

Studies indicate that while soil texture (particularly soil clay content) affects physical, chemical and biochemical protection of soil carbon, the non-protected carbon fraction is independent of soil texture (Plante *et al.* 2006b). Six *et al*. (2002) suggest that the physicochemical characteristics of a soil define the limit to the amount of carbon protection that may occur (see Figure 3-2). Details on the soil fractionation process that has recently been developed to isolate the unprotected and protected organic carbon pools, and used in this study, are given in Section 4.2.2.

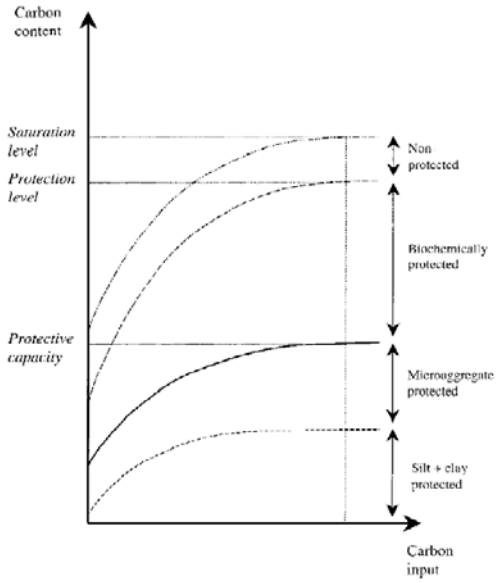

Figure 3-2. Conceptual protective and non-protective capacity to enhance storage of carbon in soil according to type of soil organic carbon (Source: Six *et al.* 2002).
The protective capacity of soil (which governs the silt and clay protected C and microaggregate protected C pools), the biochemically stabilized C pool and the unprotected C pool define a maximum C content for soils. The pool size of each fraction is determined by their unique stabilizing mechanisms.

3.1.3. Soil organic carbon saturation

Management practices that decrease soil disturbance and increase the amount of carbon added to the soil generally increase both the soil fertility and SOC content, however, the efficiency of these practices to store SOC may not only depend on the amount of carbon added but also how far a soil is from its saturation level (i.e. saturation deficit) (Stewart *et al.* 2009). The carbon saturation hypothesis suggests an ultimate soil carbon stabilisation capacity defined by the four SOC pools capable of carbon saturation (i.e. non-protected, physically protected, chemically protected and biochemically protected) (Stewart *et al.* 2009) (see Figure 3-2).

Previous studies have found that certain soils show little or no increase in stable (i.e. steady-state) SOC with increasing carbon input levels which suggests that SOC can become saturated with respect to carbon input (Stewart *et al.* 2007). Studies have also observed a direct relationship between the silt plus clay content of soil and the amount of silt and clay protected soil carbon, that indicates a saturation level for silt and clay associated carbon (Hassink 1997; Six *et al.* 2002). The theoretical relationship between input level and SOC contents at steady-state, with and without carbon saturation, is illustrated in Figure 3-3.

If it is assumed there is no carbon saturation, which previous studies have often observed, there is no limit to the soil carbon content as steady-state carbon rates increase (see Figure 3-3b). However, assuming carbon saturation there is a maximum equilibrium carbon level that will be reached when the carbon input is maximised (see Figure 3-3d). The potential for soil carbon saturation implies that the greatest efficiency in soil carbon sequestration would be in soils well below their soil saturation level (Stewart *et al.* 2007).

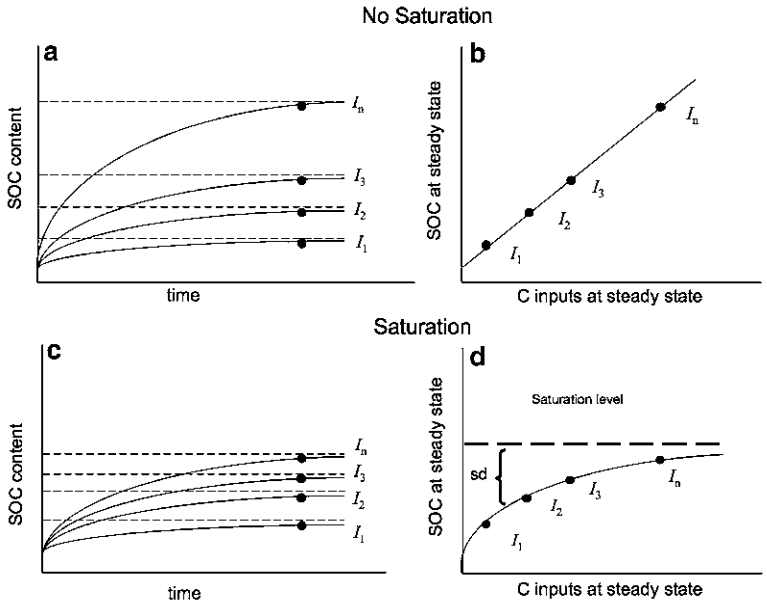

Figure 3-3. Theoretical relationship between input level (I, with I_1 being the lowest input level) and SOC contents at steady-state, with and without carbon saturation (Source: Stewart *et al.* 2007).

3.1.4. Modelling soil organic carbon dynamics

The current conceptual understanding of SOC dynamics in mineral soils has been encompassed within a plant-soil nutrient cycling model known as the CENTURY model (Parton *et al.* 1987). The CENTURY model has been applied to a variety of soils to predict changes in organic matter pools and fluxes in response to various scenarios including cropping practices, timber harvest and climate change (Bechtold and Naiman 2009).

Recently in a study by Bechtold and Naiman (2009) the soil component of the CENTURY model was combined with a simulation model of fluvial deposition and forest production to predict changes in soil carbon and nitrogen during primary succession on the floodplain and terraces of the Queets River, Washington, USA. The model simulated soil carbon and nitrogen cycling as bare sediments evolved to mature forests. The three interacting components of the organic matter simulation model including the soil, sedimentary and forest submodels as described by the CENTURY model are shown in Figure 3-4. The soil component of the CENTURY model uses soil texture (i.e. sand, silt and clay concentration) as a primary variable in the simulation of organic matter accumulation (Figure 3-4).

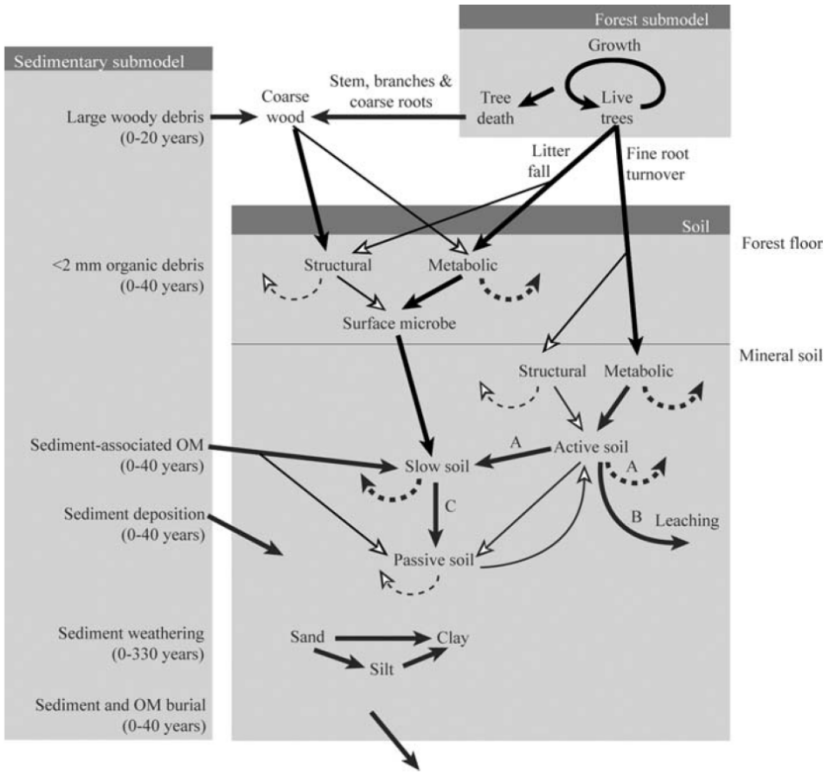

Figure 3-4. Organic matter simulation model as described by the CENTURY model (Source: Bechtold and Naiman 2009). *Arrow thickness* distinguishes major from minor fluxes. *Dashed arrows* indicate gaseous CO_2 outputs due to respiration. *Letters* indicate fluxes influenced by soil texture: *A*, silt and clay inhibit decomposition of active soil organic matter (OM); *B*, silt and clay reduce leaching by adsorbing OM and reducing hydrologic flux; and *C*, passive OM is formed by OM association with clays.

Bechtold and Naiman (2009) compared their model to soil data collected from 25 sites ranging in age from three to 330 years relative to initial plant colonisation. The simulated soil carbon accumulated rapidly to near-plateau concentrations of approximately 4,000 g/m^2 after about 100 years, and closely matched that observed in field studies (Figure 3-5). Their model was however observed to underestimate the soil nitrogen concentrations (see Figure 3-5), and this was thought to be due to failure of the model to account for nitrogen enrichment of an organic matter pool after its initial formation (Bechtold and Naiman 2009).

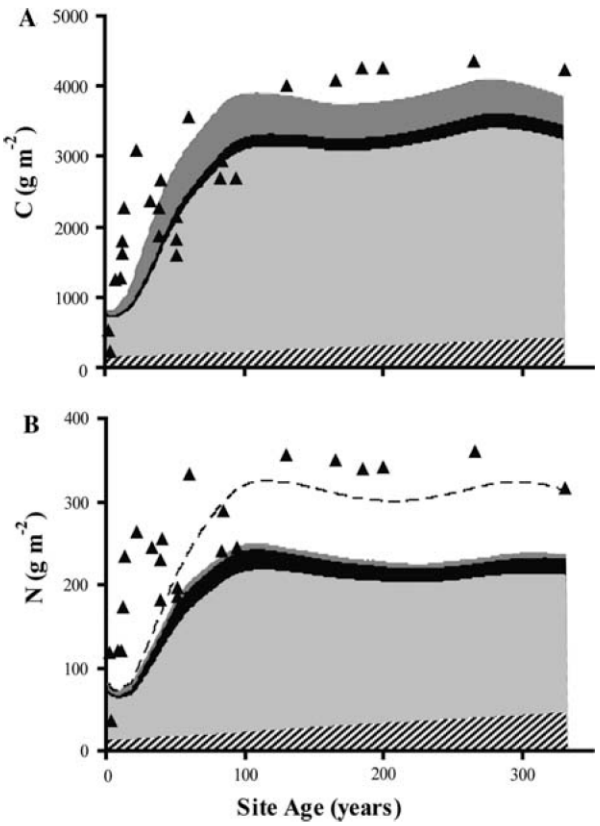

Figure 3-5. Soil carbon (A) and nitrogen (B) simulated over 330 years of floodplain development (Source: Bechtold and Naiman 2009).

Total C and N accumulation is indicated by sum of shaded areas. Shaded areas indicate sizes of individual soil pools: *dark grey* - surface and root litter; *black* - active pool; *light grey* - slow pool; *diagonal bars* - passive pool. *Triangles* indicate C and N measured in field studies. *Dashed line* in **B** indicates total simulated N when the model was altered to allow N-enrichment of structural litter and slow pool N after initial formation.

3.1.5. Soil carbon pool dynamics in restored marshes

There has been a widespread loss of marsh habitat as a consequence of development, particularly in coastal areas (Madrid *et al.* 2012). Although many wetlands have been restored or created over the past several decades, the degree of recovery of the ecosystem structure (driven mostly by plant assemblages) and functioning (driven primarily by the storage of carbon in wetland soils) has often been unclear (Moreno-Mateos *et al.* 2012).

A recent study by Moreno-Mateos *et al.* (2012) examined the degree of recovery of ecosystem structure and functioning following wetland restoration. The results indicated that the recovery of wetlands following restoration is often slow and incomplete. Moreno-Mateos *et al.* (2012) examined data from more than 600 wetland sites throughout the world, and showed that even a century after restoration biological structure and functioning remained on average 26% and 23% lower, respectively, than in reference sites.

The results of the study by Moreno-Mateos *et al.* (2012) clearly showed that the storage of both carbon and nitrogen were substantially reduced after degradation from preimpact levels, although phosphorus storage seemed unaffected (see Figure 3-6). Figure 3-6 shows that carbon storage initially increased slightly following restoration, but then plateaued below reference levels after 20 years following restoration. Nitrogen storage was observed to slowly but steadily increase (Figure 3-6).

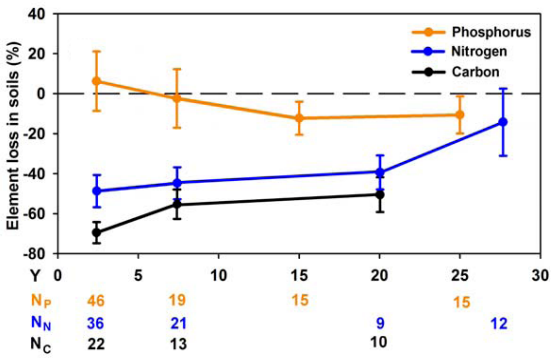

Figure 3-6. Recovery trajectories of created and restored wetlands (Source: Moreno-Mateos *et al.* 2012).
Chronosequences of the means (±SE) of the element loss in soils of restored or created wetlands. The zero value dashed line represents reference wetlands (N, number of data points used to calculate the mean per age class; Y, years after restoration).

Wetland degradation usually results in a reduction of stored carbon as the onset of aerobic conditions accelerates microbial respiration which oxidises accumulated organic carbon (Mitsch and Gosselink 2007). The presence of greater anaerobic conditions following restoration allow stores of organic carbon to slowly reaccumulate in the soil, however, Moreno-Mateos *et al.* (2012) results show that even 20 years following restoration carbon storage was 50% lower than in reference wetlands (Figure 3-6). The study also found the average organic matter concentrations remained only 62% of the concentration at the reference wetlands 20–30 years following restoration.

The storage of nitrogen was also found to be significantly lower 30 years after wetland restoration (Figure 3-6). The aerobic conditions observed in degraded wetlands are also known to disturb nitrogen storage and cycling, allowing mineralisation of organic nitrogen and transformation of ammonium to nitrate (Mitsch and Gosselink 2007). The nitrate formed is rapidly processed by both microorganisms and plants, consequently leaving the original pool of nitrogen in the soil depleted or unavailable (Moreno-Mateos *et al.* 2012). The depletion or unavailability of soil nitrogen can limit wetland productivity and can therefore slow down carbon storage (van Groenigen *et al.* 2006).

The data analysed by Moreno-Mateos *et al.* (2012) showed that even after 50 to 100 years restored wetlands recovered to an average of 74% of their biogeochemical functioning relative to reference wetlands. The results also suggested that the size of the ecosystem and the environmental setting affect the rate of recovery; wetland areas greater than 100 hectares and wetlands in warm (temperate and tropical) climates recovered more rapidly compared to smaller wetlands and those restored in cold climates.

Madrid *et al.* (2012) measured the net plant carbon capture in wetland vegetation and showed that the annual carbon production of constructed wetlands in a brackish marsh can be substantially less than that of surrounding reference wetlands. The study assessed the relative carbon capture by emergent and submerged vegetation in constructed marshes (2-3 years old) and a reference marsh. While the study found that submerged vegetation captured less carbon (0.1–0.3 kg/m^2) than emergent vegetation (0.2–1.7 kg/m^2), the constructed marshes were found to contain an order of magnitude less emergent habitat than the reference marsh. The lower emergent habitat in the constructed marshes meant the annual carbon production of entire constructed areas was less than half that of the reference area.

3.1.6. Soil carbon pool dynamics in salt marshes

Coast marshes are one of the most productive ecosystems on earth and are known to sequester large quantities of organic carbon (Madrid *et al.* 2012). Mangroves for example represent approximately 15% of carbon stored in marine sediments (Jennerjahn and Ittekkot 2002). Saline coastal marshes generally also have low emissions of the potent greenhouse gas methane compared to freshwater inland wetlands (Bartlett and Harris 1993), and therefore play a vital role in the global carbon cycle. While the carbon density of tidal saline wetland sediments is usually less than that in freshwater wetlands, previous studies have found that there is significant variation and uncertainty in carbon storage in tidal saline wetlands (Chmura *et al.* 2003).

A recent study by Liversley and Andrusiak (2012) examined carbon storage in temperate mangrove and salt marsh sediments along a natural transition from melaleuca woodland, salt marsh and into

mangroves along the Mornington Peninsula edge of Westernport Bay, Victoria. The study found the sediment carbon density was significantly greater in the salt marsh compared to the mangrove. The sediment carbon density in the salt marsh was approximately 168 Mg C/ha (16.9 kg C/m^2) which was comparable to that measured globally, whereas the mangrove sediment carbon density of 145 Mg C/ha (14.5 kg C/m^2) was amongst the lowest recorded. The sediment carbon density of tidal saline wetlands is expected to decrease as mean annual temperatures increases, in response to greater decomposition rates (Chmura *et al.* 2003). The findings by Liversley and Andrusiak (2012) indicate that mangrove sediments from cooler, drier temperate latitudes may store less carbon than mangroves in warmer and wetter tropical latitudes.

3.2 Introduction to this study

As a result of prolonged drought, combined with management practices upstream in the Murray-Darling catchment, the Lower Lakes of Lake Alexandrina and Lake Albert have recently experienced their first major drying phase since the introduction of barrages more than 50 years ago (Simpson *et al.* 2008; Sullivan *et al.* 2008). Concurrently, it was identified that the Lower Lakes were also being impacted by the presence of acid sulfate soil materials (Fitzpatrick *et al.* 2008). As a consequence of unprecedented low water levels, extensive areas of acid sulfate soils were exposed in the Lower Lakes which resulted in soil acidification (pH<4) over large areas and localised acidification of surface waters (DENR 2010).

To inform management decision making, a research program was undertaken to fill critical knowledge gaps related to the risks posed by exposure of acid sulfate soils in the Lower Lakes (DENR 2010). The research areas examined in this program included:

- an acid sulfate soil spatial heterogeneity/mapping survey;
- measurement of acid generation rates;
- assessment of the in-situ contaminant generation, transport and neutralisation processes;
- laboratory and field studies of the potential for mobilisation of contaminants following inundation with seawater compared to river water ; and
- geochemical modelling of lake water quality.

A study by Sullivan *et al*. (2010) examined the response of exposed Lower Lakes soil materials to wetting with seawater and river water. Among other key findings, Sullivan *et al*. (2010) identified that the major factor limiting sulfate reduction in the Lower Lakes sediments was the availability of organic carbon. Given the potential importance of sulfate reduction in relation to critical sediment/water aspects (e.g. the development of alkalinity in the sediments), Sullivan *et al*.'s (2010) research supported the practical options of enhancing the availability of organic carbon in the Lower Lakes environment being undertaken by the Department for Environment, Water and Natural Resources. The continuation of the bioremediation program of Lower Lakes sites through enhancing organic carbon availability was supported through scientific research as a feasible management option.

Further studies by Sullivan *et al*. (2011, 2012b) examined several key locations around the Lower Lakes showing a range of vegetation treatments (in terms of both the vegetation species and timing of plantings), as well as unvegetated control sites. The results of this study indicate that bioremediation of the exposed acidified lake sediments by vegetation produced substantial environmental benefits from a combination of vegetation-associated processes including the provision of alkalinity from plant roots as well as from the vegetation minimising soil erosion and hence preventing the exposure of severely acidic subsoils that often occurred under unvegetated sites.

At the same time, the studies by Sullivan *et al*. (2011, 2012b) also highlighted the large differences in organic input from different bioremediating vegetation. Where perennial species that survived inundation (e.g. reeds such as *phragmites*) were used for bioremediation a continuation of the supply of organic carbon to the sediments is experienced for long times after lake refilling, whereas where annual or relatively short vegetation (that was covered by the inundating waters) was used (e.g. Bevy rye, rushes, natural species like *cotula*) the supply of organic carbon to the sediment was limited to that produced prior to vegetative death caused by inundation.

One of the studies last year (Sullivan *et al.* 2012a) monitored the changes in carbon status in the soils/sediments under three different vegetation types around the Lower Lake (including *Schoenoplectus validus*, *Phragmites australis,* and *Melaleuca halmaturorum*). At the constantly inundated sites containing *Schoenoplectus validus* and *Phragmites australis,* revegetation had increased the storage of organic carbon considerably within the surface layers after only a few years of growth (Sullivan *et al.* 2012a). The initial rates of organic carbon increase at these sites were 866 kg C ha^{-1} yr^{-1} for the site under *Phragmites australis*, and 670 kg C ha^{-1} yr^{-1} and 903 kg C ha-1 yr-1 for

the *Schoenoplectus validus* sites. These rates of organic carbon increase accord with the rates typically found for such vegetated situations.

The study by Sullivan *et al.* (2012a) also observed that the organic carbon increases at the inundated sites under *Schoenoplectus validus* and *Phragmites australis* were almost totally in the relatively short-lived non-protected soil carbon pool, with the main contributor being the coarse (> 250 µm) particulate organic matter fraction (cPOM). These findings indicate that the increase and maintenance of the additional stored carbon under the bioremediating vegetation is likely to be contingent on the maintenance of the vegetation and the consequent supply of organic matter to this pool, and of constantly inundating conditions.

The ongoing supply of organic carbon to the sediments is thus a critical consideration as organic carbon is the critical energy source necessary to drive many of the likely ongoing remediation processes in these sediments such as sulfate reduction. It is thus critical to gain an adequate understanding of the carbon production and cycling under different types of vegetation to better gauge the likely effectiveness of such vegetation on long term bioremediation, as well as on the effect of these vegetation types on carbon accumulation and sequestration in these sediments and soils.

This project aims to monitor the changes in carbon status in the sediments under four different vegetation types around the Lower Lakes in terms of their soil carbon pools.

3.3 Sampling strategy

In this study sediments were collected from sites around the Lower Lakes in May 2013 including Hunters Creek (Hindmarsh Island) and three sites around Lake Alexandrina (including Tolderol, Loveday Bay and Point Malcolm). The locations of the four sampling sites are shown below in Figure 3-7.

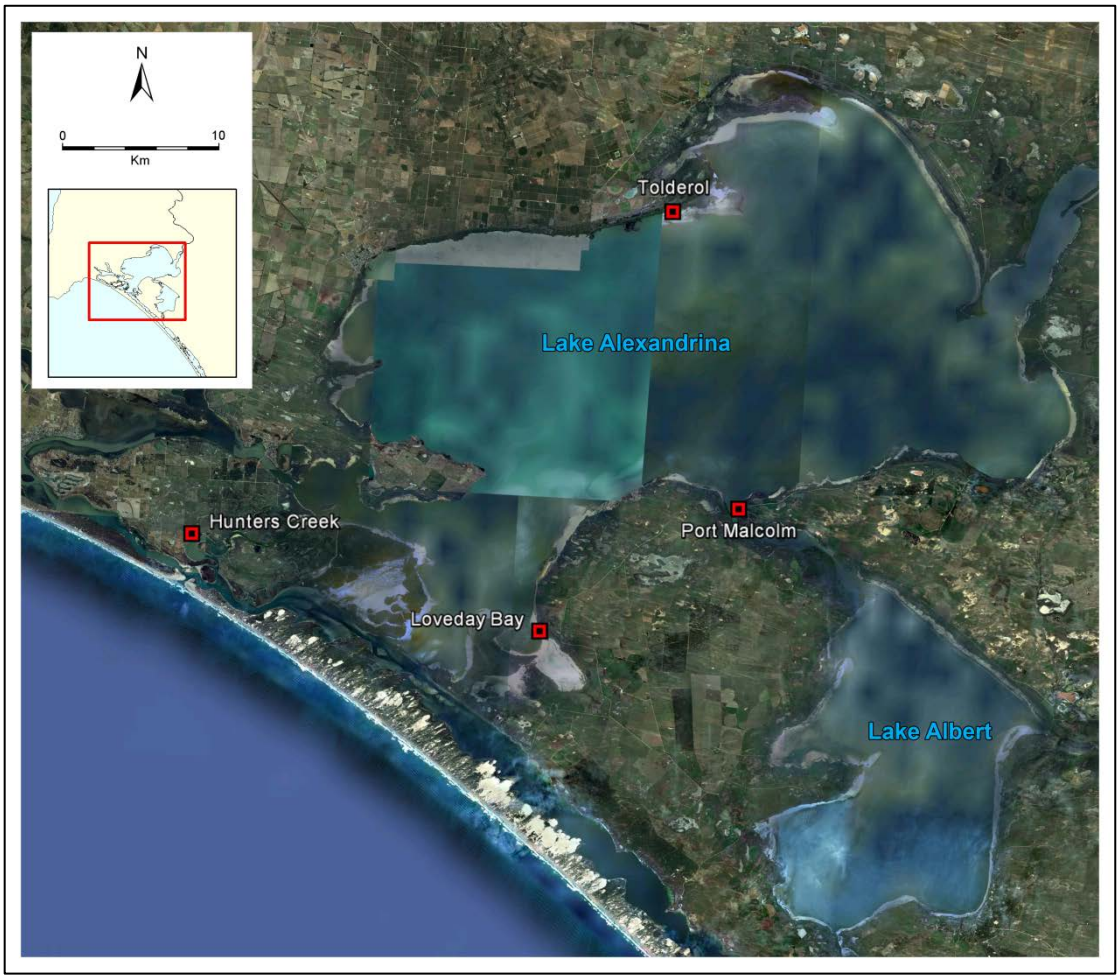

Figure 3-7. Map showing sampling sites around the Lower Lakes (Source: Google Maps).

The carbon status was examined at twelve locations across the four sites around the Lower Lakes between 29th and 31st May 2013. The carbon status was assessed in the sediments under four different vegetation types including:

1) *Bolboschoenus* (Hunters Creek and Point Malcolm),
2) *Phragmites australis* (Tolderol, Loveday Bay and Point Malcolm),
3) *Schoenoplectus validus* (Loveday Bay and Point Malcolm), and
4) *Schoenoplectus pungens* (Loveday Bay and Point Malcolm).

The carbon status was also assessed at a single control site at each of the four sites that were without vegetation at the time of sampling.

A summary of the twelve locations examined in the Lower Lakes is presented below in Table 3-1.

Table 3-1. Summary of the locations and vegetation examined in the Lower Lakes (May 2013).

Site	Vegetation
Hunters Creek, Hindmarsh Island	i. Control (no vegetation)
	ii. *Bolboschoenus*
Tolderol, Lake Alexandrina	i. Control (no vegetation)
	ii. *Phragmites australis*
Loveday Bay, Lake Alexandrina	i. Control (no vegetation)
	ii. *Phragmites australis*
	iii. *Schoenoplectus validus*
	iv. *Schoenoplectus pungens*
Point Malcolm, Lake Alexandrina	i. Control (no vegetation)
	ii. *Bolboschoenus*
	iii. *Schoenoplectus pungens*
	iv. *Schoenoplectus validus*

3.4 Lower Lakes site locations and characteristics

Maps showing the sampling locations and photographs of the landscape at each site are presented in Sections 3.4.1 to 3.4.4.

3.4.1 Hunters Creek, Hindmarsh Island site characteristics

Figure 3-8. Hunters Creek sampling locations (Source: Google Maps).

Figure 3-9. *Bolboschoenus* at Hunters Creek site.

3.4.2 Tolderol site characteristics

Figure 3-10. Tolderol sampling locations (Source: Google Maps).

Figure 3-11. *Phragmites australis* site at Tolderol.

3.4.3 Loveday Bay site characteristics

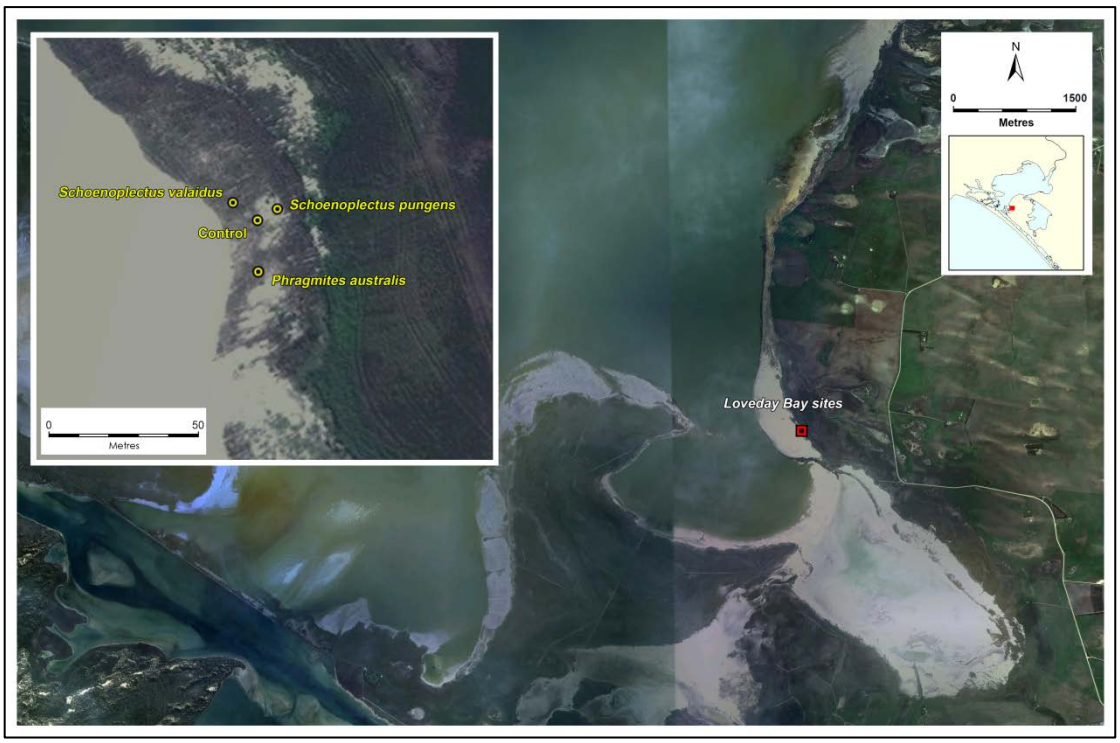

Figure 3-12. Loveday Bay sampling locations (Source: Google Maps).

Figure 3-13. View of Loveday Bay site in May 2013.

Figure 3-14. *Phragmites australis* site at Loveday Bay.

Figure 3-15. Sediment cores collected from the *Phragmites australis* site at Loveday Bay.

Figure 3-16. *Schoenoplectus validus* site at Loveday Bay.

Figure 3-17. Sediment cores collected from the *Schoenoplectus validus* site at Loveday Bay.

Figure 3-18. *Schoenoplectus pungens* site at Loveday Bay.

Figure 3-19. Sediment cores collected from the *Schoenoplectus pungens* site at Loveday Bay.

Figure 3-20. Sediment cores collected from the control site at Loveday Bay.

3.4.4 Point Malcolm site characteristics

Figure 3-21. Point Malcolm sampling locations (Source: Google Maps).

Figure 3-22. View of Point Malcolm sites in May 2013. (All sampling sites located within the yellow box).

Figure 3-23. *Bolboschoenus* site at Point Malcolm.

Figure 3-24. Sediment cores collected from the *Bolboschoenus* site at Point Malcolm.

Figure 3-25. *Schoenoplectus validus* site at Point Malcolm.

Figure 3-26. Sediment cores collected from the *Schoenoplectus validus* site at Point Malcolm.

Figure 3-27. *Schoenoplectus pungens* site at Point Malcolm.

Figure 3-28. Sediment cores collected from the *Schoenoplectus pungens* site at Point Malcolm.

Figure 3-29. Sediment cores collected from the control site at Point Malcolm.

4.0 Materials and methods

The methodology followed in this study allows the assessment of carbon in the various carbon pools in the sediments. The experimental approach follows that of Stewart *et al.* (2009) and measured carbon changes in the sixteen pools most relevant to carbon turnover (including the chemical, physical, biochemical, and non-protected carbon pools in these sediments).

4.1 Field sampling of sediments

Field sampling at the four sites around the Lower Lakes was undertaken between 29th and 31st May 2013. Intact sediment profiles were collected from a total of twelve locations (see Table 3-1). Two replicate sediment profiles to a maximum depth of 40 cm were collected from each location. Each sediment profile was sub-divided into seven soil layers; the surface layers were divided into 2.5 cm increments (i.e. 0-2.5 cm, 2.5-5.0 cm), then in 5 cm increments to 20 cm, and 10 cm increments from 20 cm to 40 cm. Core refusal due to the presence of calcareous often occurred at the Point Malcolm sampling locations at 30-35 cm depth (see Table 9-1, Appendix 1 for further details). All sediment materials were transported in sealed plastic bags in iceboxes, and were refrigerated on return to the Southern Cross GeoScience laboratory.

Sediment profile descriptions and global positioning system (GPS) coordinates for each site are presented in Appendix 1 (Table 9-1).

4.2 Laboratory analysis methods

4.2.1 General comments

All laboratory glassware and plastic-ware were cleaned by soaking in 5% (v/v) HCl for at least 24 hours, followed by repeated rinsing with deionised water. Reagents were analytical grade and all reagent solutions were prepared with deionised water (milliQ). All solid-phase results are presented on a dry weight basis (except where otherwise noted).

4.2.2 Sediment analyses

The parameters measured on the sediment layers collected from the twelve locations included:

- Moisture content
- Bulk density
- pH (1:5 soil:water)
- Electrical conductivity (1:5 soil:water)
- Total carbon and nitrogen
- Total organic carbon
- Carbonate content
- Detailed organic carbon fractionation (16 carbon pools)

The moisture content was determined by weight loss due to drying at 105°C. The bulk density was calculated following weighing a known volume of each sediment layer before and after oven-drying at 105°C. Sediments for further analysis (with the exception of materials that underwent the detailed organic carbon fractionation analyses which were initially dried at 40°C) were oven-dried at 60°C and sieved (<2 mm) prior to being ring mill ground. The detailed organic carbon fractionation analyses were performed on the sample materials after wet sieving to <2 mm.

Electrical conductivity (EC) and pH were determined by direct insertion of calibrated electrodes into a 1:5 soil:water extract linked to a TPS WP-81 meter. Total carbon (%C) and total nitrogen (%N) were measured on powdered oven-dried samples by combustion using a LECO-CNS 2000 analyser. The total organic carbon and carbonate contents were also determined by a LECO-CNS 2000 analyser following the treatment with 1.0 M HCl (Ahern *et al.* 2004). The carbonate content was determined from the difference between the total carbon fraction and the total organic carbon (TOC) fraction remaining after acid treatment.

Separation of the various carbon fractions was accomplished by a combination of physical and chemical fractionation techniques using a three-step process from Stewart *et al.* (2009) (see Figure 4-1). A summary of the sixteen carbon fractions analysed is given in Table 4-1. Note in this study a 63 µm mesh size sieve was used instead of the 53 µm sieve outlined in Stewart *et al.* (2009).

Table 4-1. Summary of the carbon fractions analysed in the sediments from the Lower Lakes (Adapted from Stewart *et al.* 2009).

Carbon Fraction	Description
cPOM	Coarse non-protected particulate organic matter (>250 µm)
LF	Fine non-protected POM (lighter than 1.85 g cm^{-3}, 63–250 µm)
iPOM	Microaggregate-protected POM (heavier than 1.85 g cm^{-3}, >63 µm in size)
µagg	Microaggregate fraction (63–250 µm)
µSilt	Microaggregate-derived silt-sized fraction (heavier than 1.85 g cm^{-3} 2-63 µm)
µClay	Microaggregate-derived clay-sized fraction (heavier than 1.85 g cm^{-3}, <2 µm)
NH-dSilt	Non-hydrolysable easily dispersed silt-sized fraction (acid-resistant 2-63 µm)
NH-dClay	Non-hydrolysable easily dispersed clay-sized fraction (acid-resistant <2 µm)
H-dSilt	Hydrolysable easily dispersed silt-sized fraction (acid-soluble 2-63 µm)
H-dClay	Hydrolysable easily dispersed clay-sized fraction (acid-soluble <2 µm)
NH-µSilt	Non-hydrolysable microaggregate-derived silt-sized fraction (acid-resistant 2-63 µm)
NH-µClay	Non-hydrolysable microaggregate-derived clay-sized fraction (acid-resistant <2 µm)
H-µSilt	Hydrolysable microaggregate-derived silt-sized fraction (acid-soluble 2-63µm)
H-µClay	Hydrolysable microaggregate-derived clay-sized fraction (acid-soluble <2 µm)
dSilt	Easily dispersed silt-sized fraction (acid-soluble 2-63 µm)
dClay	Easily dispersed clay-sized fraction (acid-soluble <2 µm)

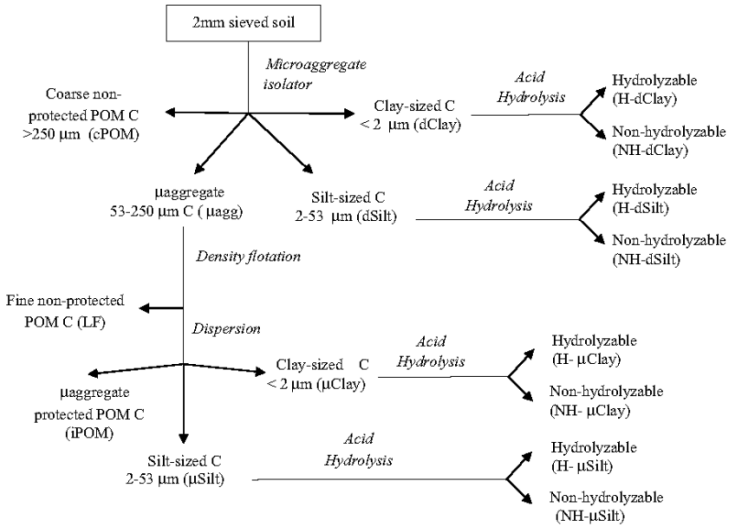

Figure 4-1. Soil fractionation scheme that isolates the four hypothesised C pools; non-protected, physically protected (microaggregate), the chemically protected (silt + clay) and biochemically protected pools (Source: Stewart *et al.* 2009).

The three-step process followed included: (i) the partial dispersion and physical fractionation of the soil to obtain the >250 µm (coarse non-protected particulate organic matter, cPOM), 63–250 µm (microaggregate fraction, µagg), and <63 µm (easily dispersed silt and clay, dSilt and dClay) fractions; (ii) further fractionation of the microaggregate fraction isolated in the first step; and (iii) acid hydrolysis of each of the isolated silt- and clay-sized fractions. While the three-step process followed isolates a total of sixteen fractions, some of the carbon fractions are composites of others (e.g. µagg is composed of LF, iPOM, µSilt and µClay, and the latter two are each composed of hydrolysable and non-hydrolysable portions) (Stewart *et al.* 2009).

A summary of the laboratory procedure followed in this study is presented in Appendix 2. The carbon fractions were quantified using a LECO-CNS 2000 analyser. The total organic carbon (TOC) content was determined following the removal of inorganic carbon by treatment with 1.0 M HCl.

The fractionation procedure followed isolates four hypothesized carbon pools (Stewart *et al.* 2009) including:

- ***Non-protected C pool***: consists of the cPOM fraction, isolated during the first dispersion step, and the LF fraction isolated during the second fractionation step.
- ***Physically protected C pool***: consists of the µagg fraction as a whole and the iPOM.
- ***Chemically protected pool***: corresponds to the hydrolysable portion of the silt- and clay-sized fractions isolated during the initial dispersion (H-dSilt and H-dClay).
- ***Biochemically protected pool***: corresponds to the non-hydrolysable C remaining in the silt and clay fractions after acid hydrolysis (NH-dSilt and NH-dClay).

Sediment data and additional carbon fractionation graphs are presented in Appendix 3 (Tables 9-2 to 9-13) and Appendix 4 (Figures 9-1 to 9-27), respectively,

4.2.3 Quality assurance and quality control

For all tests and analyses, the Quality Assurance and Quality Control procedures were equivalent to those endorsed by NATA (National Association of Testing Authorities). The standard procedures followed included the monitoring of blanks, duplicate analysis of at least 1 in 10 samples, and the inclusion of standards in each batch.

Blanks were collected for laboratory or field samples to examine whether contaminants had been introduced to the sample. Reagent blanks and method blanks were prepared and analysed for each method. All blanks examined here were either at, or very close to, the limits of detection.

Duplicates were prepared for all experiments and analysed separately. Selected analytical duplicate samples were prepared by dividing a test sample into two, then analysing these sub-samples separately. On average, the frequencies of quality control samples processed were: 10% blanks, ≥ 10% laboratory duplicates and 5% laboratory controls. The analytical precision was acceptable for all analyses. For example, for values of sufficient magnitude the analytical precision was ±10% for pH, ±11% for total C and ±7% for TOC.

5.0 Results

5.1 General sediment condition

5.1.1 Hunters Creek, Hindmarsh Island

5.1.1.1 pH(1:5, soil:water)

The pHs of the sediments at the Hunters Creek control site were near neutral, ranging between 6.4 at the surface to 6.9 at depth (Figure 5-1). The pHs of the sediments at the *Bolboschoenus* site were often substantially lower than the control site and decreased with depth to a minimum pH of 4.2 in the 20-30 cm sediment layer. The pH of the sediments in the 30-40 cm layer was similar at both sites.

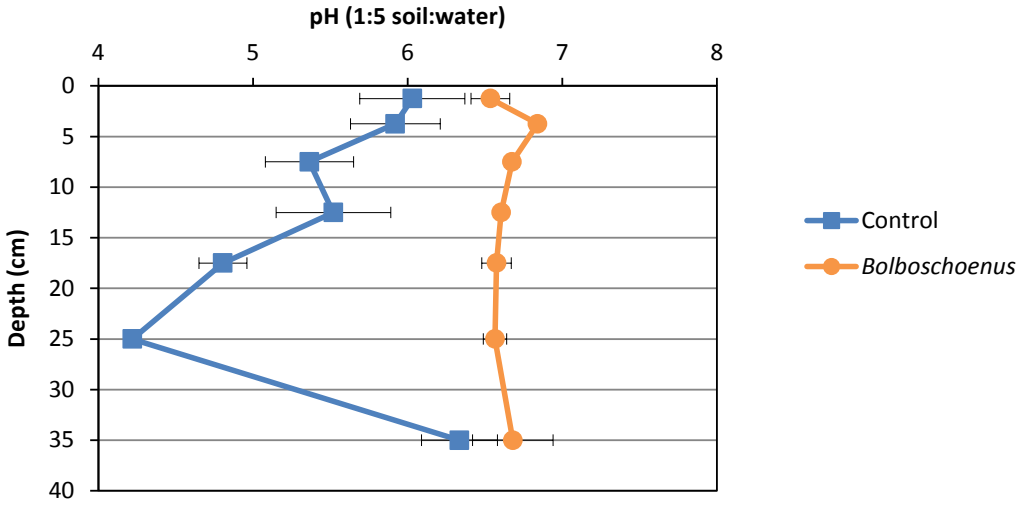

Figure 5-1. pH at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

5.1.1.2 Electrical conductivity (EC)

The ECs of the sediments at the *Bolboschoenus* site were substantially higher than those measured at the control site, ranging between 2,797 and 4,080 µS/cm (Figure 5-2). The ECs measured at the control site were <2,100 µS/cm. This increase is presumably the effect of the vegetation 'pumping out' water from the sediment via evapotranspiration from the leaves resulting in an accumulation of salts in eth sediment. The ECs of the sediments at the both the control and the *Bolboschoenus* sites were often observed to decrease with depth.

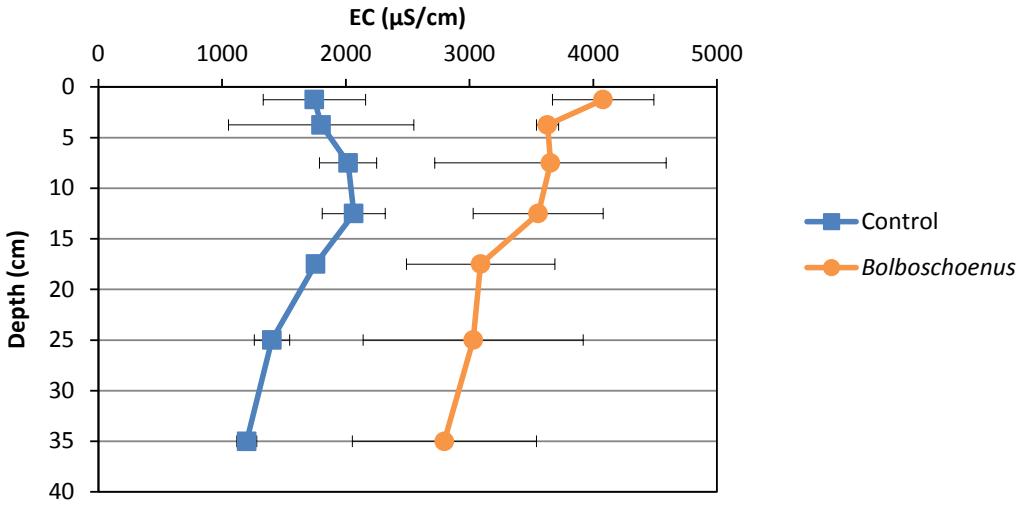

Figure 5-2. EC at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

5.1.1.3 Total carbon, organic and inorganic carbon

The total carbon, organic and inorganic carbon contents measured at the Hunters Creek control and *Bolboschoenus* sites are shown below in Figures 5-3, 5-4 and 5-5, respectively.

The total organic carbon contents show a much higher concentration in the top 40 cm of the sediment under *Bolboschoenus* when compared to the control site (Figure 5-4). The difference in the total organic carbon contents between the sites is observed to decrease with depth. There is also a steady decrease in the total organic carbon contents with depth at both sites, however, the decrease is more pronounced at the *Bolboschoenus* site.

The data indicate that there was more carbonate in the surface layer of the sediments (i.e. 0-2.5 cm) at the *Bolboschoenus* site, although there was less carbonate at this site when compared to the control in deeper profile layers (Figure 5.5). The accumulation of carbonate in the surface layer of the *Bolboschoenus* site is probably due to biological accumulation of fauna living on the sediment surface.

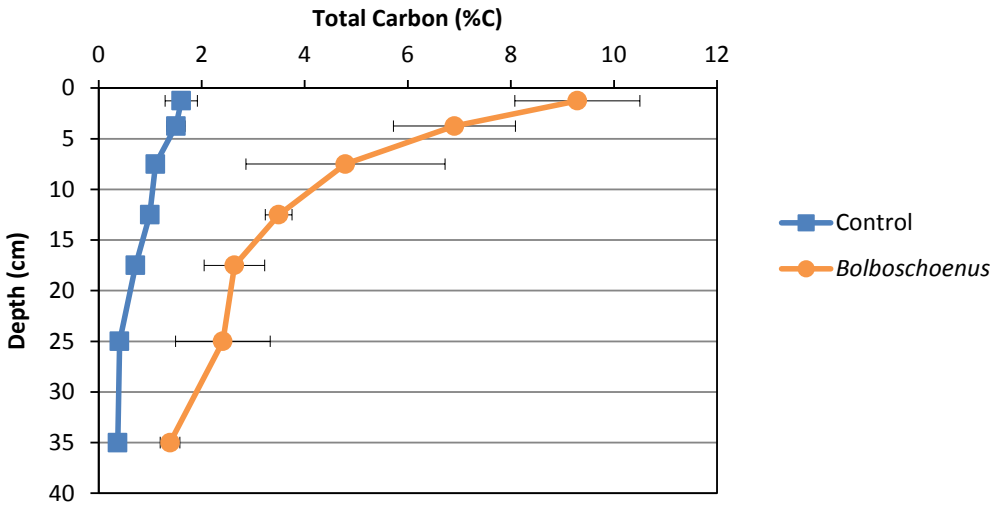

Figure 5-3. Total carbon at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

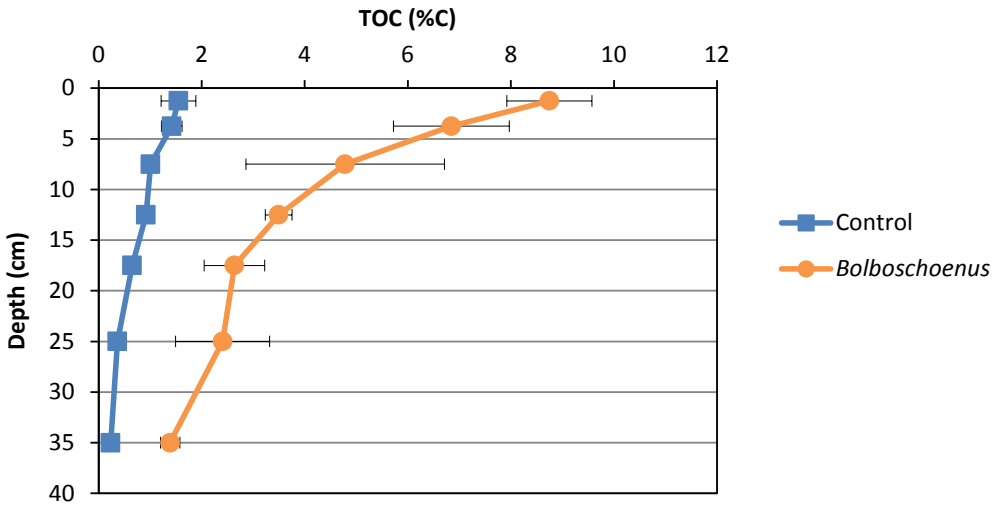

Figure 5-4. Total organic carbon at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

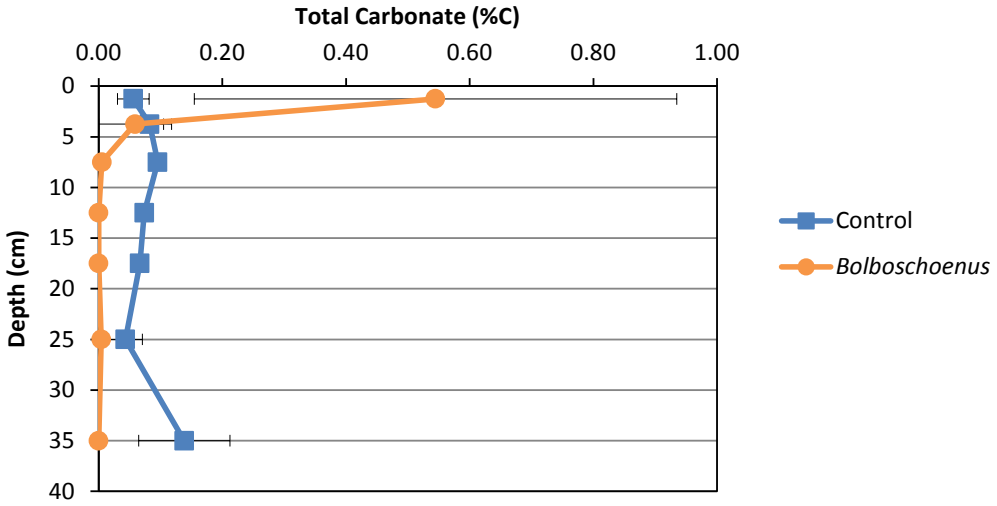

Figure 5-5. Carbonate (inorganic carbon) content at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

The quantity of carbon throughout the 40 cm profile has been converted from the total organic carbon contents (in %) using the bulk densities of the layers (Figure 5-6). In terms of carbon accumulation, this data shows that carbon has accumulated in these sediments at the *Bolboschoenus* site compared to the control site largely in the Non-protected pool (i.e. 6.49 mg C cm^{-3} cf. 2.77 mg C cm^{-3}). However, the physically and biochemically protected pools were also higher at the *Bolboschoenus* site. The Physically protected pool was 3.50 mg C cm^{-3} at *Bolboschoenus* site compared to 3.11 mg C cm^{-3} at the control site. The difference was slightly higher in the Biochemically protected pool with 1.61 mg C cm^{-3} at the *Bolboschoenus* site compared to 0.79 mg C cm^{-3} at the control site. The chemically protect pools were similar at the vegetated and control sites, and only contained low carbon contents (i.e. <0.10 mg C cm^{-3}).

As a large proportion of the carbon storage in the sediment (approximately 76%) is within the Non-protected (mainly the cPOM) pool, this would indicate that much of the stored carbon is liable to decomposition within the short term. However, approximately a quarter of the carbon storage is observed in the physically and biochemically protected pools which would be stored within the sediment in the longer term.

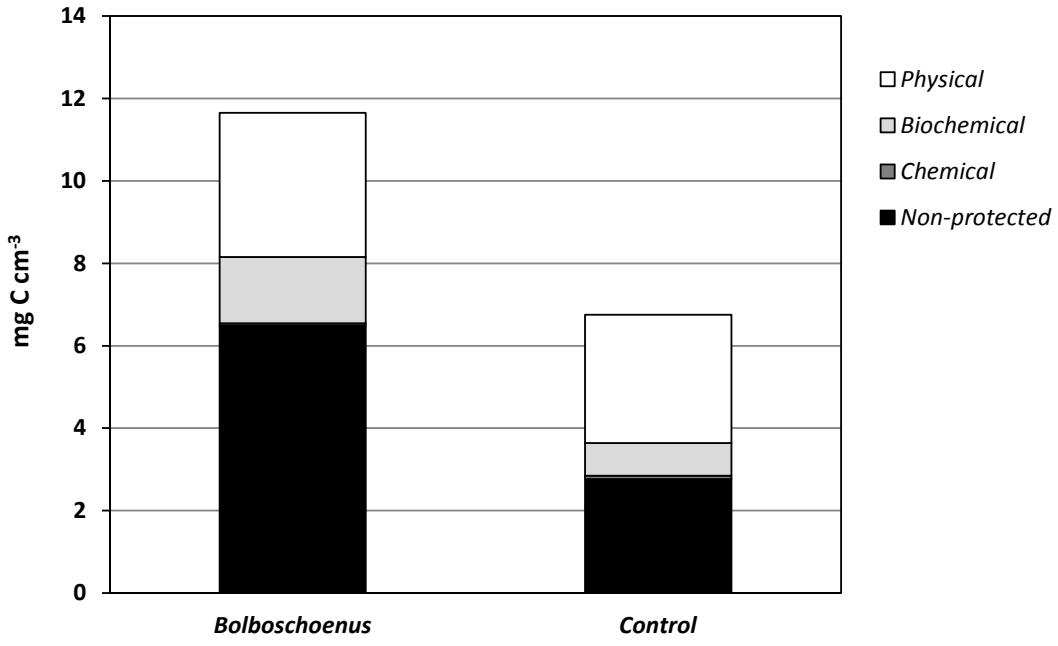

Figure 5-6. The carbon pools in the upper 40 cm of sediment at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

5.1.1.4 Total nitrogen

The total nitrogen contents in the sediments were higher at the *Bolboschoenus* site than the control site throughout the sediment profile (Figure 5-7). The total nitrogen contents showed the same trend as the total carbon contents at the Hunters Creeks sites with a decrease in concentration observed with depth at both sites.

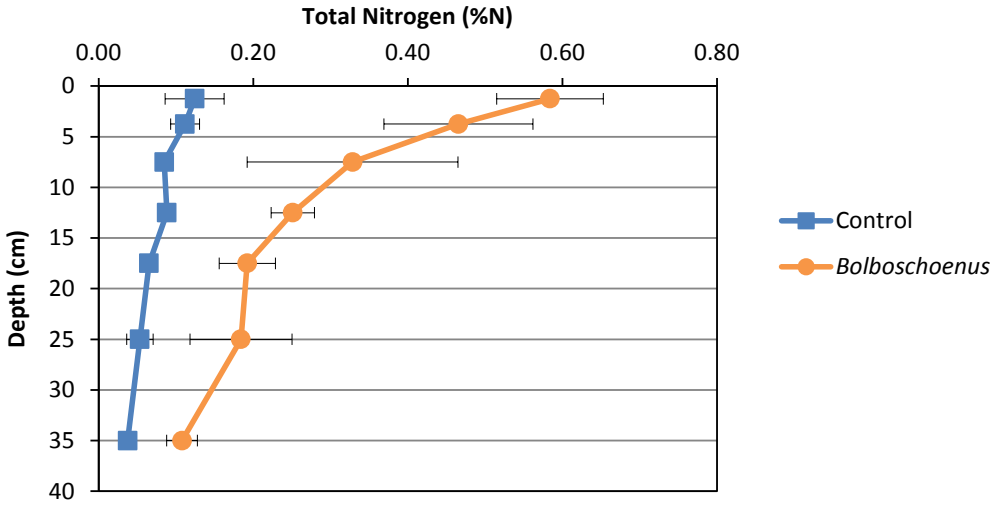

Figure 5-7. Total nitrogen at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

5.1.2 Tolderol, Lake Alexandrina

5.1.2.1 pH(1:5, soil:water)

The pHs of the sediments at the Tolderol control generally decreased with depth (Figure 5-8). The pHs of the sediments at the Tolderol control site were near neutral, ranging between 6.3 at the surface to 7.4 at depth. The pHs of the sediments at the *Phragmites australis* site were always lower than the control site, with a minimum pH of 5.7 in the 15-30 cm sediment layers. The pH of the sediments in the 30-40 cm layer was similar at both sites.

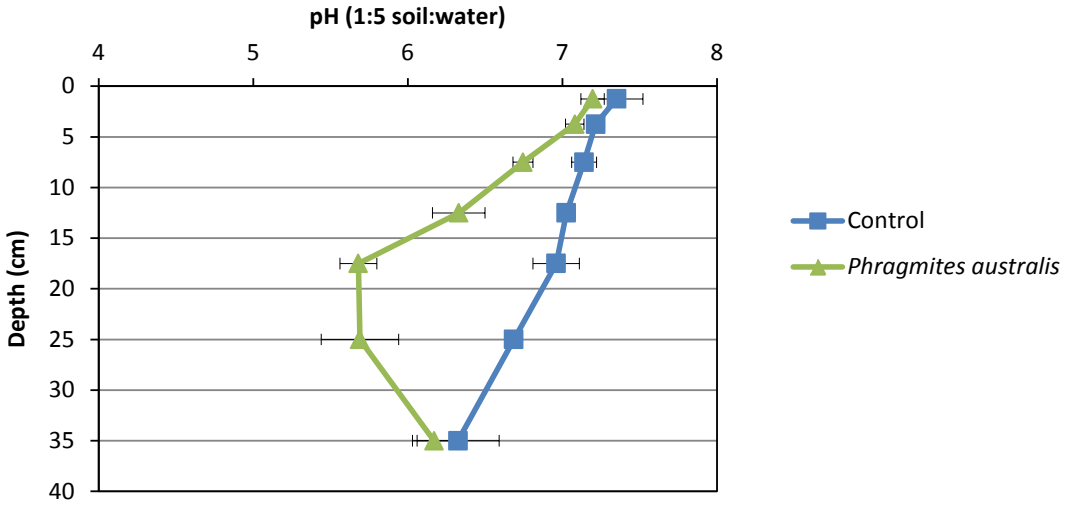

Figure 5-8. pH at the Tolderol control (no vegetation) and *Phragmites australis* sites.

5.1.2.2 Electrical conductivity (EC)

The ECs of the sediments at the *Phragmites australis* site were similar to those observed in the control, ranging between 45 and 131 µS/cm (Figure 5-9). The sediments were slightly more saline at the *Phragmites australis* site than those of the control site from 5 to 30 cm depth but the EC values at both sites can be considered to be relatively low.

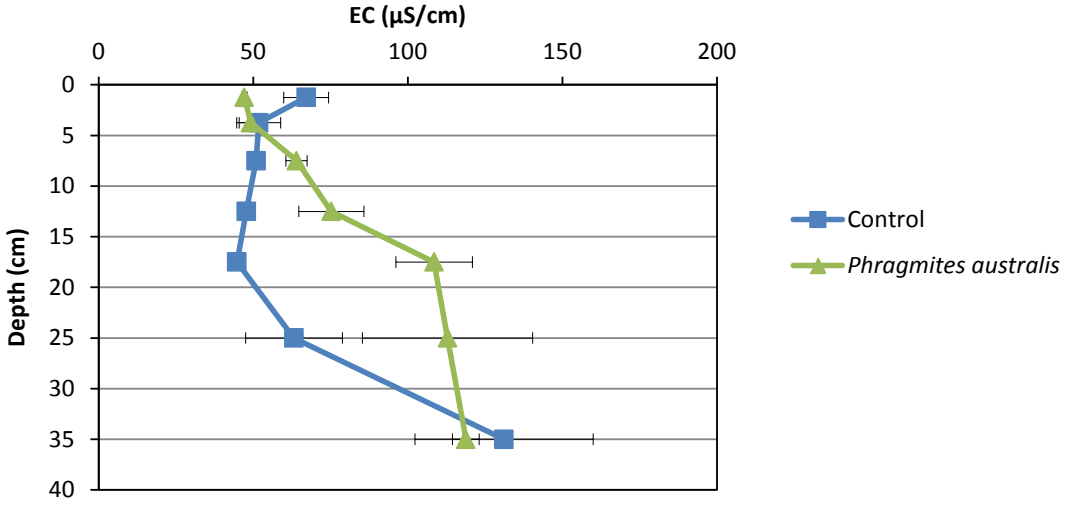

Figure 5-9. EC at the Tolderol control (no vegetation) and *Phragmites australis* sites.

5.1.2.3 Total carbon, organic and inorganic carbon

The total carbon, organic and inorganic carbon contents measured at the Tolderol control and *Phragmites australis* sites are shown below in Figures 5-10, 5-11 and 5-12, respectively.

The total organic carbon contents indicate a slightly higher concentration (of up to 0.06% C in the 15-20 cm layer) throughout the profile under *Phragmites australis* (Figure 5-11).

The low carbonate contents of the sediments at the *Phragmites australis* site (i.e. ≤ 0.05) were at similar concentrations to those at the control site (Figure 5-12).

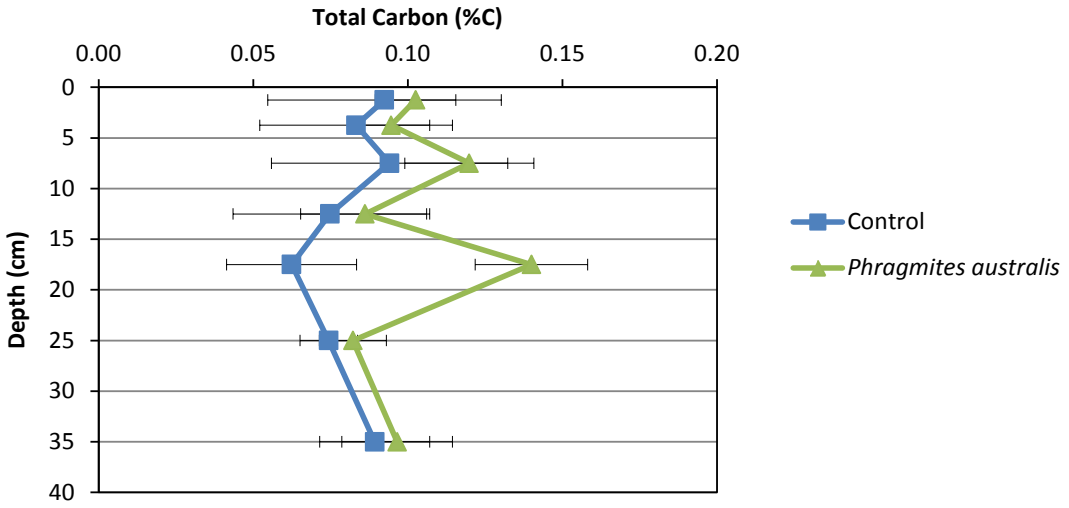

Figure 5-10. Total carbon at the Tolderol control (no vegetation) and *Phragmites australis* sites.

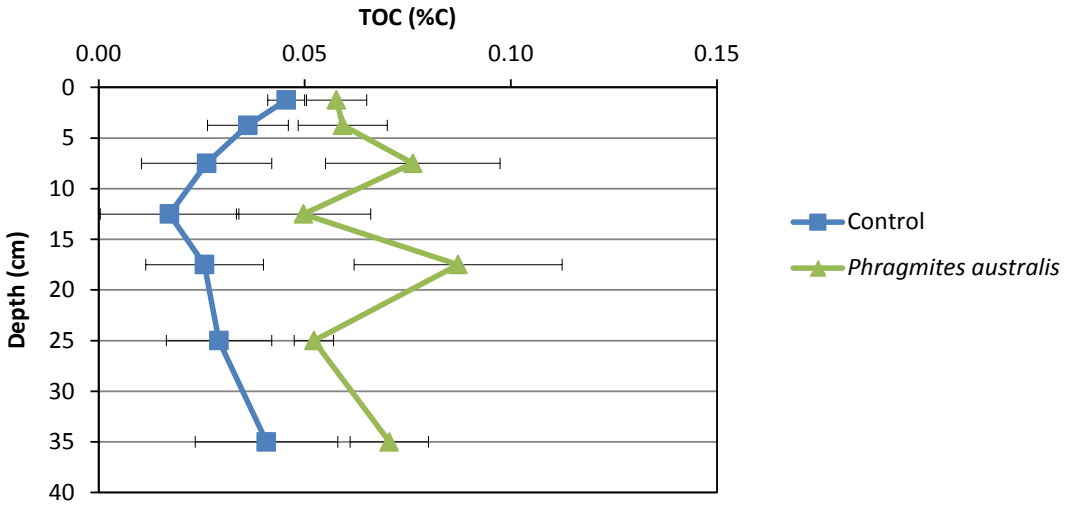

Figure 5-11. Total organic carbon at the Tolderol control (no vegetation) and *Phragmites australis* sites.

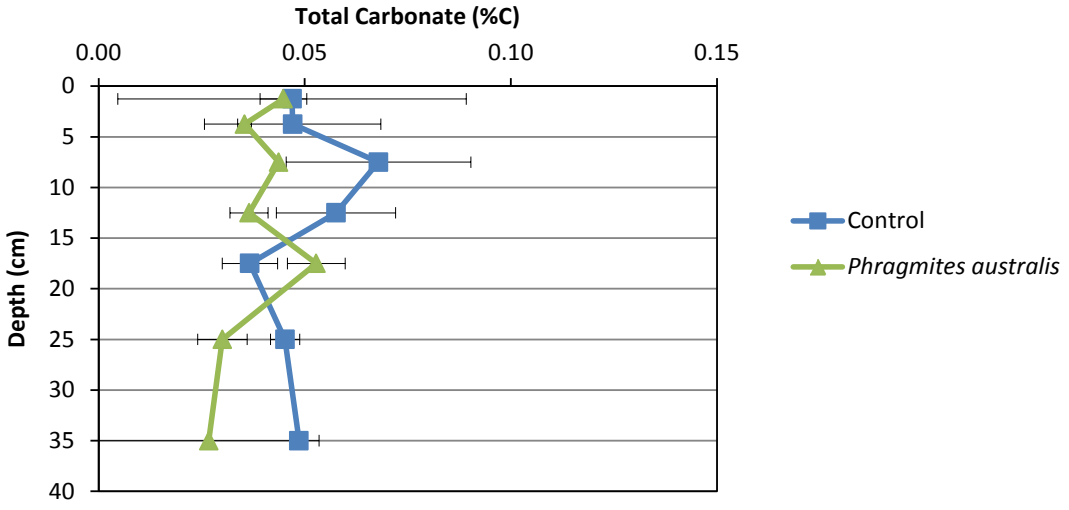

Figure 5-12. Carbonate (inorganic carbon) content at the Tolderol control (no vegetation) and *Phragmites australis* sites.

The quantity of carbon throughout the 40 cm profile has been converted from the total organic carbon contents (in %) using the bulk densities of the layers (Figure 5-13). In terms of carbon accumulation, this data shows that carbon has accumulated in these sediments at the *Phragmites australis* site compared to the control site mainly in the Physically Protected pool (i.e. 1.08 mg C cm^{-3} cf. 0.82 mg C cm^{-3}). However, the data also shows carbon accumulation in the Non-protected pool at the *Phragmites australis* site (i.e. 0.32 mg C cm^{-3} cf. 0.21 mg C cm^{-3}). Both the Chemical and Biochemical protected carbon pools were not quantified at these sites.

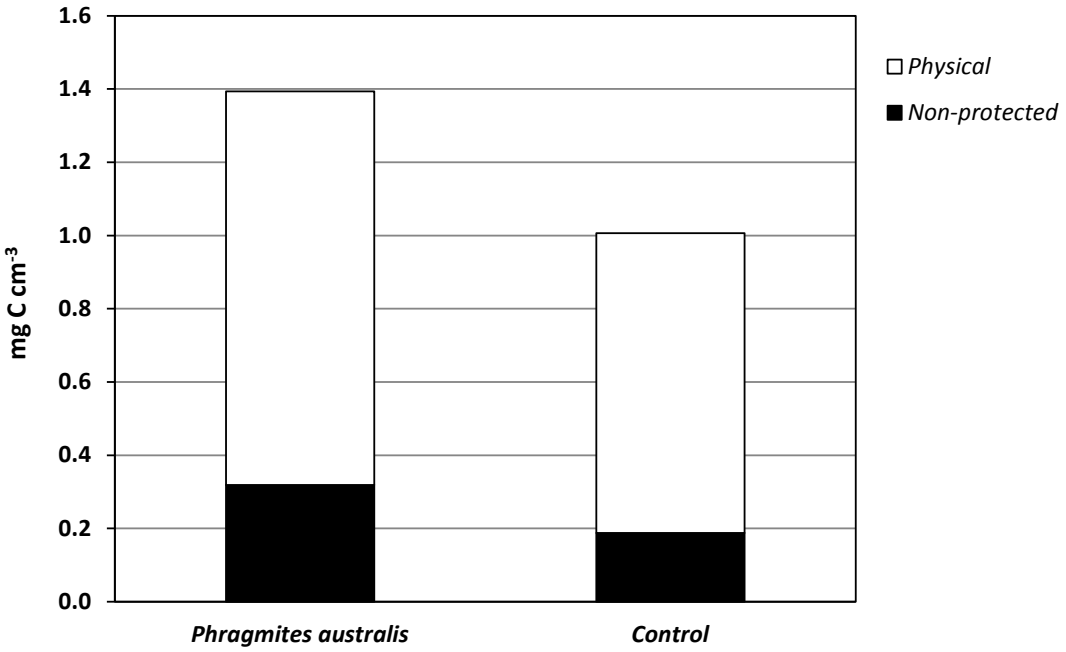

Figure 5-13. The carbon pools in the upper 40 cm of sediment at the Tolderol control (no vegetation) and *Phragmites australis* sites.

5.1.2.4 Total nitrogen

The total nitrogen contents in the sediments were low (<0.03 %N) in both the control site and the site under the *Phragmites australis* at Tolderol (Figure 5-14).

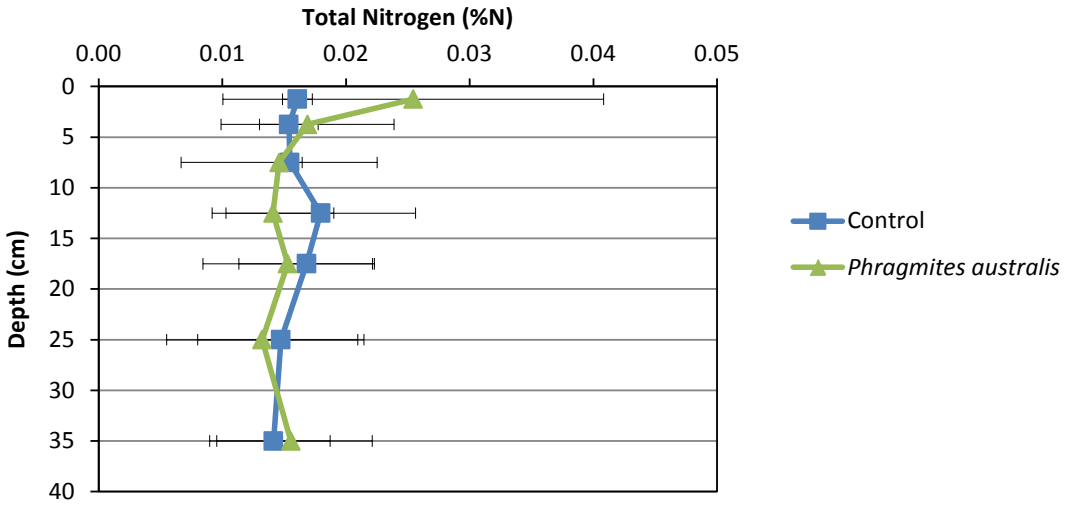

Figure 5-14. Total nitrogen at the Tolderol control (no vegetation) and *Phragmites australis* sites.

5.1.3 Loveday Bay, Lake Alexandrina

5.1.3.1 pH(1:5, soil:water)

The pHs of the sediments at the Loveday Bay sites ranged between 5.1 and 8.1 (Figure 5-15). Slightly higher pHs were observed in the surface layers (i.e. 0-10 cm) at the vegetated sites when compared to the control site. Deeper in the profile (i.e. 15-30 cm) the *Phragmites australis* and *Schoenoplectus validus* sites were more acidic that the control site. The pH of all sites was similar in the 30-40 cm layer.

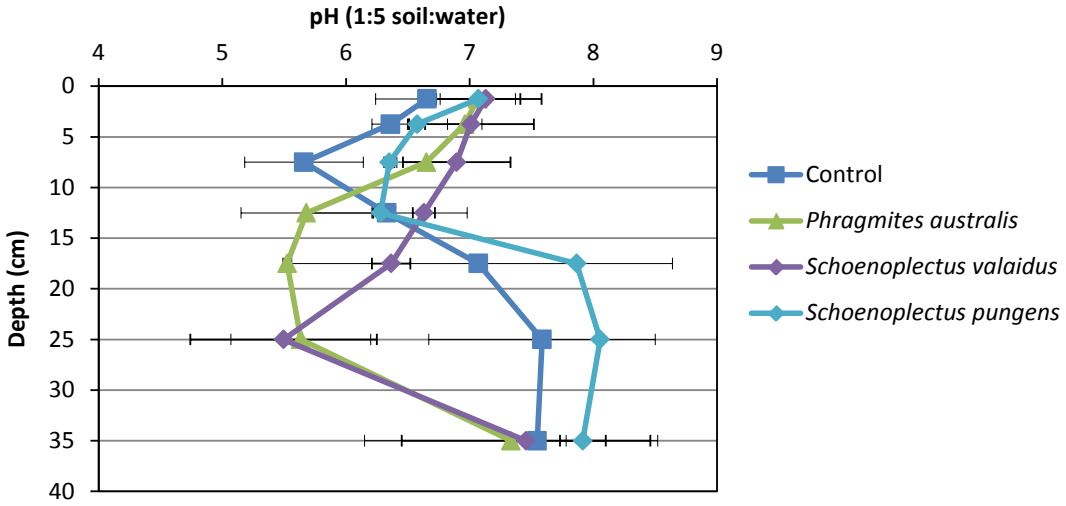

Figure 5-15. pH at the Loveday Bay control (no vegetation) and vegetated sites.

5.1.3.2 Electrical conductivity (EC)

The ECs of the sediments at the vegetated sites were usually similar to those observed in the control, ranging between 35 and 168 µS/cm (Figure 5-9). The sediment was slightly more saline in the surface layer (i.e. 0-2.5 cm) at the *Phragmites australis* site which had the highest EC.

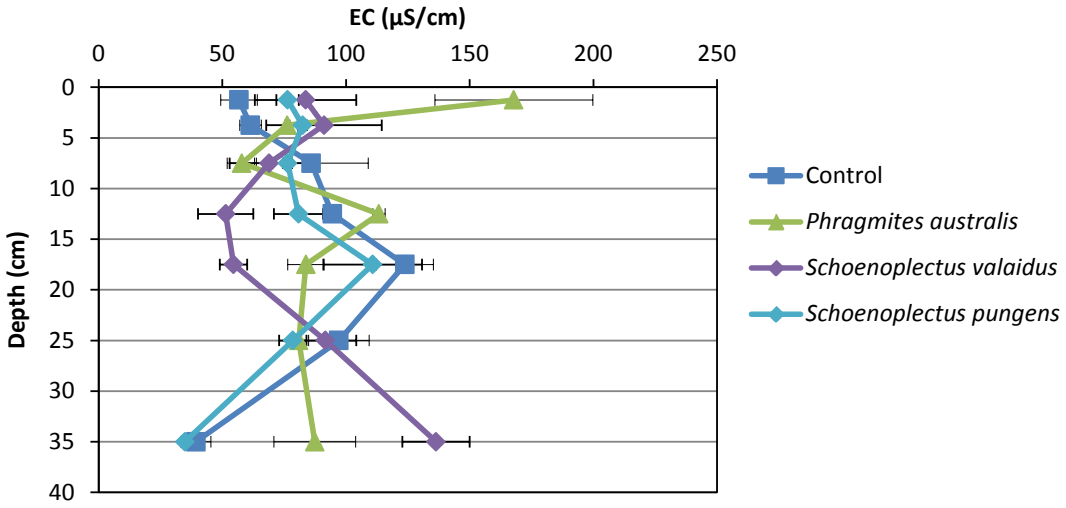

Figure 5-16. EC at the Loveday Bay control (no vegetation) and vegetated sites.

5.1.3.3 Total carbon, organic and inorganic carbon

The total carbon, organic and inorganic carbon contents measured at the Loveday Bay control and vegetated sites (i.e. *Phragmites australis*, *Schoenoplectus validus and Schoenoplectus pungens*) are shown below in Figures 5-17, 5-18 and 5-19, respectively.

A comparison of the total organic carbon contents indicate a much higher concentration in the *Phragmites australis* and *Schoenoplectus validus* sediment profiles compared to that observed in the control site profiles (Figure 5-18). The higher total organic carbon contents were particularly evident in the top 5 cm. The total organic carbon contents of the *Schoenoplectus pungens* site were similar to that measured at the control site.

The low carbonate contents of the sediments at the vegetated sites (i.e. ≤ 0.06) were at similar concentrations to those at the control site (Figure 5-19).

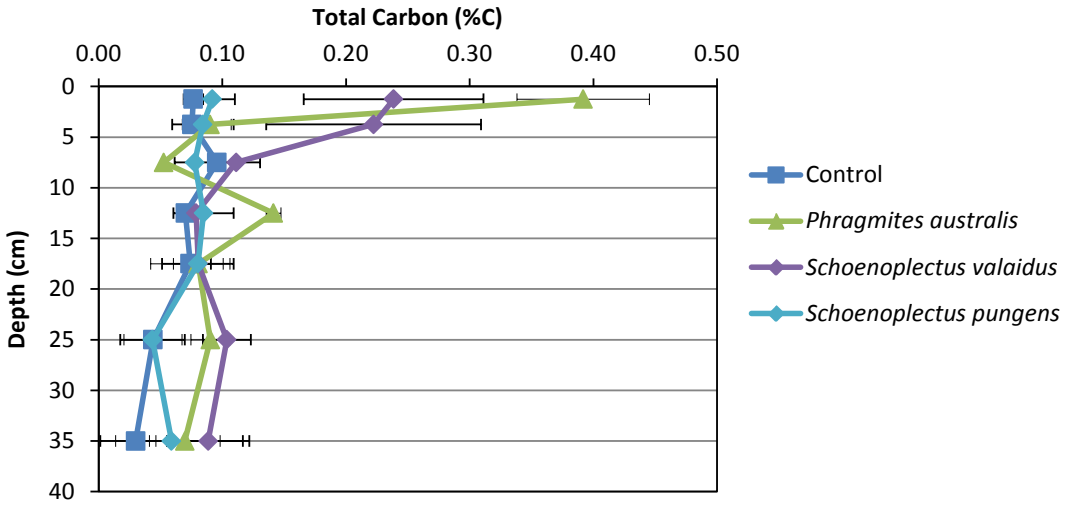

Figure 5-17. Total carbon at the Loveday Bay control (no vegetation) and vegetated sites.

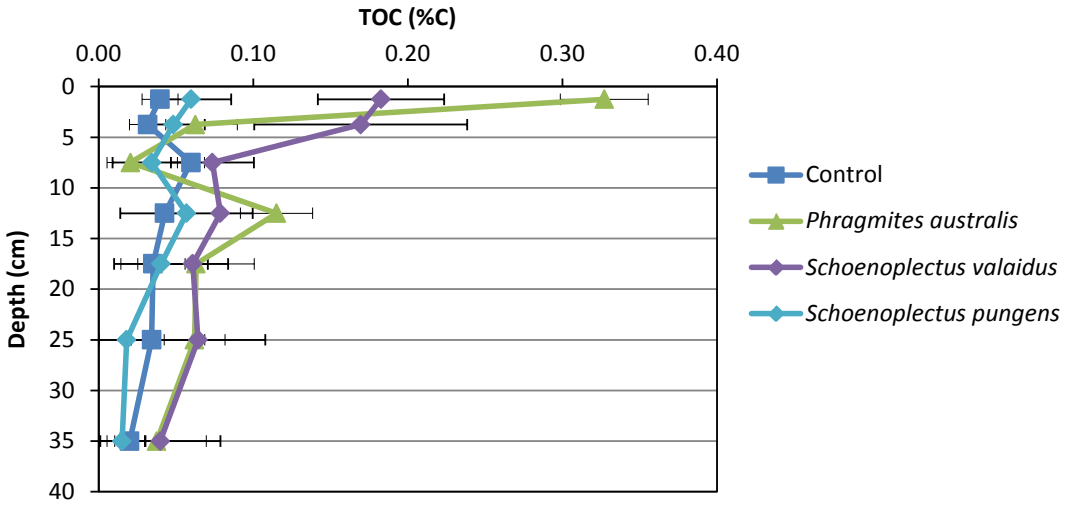

Figure 5-18. Total organic carbon at the Loveday Bay control (no vegetation) and vegetated sites.

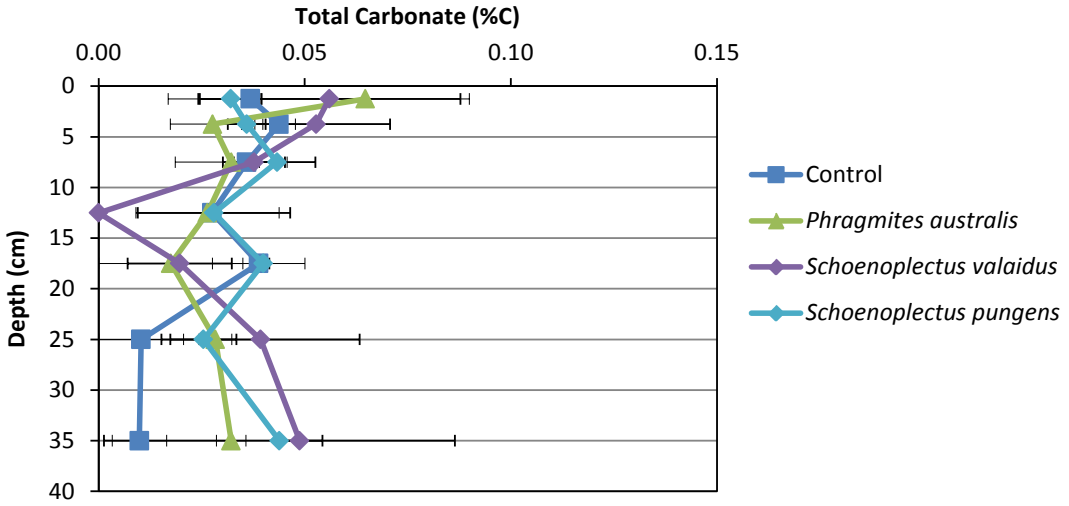

Figure 5-19. Carbonate (inorganic carbon) content at the Loveday Bay control (no vegetation) and vegetated sites.

The quantity of carbon throughout the 40 cm profile has been converted from the total organic carbon contents (in %) using the bulk densities of the layers (Figure 5-20). In terms of carbon accumulation, this data shows that carbon has accumulated in these sediments at the *Phragmites australis* and *Schoenoplectus validus* sites compared to the control site mainly in the Non-protected pool (i.e. 0.67 and 0.73 mg C cm^{-3} respectively cf. 0.40 mg C cm^{-3}). The physically protected pool was also slightly higher at the *Schoenoplectus validus site* (i.e. 0.46 mg C cm^{-3} cf. 0. 35 mg C cm^{-3}). The Non-protected carbon pool at the *Schoenoplectus pungens* site is similar to that observed at the control site, although this vegetated site has a slightly lower Physically protected pool when compared to the control site. Both the Chemical and Biochemical protected carbon pools were not quantified at these sites.

As most of this increase in carbon storage in the sediment is within the Non-protected (mainly the cPOM) pool, this would indicate that this stored carbon is liable to decomposition within the short term.

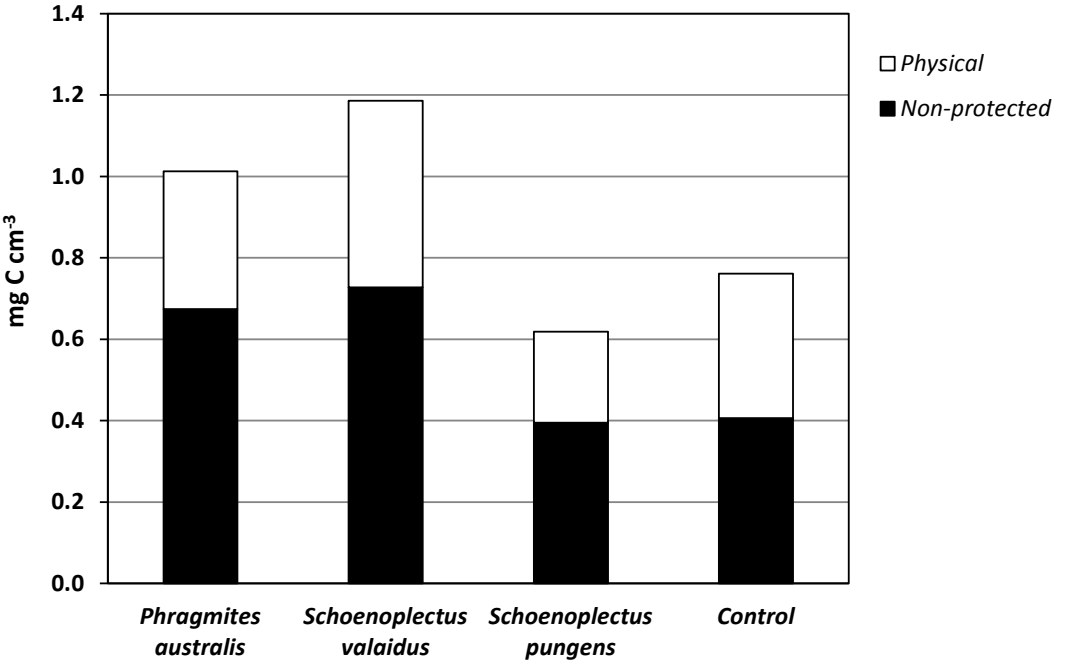

Figure 5-20. The carbon pools in the upper 40 cm of sediment at the Loveday Bay control (no vegetation) and vegetated sites.

5.1.3.4 Total nitrogen

The total nitrogen contents in the sediments were low (≤ 0.04 %N) in the control site and the sites under vegetation at Loveday Bay (Figure 5-21).

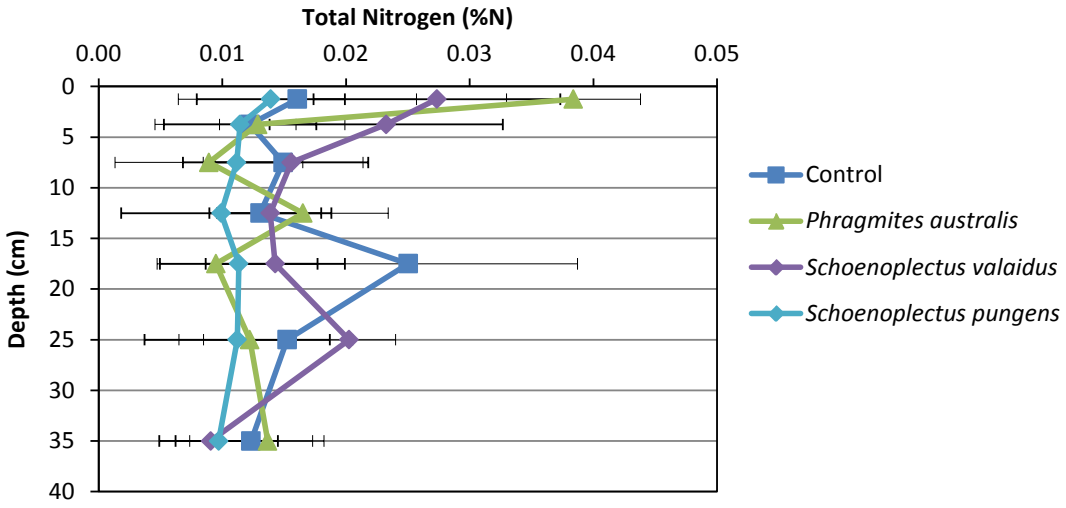

Figure 5-21. Total nitrogen at the Loveday Bay control (no vegetation) and vegetated sites.

5.1.4 Point Malcolm, Lake Alexandrina

5.1.4.1 pH(1:5, soil:water)

The pHs of the sediments under vegetation were similar to those observed at the control site, ranging between pH 8.7 and 9.2 (Figure 5-8).

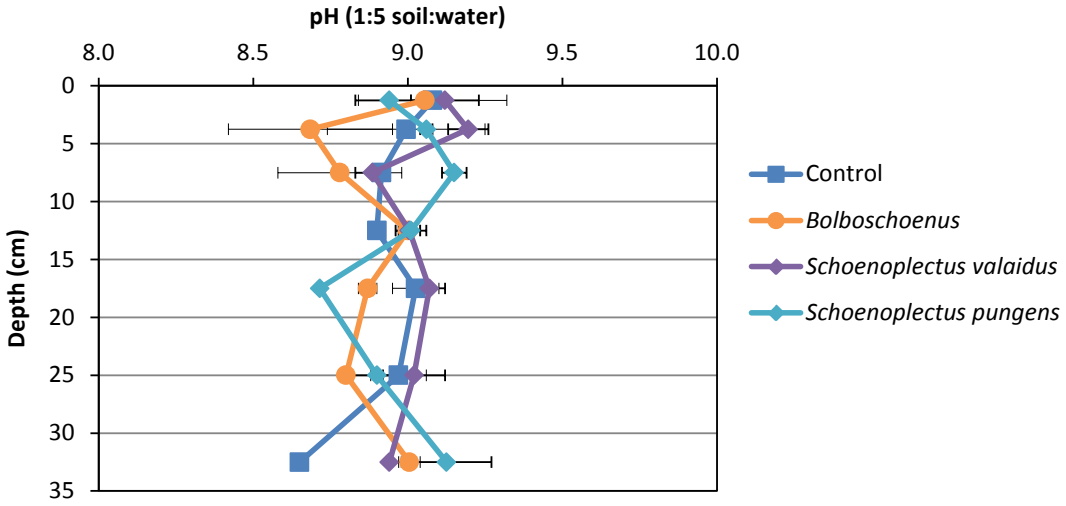

Figure 5-22. pH at the Point Malcolm control (no vegetation) and vegetated sites.

5.1.4.2 Electrical conductivity (EC)

The ECs of the sediments at the vegetated sites were similar to those observed in the control, ranging between 100 and 190 µS/cm (Figure 5-23).

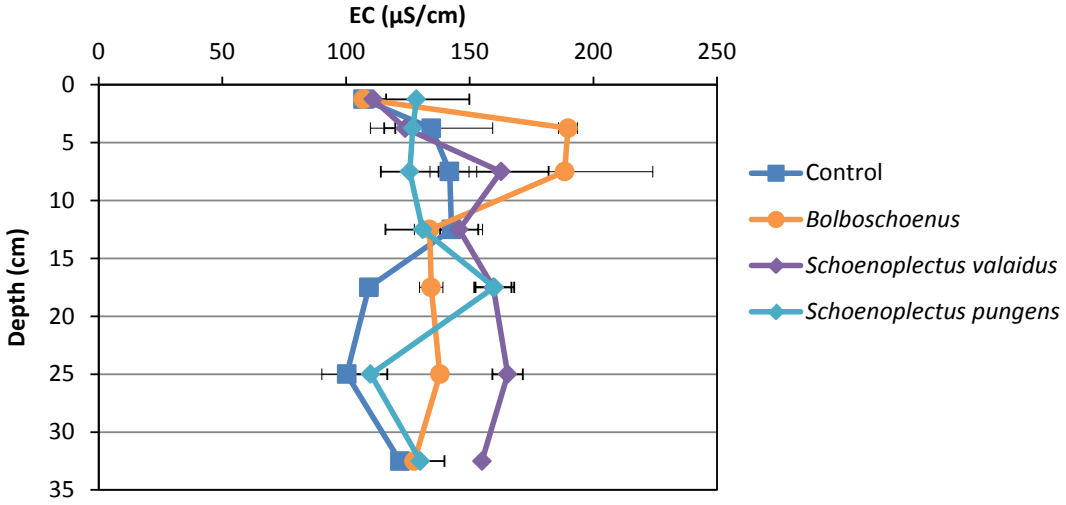

Figure 5-23. EC at the Point Malcolm control (no vegetation) and vegetated sites.

5.1.4.3 Total carbon, organic and inorganic carbon

The total carbon, organic and inorganic carbon contents measured at the Point Malcolm control and vegetated sites (i.e. *Bolboschoenus, Schoenoplectus validus and Schoenoplectus pungens)* are shown below in Figures 5-24, 5-25 and 5-26, respectively.

A comparison of the total organic carbon contents indicate a higher concentration in the *Bolboschoenus and Schoenoplectus pungens* sediment profiles compared to that observed in the control site profiles (Figure 5-25). The *Schoenoplectus pungens* sediment profile was found to have a higher total organic carbon content in the top 2.5 cm and below 15 cm when compared to the control site. The *Bolboschoenus* sediment profile only had a greater concentration between 15 and 30 cm. The total organic carbon contents of the *Schoenoplectus validus* site were similar to that measured at the control site, although the concentrations were slightly higher below a depth of 20 cm.

The carbonate contents of the sediments at the vegetated sites were often at higher concentrations than those at the control site, particularly below a depth of 15 cm (Figure 5-26).

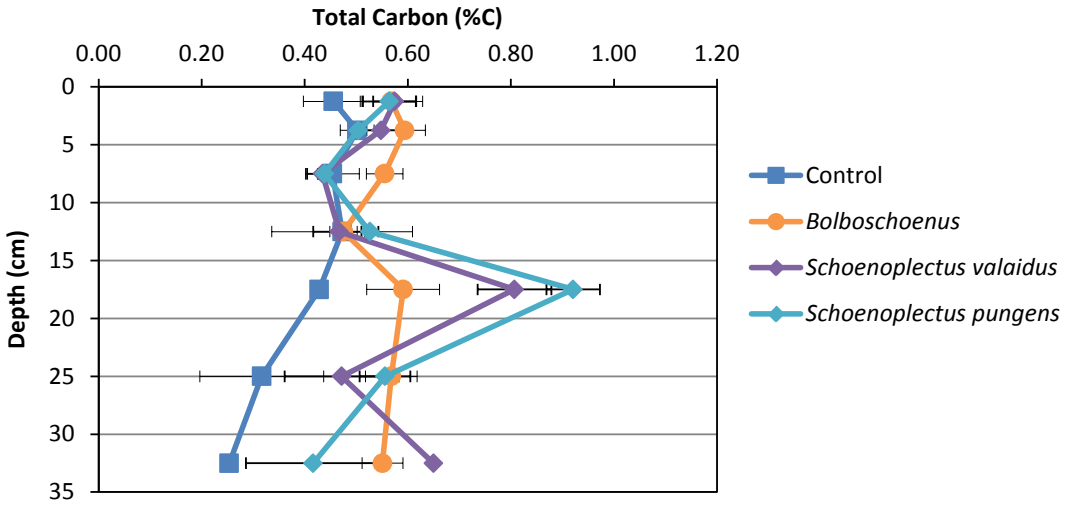

Figure 5-24. Total carbon at the Point Malcolm control (no vegetation) and vegetated sites.

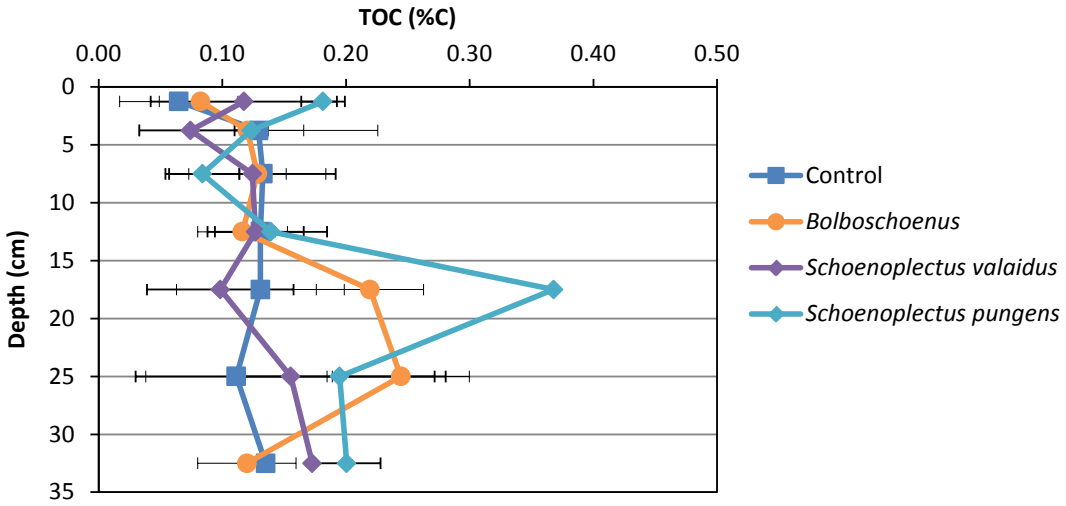

Figure 5-25. Total organic carbon at the Point Malcolm control (no vegetation) and vegetated sites.

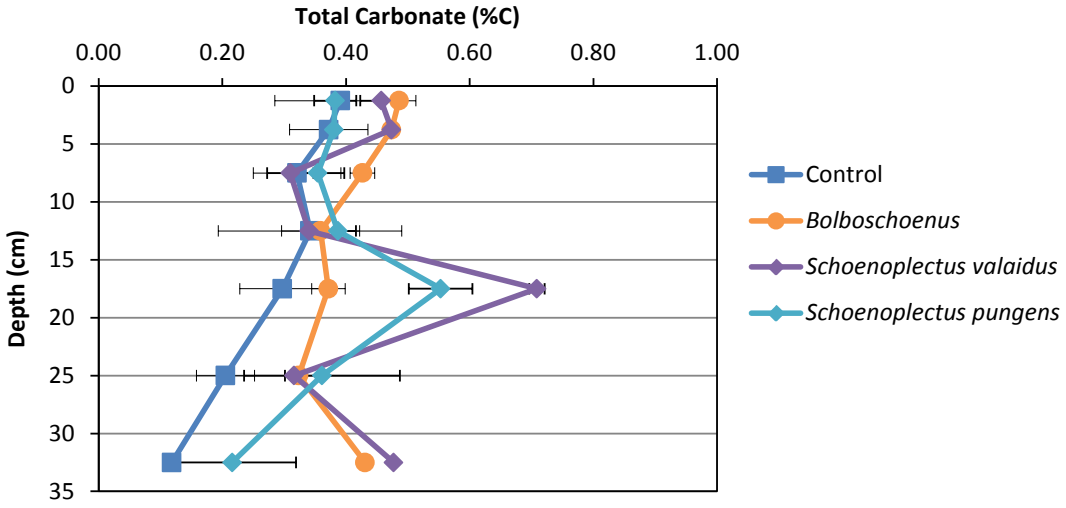

Figure 5-26. Carbonate (inorganic carbon) content at the Point Malcolm control (no vegetation) and vegetated sites.

The quantity of carbon throughout the 35 cm profile has been converted from the total organic carbon contents (in %) using the bulk densities of the layers (Figure 5-27). In terms of carbon accumulation, this data shows that carbon has accumulated in these sediments at the *Bolboschoenus and Schoenoplectus pungens* sites compared to the control site. Both these vegetated sites show that the accumulation has mainly occurred in the Non-protected pool compared to the control site (i.e. 1.65 and 1.70 mg C cm^{-3} respectively cf. 0.92 mg C cm^{-3}). However, the *Bolboschoenus and Schoenoplectus pungens* sites also have slightly higher Physically Protected pools when compared to the control site (i.e. 1.60 and 1.54 mg C cm^{-3} respectively cf. 1.32 mg C cm^{-3}). The carbon pools at the *Schoenoplectus validus* site are similar to those observed at the control site. Both the Chemical and Biochemical protected carbon pools were only quantified in two sediment layers at these sites (see Table 9-13, Appendix 3).

As most of this increase in carbon storage in the sediment is within the Non-protected (mainly the cPOM) pool, this would indicate that this stored carbon is liable to decomposition within the short term.

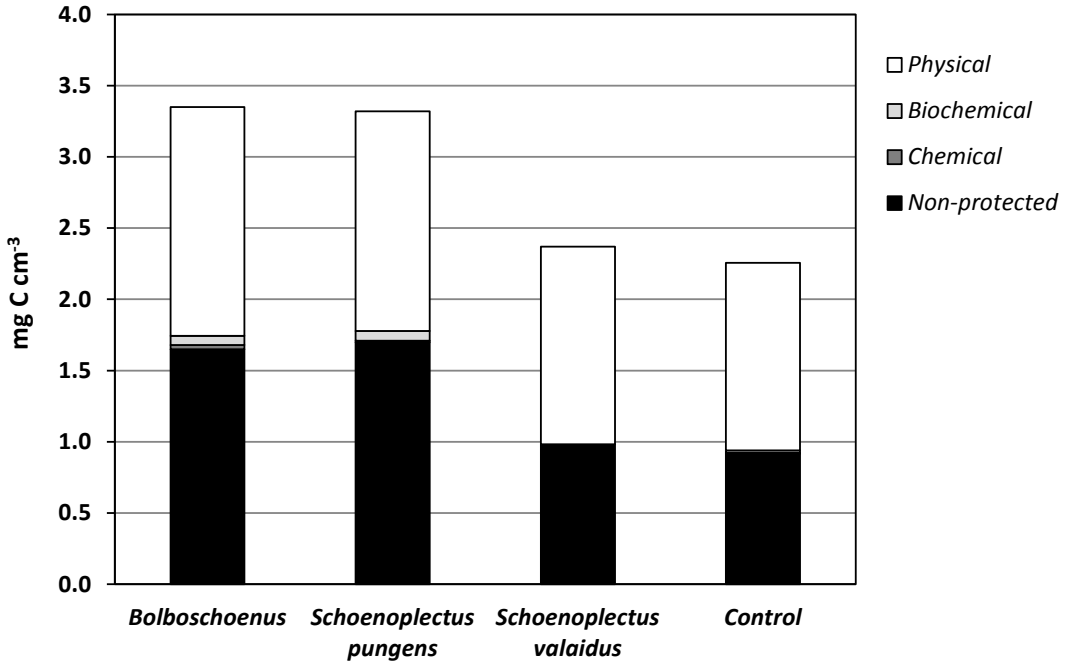

Figure 5-27. The carbon pools in the upper 35 cm of sediment at the Point Malcolm control (no vegetation) and vegetated sites.

5.1.4.4 Total nitrogen

The total nitrogen contents in the sediments were low (≤ 0.04 %N) in the control site and the sites under vegetation at Point Malcolm (Figure 5-28).

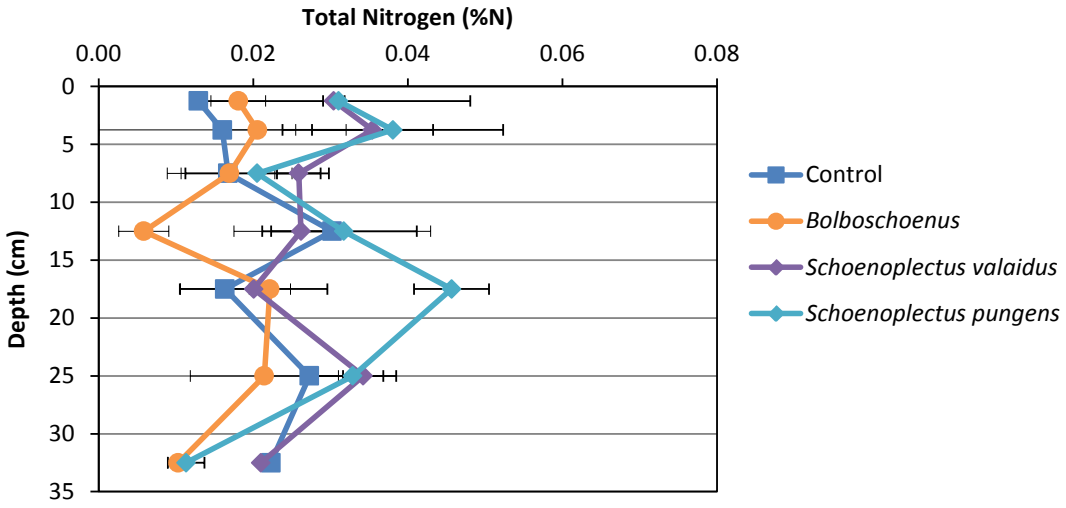

Figure 5-28. Total nitrogen at the Point Malcolm control (no vegetation) and vegetated sites.

5.2 Discussion

5.2.1 The well-established *Bolboschoenus* site at Hunters Creek

The presence of well-established *Bolboschoenus* vegetation at Hunters Creek increased the storage of organic carbon considerably within the surface layers. The total amount of enhanced organic carbon storage at this site due to the presence of *Bolboschoenus* was 20.4 tonnes C ha^{-1}. Therefore assuming the *Bolboschoenus* vegetation is at or nearing its climax, *Bolboschoenus* has the potential to store ~20 tonnes C ha^{-1} in the top 40 cm of the sediment profile. Whilst this carbon is mainly (i.e. ~ 75%) in the non-protected soil carbon pool resulting from increase in the cPOM i.e. the coarse (> 250 µm)) particulate organic matter fraction, there was also significantly, due the their relative stability against decomposition, a considerable contribution from the protected soil carbon pool in both the physically protected (10% of the increase) and biochemically protected (15% of the increase) carbon pools.

Assuming again that a climax vegetation could be reached within 20 to 100 years (as is typical for wetland species (e.g. Bechtold and Naiman 2009)) the annual rate of organic matter increase would range between 200 - 1,000 kg C ha^{-1} yr^{-1}, rates similar to the initial rates of organic carbon accumulation that were observed under both *Schoenoplectus validus* and *Phragmites* in Sullivan *et al.*'s (2012a) and the current study of carbon accumulation in re-inundated sediments by Lower Lakes vegetation. For example, the initial rates of organic carbon increase observed in Sullivan *et al.*'s (2012a) study were 866 kg C ha^{-1} yr^{-1} for the *Phragmites* site at Waltowa, and 670 kg C ha^{-1} yr^{-1} and 903 kg C ha^{-1} yr^{-1} for the *Schoenoplectus validus* at Meningie and Hunters Creek, respectively. These rates are similar to those found by Craft (1997) of who, in an evaluation of four created estuarine marshes in North Carolina from 1–15 years old, found the mean accumulation of organic carbon to be 800 kg C ha^{-1} yr^{-1}. These rates are appreciably lower than the mean accumulation of organic carbon of 1,600 kg C ha^{-1} yr^{-1} observed over 10 years since reconstruction of two freshwater wetlands in Ohio by Anderson and Mitsch (2006). These rates are also similar to the mean accumulation of organic carbon of 360 kg C ha^{-1} yr^{-1} observed over 4,000 years in lake sediments by Dean and Gorham (1998). The mean organic carbon increase for small (<100 km^2) lakes are 270 kg C ha^{-1} yr^{-1} for oligotrophic lakes and 940 kg C ha^{-1} yr^{-1} for meso-eutrophic lakes (Mulholland and Elwood 1982). Thus the initial rates of organic carbon increase determined in this study for well-established *Bolboschoenus* vegetation at Hunters Creek can be considered as in accord with the rates typically found for such situations.

Critically different to the findings of Sullivan *et al.*'s (2012a) study was the considerable amounts of carbon accumulating in both the physically- and biochemically-protected sediment carbon pools under the well-established *Bolboschoenus* vegetation at Hunters Creek. The cPOM fraction in the non-protected soil carbon pool is considered to be a relatively short-lived carbon pool (Six *et al*. 2002). Thus whilst the increase and maintenance of ~75% of the additional stored carbon under the *Bolboschoenus* vegetation at Hunters Creek is in the non-protected soil carbon pool that is likely to be contingent on the maintenance of the vegetation and the consequent supply of organic matter to this pool, a considerable proportion (~25%) of the total accumulated carbon is well protected against decomposition. This result is contrast to the carbon accumulating under both *Schoenoplectus validus* and *Phragmites* in Sullivan *et al.*'s (2012a) study which was all in the unprotected carbon pool. This contrast is likely due to the clayey texture of the Hunters Creek sediments contrasting with the sandy textures of the sediments under both *Schoenoplectus validus* and *Phragmites* examined in Sullivan *et al.*'s (2012a) study.

It is interesting that whereas the relative amount of carbon that increased in both the non-protected and biochemically protected soil carbon pools under the well-established *Bolboschoenus* vegetation at Hunters Creek was about 50%, the relative amount of carbon increase in the physically protected fraction was only about 17% perhaps indicating that the processes of physical protection in permanently inundated and relatively unstructured sediments may be limited cf. that afforded in well-structured well-drained upland soil materials.

Of course, the non-protected carbon pool in these sediments is important for the ecological health of the lake sediments being a food source to benthic and other biota and being available to drive biochemically-driven processes in the sediment such as sulfate reduction.

The rates of inorganic carbon (carbonate) accumulation due to the presence of vegetation at the three constantly inundated sites were low to negligible compared to the rates of organic carbon accumulation excepting that a sharp accumulation of carbonate was observed in the surface layer

of the *Bolboschoenus* site most likely due to the accumulation of carbonate-producing fauna active in the sediment surface layers.

5.2.2 The more recently revegetated sites at Tolderol, Loveday Bay and Point Malcolm

5.2.2.1 The Tolderol site

The relatively vigorous growth of *Phragmites australis* at the Tolderol site since 2010 (Fig. 3-11) increased the storage of organic carbon considerably within the top 40 cm layer of the sediment after only a few years of growth. The initial rate of organic carbon increase under *Phragmites australis* at the Tolderol site assuming 3 years of accumulation was 499 kg C ha^{-1} yr^{-1}. No appreciable inorganic carbon (carbonate) accumulation was observed at this site due to the presence of vegetation.

The rate of organic carbon increase was mainly (~66%) in the physically-protected soil carbon pool but also considerable in the non-protected carbon pool (~33%) with the main contributor in this pool being the cPOM (i.e. the coarse (> 250 µm) particulate organic matter). The cPOM fraction is considered to be a relatively short-lived carbon pool (Six *et al*. 2002). Thus the increase and maintenance of most of the additional stored carbon under the *Phragmites australis* at the Tolderol site is not likely to be contingent on the maintenance of the vegetation and the consequent supply of organic matter to this pool: a different result to that observed under *Phragmites australis* at Waltowa in the Sullivan *et al.* (2012a) study.

The physically-protected carbon pool at this site is protected from degradation by its inclusion in microaggregates (defined as 53–250 µm aggregates) in the sediment. The considerable proportion of sequestered carbon of this pool (relative to the total carbon pool) may seem surprising given the sandy texture of these sediments and the consequent lack of appreciable amounts of the clay and silt fractions necessary to form microaggregates (Plante *et al.* 2006b), but can be reconciled by the extremely low total organic carbon contents of these sediments (i.e. < 0.10 % C). This physically-protected carbon pool is considered to be a slow carbon pool with turnover rates of ~ 100 years (Six and Jastrow 2002).

Given the sandy texture of the sediments at this site it is not surprising that both the biochemically- and chemically-protected carbon pools (i.e. the hydrolysable and non-hydrolysable carbon in the clay and silt fractions, respectively) were negligible in these sediments.

The initial rates of organic carbon increase under *Phragmites australis* at this sites was 499 kg C ha^{-1} yr^{-1}, similar to those found for wetlands by Dean and Gorham (1998), Craft (1997), Mulholland and Elwood (1982) and Sullivan *et al.* (2012a). Although this rate was appreciably lower than that found for a wetland by Anderson and Mitsch (2006), we consider that the initial rates of organic carbon increase determined in this study for this site under *Phragmites australis* can be considered as in accord with the rates typically found for wetlands.

As long as the *Phragmites australis* at this site continues to grow and the site remains inundated then the organic carbon accumulation rate observed at this site since lake re-inundation is likely to continue for decades (e.g. Moreno-Mateos *et al.* 2012). However, if the Lower Lakes experience low water levels again as they did immediately prior to 2010 then ~33 % of this accumulated organic carbon, residing in the non-protected (mainly cPOM) pool, would be expected to be rapidly consumed as the sediment biogeochemical regime changes from a reducing to an oxidising condition.

5.2.2.2 The Loveday Bay site

The vigour of the three vegetation types at the Loveday Bay site was variable with the *Phragmites australis* showing the greatest vigour (Fig. 3-14), followed closely by *Schoenoplectus validus* (Fig. 3-16), followed by the relatively poor vigour exhibited by *Schoenoplectus pungens* (Fig. 3-18). The organic carbon accumulation rates at the Loveday Bay site since revegetation reflect these variations in vegetative vigour. The growth of both the *Phragmites australis* and *Schoenoplectus validus* had increased the storage of organic carbon considerably within the top 40 cm layer of the sediment, whilst there was no observable increase in organic matter under the *Schoenoplectus pungens*. It is considered that the poor vigour of the *Schoenoplectus pungens* vegetation, combined with its position slightly incongruent to the other three sampling sites in terms of distance

from the shoreline, precluded any observable contribution by this vegetation to the accumulation of organic matter at this site. The initial rate of organic carbon increase under *Phragmites australis* at the Loveday Bay site assuming 3 years of accumulation was 480 kg C ha^{-1} yr^{-1}. The initial rate of organic carbon increase under *Schoenoplectus validus* at the Loveday Bay site again assuming 3 years of accumulation was 560 kg C ha^{-1} yr^{-1}. No inorganic carbon (carbonate) accumulation was observed at this site due to the presence of vegetation.

In contrast to the results for *Phragmites australis* at Tolderol, the sediment organic carbon increase observed under both *Phragmites australis* and *Schoenoplectus validus* at this site was mainly (i.e. ~75%) in the non-protected carbon pool. This carbon pool is considered to be a relatively short-lived carbon pool in upland soils (Six *et al*. 2002). Thus the increase and maintenance of most of the additional stored carbon under both *Phragmites australis* and *Schoenoplectus validus* at the Loveday Bay site is likely to be contingent on the maintenance of the vegetation and the consequent supply of organic matter to this pool: a similar result to that observed under *Phragmites australis* in the Sullivan *et al.* (2012a) study. Again, the non-protected carbon pool in the sediment is no doubt important for the ecology of the lake sediments being a food source to benthic and other biota and being an energy source that is capable of driving a multitude of biochemically-driven processes in these sediments (e.g. sulfate reduction).

There was a considerable (i.e. ~25% of the total organic carbon) pool of physically-protected carbon under both *Phragmites australis* and *Schoenoplectus validus at this site*. The considerable size of this pool (relative to the total carbon pool) may seem surprising given the sandy texture of these sediments and the consequent lack of appreciable amounts of the clay and silt fractions necessary to form microaggregates (Plante *et al.* 2006b), but can be reconciled by the extremely low total organic carbon contents of these sediments (i.e. generally < 0.10 % C). This physically-protected carbon pool is considered to be a slow carbon pool in upland soils with turnover rates of ~100 years (Six and Jastrow 2002).

Given the sandy texture of the sediments at this site it is not surprising that the biochemically- and chemically-protected carbon pools (i.e. the hydrolysable and non-hydrolysable carbon in the clay and silt fractions, respectively) were negligible in these sediments.

The initial total rates of organic carbon increase under both *Phragmites australis* and *Schoenoplectus validus* at this site of 480 and 560 kg C ha^{-1} yr^{-1}, respectively, are similar to those found under *Phragmites australis* at the Tolderol site and more generally for wetlands by Dean and Gorham (1998), Craft (1997), Mulholland and Elwood (1982) and Sullivan *et al.* (2012a). They were however appreciably lower than that found for a wetland by Anderson and Mitsch (2006). Thus, the initial rates of organic carbon increase determined in this study for this site under *Phragmites australis* and *Schoenoplectus validus* can be considered as in accord with the rates typically found for wetlands.

As long as the *Phragmites australis* and *Schoenoplectus validus* at this site continue to grow and the site remains inundated then the organic carbon accumulation rate observed at this site since lake re-inundation is likely to continue for decades (e.g. Moreno-Mateos *et al.* 2012). However, if the Lower Lakes experience low water levels again as they did immediately prior to 2010 then ~75 % of this accumulated organic carbon, residing in the non-protected (mainly cPOM) pool, would be expected to rapidly be consumed as the sediment biogeochemical regime changes from a reducing to an oxidising condition.

5.2.2.3 The Point Malcolm site

The vigour of the three vegetation types at the Point Malcolm site was similar (Figs. 3-23, 3-25 and 3-27) and it appeared from aerial photos (Fig. 3-21) that unlike the other recently revegetated sites examined in this study, this study site was revegetating prior to the lake refilling in 2010. For this reason we have used a revegetation time of 4 years for the vegetation at these sites. The organic carbon accumulation rates at this site were considerable and similar under both the *Schoenoplectus pungens* and *Bolboschoenus*, whereas the organic carbon accumulation rates under the *Schoenoplectus validus* was much lower than was observed under the other two vegetation types.

The initial rate of organic carbon increase within the top 40 cm layer of the sediment under *Bolboschoenus* at this site assuming 4 years of accumulation was 1,050 kg C ha^{-1} yr^{-1} and under *Schoenoplectus pungens* at this site was 1,101 kg C ha^{-1} yr^{-1}, whereas the initial rate of organic carbon increase within the top 40 cm layer of the sediment under *Schoenoplectus validus* was only

101 kg C ha^{-1} yr^{-1}. No appreciable inorganic carbon (carbonate) accumulation was observed at this site due to the presence of vegetation.

As for the vegetation at the Loveday Bay site, the organic carbon increase observed under both *Bolboschoenus* and *Schoenoplectus pungens* was mainly (i.e. ~75%) in the relatively short-lived non-protected carbon pool (Six *et al*. 2002). Thus the increase and maintenance of most of the additional stored carbon under the *Bolboschoenus* and *Schoenoplectus pungens* at the Point Malcolm site is likely to be contingent on the maintenance of the vegetation and the consequent supply of organic matter to this pool: a similar result to that observed under *Phragmites australis* in the Sullivan *et al.* (2012a) study. Again the non-protected carbon pool in the sediment is no doubt important for the ecology of the lake sediments being a food source to benthic and other biota and being available to drive biochemically-driven processes in the sediment such as sulfate reduction.

There was a considerable (i.e. ~20%) of the total organic carbon pool of physically-protected carbon under both *Bolboschoenus* and *Schoenoplectus pungens* at this site. This carbon is protected physically from degradation by its inclusion in microaggregates (defined as 53–250 µm aggregates) in the sediment. The considerable size of this pool (relative to the total carbon pool) may seem surprising given the sandy texture of these sediments and the consequent lack of appreciable amounts of the clay and silt fractions necessary to form microaggregates (Plante *et al.* 2006b), but can be reconciled by the extremely low total organic carbon contents of these sediments (i.e. ~0.15 % C). This physically-protected carbon pool is considered to be a slow carbon pool with turnover rates of ~100 years (Six and Jastrow 2002).

In addition, about 5 % of the total carbon under both *Bolboschoenus* and *Schoenoplectus pungens* in the sediments at this site was in the relatively long-lived biochemically-protected carbon pool (i.e. the hydrolysable carbon in the clay and silt fractions).

The initial rates of organic carbon increase under both *Bolboschoenus* and *Schoenoplectus pungens* at this site of 1050 and 1,001 kg C ha^{-1} yr^{-1}, respectively, although more to those found under *Phragmites australis* at the Tolderol site and more generally for wetlands by Dean and Gorham (1998), Craft (1997), Mulholland and Elwood (1982) and Sullivan *et al*. (2012a) were also similar to those found for a wetland by Anderson and Mitsch (2006). On the other hand the initial rates of organic carbon increase under *Schoenoplectus validus* at this site of 101 kg C ha^{-1} yr^{-1}, was appreciably lower than those generally observed for wetland sites. The reason for this is not clear. Thus the initial rates of organic carbon increase determined in this study for this site under *Bolboschoenus* and *Schoenoplectus pungens* can be considered as in accord with the rates typically found for wetlands but that under *Schoenoplectus validus* at this site only was lower than usually observed.

As long as the *Bolboschoenus* and *Schoenoplectus pungens* especially, but also the *Schoenoplectus validus,* at this site continue to grow and the site remains inundated then the organic carbon accumulation rates observed at this site since lake reinundation are likely to continue for decades (e.g. Moreno-Mateos *et al.* 2012). However, if the Lower Lakes experience low water levels again as for 2010, then ~75% of this accumulated organic carbon, residing in the non-protected (mainly cPOM) pool, would be expected to rapidly be consumed as the sediment biogeochemical regime changes from a reducing to a more oxidising condition.

5.2.3 Comparison of organic carbon increases across sites and vegetation types

A comparison of the organic carbon increases according to vegetation type as determined in this study and that of Sullivan *et al.* (2012a) is shown in Figure 5-29. This figure shows that the mean organic carbon increases for all four Lower Lakes' sedges were similar ranged between 580 - 1,050 kg C ha^{-1} yr^{-1} indicating that the carbon sequestration rates were relatively independent of the type of sedge. This is important as clearly the type of sedge existing should not markedly alter the rates of carbon accumulations in the sediments of the Lower Lakes.

Figure 5-29 also clearly shows that revegetation by sedges around the Lower Lakes has increased the storage of organic carbon in the sediments considerably within the surface layers after only a few years of growth. The observed rates of organic carbon increase are in accord with the rates typically found for such wetland situations and importantly should be expected to continue for many decades. For example, the rates observed here are similar to those found by Craft (1997) who, in an evaluation of four created estuarine marshes in North Carolina from 1–15 years old, found the mean accumulation of organic carbon to be 800 kg C ha^{-1} yr^{-1}. These rates are slightly lower than the

mean accumulation of organic carbon of 1,600 kg C ha^{-1} yr^{-1} observed over 10 years since reconstruction of two freshwater wetlands in Ohio by Anderson and Mitsch (2006). These rates are also slightly higher than the mean accumulation of organic carbon of 360 kg C ha^{-1} yr^{-1} observed over 4,000 years in lake sediments by Dean and Gorham (1998). The mean organic carbon increase for small (<100 km^2) lakes are 270 kg C ha^{-1} yr^{-1} for oligotrophic lakes and 940 kg C ha^{-1} yr^{-1} for meso-eutrophic lakes (Mulholland and Elwood 1982).

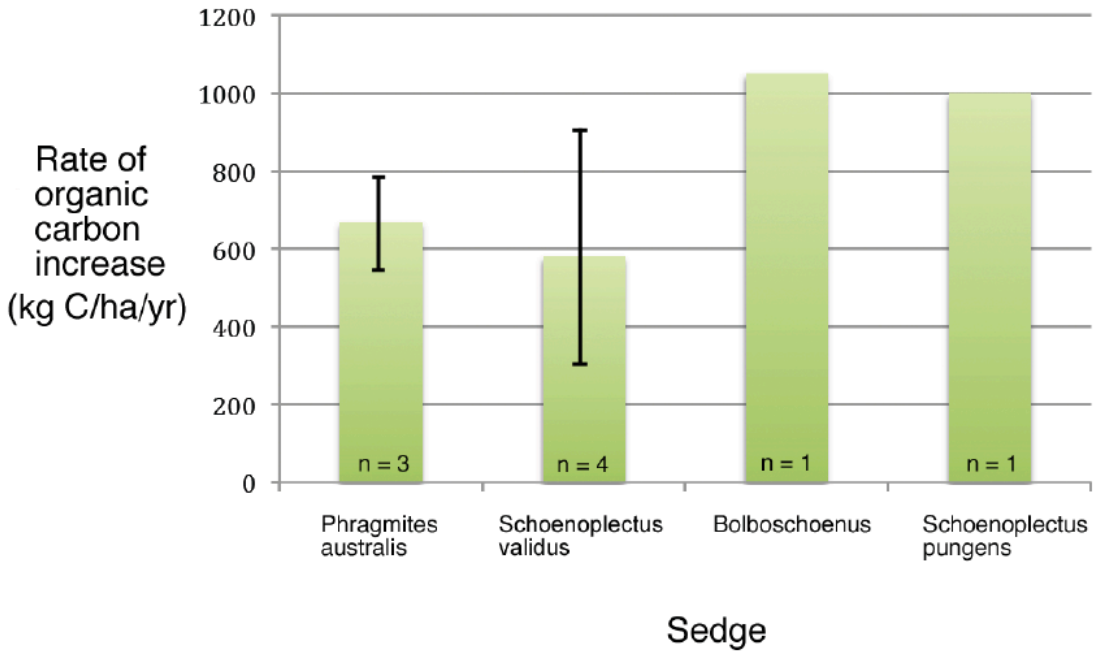

Figure 5-29. Comparison of rates of organic carbon increase according to sedge type in the Lower Lakes as observed in this study and the study of Sullivan *et al.* (2012a). n indicates the number of rate estimates for each sedge type. The error bars indicate standard deviation.

Figure 5-30 shows the pools in which these carbon increases are occurring for all sedges examined in this study and that of Sullivan *et al.* (2012a). Most of the organic carbon increase in these sediments was in the non-protected pool (with the main contributor being the cPOM (i.e. the coarse (> 250 µm) particulate organic matter), but there were also considerable increases in the physically-protected pool (~15%) and to a lesser extent, the biochemically-protected carbon pool (~5%). The physically-protected and biochemically-protected carbon pools are considered important for secure carbon sequestration in soil because of their slow turnover rates (Six *et al.* 2002). Interestingly the well-established *Bolboschoenus* site at Hunters Creek (Fig. 3-9) exhibited similar patterns in the carbon pool increase (non-protected, 75%; physically-protected, 10%; biochemically-protected, 15%) suggesting this pattern of carbon accumulation will persist as the revegetating sedges mature around the Lower Lakes.

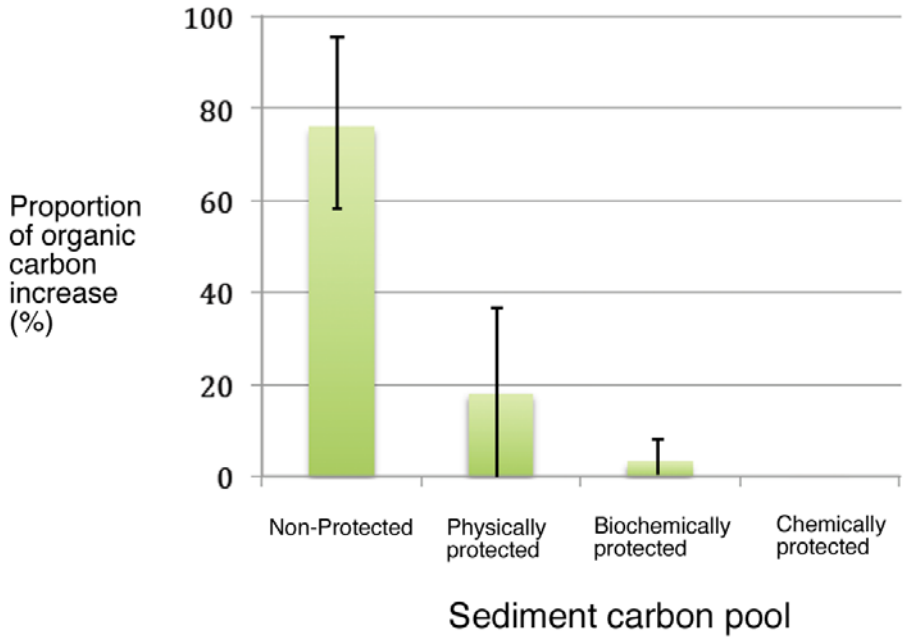

Figure 5-30. The sediment carbon pools in which the organic carbon increases are occurring due to sedge revegetation in the Lower Lakes. This analysis includes all the data for the sedges in the Lower Lakes as observed in this study and the study of Sullivan *et al.* (2012a). The error bars indicate standard deviation.

6.0 Conclusions

The key findings of this study are:

1) At all of the recently revegetated sites (i.e. the Tolderol, Loveday Bay and Point Malcolm sites) bioremediation by revegetation has increased the storage of organic carbon considerably within the sediment surface layers after only a few years of growth. The mean organic carbon increases for all four Lower Lakes' sedges were similar ranged between 580 - 1,050 kg C ha^{-1} yr^{-1} indicating that the carbon sequestration rates were relatively independent of the type of sedge growing. This is important as it indicates that the rates of carbon accumulations in the sediments of the Lower Lakes will not be markedly affected by the type of sedges that are used for revegetation. The rates of organic carbon increase observed are in accord with the rates that have been found for similar situations.

2) At the well-established *Bolboschoenus* vegetation at Hunters Creek, the amount of enhanced organic carbon storage at this site due to the presence of *Bolboschoenus* was 20.4 tonnes C ha^{-1}. This likely represents an annual rate of organic carbon of between 200 - 1,000 kg C ha^{-1} yr^{-1}. This range essentially encompasses the initial rates of organic carbon accumulation that were stored under both *Schoenoplectus validus* and *Phragmites* in Sullivan *et al.*'s (2012a) study of carbon accumulation in re-inundated sediments by Lower Lakes vegetation, as well as for the vegetation at the other sites in this present study, and those for wetlands internationally.

3) The rates of inorganic carbon (carbonate) accumulation due to the presence of vegetation at all sites were very low to negligible compared to the rates of organic carbon accumulation.

4) These organic carbon increases at most of the recently revegetated sites and also at the well-established *Bolboschoenus* site at Hunters Creek were dominantly (i.e. ~75%) in the relatively short-lived non-protected soil carbon pool with the main contributor being the cPOM (i.e. the coarse (> 250 µm) particulate organic matter). This pool is readily available to biota and hence important for the ecology of the lakes. However, the increase and maintenance of the additional stored carbon under the bioremediating vegetation, being mainly in the relatively short-lived non-protected soil carbon pool, is likely to be to a considerable extent contingent also on the maintenance of 1) the vegetation and the consequent supply of organic matter to this pool, and 2) inundating conditions.

5) A considerable proportion of the accumulating organic carbon in the sediments were in the physically-protected pool (~15%) and to a lesser extent, the biochemically-protected carbon pool (~5%) both considered important for secure carbon sequestration in soil because of their slow turnover rates. Interestingly the well-established *Bolboschoenus* site at Hunters Creek exhibited similar patterns in the carbon pool increase (non-protected, 75%; physically-protected, 10%; biochemically-protected, 15%) suggesting this pattern of protected carbon accumulation will persist as the revegetating sedges mature around the Lower Lakes.

7.0 Recommendations

1) The data clearly shows that the main carbon pools that were accumulating in these sediments during these early stages of vegetation establishment were: i. the non-protected pool, a pool considered prone to removal via oxidation and ii. the physically-protected pool, a pool considered relatively resistant to decomposition in upland soils with turnover rates of ~100 years. Although the lability of these pools has been demonstrated in upland soil conditions, this has not been examined previously for lake sediments either during inundation or after drying events. We recommend that such a study be undertaken to examine the turnover rates of these carbon pools in wetland sediments in order to be able to predict fate of carbon sequestered in these sediments both under greater durations of inundation, and under re-exposure of these sediments to the atmosphere during any repeat of the drought conditions experienced during 2007-2010.

2) That further more detailed studies be undertaken of carbon pool accumulation in sediments under the vegetation occurring in wetlands along the River Murray that experience relatively frequent periodic wetting and drying cycles: a situation considerably different to that occurring in the Lower Lakes situation that was the focus of this study where drying periods only occur in exceptional circumstances such as the 2007-2010 drought.

8.0 References

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9.0 Appendices

APPENDIX 1. Site and sample descriptions

Table 9-1. Site and profile descriptions.

Location	Vegetation	Date	Profile ID	GPS Co-ordinates Zone East, North.	Location and Profile Remarks
Hunters Creek, Hindmarsh Island	*Bolboschoenus*	29/05/13	1A, 1B	54H 0308284, 6065544	
	Control (no vegetation)	29/05/13	2A, 2B	54H 0308283, 6065541	
Tolderol, Lake Alexandrina	Control (no vegetation)	29/05/13	3A, 3B	54H 0331384, 6083652	
	Phragmites australis	29/05/13	4A,4B	54H 0331392, 6083651	
Loveday Bay, Lake Alexandrina	Control (no vegetation)	30/05/13	5A,5B	54H 0326292, 6061994	0-2.5 cm: Yellowish sand. 2.5-14 cm: Dark grey sand. 14-50 cm: Very light grey sand with green/blue segregations.
	Phragmites australis	30/05/13	6A,6B	54H 0326295, 6061977	0-2 cm: Root mat in clay. 2-10 cm: Very light grey sand with abundant iron segregations. 10-27 cm: Very dark grey sand. 27-45 cm: Light grey sand with some black segregations.
	Schoenoplectus validus	30/05/13	7A,7B	54H 0326284, 6062000	0-10 cm: Root material in light beige sand. 10-50 cm: Mottled beige/light grey/bark grey sand with some orange segregations. Less root material but still common.
	Schoenoplectus pungens	30/05/13	8A,8B	54H 0326297, 6061998	0-2 cm: Beige sand. 2-15 cm: Dark grey sand with some beige mottles. 15-50 cm: Light grey sand with occasional orange mottles and occasional green/blue segregations.
Point Malcolm, Lake Alexandrina	*Bolboschoenus*	30/05/13	9A,9B	54H 0335899, 6068933	0-2 cm: Beige sand. 2-13 cm: Dark grey sand. 13-35 cm: Light grey sand. Refusal of core at 35 cm (last layer sampled was 30-35 cm).
	Control (no vegetation)	30/05/13	10A,10B	54H 0335893, 6068923	0-6 cm: Light beige sand. 6-13 cm: Medium grey sand. 13-40 cm: Light grey sand with some segregations. Sampled large (2-5 cm) calcareous pebble. Only sampled to 35 cm (last layer sampled was 30-35 cm). At Point Malcolm at ~35 cm was a layer rich in calcareous stones and possibly buried A horizon.
	Schoenoplectus pungens	31/05/13	11A,11B	54H 0335897, 6068926	0-7 cm: Beige sand. 7-35 cm: Medium grey sand. At ~30 cm new surface with buried grass (?) and old A horizon. Only sampled to 35 cm (last layer sampled was 30-35 cm).
	Schoenoplectus validus	31/05/13	12A,12B	54H 0335897, 6068919	0-5 cm: Beige sand. 5-15 cm: Dark grey sand abundant root material. 15-35 cm: Light grey sand. Only sampled to 35 cm (last layer sampled was 30-35 cm).

APPENDIX 2. Laboratory procedure for carbon fractionation

SUMMARY OF LABORATORY PROCEDURE FOR CARBON FRACTIONATION

1. Soil is broken up to pass through an 8 mm sieve and air-dried at 60°C (Six *et al.* 2000; Plante *et al.* 2006b).

2. A 200g sample of soil is submerged in deionised water over a 2 mm sieve (Plante *et al.* 2006b) which is shaken up and down 3 cm 50 times over 2 mins (Six *et al.* 1998). The >2mm fraction is backwashed, oven dried at 60°C and weighed. The >2 mm floating material is discarded.

3. The water/soil sample is poured onto a 250 µm mesh screen above a 63 µm screen and gently shaken and flushed with water (Six *et al.* 2000).

4. The >250 µm material is collected (**cPOM**) and dried at 60°C.

5. Material on the 63 µm screen is wet sieved for 50 strokes over 2 mins.

6. The >63 µm fraction is collected (**µagg**) by gently backflushing the sieve, oven dried at 60°C and weighed.

7. The <63 µm suspension is centrifuged for 7 min at 127 x *g* to separate out silt-sized fraction (**dSilt**) and for 15 min at 1730 x *g* for the clay-sized fraction (**dClay**). The suspended clay fraction is flocculated with 0.25M $CaCl_2$–$MgCl_2$. Both fractions are then oven dried at 60°C and weighed.

8. From the **µagg** fraction (*from step 6*), a 5 g subsample is brought to room temperature and suspended in 35 mL of 1.85 g cm^{-3} sodium polytungstate (SPT) in a 50 mL graduated centrifuge tube. The tube is slowly reciprocally shaken 10 times (or more) to bring the sample into suspension (Six *et al.* 1998). Any material on the cap is washed into the sample with 10 mL SPT. The sample is then put under vacuum (100 kPa) for 10 mins and then allowed to equilibrate for 20 mins (Six *et al.* 1998).

9. The suspension is centrifuged for 1 hr at 1250 x *g*.

10. The floating material (**LF**) is aspirated onto a 20 µm nylon filter, rinsed thoroughly and transferred to an aluminium pan and dried at 50°C (Six *et al.* 1998).

11. The heavy fraction is rinsed twice with 50 mL deionised water and dispersed by shaking overnight with 12 glass beads (Stewart *et al.* 2009). After shaking, the sample is rinsed through a 63 µm sieve.

12. The >63 µm size fraction is flushed from the sieve, dried and weighed (**iPOM**).

13. The <63 µm size fraction is separated into **µSilt** and **µClay** by centrifugation.

14. A 0.5g sample of **dClay** and **dSilt** (*from step 7*) and **µSilt** and **µClay** (*from step 13*) is refluxed in 25 mL of 6M HCl for 16 hr. The suspensions are then washed and filtered with de-ionised water over a glass fibre filter, dried and weighed. This gives the non-hydrolysable C fractions (**NH-dSilt**, **NH-dClay**, **NH-µSilt** and **NH-µClay**) and hydrolysable C fractions (**H-dSilt**, **H-dClay**, **H-µSilt** and **H-µClay**).

APPENDIX 3. Characteristics of soil materials

Table 9-2. Soil characteristics of the Hunters Creek soil materials (May 2013).

Profile ID*	Depth Range (cm)	moisture content (%)	Bulk Density (g/cm³)	Sediment Fractions (%)					pH 1:5 soil:water	EC 1:5 soil:water (µS/cm)	Total N (%N)	Total C (%C)	Total Organic C (%C)	Total Carbonate (%C)
				>2mm	2mm – 250µm	250 – 63µm	Silt	Clay						
1A	0-2.5	84.38	0.17	27.72%	28.80%	9.79%	0.95%	0.99%	6.66	4,490	0.65	10.50	9.57	0.93
1A	2.5-5	67.21	0.39	54.44%	24.82%	10.52%	1.73%	1.44%	6.81	3,720	0.56	8.09	7.97	0.12
1A	5-10	62.26	0.50	54.54%	20.08%	15.50%	1.66%	1.15%	6.63	4,590	0.47	6.72	6.71	0.01
1A	10-15	63.00	0.52	47.26%	15.39%	26.40%	2.37%	1.59%	6.59	4,080	0.28	3.75	3.75	<0.01
1A	15-20	48.23	0.70	35.10%	13.92%	38.31%	5.80%	3.11%	6.48	3,690	0.23	3.22	3.22	<0.01
1A	20-30	47.37	0.80	30.52%	16.73%	41.38%	5.31%	2.64%	6.49	3,920	0.25	3.33	3.32	0.01
1A	30-40	50.17	0.74	15.84%	16.59%	59.24%	2.34%	2.19%	6.42	3,540	0.13	1.58	1.58	<0.01
1B	0-2.5	71.85	0.33	60.49%	17.33%	13.73%	0.67%	0.00%	6.41	3,670	0.52	8.07	7.92	0.15
1B	2.5-5	71.22	0.36	51.63%	20.39%	21.37%	1.42%	1.75%	6.87	3,540	0.37	5.72	5.72	<0.01
1B	5-10	59.31	0.56	38.27%	23.41%	30.94%	2.50%	2.33%	6.72	2,720	0.19	2.86	2.86	<0.01
1B	10-15	48.47	0.75	24.57%	16.93%	49.54%	4.67%	2.31%	6.62	3,030	0.22	3.23	3.23	<0.01
1B	15-20	31.78	1.13	19.70%	18.24%	53.18%	4.44%	2.46%	6.67	2,490	0.16	2.05	2.05	<0.01
1B	20-30	42.50	0.87	6.18%	12.70%	68.97%	7.69%	3.37%	6.64	2,140	0.12	1.49	1.49	<0.01
1B	30-40	44.79	0.88	2.91%	9.56%	75.55%	7.67%	3.20%	6.94	2,053	0.09	1.20	1.20	<0.01
2A	0-2.5	59.32	0.58	22.15%	51.45%	21.05%	0.62%	1.93%	5.69	2,160	0.16	1.92	1.89	0.03
2A	2.5-5	56.82	0.64	28.35%	51.63%	15.53%	0.83%	1.44%	5.63	2,550	0.13	1.32	1.22	0.11
2A	5-10	38.21	1.10	5.37%	25.38%	61.81%	0.30%	3.52%	5.08	2,250	0.08	0.98	0.90	0.08
2A	10-15	46.22	0.86	9.57%	14.91%	64.03%	2.43%	3.79%	5.15	2,320	0.09	1.00	0.93	0.07
2A	15-20	35.90	1.08	3.26%	10.14%	77.75%	6.11%	2.75%	4.65	1,791	0.07	0.74	0.67	0.07
2A	20-30	28.85	1.33	0.68%	8.11%	85.57%	1.87%	3.92%	4.20	1,545	0.07	0.44	0.43	0.02
2A	30-40	27.83	1.27	0.18%	19.57%	73.17%	3.70%	3.38%	6.09	1,280	0.04	0.32	0.25	0.06
2B	0-2.5	41.02	0.91	9.28%	11.15%	76.21%	0.21%	0.69%	6.37	1,332	0.09	1.29	1.21	0.08
2B	2.5-5	34.63	1.15	2.85%	17.58%	74.42%	0.32%	1.20%	6.21	1,052	0.09	1.68	1.62	0.06
2B	5-10	47.86	0.81	2.84%	29.89%	62.99%	1.41%	1.32%	5.65	1,787	0.09	1.23	1.12	0.11
2B	10-15	39.75	1.00	2.62%	18.28%	74.68%	3.25%	0.31%	5.89	1,810	0.08	0.99	0.91	0.08
2B	15-20	33.62	1.16	1.26%	8.14%	85.70%	1.56%	2.17%	4.96	1,721	0.06	0.70	0.63	0.06
2B	20-30	26.71	1.25	9.23%	7.33%	80.46%	1.30%	1.12%	4.24	1,261	0.04	0.37	0.30	0.07
2B	30-40	25.91	1.45	2.34%	4.44%	89.54%	1.46%	1.49%	6.58	1,118	0.03	0.42	0.21	0.21

** See Table 9-1 in Appendix 1 for site details.*

Table 9-3. Organic carbon fractionation (%C) of the Hunters Creek soil materials (May 2013).

Profile ID*	Depth Range (cm)	cPOM	LF	iPOM	µagg	µSilt	µClay	NH-dSilt	NH-dClay	H-dSilt	H-dClay	NH-µSilt	NH-µClay	H-µSilt	H-µClay	dSilt	dClay
1A	0-2.5	3.1807	-	0.1103	i.s.	0.1253	0.0612	0.0688	0.0840	0.0073	0.0046	0.1110	0.0623	0.0143	<0.0001	0.0761	0.0885
1A	2.5-5	2.2746	-	0.0679	0.4822	0.1774	0.0771	0.1112	0.0887	0.0056	0.0007	0.1581	0.0780	0.0193	<0.0001	0.1168	0.0893
1A	5-10	1.6538	-	0.0376	0.4343	0.1088	0.0529	0.0868	0.0548	0.0039	0.0019	0.0963	0.0589	0.0125	<0.0001	0.0908	0.0567
1A	10-15	1.0333	-	0.0520	0.3966	0.0956	0.0816	0.1008	0.0681	0.0006	<0.0001	0.0847	0.0896	0.0109	<0.0001	0.1014	0.0670
1A	15-20	0.9097	-	0.0458	0.4912	0.1222	0.0637	0.2026	0.0886	0.0206	<0.0001	0.1178	0.0733	0.0045	<0.0001	0.2232	0.0881
1A	20-30	1.0447	-	0.0404	0.5347	0.1151	0.0684	0.1806	0.0759	0.0114	<0.0001	0.1038	0.0809	0.0114	<0.0001	0.1920	0.0718
1A	30-40	0.5716	-	0.0307	0.4367	0.1447	0.1351	0.0515	0.0548	0.0020	<0.0001	0.1393	0.1508	0.0054	<0.0001	0.0535	0.0473
1B	0-2.5	1.6501	-	0.0766	0.2973	0.1424	0.0567	0.0341	-	0.0053	-	0.1233	0.0575	0.0192	<0.0001	0.0394	-
1B	2.5-5	1.4478	-	0.0527	0.4436	0.1552	0.0649	0.0591	0.0914	0.0093	0.0074	0.1349	0.0707	0.0203	<0.0001	0.0684	0.0989
1B	5-10	1.3952	-	0.0261	0.4225	0.1034	0.0902	0.0923	0.0850	0.0074	0.0053	0.0882	0.0975	0.0152	<0.0001	0.0998	0.0902
1B	10-15	1.0868	-	0.0254	0.7360	0.1165	0.0680	0.1797	0.0793	0.0008	0.0045	0.1130	0.0851	0.0035	<0.0001	0.1805	0.0838
1B	15-20	0.8846	-	0.0143	0.4322	0.0686	0.0363	0.1439	0.0669	0.0109	0.0038	-	0.0433	-	<0.0001	0.1548	0.0708
1B	20-30	0.6225	-	0.0281	0.4274	0.0759	0.0501	0.2152	0.0691	<0.0001	0.0019	-	-	-	-	0.2134	0.0710
1B	30-40	0.3977	-	0.0260	0.3247	0.0686	0.0345	0.2094	0.0692	<0.0001	0.0031	-	-	-	-	0.2091	0.0722
2A	0-2.5	0.8774	-	0.0160	0.1885	0.0658	0.0543	0.0108	0.0493	0.0008	<0.0001	0.0614	0.0588	0.0043	<0.0001	0.0116	0.0490
2A	2.5-5	0.7100	-	0.0097	0.1297	0.0598	0.0310	0.0164	0.0325	<0.0001	0.0001	0.0557	0.0346	0.0041	<0.0001	0.0162	0.0326
2A	5-10	0.4810	-	0.0311	0.2956	0.1141	0.0850	0.0014	0.0772	0.0008	0.0010	0.1100	0.1061	0.0041	<0.0001	0.0022	0.0782
2A	10-15	0.3796	-	0.0268	0.3414	0.1000	0.0749	0.0354	0.0777	0.0055	0.0029	0.0976	0.1006	0.0024	<0.0001	0.0409	0.0806
2A	15-20	0.2165	-	0.0144	0.2824	0.1021	0.0664	0.0354	0.0516	0.0089	0.0008	0.1074	0.0936	<0.0001	<0.0001	0.0443	0.0524
2A	20-30	0.1099	-	0.0277	0.2312	0.0845	0.0625	0.0198	0.0709	0.0044	0.0054	-	0.0818	-	<0.0001	0.0242	0.0763
2A	30-40	0.0687	-	0.0238	0.1238	0.0393	0.0373	0.0278	0.0618	0.0063	0.0033	-	-	-	-	0.0341	0.0651
2B	0-2.5	0.5610	-	0.0568	0.4037	0.1434	0.0350	0.0069	0.0294	0.0005	0.0005	-	-	-	-	0.0073	0.0299
2B	2.5-5	1.0019	-	0.0628	0.3503	0.1303	0.0385	-	0.0585	-	0.0022	-	-	-	-	0.0135	0.0607
2B	5-10	0.6576	-	0.0321	0.3179	0.0937	0.0362	0.0346	0.0370	0.0028	0.0010	-	-	-	-	0.0374	0.0380
2B	10-15	0.5028	-	0.0195	0.4337	0.0900	0.0426	0.0644	-	0.0116	-	-	-	-	-	0.0760	0.0059
2B	15-20	0.1963	-	0.0381	0.3863	0.1177	0.0772	0.0258	0.0424	0.0040	0.0032	0.1170	0.0972	0.0007	<0.0001	0.0298	0.0455
2B	20-30	0.0785	-	0.0169	0.2106	0.0525	0.0525	0.0182	0.0202	0.0037	0.0019	-	0.0757	-	<0.0001	0.0219	0.0221
2B	30-40	0.0292	-	0.0382	0.1842	0.0503	0.0357	0.0183	0.0267	0.0047	0.0010	-	-	-	-	0.0231	0.0277

** See Table 9-1 in Appendix 1 for site details.*

i.s. Insufficient sample

Table 9-4. Non-protected and protected organic carbon fractions (%C) of the Hunters Creek soil materials (May 2013).

Profile ID*	Depth Range (cm)	Chemical (H-dSilt + H-dClay)	Biochemical (NH-dSilt + NH-dClay)	Non-Protected (cPOM + LF#)	Physical (µagg + iPOM)
1A	0-2.5	0.0119	0.1528	3.1807	i.s.
1A	2.5-5	0.0063	0.1998	2.2746	0.5501
1A	5-10	0.0058	0.1417	1.6538	0.4719
1A	10-15	0.0006	0.1688	1.0333	0.4486
1A	15-20	0.0206	0.2912	0.9097	0.5370
1A	20-30	0.0114	0.2565	1.0447	0.5752
1A	30-40	0.0020	0.1063	0.5716	0.4674
1B	0-2.5	0.0053	0.0341	1.6501	0.3739
1B	2.5-5	0.0168	0.1505	1.4478	0.4962
1B	5-10	0.0127	0.1773	1.3952	0.4487
1B	10-15	0.0053	0.2590	1.0868	0.7614
1B	15-20	0.0148	0.2108	0.8846	0.4465
1B	20-30	0.0019	0.2843	0.6225	0.4555
1B	30-40	0.0031	0.2785	0.3977	0.3506
2A	0-2.5	0.0008	0.0601	0.8774	0.2044
2A	2.5-5	0.0001	0.0488	0.7100	0.1394
2A	5-10	0.0018	0.0786	0.4810	0.3267
2A	10-15	0.0084	0.1131	0.3796	0.3682
2A	15-20	0.0096	0.0870	0.2165	0.2968
2A	20-30	0.0098	0.0908	0.1099	0.2589
2A	30-40	0.0096	0.0896	0.0687	0.1476
2B	0-2.5	0.0009	0.0363	0.5610	0.4605
2B	2.5-5	0.0022	0.0585	1.0019	0.4131
2B	5-10	0.0038	0.0716	0.6576	0.3500
2B	10-15	0.0116	0.0644	0.5028	0.4532
2B	15-20	0.0072	0.0682	0.1963	0.4244
2B	20-30	0.0056	0.0384	0.0785	0.2275
2B	30-40	0.0057	0.0450	0.0292	0.2224

** See Table 9-1 in Appendix 1 for site details.*

 # LF carbon fraction not quantified.

i.s. Insufficient sample

Table 9-5. Soil characteristics of the Tolderol soil materials (May 2013).

Profile ID*	Depth Range (cm)	moisture content (%)	Bulk Density (g/cm³)	Sediment Fractions (%)					pH 1:5 soil:water	EC 1:5 soil:water (µS/cm)	Total N (%N)	Total C (%C)	Total Organic C (%C)	Total Carbonate (%C)
				>2mm	2mm – 250µm	250 – 63µm	Silt	Clay						
3A	0-2.5	21.30	1.58	0.00%	77.90%	19.89%	1.51%	0.02%	7.18	59.9	0.02	0.05	0.05	<0.01
3A	2.5-5	20.97	1.55	1.10%	10.43%	87.44%	0.62%	0.00%	7.16	44.7	0.02	0.05	0.03	0.03
3A	5-10	22.01	1.48	0.60%	1.20%	97.90%	0.03%	0.00%	7.06	53.2	0.02	0.06	0.01	0.05
3A	10-15	20.62	1.49	0.26%	3.34%	96.35%	0.02%	0.00%	6.97	50.5	0.03	0.04	<0.01	0.04
3A	15-20	20.53	1.52	0.00%	6.57%	93.34%	0.00%	0.00%	6.81	47.2	0.02	0.04	0.01	0.03
3A	20-30	20.02	1.55	0.01%	19.56%	80.08%	0.05%	0.01%	6.64	47.5	0.02	0.07	0.02	0.05
3A	30-40	19.85	1.46	0.82%	27.39%	71.45%	0.07%	0.05%	6.06	159.9	0.02	0.07	0.02	0.05
3B	0-2.5	21.00	1.53	0.00%	13.85%	85.92%	0.04%	0.00%	7.52	74.4	0.01	0.13	0.04	0.09
3B	2.5-5	21.61	1.54	0.07%	92.65%	7.09%	0.04%	0.00%	7.27	58.9	0.01	0.11	0.05	0.07
3B	5-10	21.86	1.57	0.00%	1.26%	98.57%	0.02%	0.00%	7.22	48.7	0.01	0.13	0.04	0.09
3B	10-15	21.35	1.50	0.00%	2.40%	97.32%	0.01%	0.00%	7.08	45.0	0.01	0.11	0.03	0.07
3B	15-20	21.31	1.50	0.00%	5.68%	94.18%	0.11%	0.00%	7.11	42.3	0.01	0.08	0.04	0.04
3B	20-30	20.72	1.49	0.11%	14.34%	85.08%	0.05%	0.00%	6.73	78.8	0.01	0.08	0.04	0.04
3B	30-40	20.81	1.52	0.09%	20.26%	79.29%	0.08%	0.03%	6.59	102.3	0.01	0.11	0.06	0.05
4A	0-2.5	22.02	1.38	0.20%	9.75%	86.00%	3.17%	0.01%	7.12	48.0	0.04	0.09	0.05	0.04
4A	2.5-5	18.53	1.42	0.30%	8.09%	88.98%	2.23%	0.01%	7.02	53.0	0.02	0.08	0.05	0.03
4A	5-10	15.54	1.40	0.26%	13.32%	85.45%	0.22%	0.01%	6.81	67.4	0.02	0.14	0.10	0.04
4A	10-15	15.05	1.53	0.00%	9.98%	88.36%	1.18%	0.02%	6.50	85.8	0.02	0.07	0.03	0.03
4A	15-20	13.55	1.56	0.06%	28.86%	70.05%	0.29%	0.04%	5.80	120.9	0.02	0.16	0.11	0.05
4A	20-30	13.25	1.46	0.00%	32.04%	67.28%	0.00%	0.05%	5.94	140.4	0.02	0.07	0.05	0.02
4A	30-40	14.46	1.53	0.00%	25.52%	73.76%	0.31%	0.04%	6.31	114.4	0.02	0.08	0.08	<0.01
4B	0-2.5	14.87	1.41	0.42%	2.54%	96.69%	0.04%	0.06%	7.27	46.2	0.01	0.12	0.07	0.05
4B	2.5-5	22.64	1.47	1.49%	3.85%	94.20%	0.08%	0.03%	7.14	45.4	0.01	0.11	0.07	0.04
4B	5-10	24.58	1.31	0.21%	1.74%	97.68%	0.06%	0.03%	6.68	60.6	0.01	0.10	0.06	0.04
4B	10-15	21.18	1.60	0.05%	7.57%	92.28%	0.03%	0.06%	6.16	64.7	0.01	0.11	0.07	0.04
4B	15-20	21.14	1.65	0.35%	22.07%	77.15%	0.02%	0.12%	5.56	96.1	0.01	0.12	0.06	0.06
4B	20-30	19.83	1.56	0.01%	16.77%	82.85%	0.07%	0.08%	5.44	85.3	0.01	0.09	0.06	0.04
4B	30-40	19.92	1.48	0.03%	21.81%	77.65%	0.08%	0.04%	6.03	123.1	0.01	0.11	0.06	0.05

** See Table 9-1 in Appendix 1 for site details.*

Table 9-6. Organic carbon fractionation (%C) of the Tolderol soil materials (May 2013).

Profile ID*	Depth Range (cm)	cPOM	LF	iPOM	µagg	µSilt	µClay	NH-dSilt	NH-dClay	H-dSilt	H-dClay	NH-µSilt	NH-µClay	H-µSilt	H-µClay	dSilt	dClay
3A	0-2.5	0.0594	-	-	0.0142	-	-	-	-	-	-	-	-	-	-	0.0009	-
3A	2.5-5	0.0093	-	-	0.0500	-	-	-	-	-	-	-	-	-	-	0.0004	-
3A	5-10	0.0016	-	-	0.0550	-	-	-	-	-	-	-	-	-	-	-	-
3A	10-15	0.0023	-	-	0.0445	-	-	-	-	-	-	-	-	-	-	-	-
3A	15-20	0.0034	-	-	0.0422	-	-	-	-	-	-	-	-	-	-	-	-
3A	20-30	0.0130	-	-	0.0378	-	-	-	-	-	-	-	-	-	-	-	-
3A	30-40	0.0223	-	-	0.0487	-	-	-	-	-	-	-	-	-	-	0.0004	0.0018
3B	0-2.5	0.0093	-	-	0.0625	-	-	-	-	-	-	-	-	-	-	0.0003	-
3B	2.5-5	0.0380	-	-	0.0052	-	-	-	-	-	-	-	-	-	-	0.0002	-
3B	5-10	0.0010	-	-	0.0746	-	-	-	-	-	-	-	-	-	-	-	-
3B	10-15	0.0009	-	-	0.0649	-	-	-	-	-	-	-	-	-	-	-	-
3B	15-20	0.0030	-	-	0.0835	-	-	-	-	-	-	-	-	-	-	0.0001	-
3B	20-30	0.0069	-	-	0.0511	-	-	-	-	-	-	-	-	-	-	0.0003	-
3B	30-40	0.0221	-	-	0.0814	-	-	-	-	-	-	-	-	-	-	0.0008	0.0012
4A	0-2.5	0.0167	-	-	0.0483	-	-	-	-	-	-	-	-	-	-	0.0032	-
4A	2.5-5	0.0121	-	-	0.0473	-	-	-	-	-	-	-	-	-	-	0.0022	0.0006
4A	5-10	0.0199	-	-	0.0942	-	-	-	-	-	-	-	-	-	-	0.0027	-
4A	10-15	0.0103	-	-	0.0700	-	-	-	-	-	-	-	-	-	-	0.0014	0.0006
4A	15-20	0.0379	-	-	0.0429	-	-	-	-	-	-	-	-	-	-	0.0010	0.0030
4A	20-30	0.0353	-	-	0.0513	-	-	-	-	-	-	-	-	-	-	-	0.0023
4A	30-40	0.0460	-	-	0.0584	-	-	-	-	-	-	-	-	-	-	0.0012	0.0021
4B	0-2.5	0.0073	-	-	0.1080	-	-	-	-	-	-	-	-	-	-	0.0004	0.0024
4B	2.5-5	0.0075	-	-	0.0967	-	-	-	-	-	-	-	-	-	-	0.0005	0.0014
4B	5-10	0.0034	-	-	0.1101	-	-	-	-	-	-	-	-	-	-	0.0003	0.0011
4B	10-15	0.0074	-	-	0.0735	-	-	-	-	-	-	-	-	-	-	0.0002	0.0017
4B	15-20	0.0157	-	-	0.0653	-	-	-	-	-	-	-	-	-	-	0.0002	0.0046
4B	20-30	0.0136	-	-	0.0768	-	-	-	-	-	-	-	-	-	-	0.0003	0.0031
4B	30-40	0.0155	-	-	0.0891	-	-	-	-	-	-	-	-	-	-	0.0006	0.0018

** See Table 9-1 in Appendix 1 for site details.*

Table 9-7. Non-protected and protected organic carbon fractions (%C) of the Tolderol soil materials (May 2013).

Profile ID*	Depth Range (cm)	Chemical (H-dSilt + H-dClay)	Biochemical (NH-dSilt + NH-dClay)	Non-Protected (cPOM + LF#)	Physical (µagg + iPOM#)
3A	0-2.5	-	-	0.0594	0.0142
3A	2.5-5	-	-	0.0093	0.0500
3A	5-10	-	-	0.0016	0.0550
3A	10-15	-	-	0.0023	0.0445
3A	15-20	-	-	0.0034	0.0422
3A	20-30	-	-	0.0130	0.0378
3A	30-40	-	-	0.0223	0.0487
3B	0-2.5	-	-	0.0093	0.0625
3B	2.5-5	-	-	0.0380	0.0052
3B	5-10	-	-	0.0010	0.0746
3B	10-15	-	-	0.0009	0.0649
3B	15-20	-	-	0.0030	0.0835
3B	20-30	-	-	0.0069	0.0511
3B	30-40	-	-	0.0221	0.0814
4A	0-2.5	-	-	0.0167	0.0483
4A	2.5-5	-	-	0.0121	0.0473
4A	5-10	-	-	0.0199	0.0942
4A	10-15	-	-	0.0103	0.0700
4A	15-20	-	-	0.0379	0.0429
4A	20-30	-	-	0.0353	0.0513
4A	30-40	-	-	0.0460	0.0584
4B	0-2.5	-	-	0.0073	0.1080
4B	2.5-5	-	-	0.0075	0.0967
4B	5-10	-	-	0.0034	0.1101
4B	10-15	-	-	0.0074	0.0735
4B	15-20	-	-	0.0157	0.0653
4B	20-30	-	-	0.0136	0.0768
4B	30-40	-	-	0.0155	0.0891

** See Table 9-1 in Appendix 1 for site details.*

 # LF and iPOM carbon fractions not quantified.

Table 9-8. Soil characteristics of the Loveday Bay soil materials (May 2013).

Profile ID*	Depth Range (cm)	moisture content (%)	Bulk Density (g/cm³)	Sediment Fractions (%)					pH 1:5 soil:water	EC 1:5 soil:water (µS/cm)	Total N (%N)	Total C (%C)	Total Organic C (%C)	Total Carbonate (%C)
				>2mm	2mm – 250µm	250 – 63µm	Silt	Clay						
5A	0-2.5	19.49	1.44	0.00%	46.56%	52.70%	0.45%	0.04%	7.07	64.1	0.03	0.07	0.05	0.02
5A	2.5-5	18.22	1.52	0.02%	49.41%	49.82%	0.20%	0.10%	6.51	65.8	0.02	0.08	0.04	0.04
5A	5-10	17.05	1.61	0.12%	63.99%	35.22%	0.25%	0.10%	5.18	109.0	0.02	0.10	0.07	0.03
5A	10-15	16.78	1.46	0.09%	61.91%	37.39%	0.14%	0.10%	6.98	93.4	0.02	0.07	0.04	0.03
5A	15-20	17.22	1.36	0.42%	61.01%	36.41%	0.78%	0.68%	8.64	112.3	0.04	0.04	0.01	0.03
5A	20-30	17.66	1.57	0.30%	60.90%	36.10%	1.71%	0.64%	8.50	84.9	0.02	0.02	<0.01	0.02
5A	30-40	18.17	1.49	0.00%	61.20%	35.91%	1.63%	0.85%	7.78	45.4	0.02	0.01	0.01	<0.01
5B	0-2.5	18.58	1.48	0.04%	55.45%	43.74%	0.02%	0.02%	6.24	49.3	0.01	0.08	0.03	0.06
5B	2.5-5	18.91	1.45	0.00%	51.92%	47.67%	0.02%	0.02%	6.21	57.0	<0.01	0.07	0.02	0.05
5B	5-10	17.00	1.45	0.41%	44.97%	54.05%	0.04%	0.04%	6.14	63.0	0.01	0.09	0.05	0.04
5B	10-15	16.92	1.50	0.06%	53.54%	45.58%	0.06%	0.09%	5.68	95.6	0.01	0.07	0.04	0.03
5B	15-20	16.49	1.52	2.05%	60.67%	36.61%	0.15%	0.07%	5.50	135.3	0.01	0.11	0.06	0.05
5B	20-30	16.81	1.38	0.16%	68.84%	29.72%	0.37%	0.42%	6.67	109.4	0.01	0.07	0.07	<0.01
5B	30-40	16.58	1.48	0.00%	47.76%	49.21%	1.09%	0.96%	7.31	33.2	0.01	0.05	0.03	0.02
6A	0-2.5	63.61	0.38	3.70%	82.72%	11.48%	0.11%	0.17%	7.37	199.8	0.04	0.45	0.36	0.09
6A	2.5-5	21.12	1.33	2.25%	91.49%	5.78%	0.03%	0.07%	7.10	77.3	0.02	0.07	0.04	0.04
6A	5-10	18.47	1.47	0.81%	93.96%	4.91%	0.03%	0.03%	6.89	52.0	0.02	0.05	0.01	0.05
6A	10-15	17.02	1.45	0.39%	79.65%	19.07%	0.35%	0.05%	6.21	110.8	0.02	0.15	0.14	0.01
6A	15-20	17.31	1.41	0.00%	73.94%	25.57%	0.09%	0.06%	5.49	91.1	0.01	0.06	0.03	0.04
6A	20-30	17.51	1.47	0.10%	73.93%	25.55%	0.04%	0.29%	6.20	80.3	0.02	0.07	0.04	0.03
6A	30-40	16.92	1.46	0.52%	85.37%	12.26%	0.63%	0.67%	8.52	103.9	0.02	0.04	0.01	0.04
6B	0-2.5	26.53	1.20	0.69%	72.48%	25.38%	0.28%	0.18%	6.76	135.9	0.03	0.34	0.30	0.04
6B	2.5-5	19.63	1.44	0.30%	79.55%	19.38%	0.09%	0.04%	6.82	75.3	0.01	0.11	0.09	0.02
6B	5-10	20.51	1.42	0.15%	88.53%	10.75%	0.01%	0.02%	6.41	63.8	<0.01	0.05	0.04	0.02
6B	10-15	22.14	1.26	1.08%	83.61%	14.45%	0.15%	0.03%	5.15	115.8	0.01	0.14	0.09	0.04
6B	15-20	18.51	1.58	0.21%	63.05%	35.71%	0.08%	0.12%	5.56	76.5	<0.01	0.10	0.10	<0.01
6B	20-30	17.11	1.45	0.00%	59.47%	39.99%	0.07%	0.03%	5.07	81.5	0.01	0.11	0.08	0.02
6B	30-40	18.90	1.40	0.09%	60.47%	37.98%	0.22%	0.31%	6.15	70.9	0.01	0.10	0.07	0.03

** See Table 9-1 in Appendix 1 for site details.*

Table 9-8 (continued). Soil characteristics of the Loveday Bay soil materials (May 2013).

Profile ID*	Depth Range (cm)	moisture content (%)	Bulk Density (g/cm³)	Sediment Fractions (%)					pH 1:5 soil:water	EC 1:5 soil:water (µS/cm)	Total N (%N)	Total C (%C)	Total Organic C (%C)	Total Carbonate (%C)
				>2mm	2mm – 250µm	250 – 63µm	Silt	Clay						
7A	0-2.5	24.11	1.28	3.36%	78.33%	16.84%	0.22%	0.13%	7.58	104.1	0.04	0.31	0.22	0.09
7A	2.5-5	24.36	1.43	2.43%	64.04%	31.97%	0.06%	0.19%	7.52	114.5	0.03	0.31	0.24	0.07
7A	5-10	22.35	1.32	3.35%	69.81%	25.75%	0.16%	0.15%	7.33	84.8	0.02	0.13	0.10	0.03
7A	10-15	18.78	1.47	0.13%	64.20%	34.83%	0.19%	0.13%	6.72	62.5	0.02	0.08	0.08	<0.01
7A	15-20	19.01	1.41	0.23%	71.52%	27.64%	0.13%	0.07%	6.52	60.1	0.02	0.07	0.04	0.03
7A	20-30	19.06	1.39	0.08%	73.08%	26.42%	0.06%	0.06%	6.25	79.2	0.02	0.08	0.02	0.06
7A	30-40	17.17	1.45	0.42%	68.02%	30.06%	0.53%	0.00%	8.46	122.8	0.01	0.06	<0.01	0.05
7B	0-2.5	20.76	1.36	2.75%	48.06%	48.25%	0.08%	0.10%	6.68	63.2	0.02	0.17	0.14	0.02
7B	2.5-5	20.86	1.41	1.61%	59.89%	37.84%	0.10%	0.09%	6.50	67.8	0.01	0.14	0.10	0.03
7B	5-10	18.94	1.36	0.91%	81.05%	17.54%	0.05%	0.08%	6.46	53.0	0.01	0.09	0.05	0.05
7B	10-15	19.52	1.34	0.67%	82.93%	15.83%	0.04%	0.06%	6.54	40.2	0.01	0.08	0.08	<0.01
7B	15-20	19.72	1.36	2.23%	78.40%	18.71%	0.11%	0.09%	6.21	49.0	0.01	0.09	0.08	0.01
7B	20-30	19.14	1.45	2.36%	60.55%	36.23%	0.17%	0.19%	4.74	104.2	0.02	0.12	0.11	0.02
7B	30-40	19.07	1.46	0.83%	60.14%	38.15%	0.21%	0.28%	6.45	150.0	0.01	0.12	0.08	0.04
8A	0-2.5	20.20	1.46	0.16%	85.62%	13.44%	0.12%	0.03%	7.41	71.9	0.01	0.07	0.03	0.04
8A	2.5-5	18.20	1.54	0.06%	75.60%	23.58%	0.25%	0.04%	6.64	84.3	0.01	0.06	0.03	0.03
8A	5-10	17.64	1.52	0.02%	74.93%	24.11%	0.37%	0.04%	6.31	74.6	0.01	0.06	0.01	0.05
8A	10-15	16.76	1.45	0.02%	88.04%	11.29%	0.19%	0.04%	6.22	70.9	<0.01	0.06	0.01	0.05
8A	15-20	17.37	1.45	0.44%	84.13%	14.78%	0.10%	0.07%	7.85	90.8	<0.01	0.05	0.01	0.04
8A	20-30	16.96	1.46	0.87%	85.64%	11.46%	0.97%	0.39%	8.07	73.0	<0.01	0.02	<0.01	0.02
8A	30-40	19.23	1.47	0.01%	62.03%	34.54%	1.93%	1.13%	7.73	34.7	<0.01	<0.01	<0.01	<0.01
8B	0-2.5	19.26	1.31	1.26%	63.00%	35.22%	0.03%	0.04%	6.73	80.9	0.02	0.11	0.09	0.02
8B	2.5-5	18.92	1.34	0.19%	72.38%	26.92%	0.05%	0.04%	6.51	80.6	0.02	0.11	0.07	0.04
8B	5-10	17.93	1.48	0.15%	72.14%	27.34%	0.04%	0.05%	6.39	78.2	0.02	0.09	0.06	0.03
8B	10-15	17.75	1.45	0.14%	72.12%	27.05%	0.14%	0.00%	6.34	90.7	0.02	0.11	0.10	0.01
8B	15-20	18.16	1.42	0.49%	73.53%	25.16%	0.07%	0.00%	7.88	130.7	0.02	0.11	0.07	0.04
8B	20-30	17.82	1.57	0.34%	54.23%	42.00%	1.73%	1.31%	8.04	84.0	0.02	0.07	0.04	0.03
8B	30-40	17.62	1.46	0.00%	61.35%	36.28%	1.03%	0.56%	8.10	35.0	0.01	0.12	0.03	0.09

** See Table 9-1 in Appendix 1 for site details.*

Table 9-9. Organic carbon fractionation (%C) of the Loveday Bay soil materials (May 2013).

Profile ID*	Depth Range (cm)	cPOM	LF	iPOM	µagg	µSilt	µClay	NH-dSilt	NH-dClay	H-dSilt	H-dClay	NH-µSilt	NH-µClay	H-µSilt	H-µClay	dSilt	dClay
5A	0-2.5	0.0388	-	-	0.0523	-	-	-	-	-	-	-	-	-	-	0.0031	0.0032
5A	2.5-5	0.0515	-	-	0.0524	-	-	-	-	-	-	-	-	-	-	0.0025	0.0040
5A	5-10	0.0527	-	-	0.0413	-	-	-	-	-	-	-	-	-	-	0.0023	0.0044
5A	10-15	0.0454	-	-	0.0315	-	-	-	-	-	-	-	-	-	-	0.0013	0.0047
5A	15-20	0.0132	-	-	0.0086	-	-	-	0.0048	-	0.0003	-	-	-	-	0.0040	0.0051
5A	20-30	0.0215	-	-	<0.0001	-	-	-	-	-	-	-	-	-	-	0.0062	0.0040
5A	30-40	0.0265	-	-	0.0084	-	-	-	-	-	-	-	-	-	-	0.0101	0.0042
5B	0-2.5	0.0128	-	-	0.0327	-	-	-	-	-	-	-	-	-	-	-	0.0015
5B	2.5-5	0.0197	-	-	0.0294	-	-	-	-	-	-	-	-	-	-	-	0.0011
5B	5-10	0.0243	-	-	0.0350	-	-	-	-	-	-	-	-	-	-	0.0013	0.0020
5B	10-15	0.0236	-	-	0.0386	-	-	-	-	-	-	-	-	-	-	0.0003	0.0034
5B	15-20	0.0315	-	-	0.0530	-	-	-	-	-	-	-	-	-	-	0.0032	0.0030
5B	20-30	0.0262	-	-	0.0264	-	-	-	-	-	-	-	-	-	-	0.0028	0.0037
5B	30-40	0.0162	-	-	0.0112	-	-	-	-	-	-	-	-	-	-	0.0067	0.0052
6A	0-2.5	0.2889	-	-	0.0594	-	-	-	-	-	-	-	-	-	-	0.0052	0.0107
6A	2.5-5	0.0616	-	-	0.0095	-	-	-	-	-	-	-	-	-	-	0.0008	0.0040
6A	5-10	0.0773	-	-	0.0057	-	-	-	-	-	-	-	-	-	-	0.0009	0.0016
6A	10-15	0.0759	-	-	0.0283	-	-	-	-	-	-	-	-	-	-	0.0071	0.0021
6A	15-20	0.0595	-	-	0.0179	-	-	-	-	-	-	-	-	-	-	0.0005	0.0032
6A	20-30	0.0603	-	-	0.0204	-	-	-	-	-	-	-	-	-	-	0.0007	0.0052
6A	30-40	0.0264	-	-	0.0118	-	-	-	-	-	-	-	-	-	-	0.0042	0.0074
6B	0-2.5	0.2348	-	-	0.0982	-	-	-	-	-	-	-	-	-	-	0.0133	0.0095
6B	2.5-5	0.0692	-	-	0.0282	-	-	-	-	-	-	-	-	-	-	0.0032	0.0021
6B	5-10	0.0283	-	-	0.0071	-	-	-	-	-	-	-	-	-	-	0.0004	-
6B	10-15	0.0301	-	-	0.0168	-	-	-	-	-	-	-	-	-	-	0.0044	-
6B	15-20	0.0284	-	-	0.0286	-	-	-	-	-	-	-	-	-	-	0.0013	0.0065
6B	20-30	0.0238	-	-	0.0406	-	-	-	-	-	-	-	-	-	-	0.0021	0.0020
6B	30-40	0.0115	-	-	0.0324	-	-	-	-	-	-	-	-	-	-	0.0034	0.0059

** See Table 9-1 in Appendix 1 for site details.*

Table 9-9 (continued). Organic carbon fractionation (%C) of the Loveday Bay soil materials (May 2013).

Profile ID*	Depth Range (cm)	cPOM	LF	iPOM	µagg	µSilt	µClay	NH-dSilt	NH-dClay	H-dSilt	H-dClay	NH-µSilt	NH-µClay	H-µSilt	H-µClay	dSilt	dClay
7A	0-2.5	0.1617	-	-	0.0495	-	-	-	-	-	-	-	-	-	-	0.0039	0.0078
7A	2.5-5	0.1303	-	-	0.0703	-	-	-	-	-	-	-	-	-	-	0.0029	0.0100
7A	5-10	0.0897	-	-	0.0566	-	-	-	-	-	-	-	-	-	-	0.0057	0.0073
7A	10-15	0.0626	-	-	0.0439	-	-	-	-	-	-	-	-	-	-	0.0044	0.0048
7A	15-20	0.0468	-	-	0.0260	-	-	-	-	-	-	-	-	-	-	0.0022	0.0035
7A	20-30	0.0588	-	-	0.0346	-	-	-	-	-	-	-	-	-	-	0.0005	0.0035
7A	30-40	0.0260	-	-	0.0204	-	-	-	-	-	-	-	-	-	-	0.0025	0.0001
7B	0-2.5	0.0577	-	-	0.0576	-	-	-	-	-	-	-	-	-	-	0.0019	0.0056
7B	2.5-5	0.0569	-	-	0.0403	-	-	-	-	-	-	-	-	-	-	0.0024	0.0045
7B	5-10	0.0673	-	-	0.0139	-	-	-	-	-	-	-	-	-	-	0.0007	0.0040
7B	10-15	0.0290	-	-	0.0080	-	-	-	-	-	-	-	-	-	-	0.0009	0.0029
7B	15-20	0.0337	-	-	0.0149	-	-	-	-	-	-	-	-	-	-	0.0028	0.0035
7B	20-30	0.0436	-	-	0.0389	-	-	-	-	-	-	-	-	-	-	0.0033	0.0070
7B	30-40	0.0235	-	-	0.0318	-	-	-	-	-	-	-	-	-	-	0.0035	0.0056
8A	0-2.5	0.0706	-	-	0.0133	-	-	-	-	-	-	-	-	-	-	0.0003	0.0018
8A	2.5-5	0.0510	-	-	0.0186	-	-	-	-	-	-	-	-	-	-	0.0006	0.0024
8A	5-10	0.0506	-	-	0.0236	-	-	-	-	-	-	-	-	-	-	0.0009	0.0027
8A	10-15	0.0647	-	-	0.0126	-	-	-	-	-	-	-	-	-	-	0.0008	0.0024
8A	15-20	0.0526	-	-	0.0176	-	-	-	-	-	-	-	-	-	-	0.0006	0.0033
8A	20-30	0.0197	-	-	0.0093	-	-	-	-	-	-	-	-	-	-	0.0046	0.0024
8A	30-40	<0.0001	-	-	0.0193	-	-	-	-	-	-	-	-	-	-	0.0083	0.0050
8B	0-2.5	0.0479	-	-	0.0322	-	-	-	-	-	-	-	-	-	-	0.0005	0.0020
8B	2.5-5	0.0318	-	-	0.0192	-	-	-	-	-	-	-	-	-	-	0.0005	0.0023
8B	5-10	0.0476	-	-	0.0190	-	-	-	-	-	-	-	-	-	-	0.0009	0.0027
8B	10-15	0.0245	-	-	0.0215	-	-	-	-	-	-	-	-	-	-	0.0020	-
8B	15-20	0.0265	-	-	0.0190	-	-	-	-	-	-	-	-	-	-	0.0013	-
8B	20-30	0.0125	-	-	0.0060	-	-	-	-	-	-	-	-	-	-	0.0102	0.0084
8B	30-40	0.0006	-	-	0.0103	-	-	-	-	-	-	-	-	-	-	0.0051	0.0031

** See Table 9-1 in Appendix 1 for site details.*

Table 9-10. Non-protected and protected organic carbon fractions (%C) of the Loveday Bay soil materials (May 2013).

Profile ID*	Depth Range (cm)	Chemical (H-dSilt + H-dClay)	Biochemical (NH-dSilt + NH-dClay)	Non-Protected (cPOM + LF#)	Physical (µagg + iPOM#)
5A	0-2.5	-	-	0.0388	0.0523
5A	2.5-5	-	-	0.0515	0.0524
5A	5-10	-	-	0.0527	0.0413
5A	10-15	-	-	0.0454	0.0315
5A	15-20	-	-	0.0132	0.0086
5A	20-30	-	-	0.0215	<0.0001
5A	30-40	-	-	0.0265	0.0084
5B	0-2.5	-	-	0.0128	0.0327
5B	2.5-5	-	-	0.0197	0.0294
5B	5-10	-	-	0.0243	0.0350
5B	10-15	-	-	0.0236	0.0386
5B	15-20	-	-	0.0315	0.0530
5B	20-30	-	-	0.0262	0.0264
5B	30-40	-	-	0.0162	0.0112
6A	0-2.5	-	-	0.2889	0.0594
6A	2.5-5	-	-	0.0616	0.0095
6A	5-10	-	-	0.0773	0.0057
6A	10-15	-	-	0.0759	0.0283
6A	15-20	-	-	0.0595	0.0179
6A	20-30	-	-	0.0603	0.0204
6A	30-40	-	-	0.0264	0.0118
6B	0-2.5	-	-	0.2348	0.0982
6B	2.5-5	-	-	0.0692	0.0282
6B	5-10	-	-	0.0283	0.0071
6B	10-15	-	-	0.0301	0.0168
6B	15-20	-	-	0.0284	0.0286
6B	20-30	-	-	0.0238	0.0406
6B	30-40	-	-	0.0115	0.0324
7A	0-2.5	-	-	0.1617	0.0495
7A	2.5-5	-	-	0.1303	0.0703
7A	5-10	-	-	0.0897	0.0566
7A	10-15	-	-	0.0626	0.0439
7A	15-20	-	-	0.0468	0.0260
7A	20-30	-	-	0.0588	0.0346
7A	30-40	-	-	0.0260	0.0204
7B	0-2.5	-	-	0.0577	0.0576
7B	2.5-5	-	-	0.0569	0.0403
7B	5-10	-	-	0.0673	0.0139
7B	10-15	-	-	0.0290	0.0080
7B	15-20	-	-	0.0337	0.0149
7B	20-30	-	-	0.0436	0.0389
7B	30-40	-	-	0.0235	0.0318

** See Table 9-1 in Appendix 1 for site details.*

 # LF and iPOM carbon fractions not quantified.

Table 9-10 (continued). Non-protected and protected organic carbon fractions (%C) of the Loveday Bay soil materials (May 2013).

Profile ID*	Depth Range (cm)	Chemical (H-dSilt + H-dClay)	Biochemical (NH-dSilt + NH-dClay)	Non-Protected (cPOM + LF#)	Physical (µagg + iPOM#)
8A	0-2.5	-	-	0.0706	0.0133
8A	2.5-5	-	-	0.0510	0.0186
8A	5-10	-	-	0.0506	0.0236
8A	10-15	-	-	0.0647	0.0126
8A	15-20	-	-	0.0526	0.0176
8A	20-30	-	-	0.0197	0.0093
8A	30-40	-	-	<0.0001	0.0193
8B	0-2.5	-	-	0.0479	0.0322
8B	2.5-5	-	-	0.0318	0.0192
8B	5-10	-	-	0.0476	0.0190
8B	10-15	-	-	0.0245	0.0215
8B	15-20	-	-	0.0265	0.0190
8B	20-30	-	-	0.0125	0.0060
8B	30-40	-	-	0.0006	0.0103

** See Table 9-1 in Appendix 1 for site details.*

 # LF and iPOM carbon fractions not quantified.

Table 9-11. Soil characteristics of the Point Malcolm soil materials (May 2013).

Profile ID*	Depth Range (cm)	moisture content (%)	Bulk Density (g/cm³)	Sediment Fractions (%)					pH 1:5 soil:water	EC 1:5 soil:water (µS/cm)	Total N (%N)	Total C (%C)	Total Organic C (%C)	Total Carbonate (%C)
				>2mm	2mm – 250µm	250 – 63µm	Silt	Clay						
9A	0-2.5	20.70	1.30	1.29%	35.76%	62.35%	0.00%	0.11%	9.01	103.5	0.02	0.63	0.12	0.51
9A	2.5-5	21.11	1.41	2.35%	26.13%	69.84%	0.54%	0.30%	8.42	193.6	0.03	0.63	0.17	0.47
9A	5-10	19.99	1.44	0.87%	40.41%	57.56%	0.37%	0.17%	8.58	224.0	0.03	0.59	0.18	0.41
9A	10-15	18.59	1.34	0.46%	36.33%	62.05%	0.66%	0.15%	8.96	127.6	<0.01	0.45	0.15	0.30
9A	15-20	17.99	1.27	0.65%	19.46%	73.49%	5.48%	0.92%	8.84	129.7	0.02	0.66	0.26	0.40
9A	20-30	20.55	1.37	1.73%	17.94%	75.16%	0.50%	1.74%	8.78	140.8	0.03	0.62	0.30	0.32
9A	30-35	18.33	1.38	0.93%	22.03%	75.37%	0.58%	0.33%	8.97	131.5	0.01	0.59	0.16	0.43
9B	0-2.5	20.91	1.48	2.31%	83.60%	12.84%	0.23%	0.10%	9.10	110.7	0.01	0.51	0.05	0.46
9B	2.5-5	20.43	1.27	6.67%	79.30%	13.53%	0.27%	0.23%	8.95	185.9	0.02	0.55	0.08	0.48
9B	5-10	19.29	1.37	0.14%	92.34%	6.63%	0.04%	0.06%	8.98	152.8	0.01	0.52	0.07	0.45
9B	10-15	19.00	1.40	2.69%	89.66%	6.62%	0.37%	0.17%	9.04	140.0	0.01	0.50	0.08	0.42
9B	15-20	23.61	1.24	3.10%	62.12%	30.07%	2.93%	0.78%	8.90	139.2	0.02	0.52	0.18	0.34
9B	20-30	17.35	1.50	5.15%	36.72%	53.88%	2.32%	1.49%	8.82	135.1	0.01	0.52	0.19	0.33
9B	30-35	18.48	1.46	1.51%	73.43%	23.32%	0.61%	0.69%	9.04	123.7	0.01	0.51	0.08	0.43
10A	0-2.5	20.12	1.32	0.35%	35.45%	63.47%	0.20%	0.09%	9.32	104.3	0.01	0.51	0.02	0.50
10A	2.5-5	19.65	1.30	0.31%	31.53%	67.39%	0.12%	0.09%	9.25	109.8	<0.01	0.47	0.03	0.44
10A	5-10	19.80	1.39	0.08%	28.92%	68.81%	1.02%	0.69%	8.93	149.7	0.01	0.51	0.11	0.39
10A	10-15	20.48	1.39	0.06%	13.24%	84.08%	1.50%	0.57%	8.89	155.2	0.04	0.61	0.12	0.49
10A	15-20	18.03	1.50	0.06%	9.79%	85.08%	0.98%	0.42%	9.10	105.7	0.02	0.43	0.06	0.37
10A	20-30	19.57	1.31	0.08%	20.51%	78.39%	0.51%	0.20%	9.06	90.2	0.03	0.20	0.04	0.16
10A	30-35	20.04	1.14	1.11%	30.85%	66.19%	0.57%	0.16%	8.65	121.8	0.02	0.25	0.14	0.12
10B	0-2.5	19.76	1.53	2.74%	5.37%	91.44%	0.06%	0.08%	8.84	109.6	0.01	0.40	0.11	0.28
10B	2.5-5	19.37	1.46	0.50%	8.29%	89.78%	0.36%	0.35%	8.74	159.3	0.03	0.53	0.23	0.31
10B	5-10	19.22	1.46	0.17%	7.86%	90.55%	0.23%	0.65%	8.90	134.0	0.02	0.40	0.15	0.25
10B	10-15	18.93	1.55	0.22%	5.06%	93.64%	0.26%	0.45%	8.91	130.2	0.02	0.34	0.14	0.19
10B	15-20	18.09	1.56	0.29%	4.97%	93.59%	0.20%	0.36%	8.95	112.8	0.01	0.43	0.20	0.23
10B	20-30	22.06	1.45	0.47%	11.11%	86.91%	0.58%	0.41%	8.88	110.5	0.02	0.44	0.18	0.25

** See Table 9-1 in Appendix 1 for site details.*

Table 9-11 (continued). Soil characteristics of the Point Malcolm soil materials (May 2013).

Profile ID*	Depth Range (cm)	moisture content (%)	Bulk Density (g/cm³)	Sediment Fractions (%)					pH 1:5 soil:water	EC 1:5 soil:water (µS/cm)	Total N (%N)	Total C (%C)	Total Organic C (%C)	Total Carbonate (%C)
				>2mm	2mm – 250µm	250 – 63µm	Silt	Clay						
11A	0-2.5	24.37	1.39	1.87%	82.59%	14.49%	0.18%	0.14%	8.83	149.8	0.05	0.62	0.20	0.42
11A	2.5-5	22.67	1.46	12.08%	77.63%	9.57%	0.08%	0.15%	9.04	134.0	0.05	0.49	0.11	0.38
11A	5-10	19.43	1.49	1.51%	91.64%	6.42%	0.06%	0.10%	9.19	137.4	0.01	0.45	0.05	0.40
11A	10-15	19.75	1.40	0.16%	18.45%	78.38%	2.08%	0.93%	9.06	115.9	0.04	0.51	0.09	0.42
11A	15-20	23.26	1.39	2.95%	69.94%	23.24%	0.94%	1.32%	8.71	151.9	0.05	0.97	0.37	0.60
11A	20-30	20.17	1.42	1.94%	90.93%	5.62%	0.40%	0.55%	9.01	103.2	0.03	0.60	0.12	0.49
11A	30-35	19.71	n.a.	0.97%	15.23%	83.22%	0.03%	0.00%	9.27	139.8	0.01	0.29	0.17	0.11
11B	0-2.5	20.97	1.50	2.96%	20.69%	75.69%	0.09%	0.12%	9.05	107.1	0.01	0.51	0.16	0.35
11B	2.5-5	19.73	1.47	0.94%	22.11%	76.35%	0.09%	0.19%	9.08	119.9	0.02	0.52	0.14	0.38
11B	5-10	19.06	1.58	0.52%	24.71%	73.94%	0.13%	0.21%	9.11	114.1	0.03	0.43	0.11	0.31
11B	10-15	21.37	1.49	0.39%	17.85%	79.96%	0.44%	0.77%	8.96	146.1	0.02	0.54	0.18	0.36
11B	15-20	22.55	1.38	1.31%	7.28%	86.25%	3.02%	1.43%	8.72	168.0	0.04	0.87	0.37	0.50
11B	20-30	18.48	1.52	2.38%	10.20%	84.07%	1.47%	1.11%	8.79	116.7	0.04	0.51	0.27	0.23
11B	30-35	21.60	n.a.	0.62%	16.76%	82.13%	0.25%	0.35%	8.98	120.3	0.01	0.55	0.23	0.32
12A	0-2.5	21.96	1.41	9.85%	33.90%	55.54%	0.05%	0.14%	9.23	105.8	0.03	0.53	0.04	0.49
12A	2.5-5	20.35	1.41	7.22%	77.82%	14.69%	0.02%	0.08%	9.26	115.5	0.04	0.51	0.03	0.48
12A	5-10	22.85	1.30	5.45%	27.76%	66.15%	0.06%	0.11%	8.94	181.9	0.02	0.40	0.06	0.35
12A	10-15	18.19	1.54	1.03%	39.26%	59.01%	0.06%	0.19%	9.04	153.4	0.02	0.42	0.09	0.33
12A	15-20	19.34	1.48	0.07%	17.24%	81.86%	0.14%	0.23%	9.12	166.9	0.01	0.74	0.04	0.70
12A	20-30	18.80	1.53	0.13%	64.67%	34.52%	0.09%	0.31%	9.12	159.2	0.04	0.36	0.03	0.33
12B	0-2.5	21.12	1.51	1.60%	38.98%	58.50%	0.03%	0.18%	9.01	116.2	0.03	0.62	0.19	0.42
12B	2.5-5	20.21	1.44	0.40%	29.42%	69.13%	0.08%	0.18%	9.13	132.4	0.03	0.59	0.12	0.47
12B	5-10	19.56	1.50	0.41%	33.81%	64.73%	0.13%	0.16%	8.83	143.5	0.03	0.46	0.19	0.27
12B	10-15	19.66	1.51	0.37%	19.27%	79.69%	0.10%	0.19%	8.97	138.1	0.03	0.52	0.17	0.35
12B	15-20	21.81	1.45	0.08%	7.59%	91.34%	0.20%	0.24%	9.02	152.3	0.03	0.88	0.16	0.72
12B	20-30	20.51	1.48	0.82%	26.12%	71.22%	0.50%	0.46%	8.92	171.5	0.03	0.58	0.28	0.30
12B	30-35	21.31	1.52	1.56%	37.52%	59.18%	0.20%	0.46%	8.94	155.0	0.02	0.65	0.17	0.48

** See Table 9-1 in Appendix 1 for site details.*

Table 9-12. Organic carbon fractionation (%C) of the Point Malcolm soil materials (May 2013).

Profile ID*	Depth Range (cm)	cPOM	LF	iPOM	µagg	µSilt	µClay	NH-dSilt	NH-dClay	H-dSilt	H-dClay	NH-µSilt	NH-µClay	H-µSilt	H-µClay	dSilt	dClay
9A	0-2.5	0.0452	-	-	0.0798	-	-	-	-	-	-	-	-	-	-	-	0.0043
9A	2.5-5	0.0545	-	-	0.1027	-	-	-	-	-	-	-	-	-	-	0.0107	0.0128
9A	5-10	0.0584	-	-	0.0915	-	-	-	-	-	-	-	-	-	-	0.0104	0.0087
9A	10-15	0.0616	-	-	0.0738	-	-	-	-	-	-	-	-	-	-	0.0120	0.0052
9A	15-20	0.0423	-	-	0.2367	-	-	-	-	-	-	-	-	-	-	0.0633	0.0220
9A	20-30	0.0858	-	-	0.2105	-	-	0.0038	0.0277	0.0016	0.0136	-	-	-	-	0.0054	0.0413
9A	30-35	0.0464	-	-	0.1115	-	-	-	-	-	-	-	-	-	-	0.0077	0.0093
9B	0-2.5	0.0100	-	-	0.0138	-	-	-	-	-	-	-	-	-	-	0.0015	0.0034
9B	2.5-5	0.1237	-	-	0.0162	-	-	-	-	-	-	-	-	-	-	0.0026	0.0078
9B	5-10	0.1634	-	-	0.0101	-	-	-	-	-	-	-	-	-	-	0.0006	0.0020
9B	10-15	0.0941	-	-	0.0176	-	-	-	-	-	-	-	-	-	-	0.0065	0.0047
9B	15-20	0.2640	-	-	0.0933	-	-	-	-	-	-	-	-	-	-	0.0450	0.0161
9B	20-30	0.2574	-	-	0.2023	-	-	-	-	-	-	-	-	-	-	0.0282	0.0282
9B	30-35	0.1351	-	-	0.0558	-	-	-	-	-	-	-	-	-	-	0.0107	0.0141
10A	0-2.5	0.0349	-	-	0.0736	-	-	-	-	-	-	-	-	-	-	0.0040	0.0039
10A	2.5-5	0.0342	-	-	0.0761	-	-	-	-	-	-	-	-	-	-	0.0021	0.0040
10A	5-10	0.0667	-	-	0.1115	-	-	-	-	-	-	-	-	-	-	0.0142	0.0185
10A	10-15	0.0415	-	-	0.1497	-	-	0.0175	-	0.0055	-	-	-	-	-	0.0230	0.0136
10A	15-20	0.0240	-	-	0.0868	-	-	-	-	-	-	-	-	-	-	0.0077	0.0091
10A	20-30	0.0528	-	-	0.0745	-	-	-	-	-	-	-	-	-	-	0.0075	0.0054
10A	30-35	0.2654	-	-	0.0708	-	-	-	-	-	-	-	-	-	-	0.0067	0.0059
10B	0-2.5	0.0106	-	-	0.1320	-	-	-	-	-	-	-	-	-	-	-	0.0036
10B	2.5-5	0.0330	-	-	0.1305	-	-	-	-	-	-	-	-	-	-	0.0083	0.0112
10B	5-10	0.0240	-	-	0.0963	-	-	-	-	-	-	-	-	-	-	0.0031	0.0160
10B	10-15	0.0195	-	-	0.0903	-	-	-	-	-	-	-	-	-	-	0.0036	0.0093
10B	15-20	0.0360	-	-	0.0902	-	-	-	-	-	-	-	-	-	-	0.0031	0.0091
10B	20-30	0.0506	-	-	0.0959	-	-	-	-	-	-	-	-	-	-	0.0104	0.0105

** See Table 9-1 in Appendix 1 for site details.*

Table 9-12 (continued). Organic carbon fractionation (%C) of the Point Malcolm soil materials (May 2013).

Profile ID*	Depth Range (cm)	cPOM	LF	iPOM	µagg	µSilt	µClay	NH-dSilt	NH-dClay	H-dSilt	H-dClay	NH-µSilt	NH-µClay	H-µSilt	H-µClay	dSilt	dClay
11A	0-2.5	0.2011	-	-	0.0245	-	-	-	-	-	-	-	-	-	-	0.0021	0.0053
11A	2.5-5	0.1355	-	-	0.0158	-	-	-	-	-	-	-	-	-	-	0.0022	0.0060
11A	5-10	0.1187	-	-	0.0116	-	-	-	-	-	-	-	-	-	-	0.0009	0.0032
11A	10-15	0.0538	-	-	0.1372	-	-	0.0263	0.0181	0.0020	0.0054	-	-	-	-	0.0283	0.0235
11A	15-20	0.3046	-	-	0.0983	-	-	-	0.0240	-	0.0031	-	-	-	-	0.0123	0.0271
11A	20-30	0.2251	-	-	0.0238	-	-	-	-	-	-	-	-	-	-	0.0044	0.0114
11A	30-35	0.0339	-	-	0.0691	-	-	-	-	-	-	-	-	-	-	-	-
11B	0-2.5	0.0424	-	-	0.0934	-	-	-	-	-	-	-	-	-	-	0.0011	0.0049
11B	2.5-5	0.0285	-	-	0.1171	-	-	-	-	-	-	-	-	-	-	0.0017	0.0075
11B	5-10	0.0208	-	-	0.0949	-	-	-	-	-	-	-	-	-	-	0.0031	0.0089
11B	10-15	0.0628	-	-	0.1546	-	-	-	-	-	-	-	-	-	-	0.0058	0.0202
11B	15-20	0.1295	-	-	0.3065	-	-	-	-	-	-	-	-	-	-	0.0509	0.0319
11B	20-30	0.0902	-	-	0.1685	-	-	-	-	-	-	-	-	-	-	0.0197	0.0238
11B	30-35	0.0838	-	-	0.1104	-	-	-	-	-	-	-	-	-	-	0.0073	0.0174
12A	0-2.5	0.0551	-	-	0.0844	-	-	-	-	-	-	-	-	-	-	0.0008	0.0047
12A	2.5-5	0.1116	-	-	0.0170	-	-	-	-	-	-	-	-	-	-	0.0005	0.0036
12A	5-10	0.0601	-	-	0.0734	-	-	-	-	-	-	-	-	-	-	0.0009	0.0044
12A	10-15	0.0547	-	-	0.0696	-	-	-	-	-	-	-	-	-	-	0.0013	0.0083
12A	15-20	0.0261	-	-	0.1138	-	-	-	-	-	-	-	-	-	-	0.0048	0.0105
12A	20-30	0.0934	-	-	0.0318	-	-	-	-	-	-	-	-	-	-	0.0014	0.0071
12B	0-2.5	0.0744	-	-	0.0909	-	-	-	-	-	-	-	-	-	-	0.0004	0.0077
12B	2.5-5	0.0559	-	-	0.1164	-	-	-	-	-	-	-	-	-	-	0.0015	0.0081
12B	5-10	0.0713	-	-	0.0838	-	-	-	-	-	-	-	-	-	-	0.0035	0.0076
12B	10-15	0.0318	-	-	0.1036	-	-	-	-	-	-	-	-	-	-	0.0031	0.0094
12B	15-20	0.0288	-	-	0.2479	-	-	-	-	-	-	-	-	-	-	0.0087	0.0135
12B	20-30	0.0886	-	-	0.1057	-	-	-	-	-	-	-	-	-	-	0.0220	0.0215
12B	30-35	0.0724	-	-	0.0955	-	-	-	-	-	-	-	-	-	-	0.0077	0.0297

** See Table 9-1 in Appendix 1 for site details.*

Table 9-13. Non-protected and protected organic carbon fractions (%C) of the Point Malcolm soil materials (May 2013).

Profile ID*	Depth Range (cm)	Chemical (H-dSilt + H-dClay)	Biochemical (NH-dSilt + NH-dClay)	Non-Protected (cPOM + LF#)	Physical (µagg + iPOM#)
9A	0-2.5	-	-	0.0452	0.0798
9A	2.5-5	-	-	0.0545	0.1027
9A	5-10	-	-	0.0584	0.0915
9A	10-15	-	-	0.0616	0.0738
9A	15-20	-	-	0.0423	0.2367
9A	20-30	0.0152	0.0315	0.0858	0.2105
9A	30-35	-	-	0.0464	0.1115
9B	0-2.5	-	-	0.0100	0.0138
9B	2.5-5	-	-	0.1237	0.0162
9B	5-10	-	-	0.1634	0.0101
9B	10-15	-	-	0.0941	0.0176
9B	15-20	-	-	0.2640	0.0933
9B	20-30	-	-	0.2574	0.2023
9B	30-35	-	-	0.1351	0.0558
10A	0-2.5	-	-	0.0349	0.0736
10A	2.5-5	-	-	0.0342	0.0761
10A	5-10	-	-	0.0667	0.1115
10A	10-15	-	-	0.0415	0.1497
10A	15-20	-	-	0.0240	0.0868
10A	20-30	-	-	0.0528	0.0745
10A	30-35	-	-	0.2654	0.0708
10B	0-2.5	-	-	0.0106	0.1320
10B	2.5-5	-	-	0.0330	0.1305
10B	5-10	-	-	0.0240	0.0963
10B	10-15	-	-	0.0195	0.0903
10B	15-20	-	-	0.0360	0.0902
10B	20-30	-	-	0.0506	0.0959
11A	0-2.5	-	-	0.2011	0.0245
11A	2.5-5	-	-	0.1355	0.0158
11A	5-10	-	-	0.1187	0.0116
11A	10-15	0.0074	0.0444	0.0538	0.1372
11A	15-20	-	-	0.3046	0.0983
11A	20-30	-	-	0.2251	0.0238
11A	30-35	-	-	0.0339	0.0691
11B	0-2.5	-	-	0.0424	0.0934
11B	2.5-5	-	-	0.0285	0.1171
11B	5-10	-	-	0.0208	0.0949
11B	10-15	-	-	0.0628	0.1546
11B	15-20	-	-	0.1295	0.3065
11B	20-30	-	-	0.0902	0.1685
11B	30-35	-	-	0.0838	0.1104

** See Table 9-1 in Appendix 1 for site details.*

 # LF and iPOM carbon fractions not quantified.

Table 9-13 (continued). Non-protected and protected organic carbon fractions (%C) of the Point Malcolm soil materials (May 2013).

Profile ID*	Depth Range (cm)	Chemical (H-dSilt + H-dClay)	Biochemical (NH-dSilt + NH-dClay)	Non-Protected (cPOM + LF#)	Physical (µagg + iPOM#)
12A	0-2.5	-	-	0.0551	0.0844
12A	2.5-5	-	-	0.1116	0.0170
12A	5-10	-	-	0.0601	0.0734
12A	10-15	-	-	0.0547	0.0696
12A	15-20	-	-	0.0261	0.1138
12A	20-30	-	-	0.0934	0.0318
12B	0-2.5	-	-	0.0744	0.0909
12B	2.5-5	-	-	0.0559	0.1164
12B	5-10	-	-	0.0713	0.0838
12B	10-15	-	-	0.0318	0.1036
12B	15-20	-	-	0.0288	0.2479
12B	20-30	-	-	0.0886	0.1057
12B	30-35	-	-	0.0724	0.0955

** See Table 9-1 in Appendix 1 for site details.*

 # LF and iPOM carbon fractions not quantified.

APPENDIX 4. Additional carbon fractionation graphs

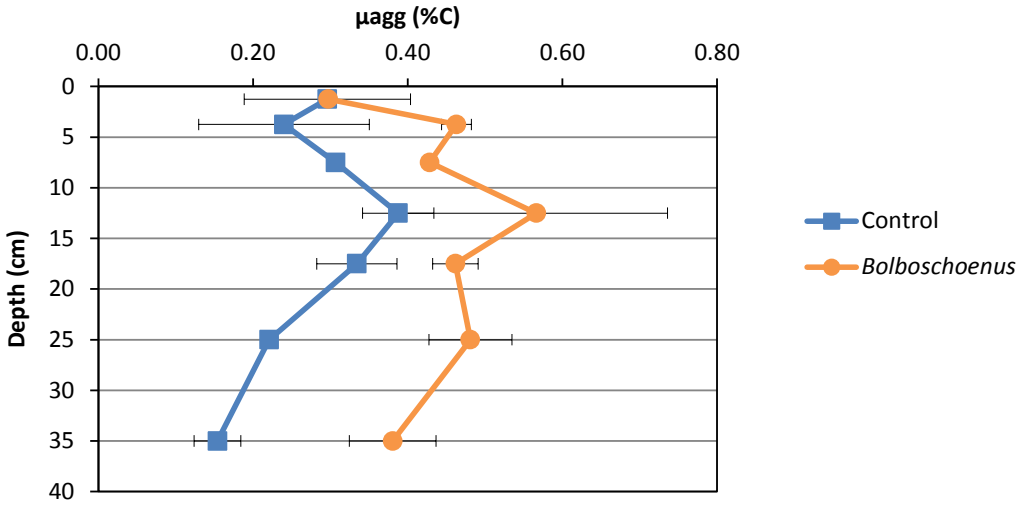

Figure 9-1. µaggregate carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

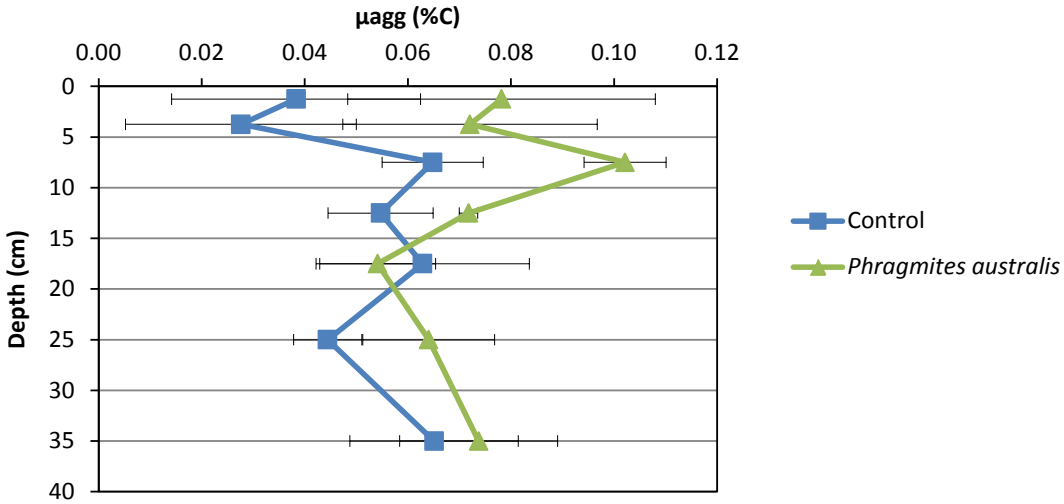

Figure 9-2. µaggregate carbon fraction at the Tolderol control (no vegetation) and *Phragmites australis* sites.

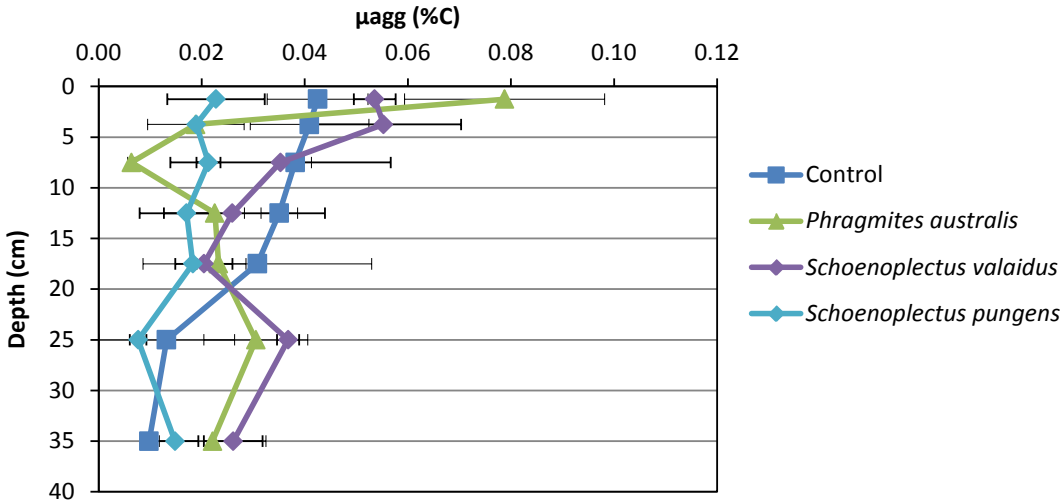

Figure 9-3. µaggregate carbon fraction at the Loveday Bay control (no vegetation) and vegetated sites.

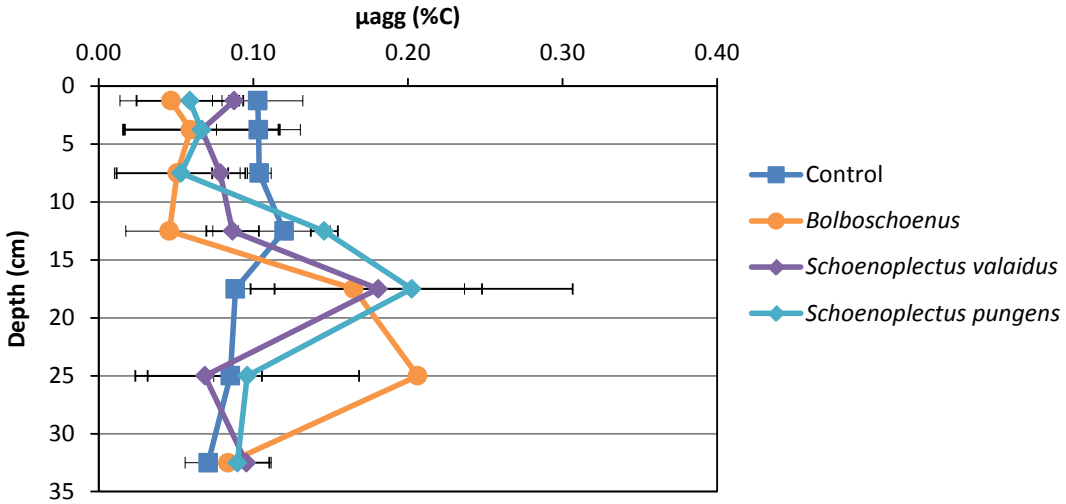

Figure 9-4. µaggregate carbon fraction at the Point Malcolm control (no vegetation) and vegetated sites.

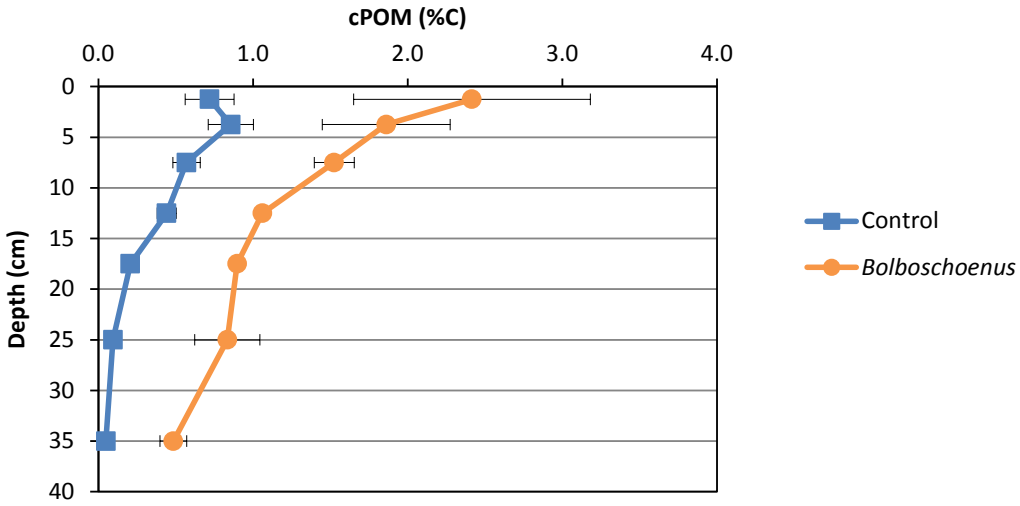

Figure 9-5. cPOM carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

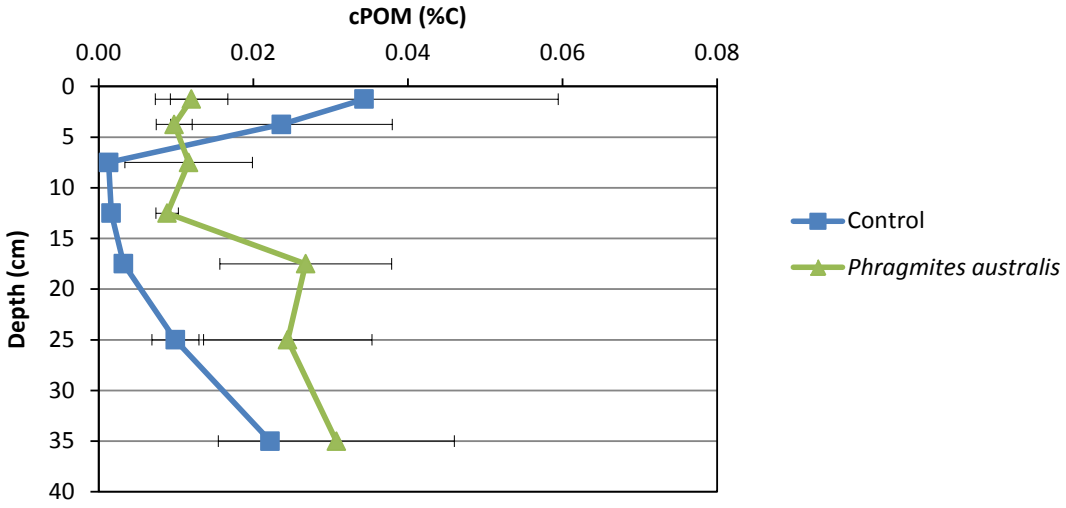

Figure 9-6. cPOM carbon fraction at the Tolderol control (no vegetation) and *Phragmites australis* sites.

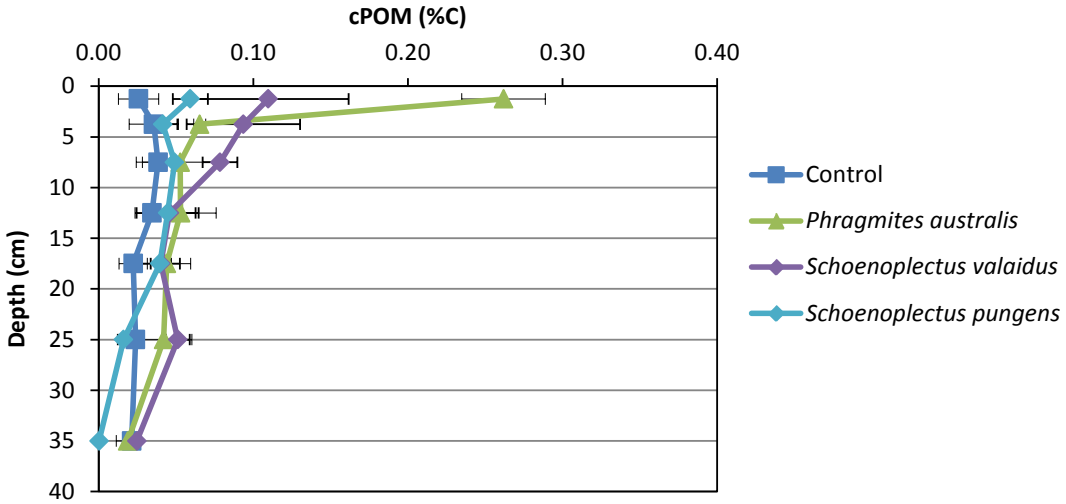

Figure 9-7. cPOM carbon fraction at the Loveday Bay control (no vegetation) and vegetated sites.

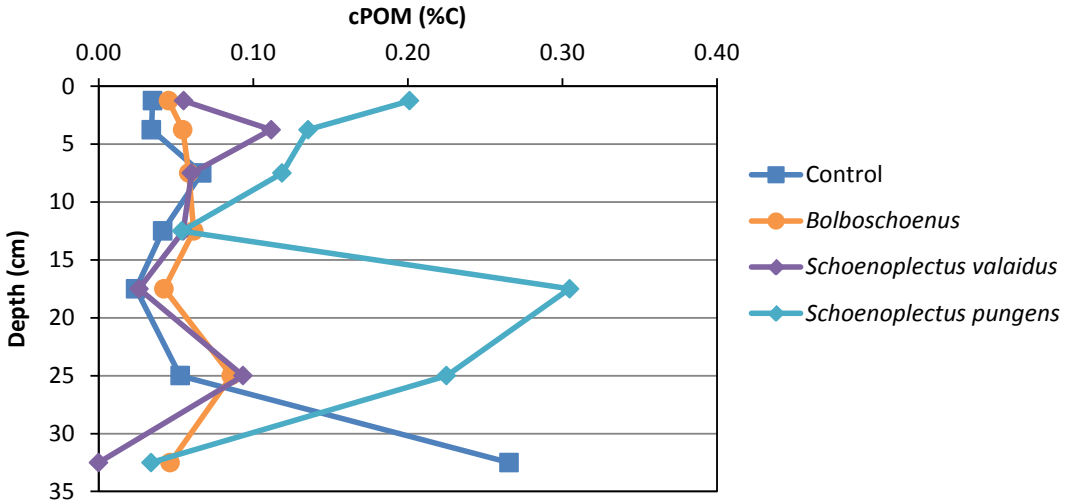

Figure 9-8. cPOM carbon fraction at the Point Malcolm control (no vegetation) and vegetated sites.

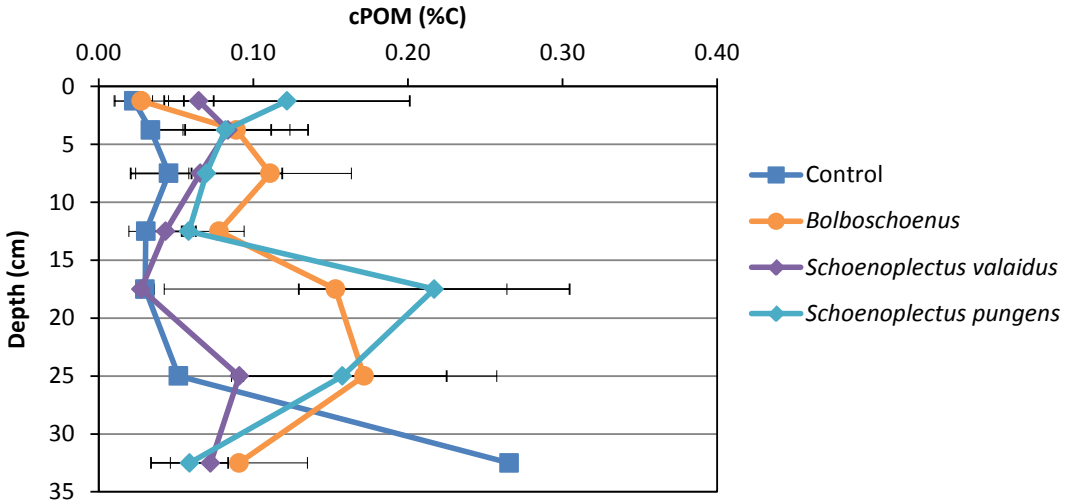

Figure 9-9. dSilt carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

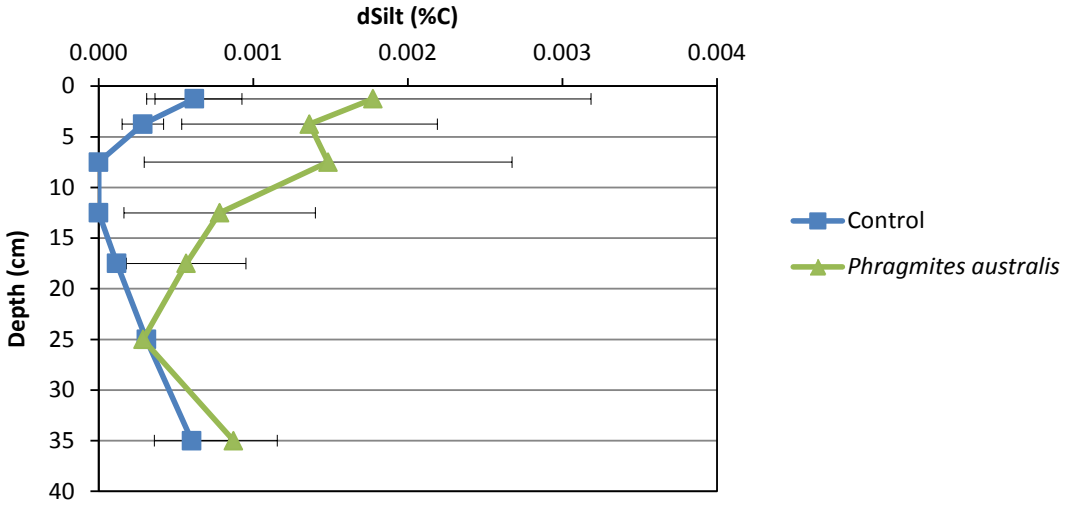

Figure 9-10. dSilt carbon fraction at the Tolderol control (no vegetation) and *Phragmites australis* sites.

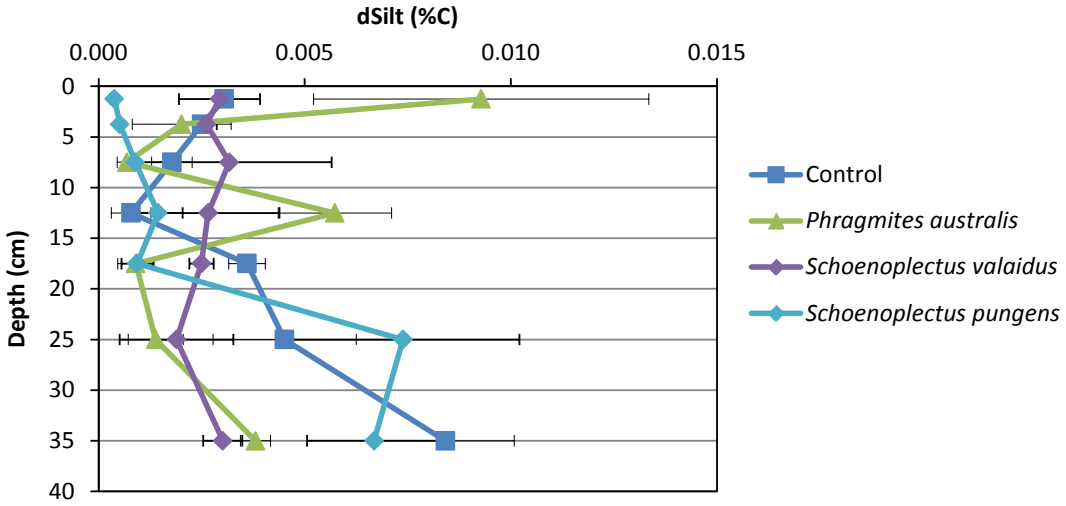

Figure 9-11. dSilt carbon fraction at the Loveday Bay control (no vegetation) and vegetated sites.

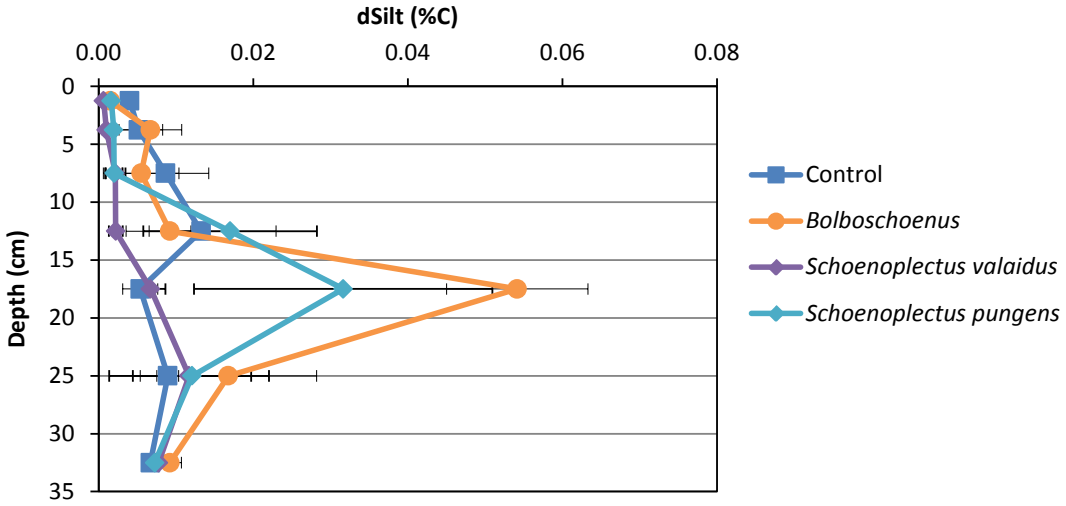

Figure 9-12. dSilt carbon fraction at the Point Malcolm control (no vegetation) and vegetated sites.

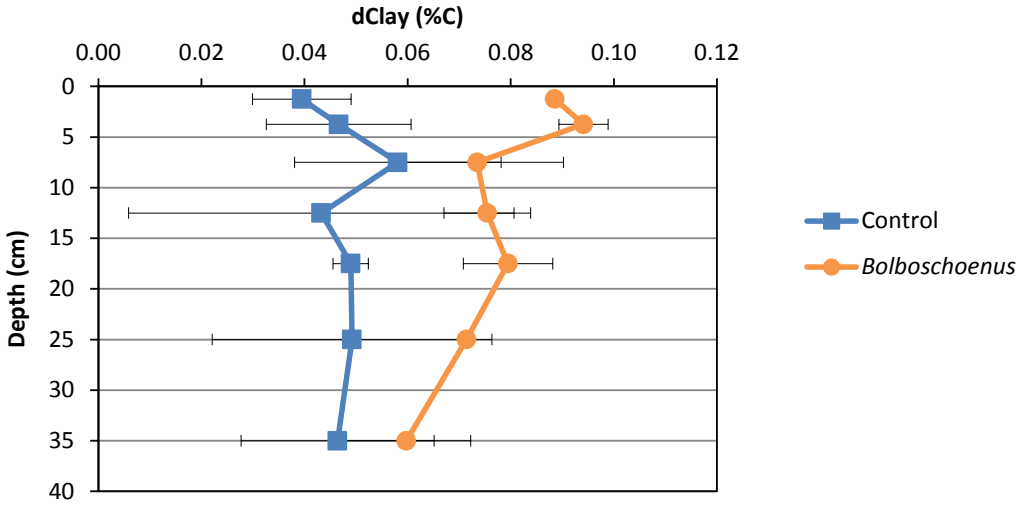

Figure 9-13. dClay carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

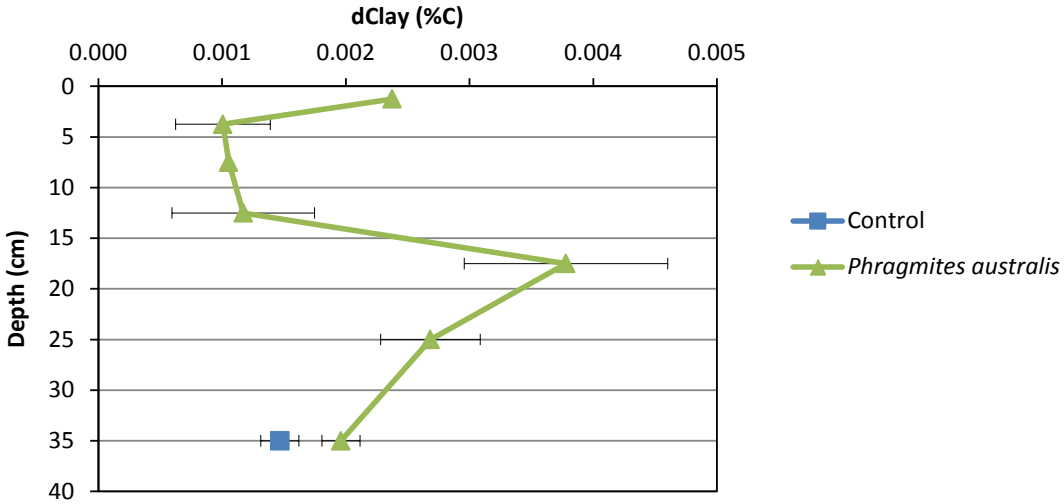

Figure 9-14. dClay carbon fraction at the Tolderol control (no vegetation) and *Phragmites australis* sites.

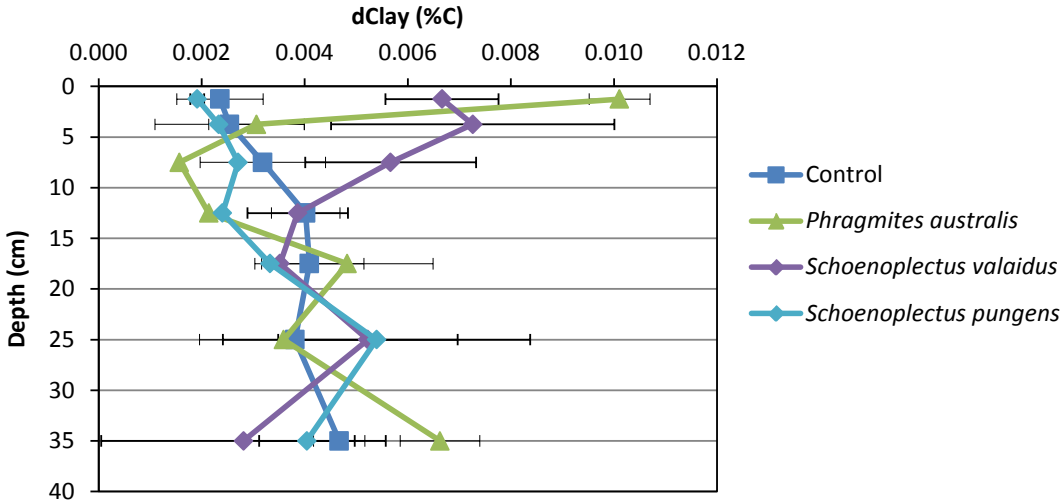

Figure 9-15. dClay carbon fraction at the Loveday Bay control (no vegetation) and vegetated sites.

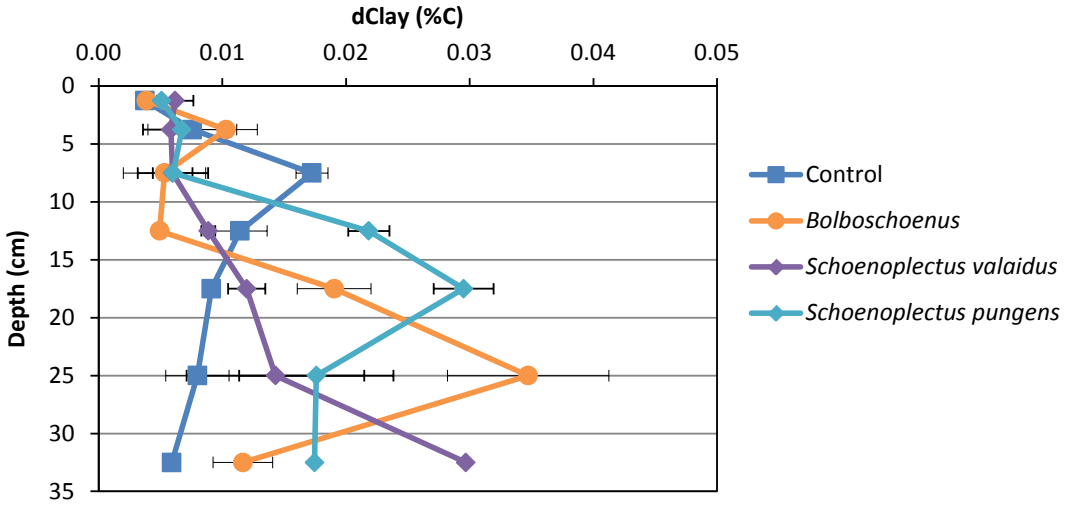

Figure 9-16. dClay carbon fraction at the Point Malcolm control (no vegetation) and vegetated sites.

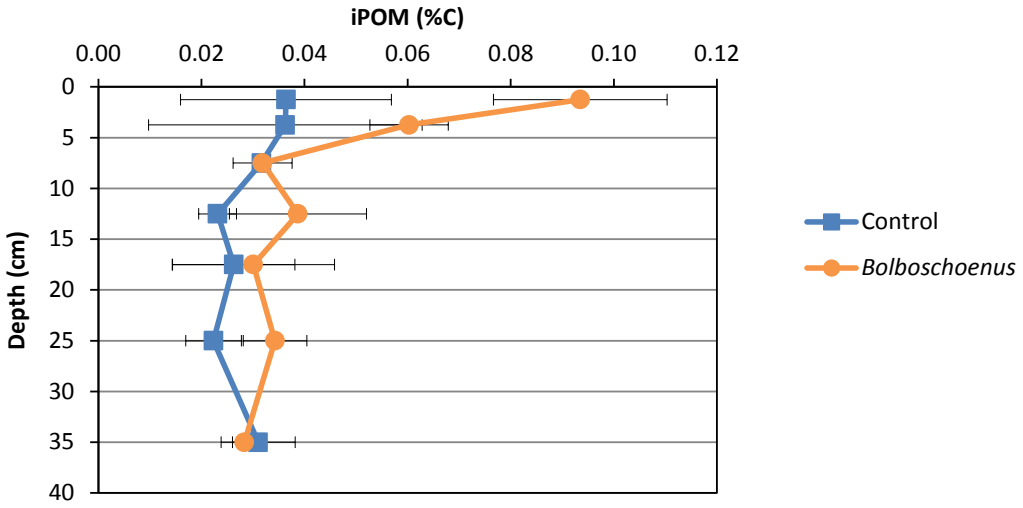

Figure 9-17. iPOM carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

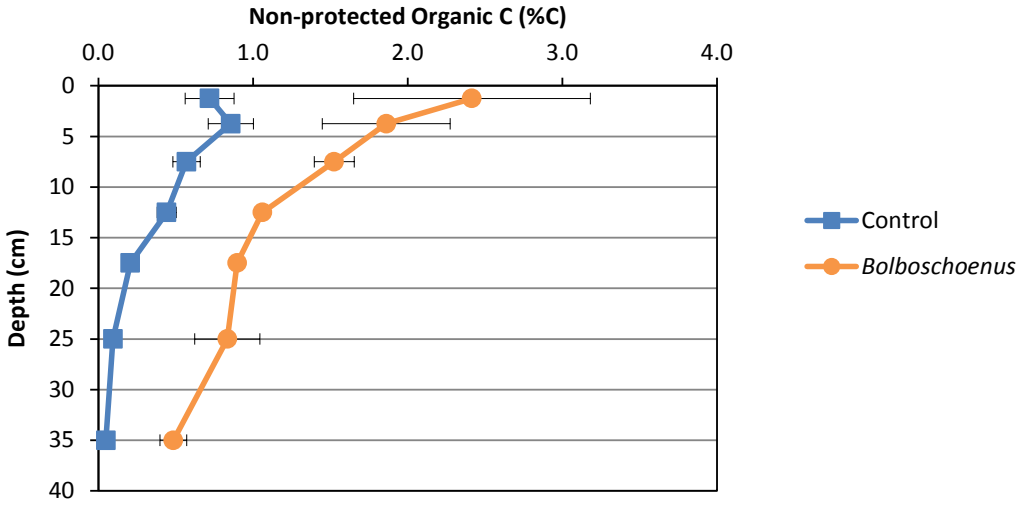

Figure 9-18. Non-protected organic carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

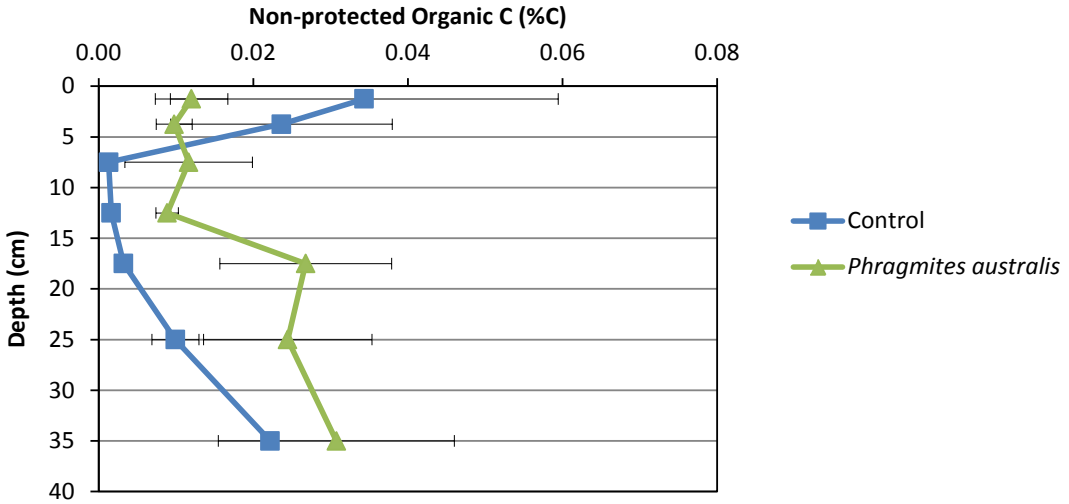

Figure 9-19. Non-protected organic carbon fraction at the Tolderol control (no vegetation) and *Phragmites australis* sites.

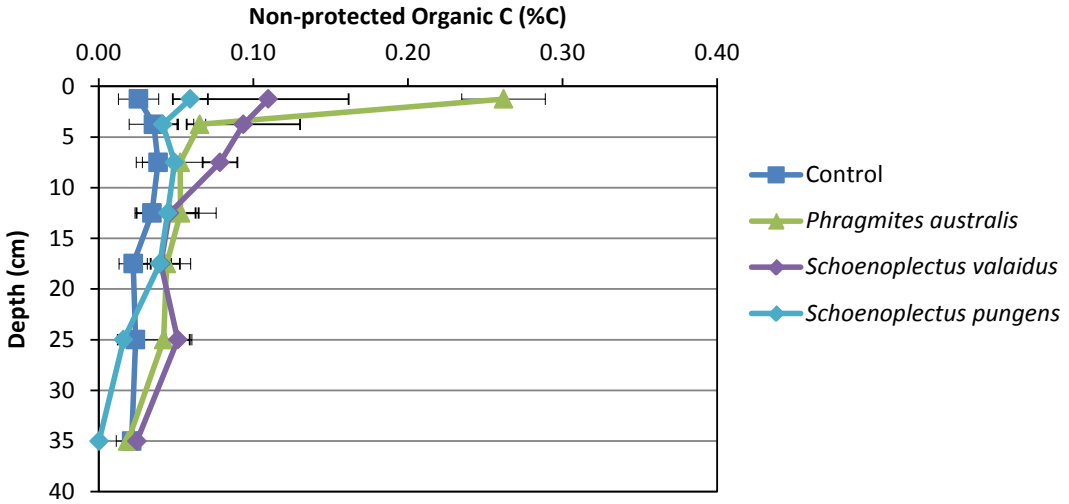

Figure 9-20. Non-protected organic carbon fraction at the Loveday Bay control (no vegetation) and vegetated sites.

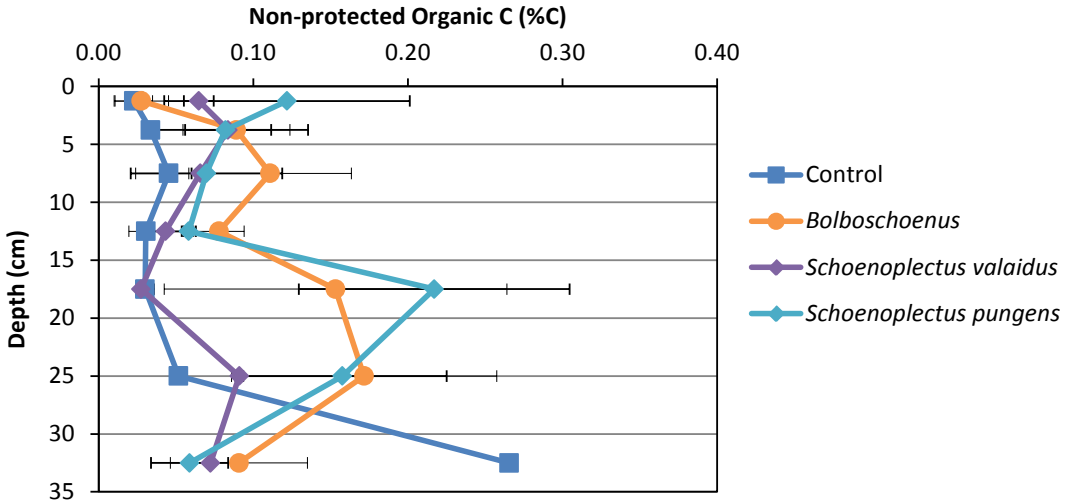

Figure 9-21. Non-protected organic carbon fraction at the Point Malcolm control (no vegetation) and vegetated sites.

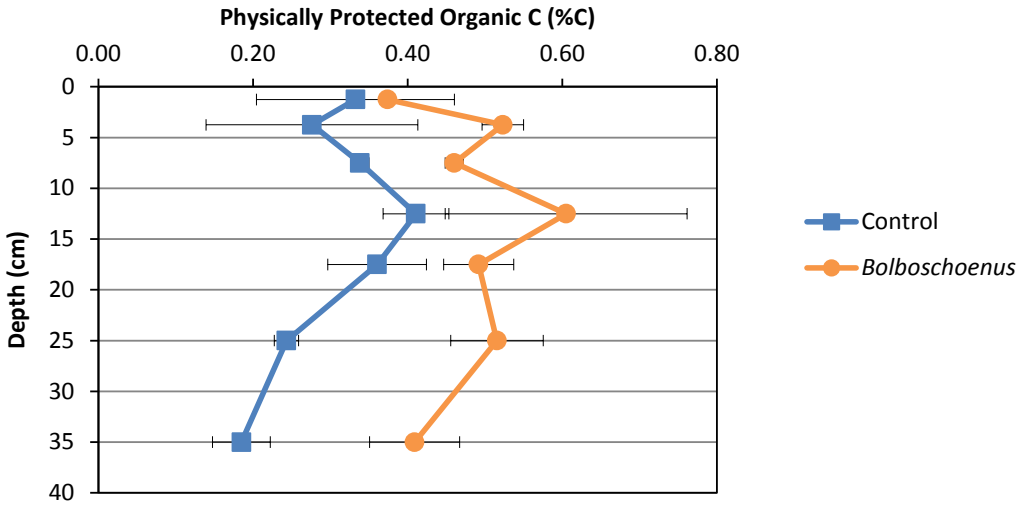

Figure 9-22. Physically protected organic carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

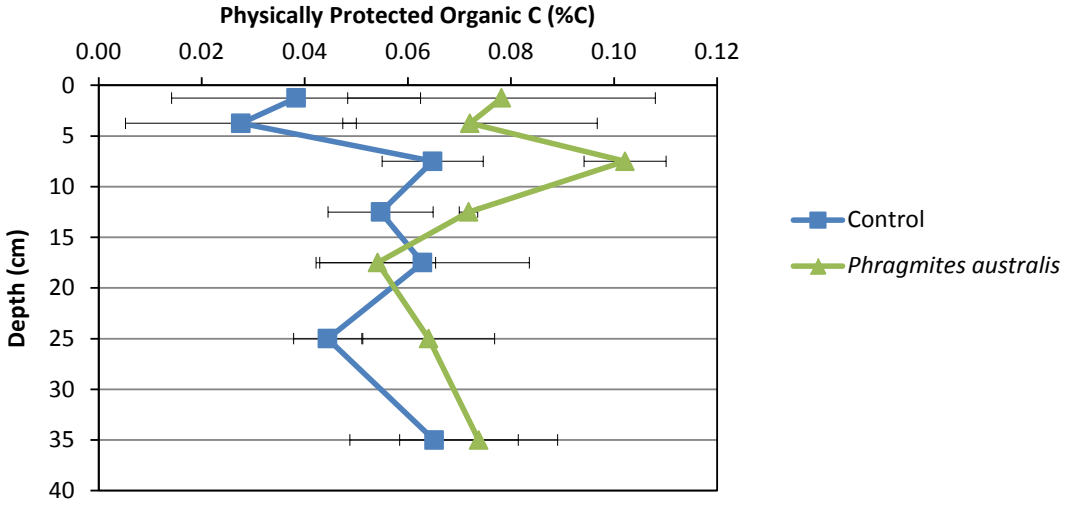

Figure 9-23. Physically protected organic carbon fraction at the Tolderol control (no vegetation) and *Phragmites australis* sites.

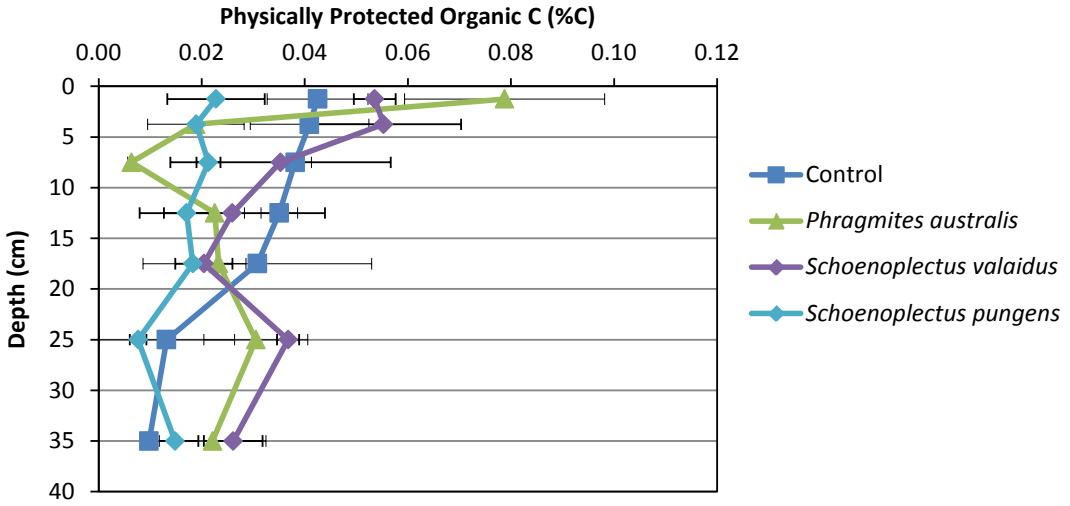

Figure 9-24. Physically protected organic carbon fraction at the Loveday Bay control (no vegetation) and vegetated sites.

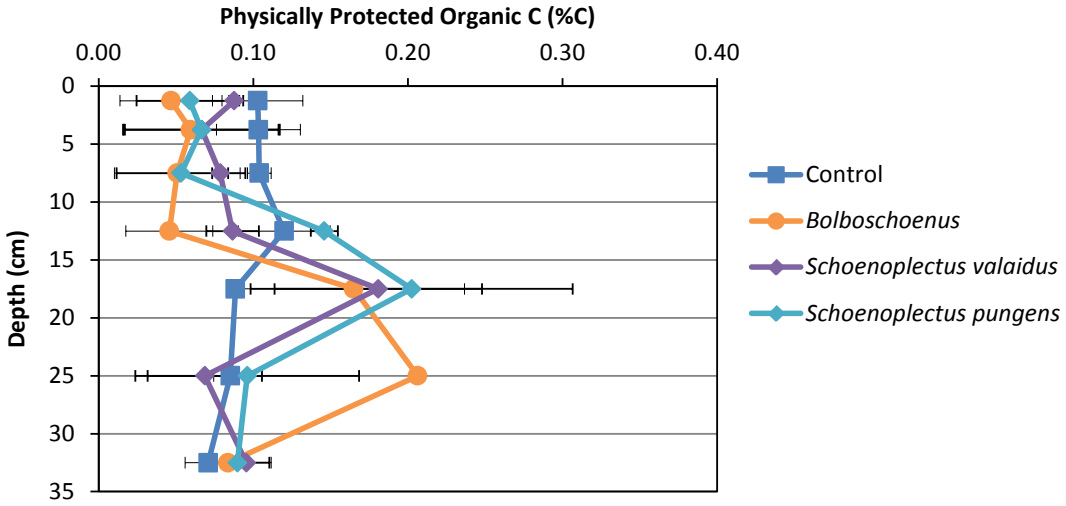

Figure 9-25. Physically protected organic carbon fraction at the Point Malcolm control (no vegetation) and vegetated sites.

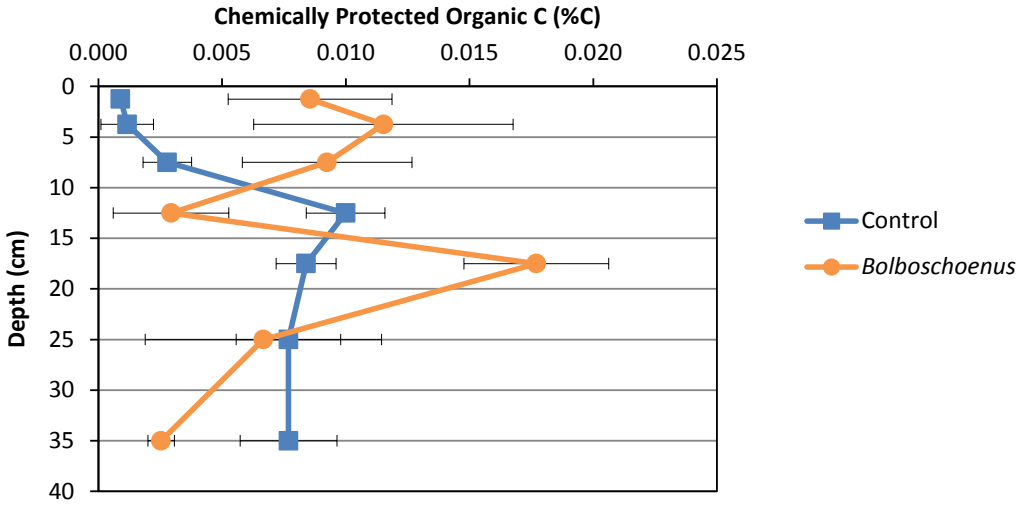

Figure 9-26. Chemically protected organic carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.

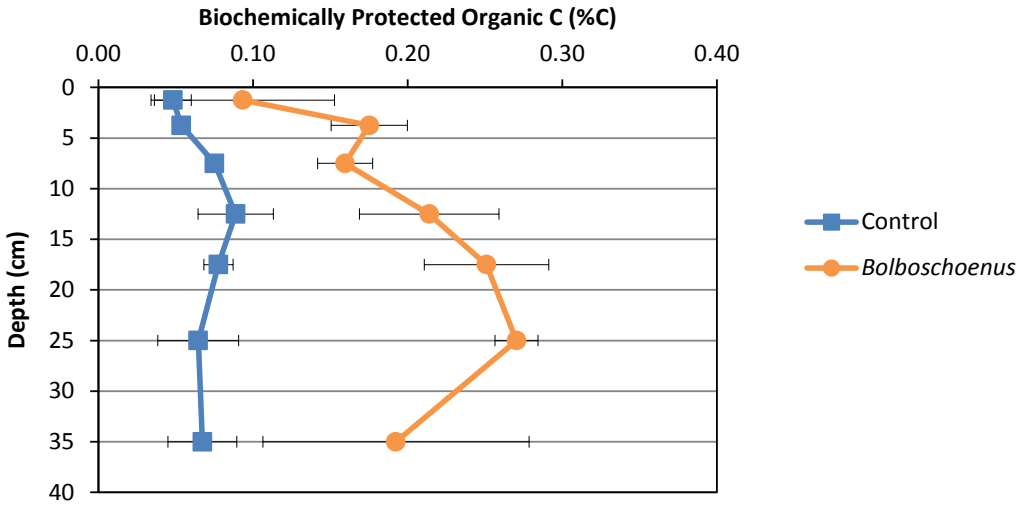

Figure 9-27. Biochemically protected organic carbon fraction at the Hunters Creek control (no vegetation) and *Bolboschoenus* sites.